FINAL REPORT

to the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM (NCHRP)

On

Project 03-78c: Guidelines for the Application of Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities

from

Kittelson & Associates, Inc.
Accessible Design for the Blind

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INTRODUCTION

The objective of this research was to develop and conduct a training and technology transfer program for the guidebook developed under NCHRP 03-78b, and published as NCHRP Report 834. The key components of this training program were to (1) develop a public affairs package and project website, (2) prepare training materials, (3) teach 6 in-person workshops per year over a two-year period for 12 training sessions (including one pilot workshop), and (4) deliver 3 webinars over the two-year period. The materials developed as part of the NCHRP 3-78b project served as the basis for this training program. The audiences for these workshops included engineers/administrators who may be responsible for making decisions about roundabout and channelized turn lane designs and installations, and Orientation & Mobility (O&M) professionals who wish to understand better the tradeoffs and considerations of roundabouts and channelized turn lanes for pedestrian access.

As part of the preparation of the training materials and case studies included in the training, the research team further identified several clarification needs and errors in the originally-published chapters in NCHRP Report 834. Accordingly, the research team prepared updated chapters, which were used throughout all trainings, and which are attached to this document.

This document serves as the final project report and training summary for project NCHRP 03-78c. The document contains the following sections:

- A summary of all workshops delivered under the contract, including participant feedback;
- Appendix A with the detailed training survey response,
- Appendix B with the final training materials;
- Appendix C with the updated Chapter 6 on Wayfinding Assessment;
- Appendix D with the updated Chapter 7 on Crossing Assessment; and
- Appendix E with the wayfinding and crossing assessment worksheets to supplement the revised Chapters 6 and 7;
- Appendix F with the case study designs used in the training course.

SUMMARY OF WORKSHOPS

The primary goal of this project was to provide training and technology transfer of the materials published as NCHRP Report 834. As part of that effort, the team delivered three national webinars, and ten in-person training workshops. Table 1 summarizes the three webinars

Table 1. Summary of Webinars

Webinar Number	Date	Distribution Outlet
1	July 26, 2017	Transportation Research Board (TRB) webinar series
2	June 20, 2018	Institute of Transportation Engineers (ITE)webinar series
3	August 1, 2018	Association of Pedestrian and Bicycle Professionals (APBP) webinar series

All three webinars were well attended with over 300 locations signing in for each event. The team estimates that the webinars reached between 600 and 1,000 transportation professionals across the U.S. and internationally.

Table 2 summarizes the workshops conducted for the project, including the date, location, and number of attendees. Overall, 118 participants attended the ten workshops, representing 25 private companies and 31 public agencies and universities.

Table 2. Summary of Workshops

Workshop Location	Date	Number of Participants
Raleigh, NC (Pilot Workshop)	August 8, 2017	9
Portland, OR	April 11, 2018	6
Columbus, OH	May 2, 2018	16
Orlando, FL	May 22, 2018	9
Atlanta, GA	May 23, 2018	7
Oakland, CA	June 6, 2018	10
Shoreview, MN	July 11, 2018	16
Albany, NY	September 19, 2018	14
Bonner Springs, KS	October 17, 2018	28
Austin, TX	November 28, 2018	3

PARTICIPANT FEEDBACK

The course instructors distributed an evaluation form to each workshop participant with the following questions:

1. The topics presented were relevant and useful (strongly agree/agree/neutral/disagree/ strongly disagree).

2. The presenters thoughtfully and thoroughly covered the technical material (strongly agree/agree/neutral/ disagree/strongly disagree).

3. The pace of the course was appropriate (strongly agree/agree/neutral/disagree/strongly disagree).

4. The institutional and implementation issues were covered well (strongly agree/agree/ neutral/ disagree/strongly disagree).

5. The exercises were helpful in thinking through planning/analysis/design/ implementation issues (strongly agree/agree/neutral/ disagree/strongly disagree).

6. I am now able to take steps toward designing accessible roundabouts and channelized turn lanes (strongly agree/agree/neutral/ disagree/strongly disagree).

7. Which parts of the workshop were most useful?

8. Which parts of the workshop were least useful or need improvement?

9. What additional knowledge and information do you wish you had gained from this workshop?

The following is a summary of the general and specific feedback from the workshops:

- Generally, the feedback was positive, 66% of respondents indicated they “strongly agree”, 31% of respondents indicated they “agree”, 3% were “neutral” to all questions. No participants indicated “disagree” or “strongly disagree.”
- For open ended responses, several respondents included that the instructors were very knowledgeable in both theory and technical aspects.
- The wayfinding portion of the class was most useful, including many examples of “good” and “bad” designs impacting wayfinding at roundabouts and channelized turn lanes.
- Participants greatly appreciated the hands-on exercises for both the wayfinding and crossing exercises.
- Calculations were cited as the least useful part of the class by some participants. Common issues attendees indicated were that the calculations were hard, they did not have a calculator, or did not have enough time for calculations.

Table 3 represents the percentage of Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree responses to all questions by training location. For example, in Columbus, Ohio 52% of all attendees indicated they agreed with the question.

Table 3. Summary of Ratings by Location

Response	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Albany, NY	67%	28%	5%	0%	0%
Atlanta, GA	91%	7%	2%	0%	0%
Austin, TX	83%	17%	0%	0%	0%
Bonner Springs, KS	60%	36%	4%	0%	0%
Columbus, OH	41%	52%	7%	0%	0%
Oakland, CA	60%	37%	3%	0%	0%
Orlando, FL	79%	21%	0%	0%	0%
Portland, OR	36%	61%	3%	0%	0%
Shoreview, MN	73%	24%	3%	0%	0%

Serving as pilot location, Raleigh, NC had a slightly different question set. However, results were very similar to the results of other training locations. Most of the class indicating that the class exceeded expectations.

CONCLUSION

The overall feedback of the class was very positive. The attendees felt that presenters were very knowledgeable and look forward to applying what they learned. The class was very eye-opening to issues many had not considered before. Participants looked forward to being able to access training materials digitally so others can benefit from the class.

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APPENDIX A – DETAILED TRAINING RESPONSE SUMMARY

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Response #	Location	The topics were relevant and useful	Presenters thoughtfully and thoroughly covered the technical material - comments	The pace of the course was appropriate.	The institutional and implementation issues were covered well	The exercises were helpful in thiking planning/analysis/design/implementation issues	I am now able to take steps toward designing accessible roundabouts and channelized turn lanes	Which parts of the workshop were most useful?	Which Parts of the workshop were least useful or need improvement?	What additional knowledge and information do you wish you had gained from this workshop?
1	Portland, OR	4	4	4	5	5	5	Left Blank	Left Blank	Left Blank
2	Portland, OR	5	5	5	5	5	5	All - Thanks!	Left Blank	Left Blank
3	Portland, OR	4	4	4	3	4	5	Examples exercises, instructor openness to discussion / questions	Left Blank	Left Blank
4	Portland, OR	5	4	4	5	4	5	I enjoyed having an expert about blind individuals ability to travel thru intersections	Guage class experience or use/need of traffic ops to determine how deep to go into #. As an engineer(soon) I appreciate it but some might need just an overview	Push Buttons
5	Portland, OR	4	4	4	4	4	4	Left Blank	Left Blank	Left Blank
6	Portland, OR	4	4	4	4	4	4	Learning what tools blind people use to navigate	Left Blank	Left Blank
7	Columbus, OH	4	4	4	4	4	4	Left Blank	Left Blank	Left Blank
8	Columbus, OH	4	5	4	4	5	4	Left Blank	Left Blank	Left Blank
9	Columbus, OH	4	5	4	4	4	4	overall well done, good examples & good pace	not great direction on what is acceptible intervention role + nose rate	see #8
10	Columbus, OH	5	5	5	5	5	4	All were very useful Learnt a lot	exercise part was too quick, esp. the route part. We couldve spent more time on them instead of wayfinding exercises	couldve got the course material ahead of the class and the spreadsheet
11	Columbus, OH	5	5	5	5	4	3	Left Blank	Left Blank	Left Blank
12	Columbus, OH	4	4	4	4	4	3	problem solving and calculations increased understanding+clarified the process. Time well spent	Left Blank	Left Blank
13	Columbus, OH	4	5	3	4	3	5	exercises were useful but were a little repetitive could probably only do two examples instead of 4	calculation task was confusing and poorly structred. Pace was a little slow at times	more guidance on trial recommendations for what acceptable rates for these probabilities.
14	Columbus, OH	5	5	5	5	4	5	Left Blank	Left Blank	Left Blank
15	Columbus, OH	4	4	4	5	5	5	working thru wayfinding features	calculation time. Clearer pic of what we are clculating. Place problem 11x17 in one pocket of binder. Fastest path in the other pocket	Left Blank
16	Orlando, FL	5	5	5	5	5	5	fundamentaks of good designin roundabout and changed islands, and how to improve	calculations were hard, but with a ltitle practice could do it. Appreciate the better understanding	illegable
17	Orlando, FL	5	5	5	4	5	4	The ada info and Janets part at the beginning was very eye opening and I wont forget it	math at the end wasn't useful to me. I don't use those calculations in my job	Very Good!
18	Orlando, FL	5	5	5	5	5	5	the exercises and presenstation	N/A	N/A
19	Orlando, FL	5	5	4	4	5	4	Left Blank	Left Blank	Left Blank
20	Orlando, FL	5	5	5	5	5	5	Everything Thanks!	None	Everything was great
21	Orlando, FL	5	4	4	4	5	5	Wayfinding exercises and discussion	number crunching	Left Blank
22	Orlando, FL	5	5	5	4	5	5	explination about how blind people precieve the road and intersections. It was very eye opening from a design perspective	calculations need some more explaination	Left Blank
23	Atlanta, GA	5	5	5	5	5	5	Wayfinding for visually impared specifically	Left Blank	Left Blank
24	Atlanta, GA	5	5	4	3	5	4	Example problems. Slides w/ photos showing crosswalk conflicts	may clarify the intent & a little section in possible implementation	Gained so much thanks!

5 - Strongly Agree, 4 -Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly Disagree

Response #	Location	The topics were relevant and useful	Presenters thoughtfully and thoroughly covered the technical material - comments	The pace of the course was appropriate.	The institutional and implementation issues were covered well	The exercises were helpful in thiking planning/analysis/design/implementation issues	I am now able to take steps toward designing accessible roundabouts and channelized turn lanes	Which parts of the workshop were most useful?	Which Parts of the workshop were least useful or need improvement?	What additional knowledge and information do you wish you had gained from this workshop?
25	Atlanta, GA	5	5	5	5	5	4	The first exercise with the different treatments of RB legs and problems vs solutions to find and implement	Left Blank	Left Blank
26	Atlanta, GA	5	5	5	5	5	5	The illustrations of bad wayfinding structures	Left Blank	Left Blank
27	Atlanta, GA	5	5	5	5	5	5	All of it was well crafted theory, research and application	I can see that some attendees need a primer on geometric speed calculation, but I did not	Left Blank
28	Atlanta, GA	5	5	5	5	5	5	Left Blank	Left Blank	Left Blank
29	Atlanta, GA	5	5	5	5	5	5	As a beginning RAB design, all info was useful, Thank You!	Left Blank	Left Blank
30	Oakland, CA	4	5	3	4	4	4	Understanding the complexity + elevation of ADA, ect	Left Blank	Left Blank
31	Oakland, CA	5	4	5	4	4	4	The seperation between the wayfinding issues and crossing issues was very useful	Probably out of scope of the class but some deviation of the equations presented or some more background info would have been helpful. I check the web to find out more information	Left Blank
32	Oakland, CA	5	5	5	4	4	4	Love the spreadsheet calculations	Left Blank	Left Blank
33	Oakland, CA	5	5	4	4	5	5	case study to understand "barriers" to sigth imparied people. Disucssion reinforcing the meaning/implications of calculations	Generally, none. Maybe more case study coverage, understand time factor	Left Blank
34	Oakland, CA	5	5	5	5	5	5	Great workshop, Thanks!	discuss issues weve had on recent projects. Would be interested in hearing from other offices	bike ramp issue
35	Oakland, CA	5	5	5	4	4	4	guidance on how to set up the geometry	Left Blank	use of the component use to understand expectations
36	Oakland, CA	4	5	5	4	3	4	Diagrams	Left Blank	Bicycle factors
37	Oakland, CA	5	5	5	5	5	5	Liked wayfinding parts, xing assessment most helpful making and justifing design decisions	Left Blank	other measures that have been unsuccessful in terms of wayfinding so we don't repeat them
38	Oakland, CA	5	5	4	4	5	4	RAB + CTL application	all good	all good
39	Oakland, CA	5	5	5	5	5	5	crossing assessment	all posts were useful	Left Blank
40	Shoreview, MN	4	5	5	4	4	4	afternoon session explaning that went into the model	pretty good, less examples on poor design. I have a good idea of what to avoid	alternate way finding signs at roundabouts for the blind. 3D printed roundabout geomtery w/ brail + noise locatore might be a helpful solution to look at
41	Shoreview, MN	4	5	5	5	5	4	the examples were very useful. Also liked the photoes	left blank	left blank
42	Shoreview, MN	5	5	5	5	5	5	left blank	left blank	probability of intervention, what % triggers implementation of a treatment? The million $ question.
43	Shoreview, MN	4	5	4	5	4	5	left blank	left blank	left blank
44	Shoreview, MN	5	5	5	5	5	5	understanding the assessment + how to apply them	it would be nice to get more info what is considered acceptable	none

5 - Strongly Agree, 4 -Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly Disagree

Response #	Location	The topics were relevant and useful	Presenters thoughtfully and thoroughly covered the technical material - comments	The pace of the course was appropriate.	The institutional and implementation issues were covered well	The exercises were helpful in thiking planning/analysis/design/implementation issues	I am now able to take steps toward designing accessible roundabouts and channelized turn lanes	Which parts of the workshop were most useful?	Which Parts of the workshop were least useful or need improvement?	What additional knowledge and information do you wish you had gained from this workshop?
45	Shoreview, MN	5	5	5	5	5	5	workshop was well done. Great info on the topic. Nice combination of study findings and engineering application	left blank	was there was info available to compare some of these measures to other types of intersections more directly. Hope to have access to electronic materials soon!
46	Shoreview, MN	5	5	4	5	5	5	this is my first experience with accessible roundabout design, very useful to have a full class and to be given things to look for in design	left blank	left blank
47	Shoreview, MN	5	5	5	5	5	5	seeing the equations to help identify what the real factors in safety and accesability	hand working problems is not important if they could be put in a spreadsheet	backing data accuracy was presented if possible to make sure it follows the numbers
48	Shoreview, MN	5	5	5	5	5	5	the analysis/assessments. The RFB was good	too much time on the wayfinding exercise	how to do mid-blocking crossings for visually impared pedestrians
49	Shoreview, MN	4	4	4	4	3	3	intersection calculations were interesting	left blank	left blank
50	Shoreview, MN	5	5	5	4	5	4	as a planner, intro/overview, design, wayfinding, crossing was useful. Janet has invaluable experience. Rare opportunity to have this much focus on needs of blind/low vision people, who are "lost within general disabilities" thanks for coming!	fastest path least useful but not a reflection on the content. Good discussion w/ that section that was to helpful	people distribute electronically so others can benefit from this.
51	Albany, NY	5	5	5	4	4	3	left blank	left blank	left blank
52	Albany, NY	5	5	5	5	5	5	left blank	left blank	left blank
53	Albany, NY	5	4	4	5	4	5	examples of design/treatments. Discussion of materials interesting	design solutions for warmer climate. Expand for colder climates	more discussion on lighting
54	Albany, NY	5	5	5	5	5	5	left blank	left blank	left blank
55	Albany, NY	5	5	5	5	5	4	info on blind people roundabouts	left blank	left blank
56	Albany, NY	5	5	5	5	5	5	performing checks, wayfinding info	N/A	N/A
57	Albany, NY	4	4	4	4	4	4	activity of wayfinding, experiences and photos	calcs were a little boring	left blank
58	Albany, NY	5	5	5	5	4	4	wayfinding assessment	probably fastest pace because its covered in other training	guidance on presenting similar info to public
59	Albany, NY	5	5	4	5	5	3	wayfinding issues/concerns	not a designer so that part was not important to me	none to think of
60	Albany, NY	4	4	3	4	5	4	Design parameters to consider	none	left blank
61	Albany, NY	5	5	5	5	5	5	left blank	left blank	left blank
62	Bonner Springs, KS	5	5	5	5	5	5	crossing assessment. Bew info and very informative. Lee/Janet did a great job	All Good	left blank
63	Bonner Springs, KS	4	5	4	4	4	4	Left Blank	describe in more detail how this agrees with or not by PROWAG	left blank
64	Bonner Springs, KS	5	5	4	4	3	4	design exercise was most helpful	wayfinding exercise was monotonus	left a good fundamental understanding for everyone
65	Bonner Springs, KS	5	5	5	5	5	5	wayfinding exercises. Nice to see problem areas and how to fix them	N/A	class did not leave me with any questions
66	Bonner Springs, KS	5	5	5	5	4	5	I had only considered sightdistance from a vehical stopping distance rather than a critical headway. Very eye opening	Left Blank	Left Blank
67	Bonner Springs, KS	5	5	5	5	5	5	Left Blank	Left Blank	Left Blank

5 - Strongly Agree, 4 -Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly Disagree

Response #	Location	The topics were relevant and useful	Presenters thoughtfully and thoroughly covered the technical material - comments	The pace of the course was appropriate.	The institutional and implementation issues were covered well	The exercises were helpful in thiking planning/analysis/design/implementation issues	I am now able to take steps toward designing accessible roundabouts and channelized turn lanes	Which parts of the workshop were most useful?	Which Parts of the workshop were least useful or need improvement?	What additional knowledge and information do you wish you had gained from this workshop?
68	Bonner Springs, KS	5	5	5	5	5	5	The exercises	Left Blank	Left Blank
69	Bonner Springs, KS	4	5	4	4	4	4	working through examples	None	None
70	Bonner Springs, KS	5	5	3	5	5	4	worksheet with the steps for the exercises	Left Blank	Left Blank
71	Bonner Springs, KS	5	5	5	5	5	4	Exercises and practical application discussion	Left Blank	Left Blank
72	Bonner Springs, KS	5	5	4	5	5	5	showing multiple ways to come to useful solutions, with concrete input	Left Blank	Left Blank
73	Bonner Springs, KS	4	5	5	5	5	4	exercises helped me gain a better understanding of the topic	nothing needed improvement	everything was good
74	Bonner Springs, KS	5	5	4	4	5	5	Showing examples of good and bad design elements and exercises	Left Blank	Left Blank
75	Bonner Springs, KS	5	5	4	4	4	5	variety of good/bad examples	handouts with increases scale and legend would help with inclass exercises	guidance on mini/turboroundabouts in regard to ped access/ design
76	Bonner Springs, KS	5	5	5	5	5	5	pictures of good/bad examples. Crossing assessment worksheet. Cross reference on layouts to sections of the book	text in some images were too small	nothing
77	Bonner Springs, KS	4	4	3	4	3	3	see below comment	intro was too long and not interesting. Most of the information from the beginning was too basic	Left Blank
78	Bonner Springs, KS	4	4	3	4	5	5	examples and handouts	pacing	Left Blank
79	Bonner Springs, KS	4	5	4	5	4	4	module 4-7. examples and talking about topics in detail	none	none
80	Bonner Springs, KS	5	5	4	4	4	4	afternoon modules were the best	Left Blank	Left Blank
81	Bonner Springs, KS	5	5	5	5	5	5	Exercises were helpful to apply technique	Left Blank	Left Blank
82	Bonner Springs, KS	5	5	4	4	4	4	module 5,6,7	first set of exercises dragged	Left Blank
83	Bonner Springs, KS	5	5	4	5	5	5	x-ing assessment	the part I missed	Left Blank
84	Bonner Springs, KS	5	5	5	5	5	5	great presenters. A little more crossing asment, less wayfinding	cant think of any	great workshop
85	Bonner Springs, KS	4	5	4	4	5	5	Calculations	a little long modules 1-3	Left Blank
86	Bonner Springs, KS	5	4	4	5	4	4	Left Blank	Left Blank	Left Blank
87	Bonner Springs, KS	4	4	4	4	4	4	the 'why' of details	none	Left Blank
88	Austin, TX	5	5	4	4	5	4	design concepts, practical applications	not well versed on higher math. Needed more time to absorb data	Good info
89	Austin, TX	5	5	5	5	5	5	Left Blank	Left Blank	Left Blank
90	Austin, TX	5	5	5	5	5	5	Left Blank	Left Blank	Left Blank

5 - Strongly Agree, 4 -Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly Disagree

Response #	Raleigh, NC Pilot Program	Instructors knowledge in the subject area	Instructors ability to effectively communicate the knowledge and skills of this course using examples and practice problems	Instructors receptiveness to my comments and needs	The handout materials were appropriate for the course	the course material was readable	I will use the course materials for future reference	This course was relevant to my current job	this course was necessary for career advancement	I would recommend this course to colleagues
92	Raleigh, NC	5	5	5	5	5	5	5	3	5
93	Raleigh, NC	5	4	5	3	4	4	4	4	3
94	Raleigh, NC	5	4	5	5	5	5	2	5	5
95	Raleigh, NC	5	4	5	5	5	4	4	3	4
96	Raleigh, NC	5	4	4	5	5	4	3	1	3
97	Raleigh, NC	5	4	4	5	5	4	4	4	4
98	Raleigh, NC	5	5	5	5	5	5	5	4	5
99	Raleigh, NC	5	5	5	5	5	5	5	4	5
100	Raleigh, NC	5	5	5	5	5	5	5	3	4

Response #	**Comments**	**Comments**	**Comments**	**Comments**	**Comments**	**Comments**
92	wayfinding training useful/transferable, to evaluating all other intersection designs + doing ADA activities	module 5-7 quickly for my planner/non-engineer brain.	EQ area slow but was expected	video of study participants would be helpful	Thanks for allowing discussion time	calculation task was confusing
93	Accessibility is an important component of design often overlooked	change yellow text in slides to orange	felt a little slow at times, especially during exercises		opened my eyes as to user(peds w/ disabilities) experience at intersection crossings	Good use of sensitivity training
94	Really great class	they were very knowledable	Covered as well as it can be		Math =(	I will be using this
95	review of RB designs in my work and very useful of treatments to be more aware of	excellent speakers	maybe a little faster		require we bring a calculator	this was my first roundabouts training
96	Very happy to have evidence based criteria to analyze crossing solutions	good mix of discussion, lecture, exercises	good one day overview		a little less examples	better understading
97	good, somewhat specialized topic. Interested how the industy adopts	knew material well	wish I had more knowledge coming in but it was a good pace		checklist speadsheet were great tools for walking through the problem	info was useful

5 - Strongly Agree, 4 -Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly Disagree

Response #	Raleigh, NC Pilot Program	Instructors knowledge in the subject area	Instructors ability to effectively communicate the knowledge and skills of this course using examples and practice problems	Instructors receptiveness to my comments and needs	The handout materials were appropriate for the course	the course material was readable	I will use the course materials for future reference	This course was relevant to my current job	this course was necessary for career advancement	I would recommend this course to colleagues
98		interesting that RFBS don't affect interbention rate	not an engineer, found some equations hard. Happy a spreadsheet exists	A bit fast pace for me		more discussion on electric vehicles; lightening, snow stockpiling. Some design solutions were only for warmer climates	this was my first real exposure to roundabout design. I fele informed on the approach that is needed to proceed with new approach to these concerns			
99		excellent topic. More people/engineers could use this class	spend less time descrbing photos	see previous comment		useful for agency staff, many of these issues and tradeoffs were new to them	class brought up issues with roundabouts that I had not considered before			
100		add statistics comparing corsses into blind people at standard intersections vs roundabouts	both presenters were well versed in theory and technical aspects	A tad dry at times but not too bad		wayfinding analysis went long	I don't design roundabouts, a roundable class would be necessary			
101		very good discussion of theory and design	presenters new material very well	topics covered well and at the appropriate pace	great presenters with thorough background material	great example problems with real worl practical situations	Im not confident in my designing skills based off lack of exerience independent of the class but I have a great understanding of key factors to look for when designing with visually impared in mind			
102		will use this material in practice in the near future					I am better able to take them into account when designing	excellent context and analysis techniques/ helpful for the specifics to make better decisions		
103		very helpful class					valuable training, I learned a lot	this was fantastic thanks		

5 - Strongly Agree, 4 -Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly Disagree

APPENDIX B – FINAL TRAINING MATERIALS

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TRB

Roundabouts and Channelized Turn Lanes: Access for Pedestrians, Particularly Those with Vision Disabilities

Module 1
Introduction and Overview

Photo: Lee Rodegerdts

KITTELSON & ASSOCIATES

Accessible Design for the Blind

Introduction and Overview

- Background
- Overview of NCHRP Report 834 and Web Document 222
- General Principles for Pedestrian Wayfinding & Crossing Tasks
- So Why Does This Matter?

Accessible Design for the Blind

Disclaimer

- The photographs in this module as used as illustrations and are not necessarily complete representations of desirable or undesirable practices in all aspects visible in the photograph.
- In many cases the sites included were designed before current good practices were developed and thus may not include what would be considered good practice today.
- In all cases, the context of the specific site location may have dictated the decisions that were made.
- That said, there may be opportunities to improve the accessibility of existing sites that fall short of desirable practices today.

BACKGROUND

Roundabout and Channelized Turn Lane Accessibility Challenges

Accessible Design for the Blind

Roundabout and CTL Accessibility Challenges

- **The crossing task for blind pedestrians**
  - Finding the crosswalk
  - Aligning to cross
  - Deciding when it is safe to cross
  - Maintaining alignment during crossing

- **Confounding challenges**
  - Uninterrupted flow (no signal)
  - Potentially high speeds
  - Ambient noise at crosswalk
  - Non-straight geometry
  - Low driver yield compliance

- **Treatments are available and can help**

Accessible Design for the Blind

Americans with Disabilities Act (1990)

- **Civil rights law**
- **Title II applies to state and local government services**
- **Applies to all programs and activities regardless of funding source**
- **New construction and alterations in public accommodations and commercial facilities (Sec. 12183)**
  - "…Discrimination … includes … a failure to design and construct facilities … that are readily accessible to and usable by individuals with disabilities, except where an entity can demonstrate that it is structurally impracticable to meet the requirements …" (emphasis added)
  - "… with respect to a facility … that is altered by, on behalf of, or for the use of an establishment…, a failure to make alterations in such a manner that, to the maximum extent feasible, the altered portions of the facility are readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs." (emphasis added)

Accessible Design for the Blind

Adapted from www.apsguide.org, Module A, Slide 20; https://www.ada.gov/pubs/adastatute08.htm

Americans with Disabilities Act Accessibility Guidelines (ADAAG) (1991/2010)

- Adopted as a final rule (enforceable standard) by DOJ and DOT in 1992
- Minimum technical provisions for access
- Section on public rights-of-way, originally Section 14 of ADAAG, was not issued as a final rule at that time
- Updated in 2010

Accessible Design for the Blind

Adapted from www.apsguide.org, Module A, Slide 21

Americans with Disabilities Act Accessibility Guidelines (ADAAG) (1991/2010) (cont.)

- **Section 103: Equivalent Facilitation**
- "Nothing in these requirements prevents the use of designs, products, or technologies as alternatives to those prescribed, provided they result in substantially equivalent or greater accessibility and usability."
- **Advisory 103 Equivalent Facilitation**
- "The responsibility for demonstrating equivalent facilitation in the event of a challenge rests with the covered entity. With the exception of transit facilities, which are covered by regulations issued by the Department of Transportation, there is no process for certifying that an alternative design provides equivalent facilitation."

Proposed Guidelines for Public Rights-of-Way (2011)

- **R306.3.1, Separation**
  - Detectable separation between sidewalk and street between crosswalks at roundabouts
- **R306.3.2, Pedestrian Activated Signal**
  - Pedestrian-activated signals with accessible pedestrian signals (APS) required for pedestrian crossings across each multilane segment
- **R306.3.4, Channelized Turn Lanes at Roundabouts**
  - Pedestrian-activated signals with APS required for pedestrian crossings at multilane channelized turn lanes
- **R306.3.5, Channelized Turn Lanes at Other Signalized Intersections**
  - Pedestrian-activated signals with APS required for pedestrian crossings at multilane channelized turn lanes
- **http://www.access-board.gov/prowac/**

Accessible Design for the Blind

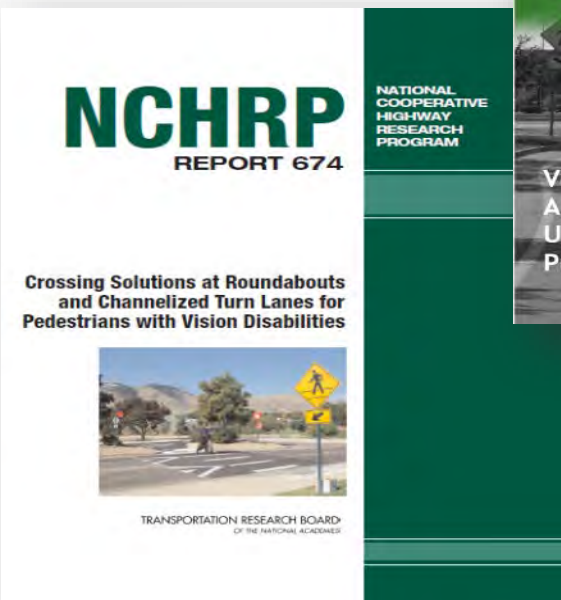
Bottom Line

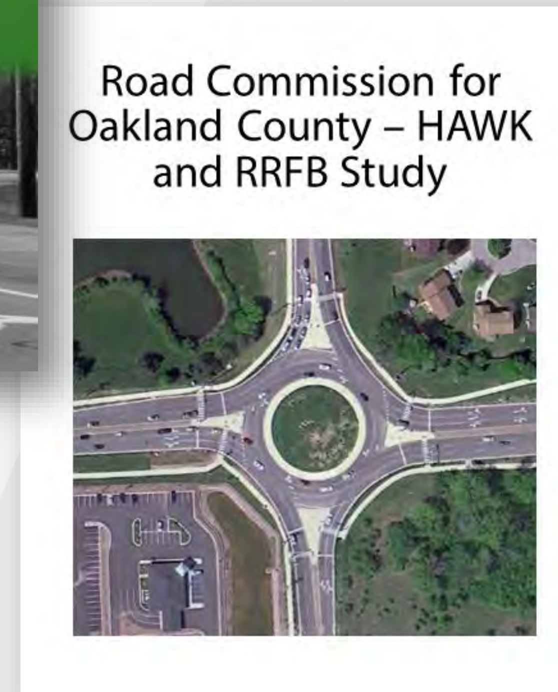
- ADA requires newly constructed or altered facilities to be accessible to the maximum extent feasible even if specific standards are not finalized
- ADA compliance is a civil rights issue
- Following MUTCD standard may not prevent ADA complaint being filed
  - Need to respond to concerns of pedestrians with disabilities
- FHWA encourages use of the proposed PROWAG as best practice

Accessible Design for the Blind

Adapted from www.apsguide.org, Module A, Slide 28

Prior Research and Literature on Roundabout Accessibility





OVERVIEW OF NCHRP REPORT 834 AND WEB DOCUMENT 222

Guidelines for the Application of Crossing Solutions at Roundabouts and Channelized Turn Lanes

Accessible Design for the Blind

NCHRP Report 834 - Goals and Objectives

- Provide useful and implementable guidance
- Define feasible range of geometric and traffic operational conditions
- Target planning and preliminary design stage
- Supported by empirical data and modeling – 4,400+ street crossings with blind participants studied since 2004
- Useful for a broad audience
- Decision-support tool for practicing engineers


Photo: Janet Barlow

PHB in Oakland County, MI


Photo: Bastian Schroeder

Speed Hump in Kissimmee, FL

Accessible Design for the Blind

NCHRP Report 834 and Web-Only Document 222 (Published Jan 2017)

Accessible Design for the Blind

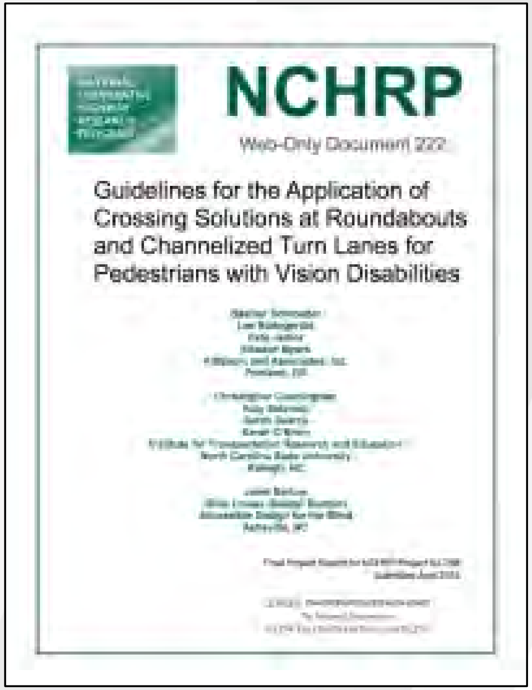
NCHRP Report 834 - Outline

1. Introduction
2. Design Process
3. General Principles for Pedestrian Wayfinding and Crossing Tasks
4. Design Principles for Pedestrian Access at Roundabouts
5. Design Principles for Pedestrian Access at Channelized Turn Lanes
6. Wayfinding Assessment
7. Crossing Assessment
8. References
9. Appendix A – Discussion of Audible Environment and Noise Effects
10. Appendix B – Summary of Crossing Treatments

Accessible Design for the Blind

NCHRP Web-Only Document 222 - Outline

1. Introduction
2. Literature Review
3. Methodology
4. Field Study Results
5. Modeling and Applications
6. Conclusions and Recommendations
7. Appendix A: Wayfinding Data Details
8. Appendix B: Yield Model Details
9. Appendix C: Risk Model Details
10. Appendix D: Crossing Sight Distance Details
11. Appendix E: Site Photo Logs
12. Appendix F: Detailed Field Study Results



Accessible Design for the Blind

GENERAL PRINCIPLES FOR PEDESTRIAN WAYFINDING & CROSSING TASKS

Accessible Design for the Blind

Travel by pedestrians who are blind

- **Limitations in vision can affect**
  - Ability to judge traffic approach speed and distance
  - Understanding drivers' intentions
  - Ability to recognize crosswalk location
  - Detection of curbs or islands, or curb ramps
- **Pedestrians who are blind DO travel to new unfamiliar intersections and cross**
  - Pedestrians who are blind do not receive ongoing training
  - Do not receive training or orientation to every location where they may cross the street
  - Most individuals who are blind do not use dog guides, and dog guides do not decide when to cross

Two categories of street crossing tasks

- **Wayfinding tasks**
  - Determining the appropriate crossing location
  - Aligning to cross (establishing a correct heading)
  - Maintaining the correct heading while crossing (staying in the crosswalk)
- **Crossing tasks**
  - Determining when to initiate crossing (accepting an appropriate gap or yield crossing opportunity)

Photo: Janet Barlow

Accessible Design for the Blind

Determining the appropriate crossing location

- **Typical techniques**
  - Stop when contact curb or edge of street in front of them
  - Some people may search for a curb ramp and/or detectable warning surface to confirm crossing location
  - Follow along landscape strip looking for any opening toward street

Photo: Janet Barlow

Landscaping or fencing may provide guidance to crosswalk location

Photo: Janet Barlow

Photo: Lukas Franck

Accessible Design for the Blind

What is Detectable to People with LOW Vision?

- **Detectable**
  - High-visibility crosswalk markings (ladder, zebra)
- **NOT Reliably Detectable**
  - Low-visibility crosswalk markings (parallel lines)
  - Colored concrete

What is Detectable by Cane or Foot for People Who Are Blind?

- **Detectable:**
  - Curb edges
  - Gravel (loose or embedded in concrete)
  - Grass and landscaping areas
  - Truncated domes (detectable warning surfaces, or DWS)
    - **When ramps were introduced to assist wheelchairs, DWS were established to replace the curb previously used by blind people to edge detection**
- **NOT Detectable (or not detectably different from a normal sidewalk):**
  - Small changes in grade (e.g., top and bottom of ramp)
  - Changes from asphalt to concrete
  - Scoring in concrete
  - Paint, thermoplastic, or other striping materials
  - Colored concrete
  - Stamped concrete

Accessible Design for the Blind

What Can Dog Guides Do and Not Do?

- **Dog Guides Can:**
  - Follow directions from their handler
  - Follow a path
  - Stop at curbs, usually stop at ramps
- **Dog Guides CANNOT:**
  - Make decisions about when to cross
  - Follow crosswalk lines

Guidance needed to crossing location on islands too

Photo: Janet Barlow

- Island may be cut-through or ramped
- Detectable warnings to indicate location of street at edge of street at cut-through paths or at base of ramp
- Gravel or grass outside of walking area to indicate area is not the walking path

Accessible Design for the Blind

Aligning to cross (establishing a correct heading)

- **Typical techniques**
  - Maintain approach alignment
  - Align with parallel traffic (traffic on the street beside them)
  - Align with perpendicular (traffic on the street they are crossing)
  - May try to use slope of ramp, alignment of curb or gutter, or detectable warning surface (truncated domes)

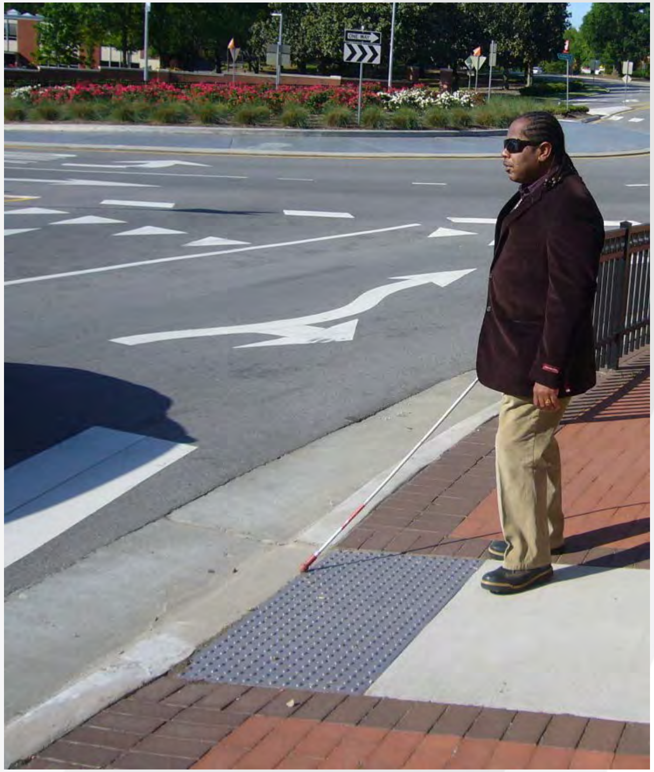


Photo: Janet Barlow

Accessible Design for the Blind

Alignment cues

Using returned curb, DWS, and gutter on ramp may help with alignment

Using returned curb, DWS, and gutter will result in poor alignment for this crossing

Accessible Design for the Blind

Maintaining the correct heading while crossing (staying in the crosswalk)

Photo: Beezy Bentzen

- Typical techniques
  - Travel parallel to straight-ahead traffic on the street beside them as they cross
- **Not possible at roundabouts or CTLs since no traffic traveling parallel to crosswalk**
  - Somewhat mitigated by shorter crossings, if the starting heading is correct

Accessible Design for the Blind

Typical Crossing Strategies

- **At signalized crossings**
  - Cross with the surge of traffic on the street parallel to their crosswalk
  - Confirm with accessible pedestrian signal, if present
- **At unsignalized crossings**
  - Cross when there is no traffic audible on the street they are crossing
    - **Less effective as traffic volume increases and large gaps become rare**
    - **Audible environment at roundabouts makes “all-quiet” unlikely due to masking sounds from other traffic**
  - Cross when yielding traffic is detected
    - **Difficulty detecting and confirming yields without vision**
    - **Vehicles may begin moving again just as pedestrian who is blind detects yielding vehicle**

SO WHY DOES THIS MATTER?

Roundabout and Channelized Turn Lane Accessibility Challenges

Accessible Design for the Blind

So Why Does This Matter?

- **Some common questions that arise:**
  - Don’t crossing treatments add cost?
  - Aren’t roundabouts supposed to get rid of signals?
  - Won’t this reduce the number of projects we can construct?
  - Why do this when I see very few blind people at this roundabouts, or for that matter, very few people at all?

- **What are your thoughts on these questions?**

Accessible Design for the Blind

Don’t crossing treatments add cost?

- Yes, although some treatment types are significantly less expensive than others
- Important to look at life-cycle costs, not just initial construction costs
- The treatment costs may be a relatively small percentage of the total cost of construction, much less the total life-cycle cost

Aren’t roundabouts supposed to get rid of signals?

- **Roundabouts and signals are not mutually exclusive**
- **Roundabouts’ greatest strength:**
  - Geometric shape that physically eliminates the most severe conflict types and minimizes the severity of others
  - Yield control at entry that allows efficient use of the intersection over a wide range of volumes from very low to quite high
- **Signals’ greatest strength:**
  - Assignment of right-of-way in priority orders that we deem most important
  - Flexibility to control a wide range of situations
- **The two together provide the best combination of safety and operational flexibility**

Won’t this reduce the number of projects we can construct?

- It could, assuming the only metric of success is the number rather than the quality of the projects built
- A project that is built that provide access to one portion of the walking population but not to another portion should not be considered a success

Why do this when I see very few blind people at this roundabouts, or for that matter, very few people at all?

- The provision of accessibility benefits all users of the intersection
- If the intersection and connecting system prove to be usable by everyone, the demand for the system will increase
- AND: It’s a matter of civil rights

Accessible Design for the Blind

TRB

Roundabouts and Channelized Turn Lanes: Access for Pedestrians, Particularly Those with Vision Disabilities

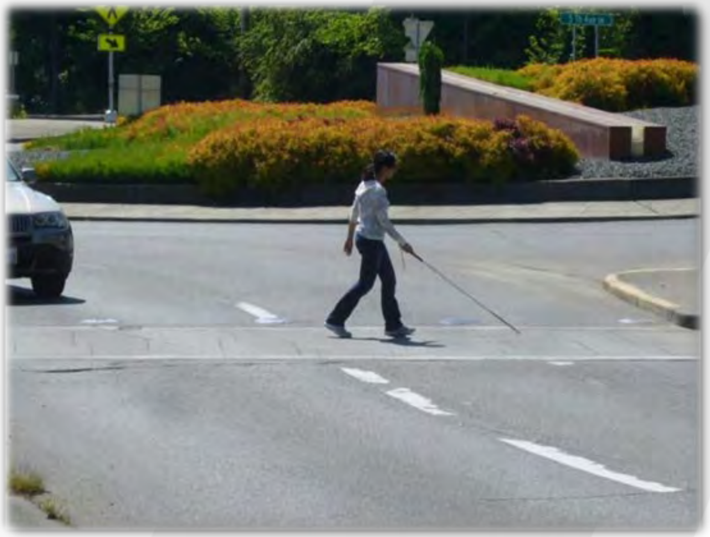


Photo: Janet Barlow

Module 2

Design Process and Concepts

KITTELSON & ASSOCIATES

Accessible Design for the Blind

Introduction and Overview

- Roundabout Design Process and Concepts
- Channelized Turn Lane Design Process and Concepts
- Overview of Possible Crossing Treatments

Guidebook

1. Introduction
2. **Design Process**
3. General Principles for Pedestrian Wayfinding & Crossing Tasks
4. **Design Principles for Pedestrian Access to Roundabouts**
5. **Design Principles for Pedestrian Access to CTLs**
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Accessible Design for the Blind

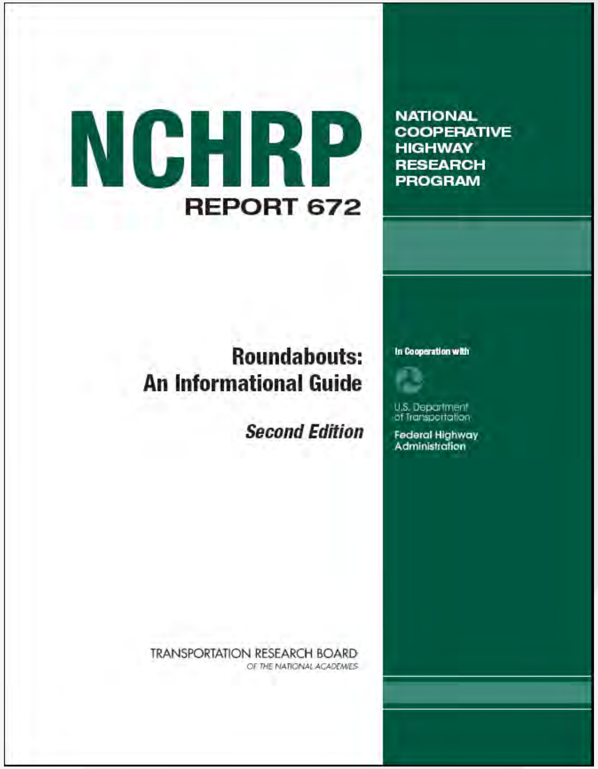
ROUNDABOUT DESIGN PROCESS AND CONCEPTS

Guidelines for the Application of Crossing Solutions at Roundabouts and Channelized Turn Lanes

Accessible Design for the Blind

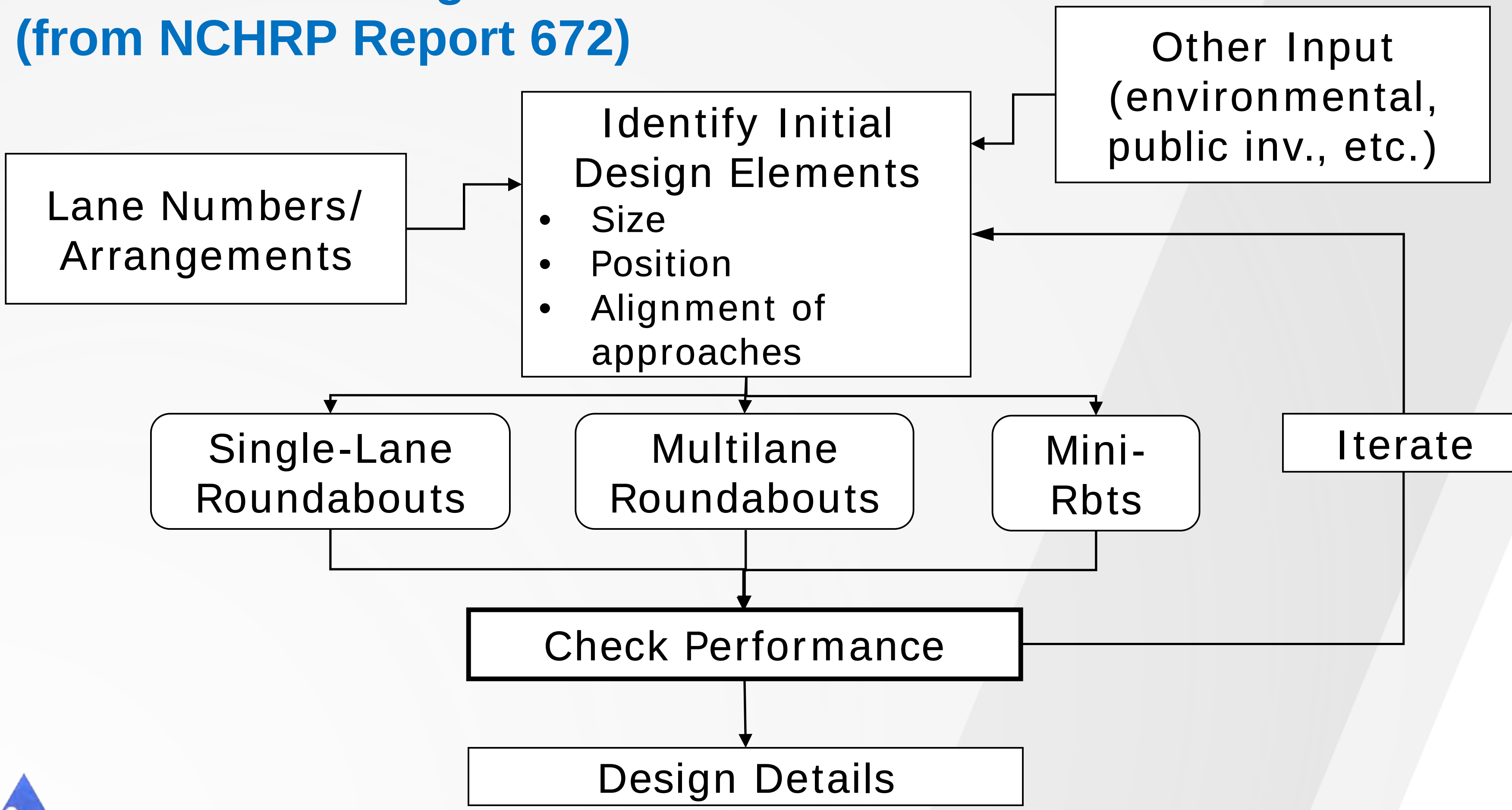
Design Process for Roundabouts

- **NCHRP Report 672: Roundabouts: An Informational Guide, Second Edition**
- **Key attributes:**
  - Performance-based
  - Iterative

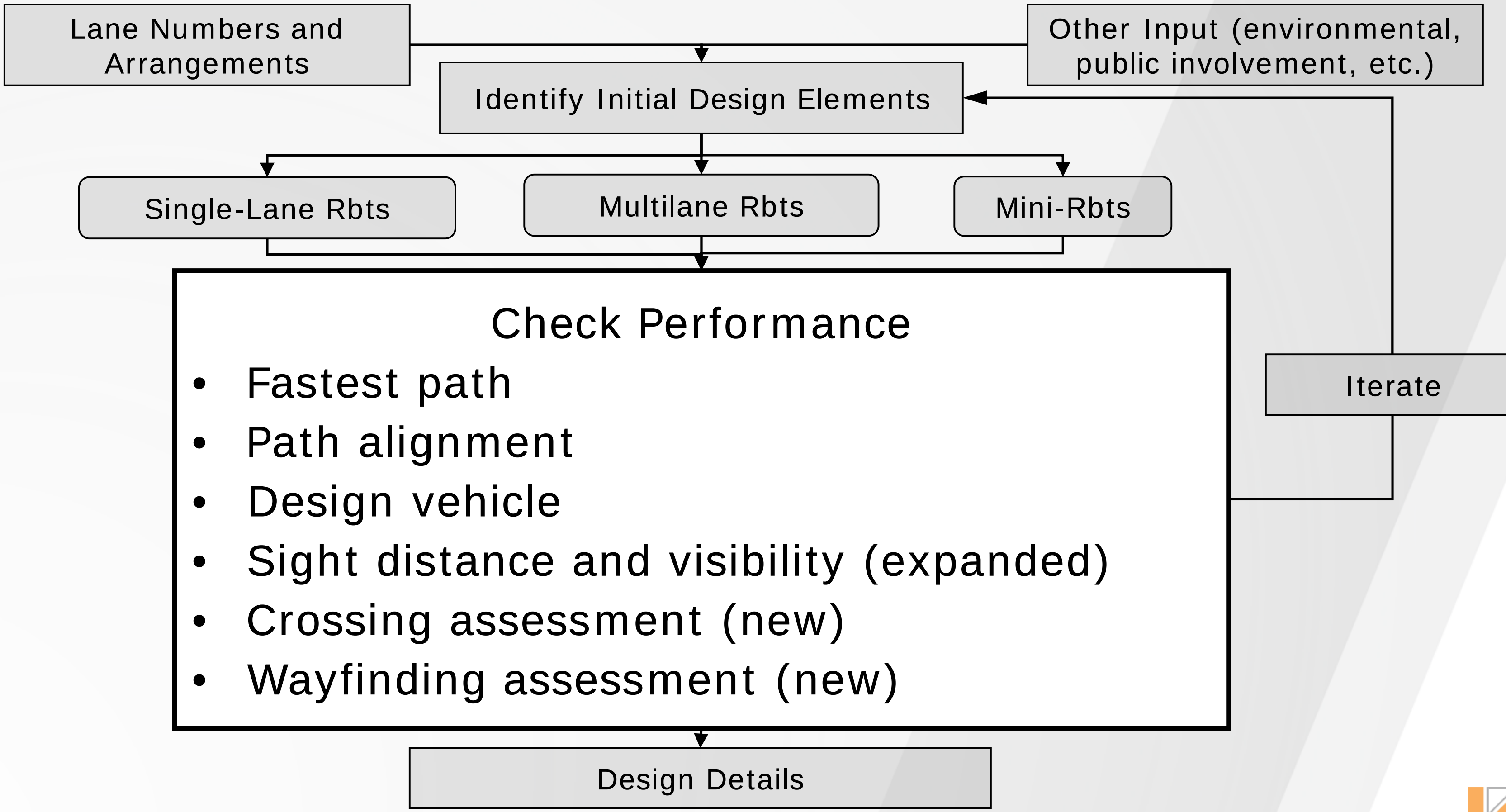


Accessible Design for the Blind

Roundabout Design Process (from NCHRP Report 672)



Roundabout Design Process



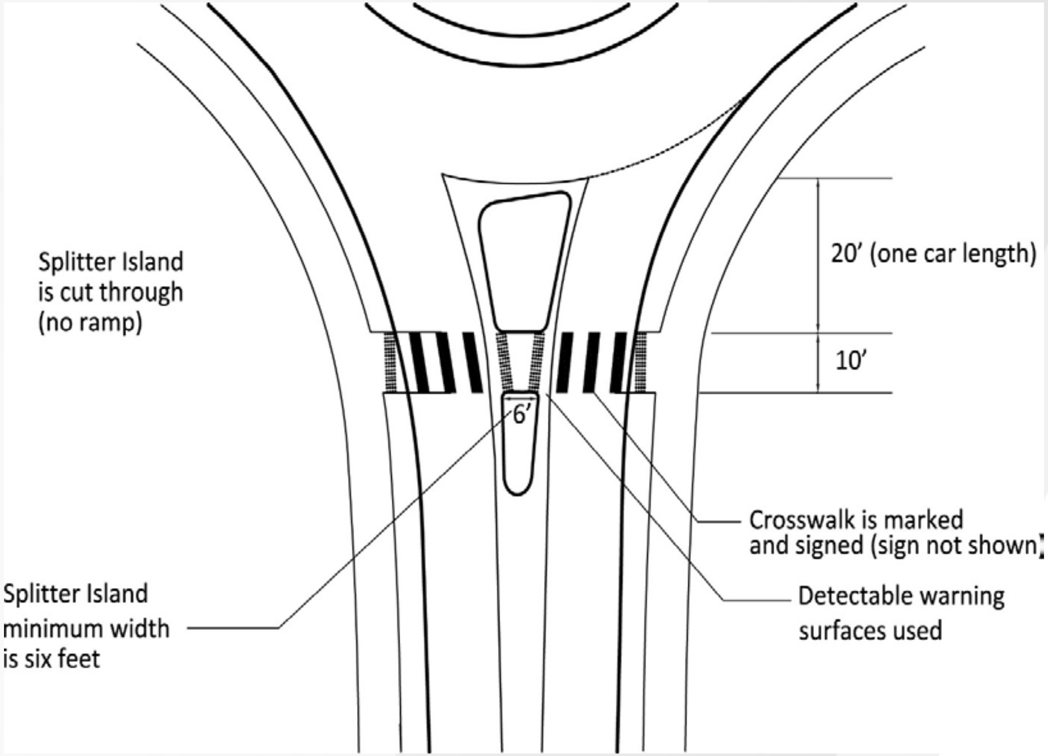
Accessible Design for the Blind

Ramp Design

- Specified by ADAAG Section 4.7
- Maximum slope of travel way: 1:12 (1 inch rise per foot)
- Maximum slope of flared sides: 1:10
- Slope must be parallel to the direction of travel
  - Otherwise creates tipping challenge for wheelchairs
- Detectable warning surface at bottom of ramp
  - Minimum 2-ft depth
  - Extend across entire width of ramp
- Level landing area at top of ramp (if perpendicular), minimum 4-ft square to enable wheelchair to turn in place and wait

Typical Crosswalk Design at Single-Lane Roundabout

- **Key features:**
  - Crosswalk set back to separate conflicts
  - Two-stage crossing
  - Detectable warnings at all hazard boundaries

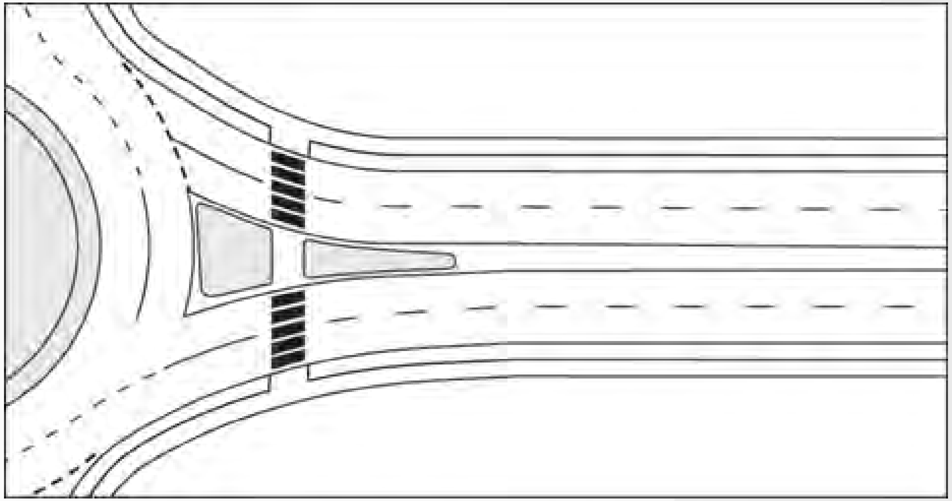


NCHRP Report 834, Figure 4-1

Accessible Design for the Blind

Alignment Options for Crosswalk: Straight Alignment

- Longer crossing distance
- Larger refuge area
- Difficult to orient curb ramp to make it perpendicular to slope for wheelchairs

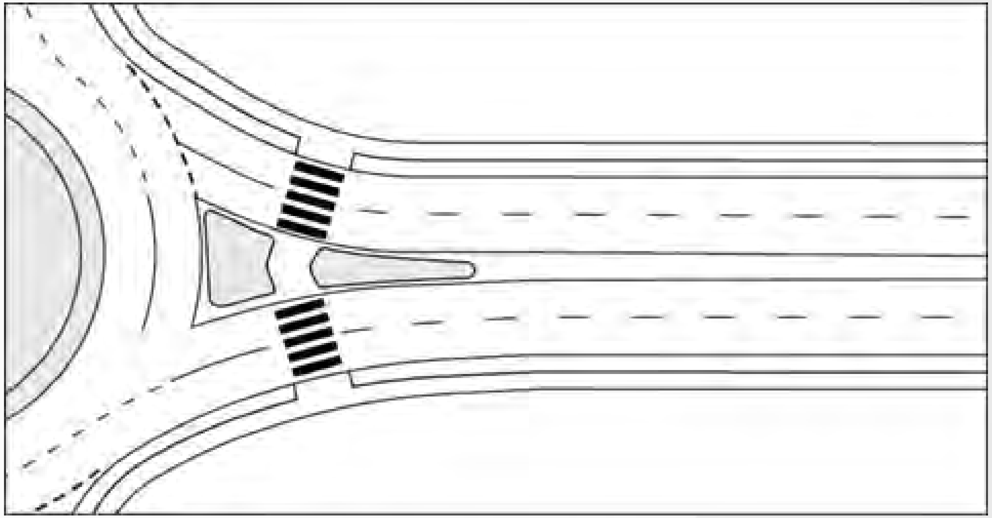


NCHRP Report 834, Figure 4-2

Accessible Design for the Blind

Alignment Options for Crosswalk: Angled Alignment

- Shortest crossing distance
- Perpendicular to curb ramps
- Angle point needs to be substantial enough to have its alignment be detectable

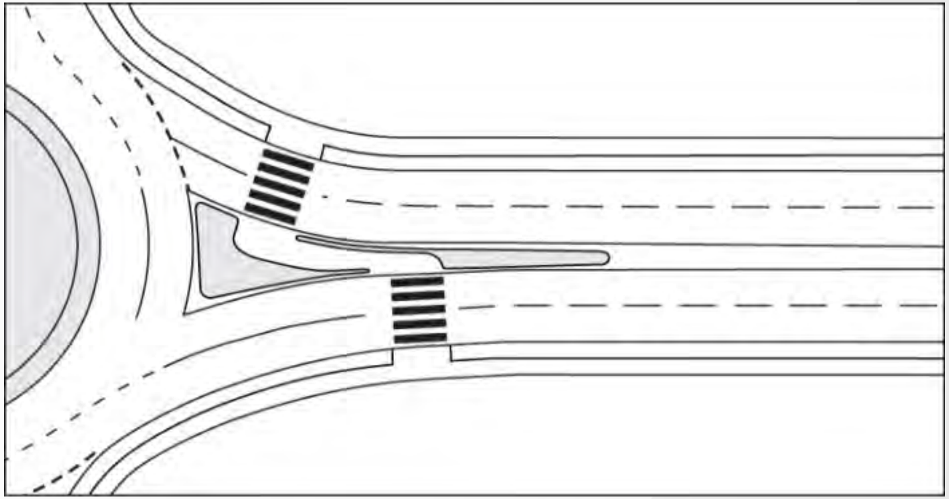


NCHRP Report 834, Figure 4-3

Accessible Design for the Blind

Alignment Options for Crosswalk: Staggered Alignment

- More visibility and reaction time for drivers to see pedestrians and active traffic control devices (if used)
- More room for queuing
- More impact to width of splitter island
- More challenging to maintain (e.g., snow removal)

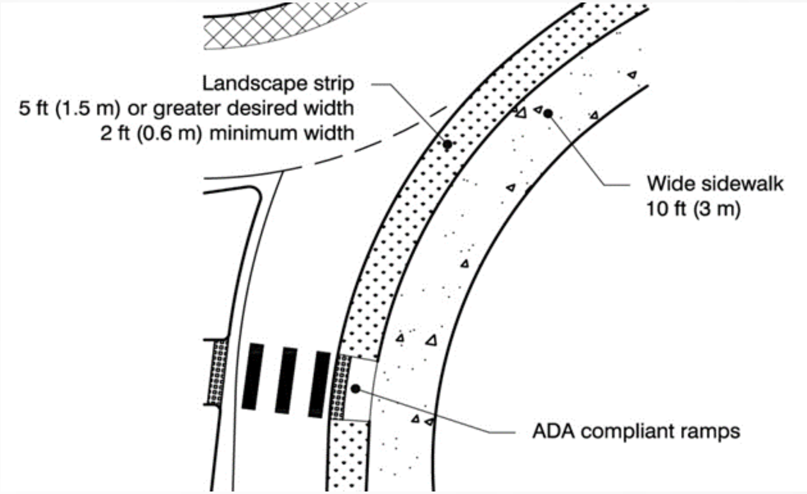


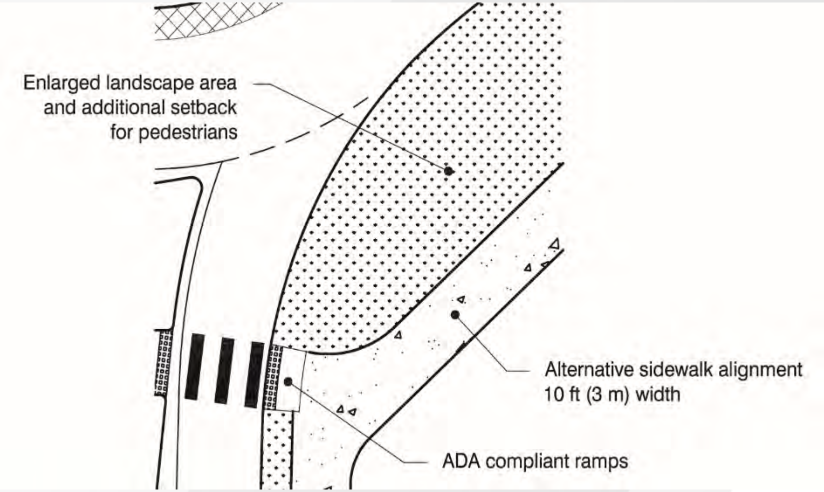
NCHRP Report 834, Figure 4-4

Accessible Design for the Blind

Sidewalk Alignment

- 10-ft minimum width for shared bicycle-pedestrian use
- Landscape or other detectable separation needed between sidewalk and circulatory roadway (PROWAG R306.3.1)



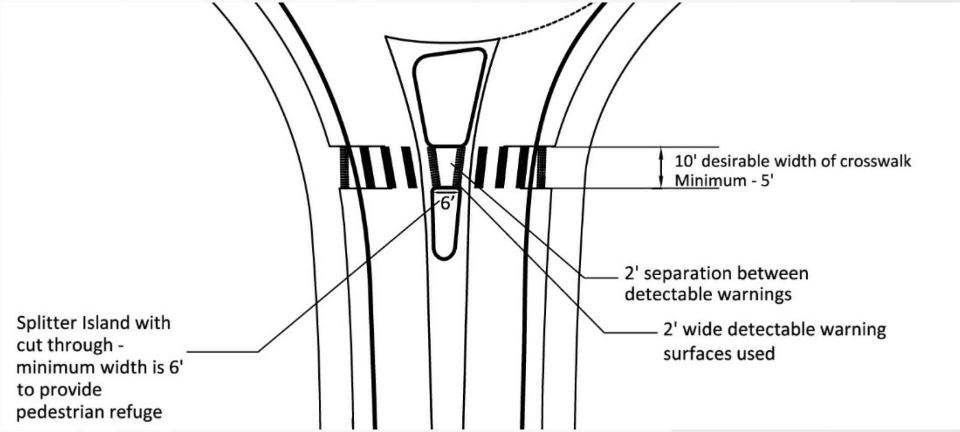


NCHRP Report 834, Figure 4-6 and 4-7

Accessible Design for the Blind

Splitter Island: Level Crossings (cut-through path or raised crosswalks)

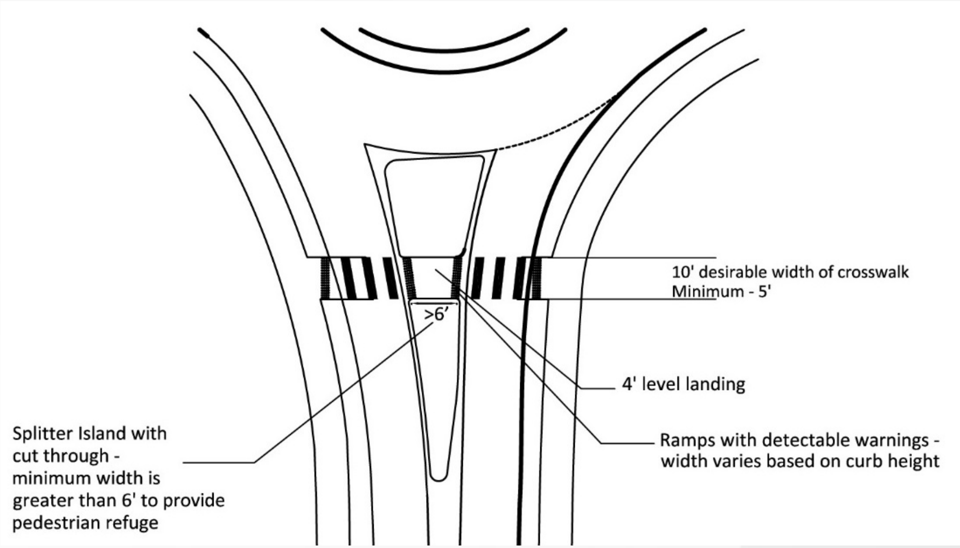
- 6-ft minimum width required at narrowest point in splitter island at crossing = 2-ft detectable warning (DW), minimum of 2-ft gap between DWs, 2-ft DW
- Also accommodates bicycle, person pushing stroller
- More width is more comfortable for all pedestrians



NCHRP Report 834, Figure 4-19

Splitter Island: Raised Path with Ramps

- Ramped island requires wider splitter island to provide 4-ft-square level landing at top of ramps

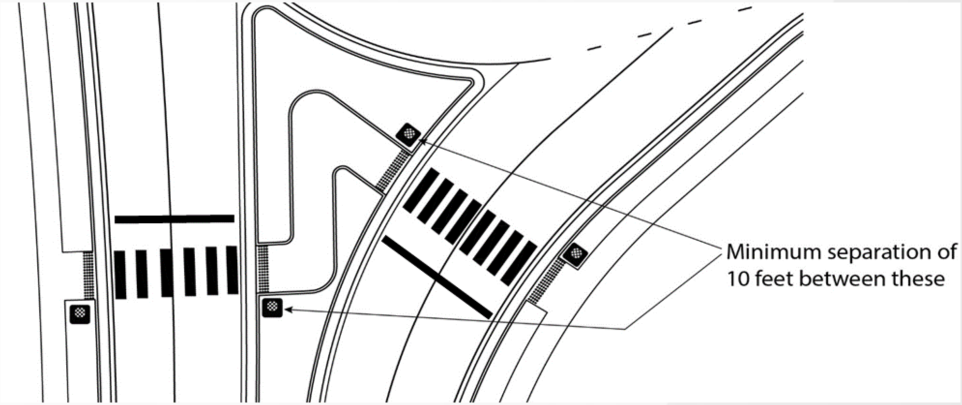


NCHRP Report 834, Figure 4-20

Accessible Design for the Blind

Location of Audible Information Device Pushbuttons

- Minimum 10-ft separation between APS pushbuttons
- Speech or tone indications
- Tactile arrow to provide help with alignment
- Vibrates during WALK interval
- Devices better on downstream side to avoid audible conflict with oncoming traffic



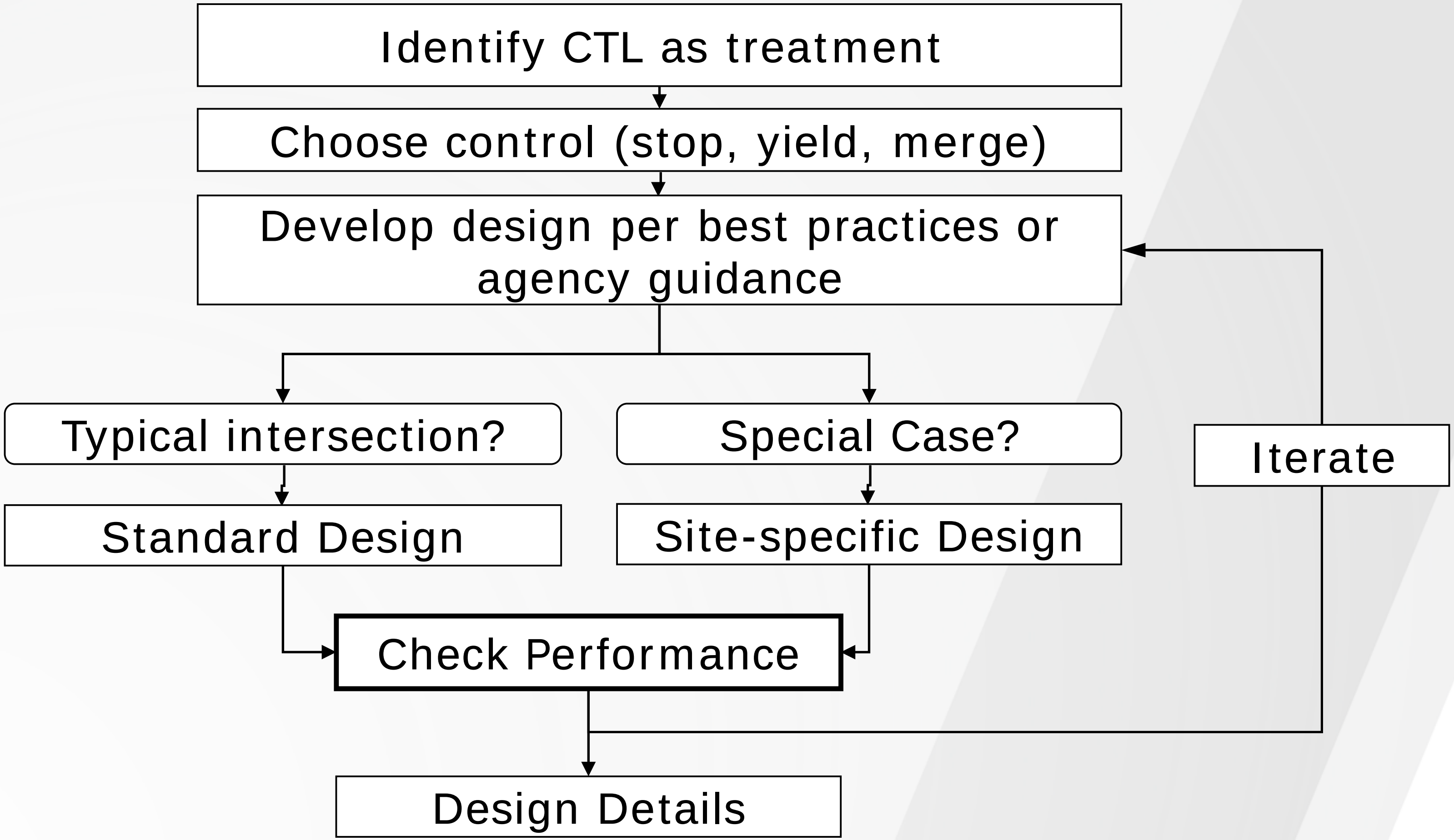
NCHRP Report 834, Figure 4-26

Accessible Design for the Blind

CHANNELIZED TURN LANES DESIGN PROCESS AND CONCEPTS

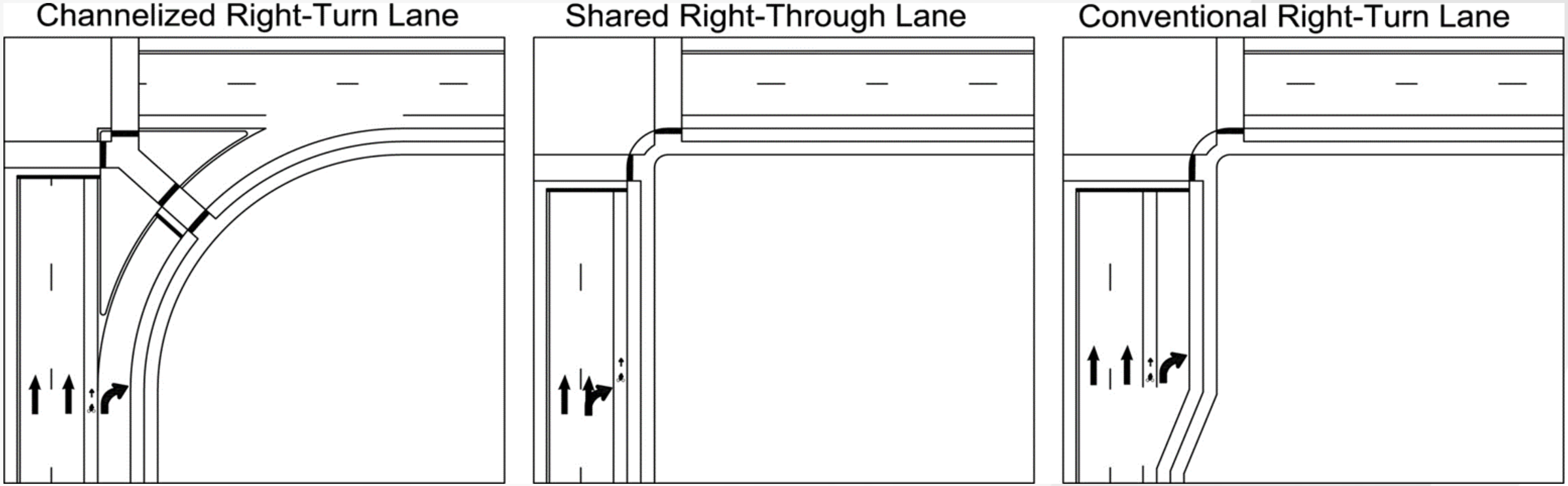
Accessible Design for the Blind

Channelized Turn Lane Design Process



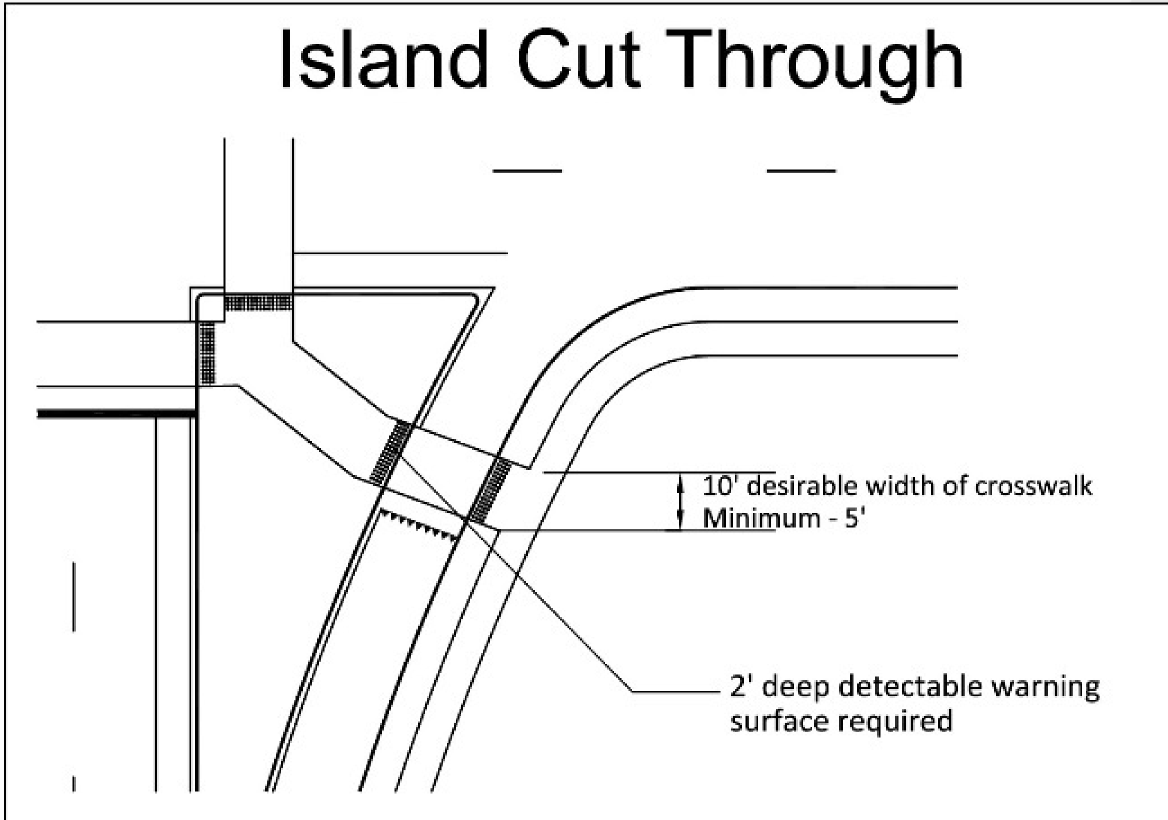
Accessible Design for the Blind

Types of Right-Turn Lanes



NCHRP Report 834, Figure 5-1

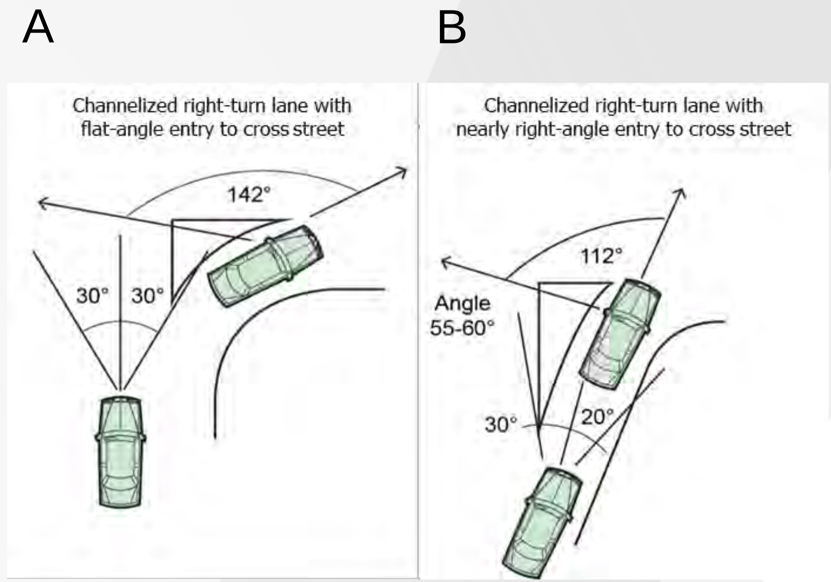
Typical Dimensions of CTL Pedestrian Path



NCHRP Report 834, Figure 5-4

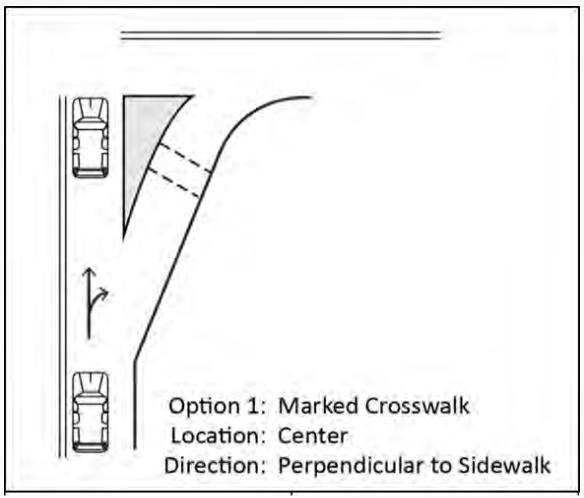
Entry Angle

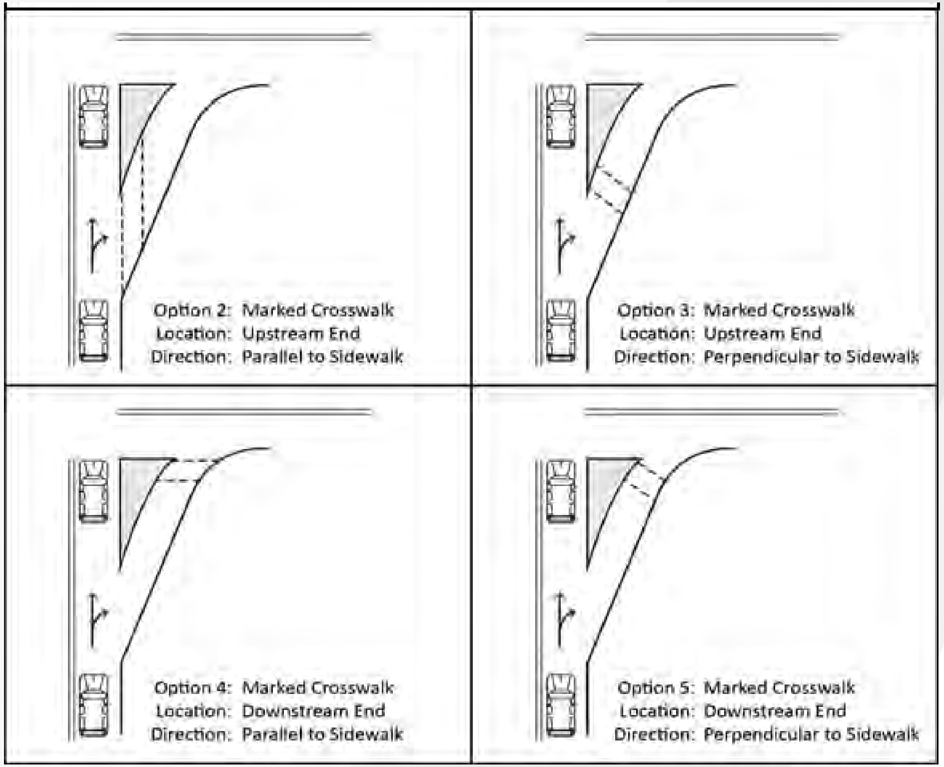
- **Large angle in A creates multiple challenges**
  - Difficult to turn head to left (especially older drivers)
  - Reduces attention in front of car and to right where pedestrians may be
  - Puts driver in acceleration mode rather than yielding mode



NCHRP Report 834, Figure 5-6

Crosswalk Alignment Options Considered



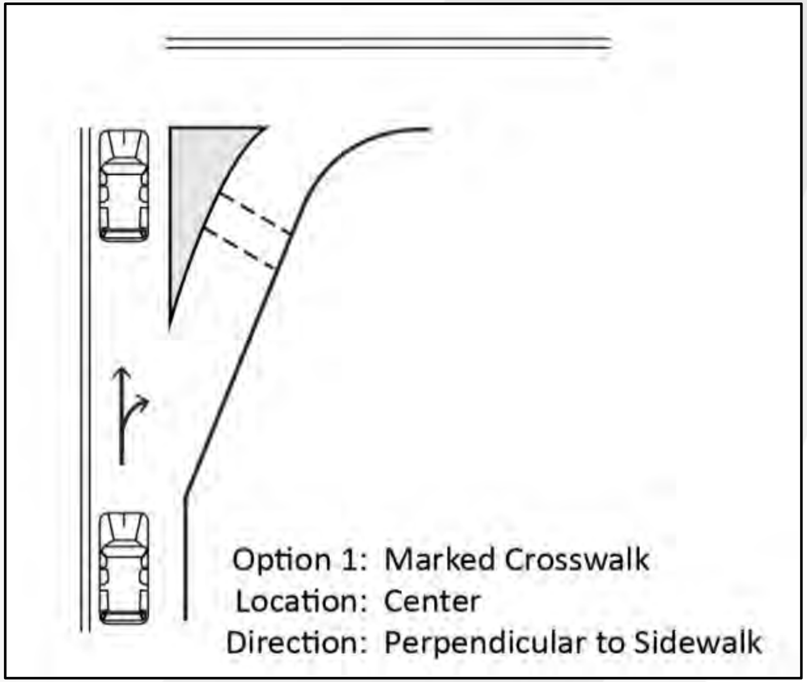


NCHRP Report 834, Figure 5-7

Accessible Design for the Blind

General CTL Design Recommendations (1/2)

- Centered crosswalk location is preferred
  - Site-specific exceptions may be necessary
- Crossing is at a 90 degree angle
- Out-of-direction travel equally distributed among pedestrian routes
- Ramps are both perpendicular to the sidewalk and aligned with the crosswalk
- Good visibility
  - Crosswalk is visible to approaching drivers
  - Clear line of sight is provided between pedestrians and approaching drivers

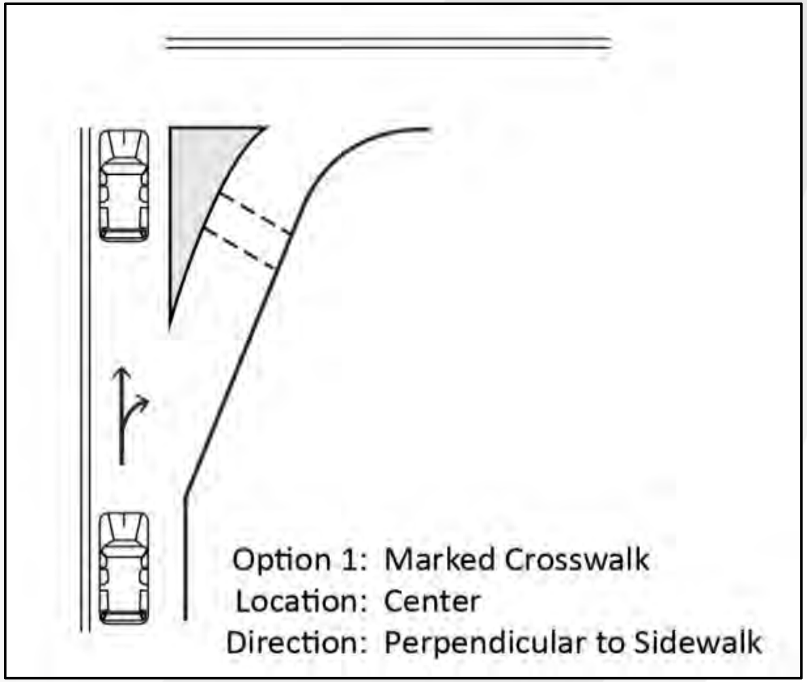


NCHRP Report 834, Figure 5-8

Accessible Design for the Blind

General CTL Design Recommendations (2/2)

- **Crosswalk may provide sufficient space for one-vehicle length of storage between the crosswalk and that stop or yield line (similar to the entry to a roundabout);**
- **Crosswalk location is likely to separate driver decision points**
  1. Interacting with the pedestrian
  2. Interacting with downstream vehicle traffic.
- **Better for wayfinding**
  - Island provides sufficient raised area on either side of the crosswalk
  - Minimizes the chance of pedestrians missing the island and stepping into the travel lanes (known as "veering")



NCHRP Report 834, Figure 5-8

OVERVIEW OF POSSIBLE CROSSING TREATMENTS

Accessible Design for the Blind

Treatments can enhance accessibility

1. **Treatments geared at reducing vehicle speeds through geometric modifications**
   – Includes speed humps, raised crosswalk, or geometric changes
2. **Treatments geared at enhancing the visibility of the crosswalk and alerting drivers**
   – Includes pedestrian actuated flashing beacons and other beacons
3. **Treatments geared at providing additional audible information to blind pedestrians**
   – Includes sound and rumble strips
4. **Treatments geared at stopping traffic and creating crossing opportunities**
   – Includes pedestrian hybrid beacons and other pedestrian signals

Raised Crosswalk

Photo: Bastian Schroeder

Pedestrian Actuated Flashing Beacon

- Governed by MUTCD Chapter 4L, Flashing Beacons
- One or more circular yellow indication
- If two indications are used, may be flashed simultaneously or alternately
- Flash rates of 50 to 60 flashes per minute
- Audible message: "Yellow lights are flashing, yellow lights are flashing."

Rectangular Rapid Flashing Beacon (RRFB)

- **NOTE: Interim Approval 21 (IA-21) for optional use of RRFBs issued on March 20, 2018. This replaces the IA terminated by FHWA on December 21, 2017**

Photo: Bastian Schroeder

Accessible Design for the Blind

Pedestrian Hybrid Beacon (PHB)

- **Audible messages:**
  - "Wait" or slow tick
  - "Walk signal is on to cross Maple Road" or rapid tick

Photos: Bastian Schroeder

Accessible Design for the Blind

Pedestrian Hybrid Beacon (PHB) Operation

Note: 2009 MUTCD allows option of pedestrian display to rest in dark at roundabouts (Section 4F.03)

Note: No green ball to cause possible confusion with yield sign

Accessible Design for the Blind

Other Treatments Considered in NCHRP Project 3-78b Research

- In-pavement signs
- Stop-controlled CTL

Photos: Bastian Schroeder

TRB

Roundabouts and Channelized Turn Lanes: Access for Pedestrians, Particularly Those with Vision Disabilities

Photo: Janet Barlow

Module 3
Wayfinding Assessment

KITTELSON & ASSOCIATES

Accessible Design for the Blind

Guidebook

1. Introduction
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Accessible Design for the Blind

Format of Wayfinding Assessment

- **Series of questions about each task**
- **Brief text information about each question**
- **Table**
  - Questions, with reference to section of guide for details
  - Note if feature is required

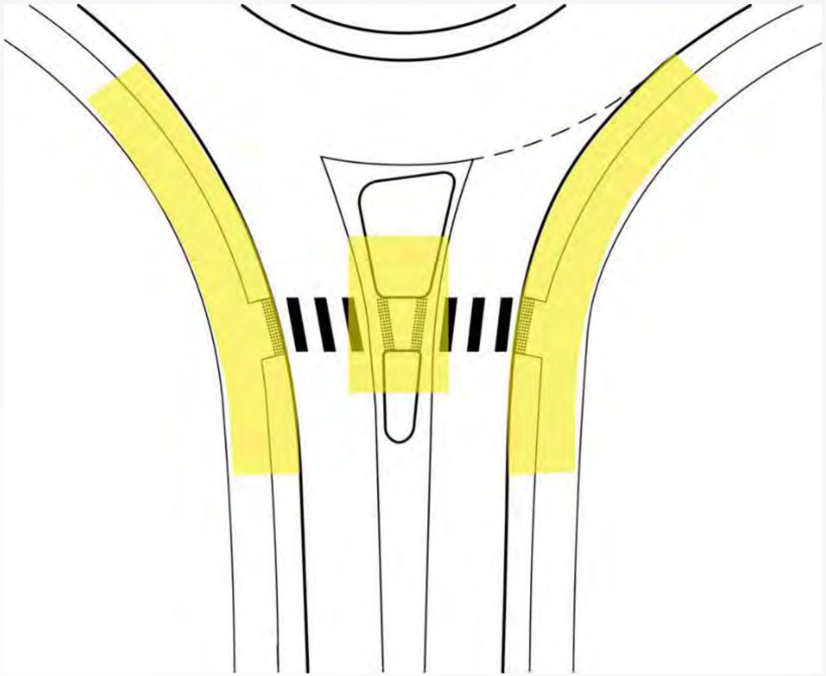
1. Do sidewalks lead to the crosswalks?	• See Section 4.1 and 5.1 for details
2. Is separation provided between sidewalk and curb?	• See Section 4.1 and 5.1 for details • Required by PROWAG-NPRM at roundabouts; good practice at CTLs
3. Is the edge of the street clearly defined by detectable warning surfaces?	• See Section 4.1 and 5.1 for details • Required by Department of Transportation ADA regulations and PROWAG-NPRM

Accessible Design for the Blind

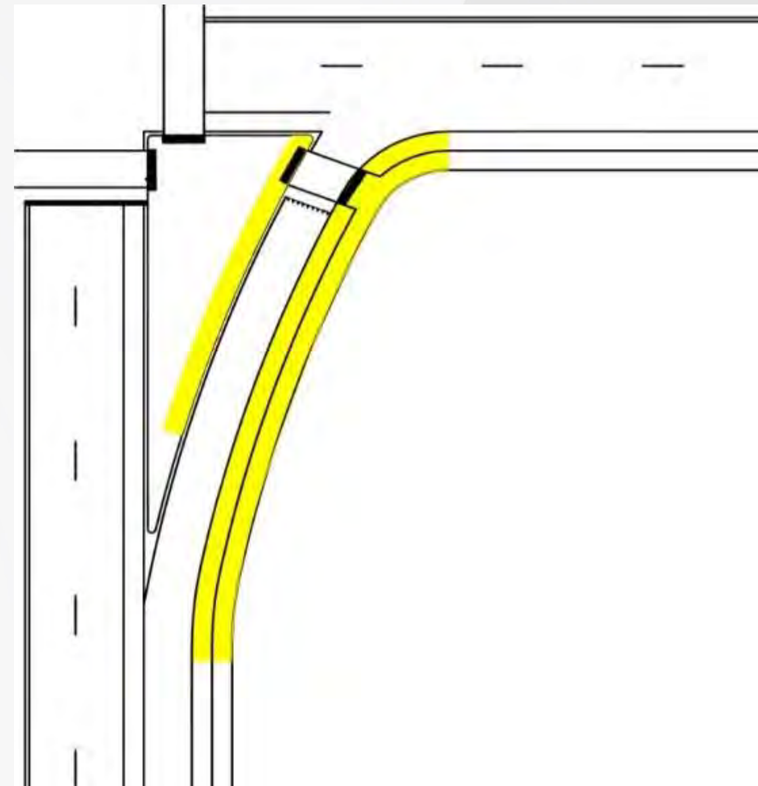
Wayfinding Assessment Question Categories

6.1. Determining the crossing location
6.2. Aligning to cross and establishing a correct heading
6.3. Maintaining correct heading while crossing (staying within the crosswalk)
6.4. Crossings from channelization and splitter islands

6.1. Determining the Crossing Location



Source: NCHRP Report 834



Source: NCHRP Report 834

6.1.1. Do sidewalks lead to the crosswalks? (1/5)

Desirable

Photo: Lee Rodegerdts

Undesirable

Photo: Lee Rodegerdts

Accessible Design for the Blind

6.1.1. Do sidewalks lead to the crosswalks? (2/5)

Desirable

Source: © Google 2017

Undesirable

Source: © Google 2017

Accessible Design for the Blind

6.1.1. Do sidewalks lead to the crosswalks? (3/5)

Undesirable

Photo: Janet Barlow

Accessible Design for the Blind

6.1.1. Do sidewalks lead to the crosswalks? (4/5)

Undesirable: No sidewalk or ramp but crosswalk marked and signed

Source: © Google 2017

Photo: Lee Rodegerdts

Accessible Design for the Blind

6.1.1. Do sidewalks lead to the crosswalks? (5/5)

Undesirable: Break in guardrail to provide "access" but no sidewalk or ramp

Source: © Google 2017

Photo: Lee Rodegerdts

Accessible Design for the Blind

6.1.2. Is separation provided between sidewalk and curb? (1/3)

Desirable: Detectable buffer

Photo: Katy Salamati

Undesirable: No detectable buffer

Photo: Lee Rodegerdts

Accessible Design for the Blind

6.1.2. Is separation provided between sidewalk and curb? (2/3)

Undesirable: No detectable buffer

Photo: Lee Rodegerdts

Undesirable: No detectable buffer

Photo: Lee Rodegerdts

Accessible Design for the Blind

6.1.2. Is separation provided between sidewalk and curb? (3/3)

Desirable: Fence provides separation where buffer is not feasible

Photo: Lee Rodegerdts

Undesirable: Space between bollards not detectable

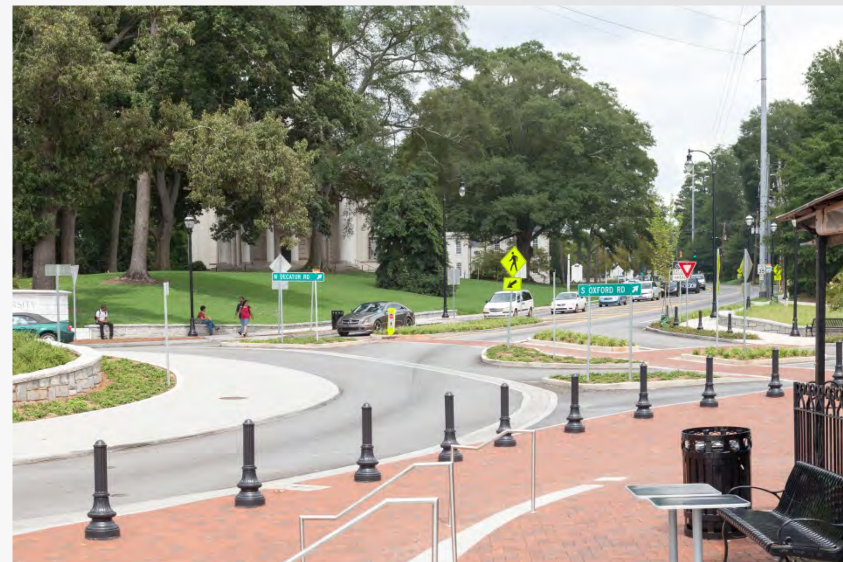


Photo: Lee Rodegerdts

6.1.3. Is the edge of the street clearly defined (outside edge)? (1/2)

Desirable: Detectable warning surface (truncated domes) at edge of street

Photo: Janet Barlow

Undesirable: DWS is not the full width of the area that is level with the street

Photo: Janet Barlow

Accessible Design for the Blind

6.1.3. Is the edge of the street clearly defined (outside edge)? (2/2)

Undesirable: External truck apron makes edge ambiguous and DWS not provided

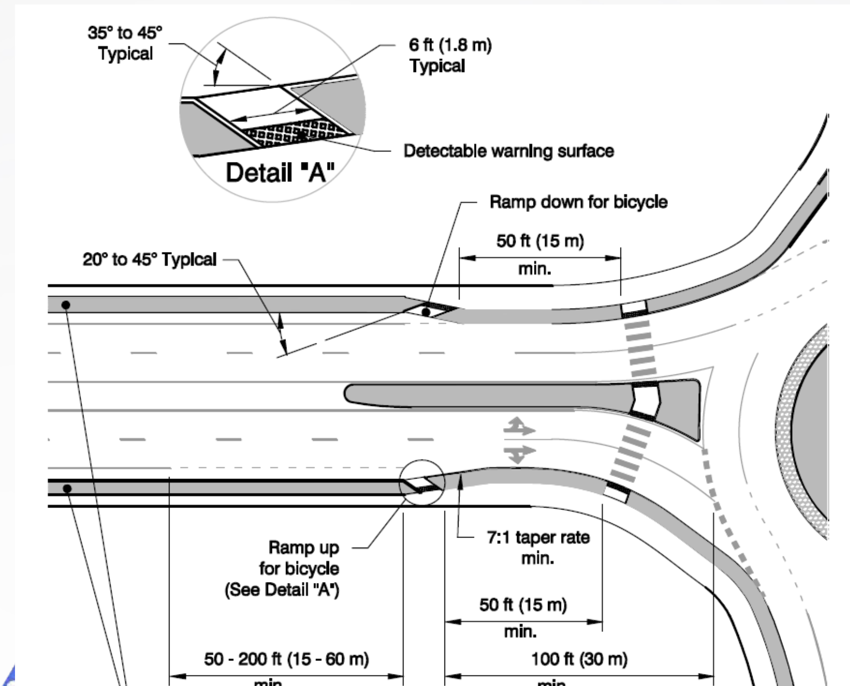
Photo: Lee Rodegerdts

Undesirable: External truck apron makes edge ambiguous and DWS not provided

Photo: Lee Rodegerdts

6.1.4. If other ramps or driveways are nearby, are they adequately delineated and separated?* (1/3)

Desirable: Bike ramp separated from pedestrian ramp, DWS at top of ramp



NCHRP Report 672, Exhibit 6-67

Desirable (mostly): Bike ramp separated from pedestrian ramp (but needs DWS)

Photo: Lee Rodegerdts

6.1.4. If other ramps or driveways are nearby, are they adequately delineated and separated?* (2/3)

Undesirable: Pedestrian ramp and driveway indistinguishable

Photo: Lee Rodegerdts

Undesirable: Bike ramp too close to pedestrian ramp

Photo: Lee Rodegerdts

Accessible Design for the Blind

6.1.4. If other ramps or driveways are nearby, are they adequately delineated and separated?* (3/3)

Undesirable: Bike ramp could be mistaken for pedestrian ramp

Photo: Janet Barlow

Undesirable: Bike ramp aligned directly with sidewalk

Photo: Janet Barlow

Accessible Design for the Blind

6.1.5. Are traffic control devices accessible?

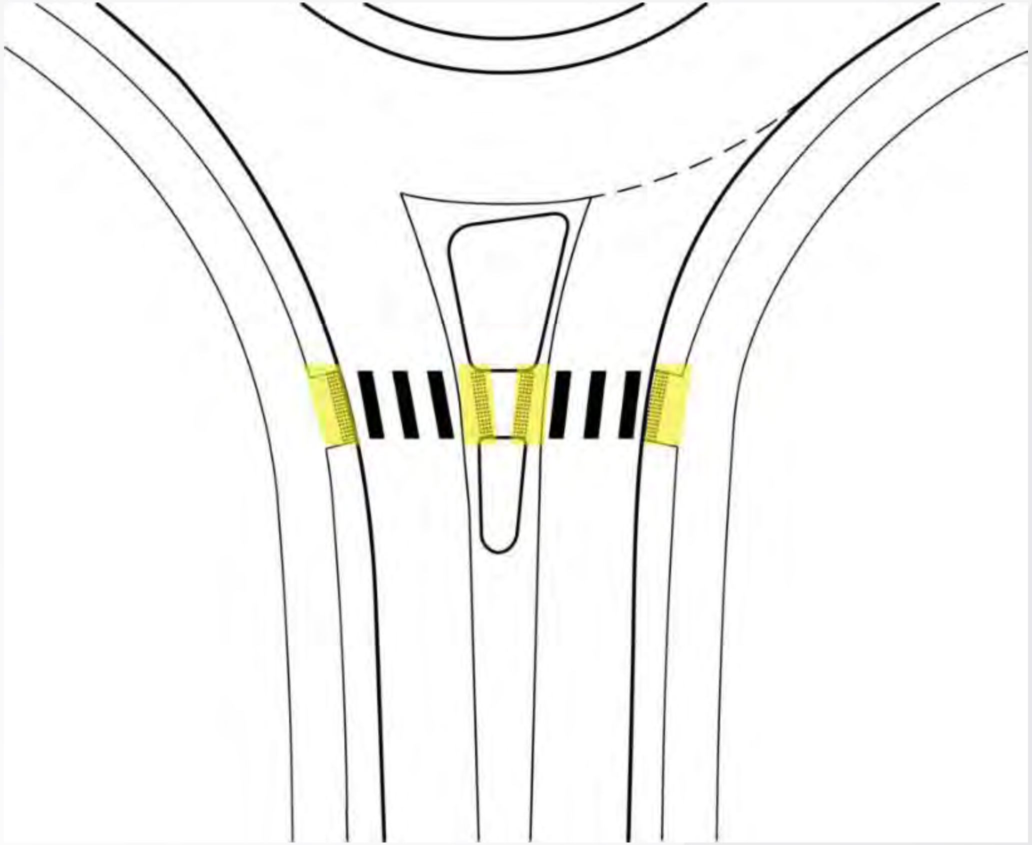
Desirable: level beside pushbutton, reachable from sidewalk

Photo: Janet Barlow

Undesirable: Push button and display too far from crosswalk

Photo: Lee Rodegerdts

6.2. Aligning to Cross and Establishing a Correct Heading



Source: NCHRP Report 834

6.2.1. Is curb ramp width the same as crosswalk width? (1/2)

Desirable

Photo: Janet Barlow

Desirable

Photo: Lee Rodegerdts

6.2.1. Is curb ramp width the same as crosswalk width? (2/2)

Undesirable: Ramp and gap in island unnecessarily narrow

Photo: Janet Barlow

Undesirable: Curb ramp unnecessarily narrow

Photo: Lee Rodegerdts

6.2.2. Is curb ramp slope aligned with crossing? (1/3)

Desirable

Photo: Lee Rodegerdts

Desirable

Photo: Janet Barlow

Accessible Design for the Blind

6.2.2. Is curb ramp slope aligned with crossing? (2/3)

Undesirable: Curb ramp aims away from crosswalk

Photo: Lee Rodegerdts

Undesirable: Curb ramp aims away from crosswalk

Photo: Janet Barlow

Accessible Design for the Blind

6.2.2. Is curb ramp slope aligned with crossing? (3/3)

Undesirable

Photo: Janet Barlow

Undesirable

Photo: Janet Barlow

Accessible Design for the Blind

6.2.3. Are ramp edges aligned with crossing? (1/2)

Desirable

Photo: Lee Rodegerdts

Undesirable: Ramp edges aim away from crosswalk

Photo: Lee Rodegerdts

Accessible Design for the Blind

6.2.3. Are ramp edges aligned with crossing? (2/2)

Undesirable: Ramp edges aim away from crosswalk

Photo: Lee Rodegerdts

Undesirable: Edges in splitter island aim away from crosswalk

Photo: Lee Rodegerdts

Accessible Design for the Blind

6.2.4. Is detectable warning aligned with slope of the curb ramp?

Desirable

Photo: Janet Barlow

Undesirable

Photo: Janet Barlow

Accessible Design for the Blind

6.2.5. Are pushbuttons in correct location?

Desirable

Photo: Janet Barlow

Undesirable: Two pushbuttons on same pole and arrows not aligned with direction of travel on crosswalk

Photo: Janet Barlow

Accessible Design for the Blind

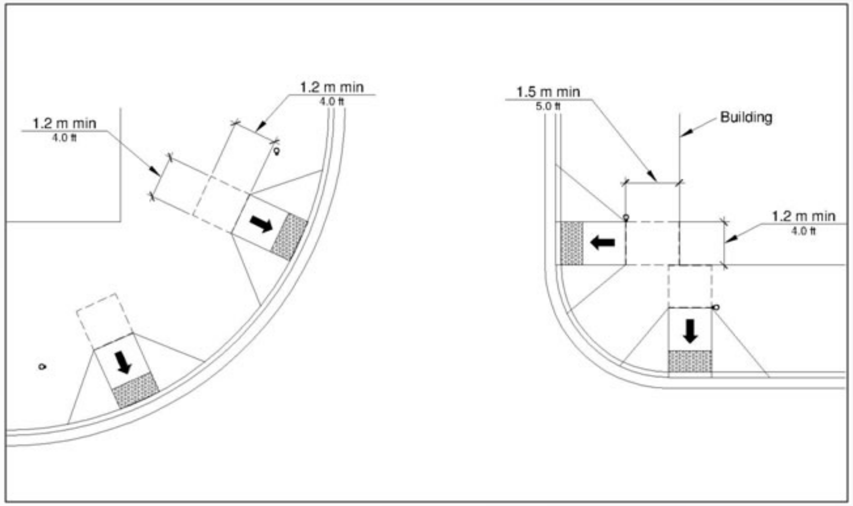
6.2.6 Is there a sufficiently level landing and turning space where the pedestrian is waiting to cross?

Undesirable: no level landing or turning space

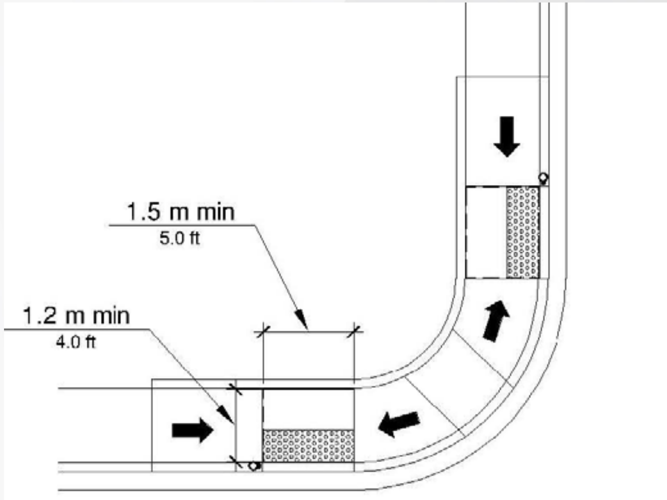
Desirable:

6.2.6 Is there a sufficiently level landing and turning space where the pedestrian is waiting to cross?

Desirable: Level landing area required at top of ramp



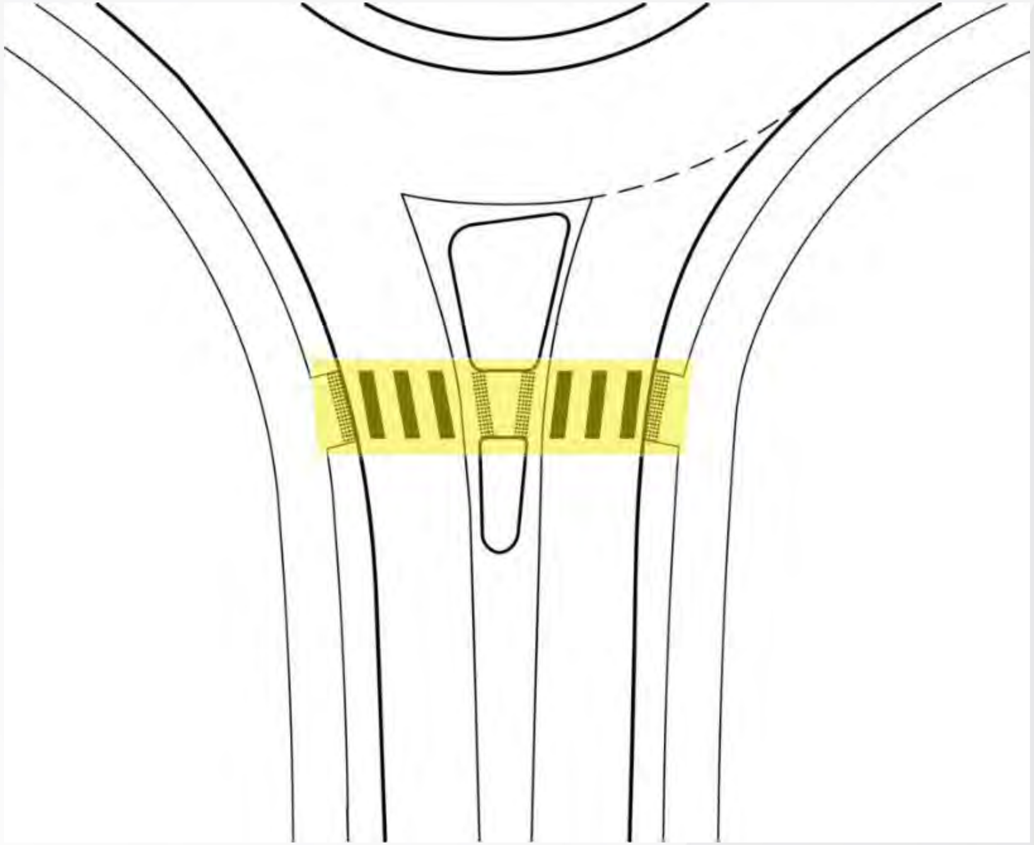
Source: PROWAG R304.2.1



Source: PROWAG R304.3.1

Accessible Design for the Blind

6.3. Maintaining Correct Heading While Crossing (Staying within the Crosswalk)



Source: NCHRP Report 834

Accessible Design for the Blind

6.3.1. Is the crossing configured at the shortest distance practical?

Desirable

Photo: Lee Rodegerdts

Undesirable

Photo: Lee Rodegerdts

6.3.2. Is the crossing aligned perpendicular to the curb and island edges?

Desirable

Photo: Lee Rodegerdts

6.3.3. Are markings clearly visible?

Desirable: High-visibility marking (zebra or ladder preferred)

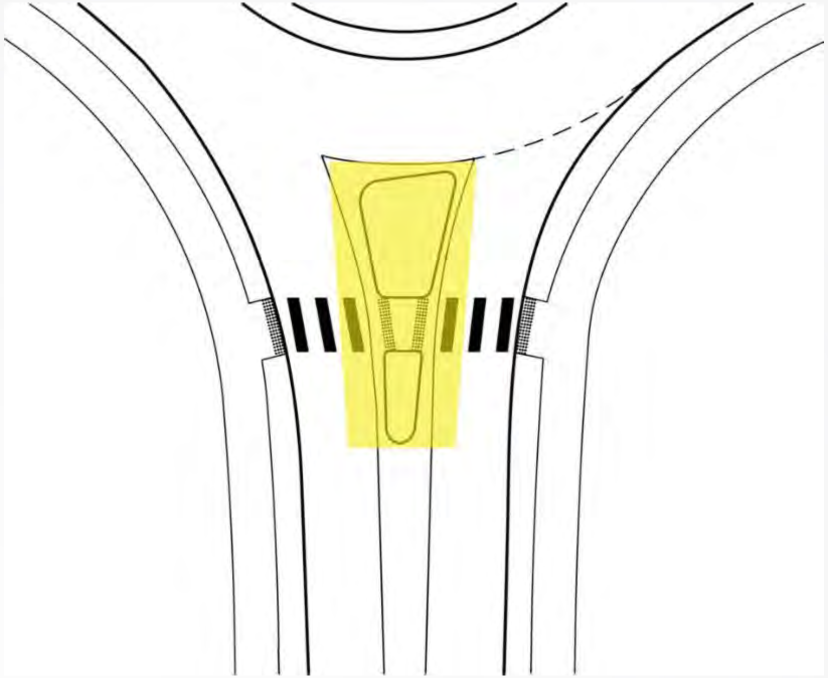
Photo: Lee Rodegerdts

Undesirable: Change in pavement color not substitute for markings

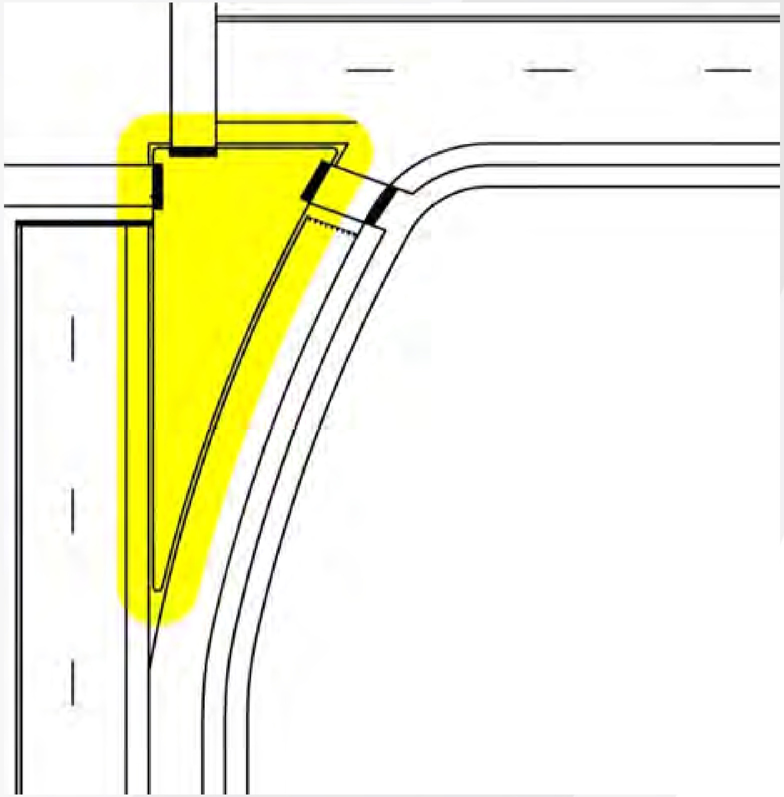
Photo: Lee Rodegerdts

Accessible Design for the Blind

6.4. Crossings from Channelization and Splitter Islands



Source: NCHRP Report 834



Source: NCHRP Report 834

Accessible Design for the Blind

6.4.1. Are islands wide enough to provide safe refuge?

Desirable

Photo: Lee Rodegerdts

Undesirable: DWS suggest refuge within splitter island but too narrow

Photo: Lee Rodegerdts

Accessible Design for the Blind

6.4.2. Are transitions to roadway clearly defined (within the island)?

Desirable: DWS at edge of street for full width of area that is level with the street (crosswalk)

Photo: Janet Barlow

Undesirable: No detectable warnings

Photo: Pete Jenior

Accessible Design for the Blind

6.4.3. Are paths through island clearly identifiable? (1/2)

Desirable: Surface materials distinguishable under foot between path and rest of island.

Photo: Janet Barlow

Undesirable: Path indistinguishable under foot from rest of island.

Photo: Janet Barlow

Accessible Design for the Blind

6.4.3. Are paths through island clearly identifiable? (2/2)

Desirable

Photo: Pete Jenior

Undesirable: Areas outside of path may be mistaken for walking surface

Photo: Janet Barlow

Accessible Design for the Blind

6.4.4. Are pushbuttons accessible? (1/2)

Desirable

Photo: Janet Barlow

Undesirable: too far back from street and too far away from sidewalk

Photo: Janet Barlow

Accessible Design for the Blind

6.4.4. Are pushbuttons accessible? (2/2)

Undesirable: Push buttons too far from pedestrian path

Photo: Janet Barlow

Undesirable: Push button behind guard rail

Photo: © Google 2017

How can this be communicated to the blind?

Photo: NC State

- We have samples!

Conclusion

- **Wayfinding issues are challenging**
- **Need to consider these issues in design**
- **Often relatively easy to modify design slightly to work better for pedestrians who are blind or who have low vision**
- **Some features are required**
  - Separation between sidewalk and curb at roundabouts
  - Detectable warnings at crossings
  - Accessible pedestrian signals or audible information devices (if signal or beacon)
- **May not be able to resolve all issues**

Accessible Design for the Blind

TRB

Roundabouts and Channelized Turn Lanes: Access for Pedestrians, Particularly Those with Vision Disabilities

Photo: Janet Barlow

Module 4

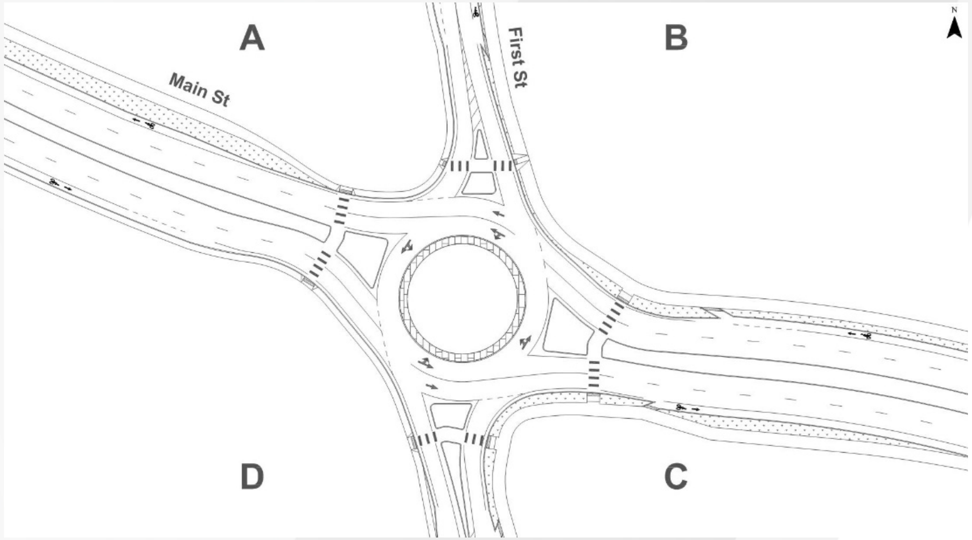
Wayfinding Exercises

KITTELSON & ASSOCIATES

Accessible Design for the Blind

Roundabout Example 1: Main St./First St.

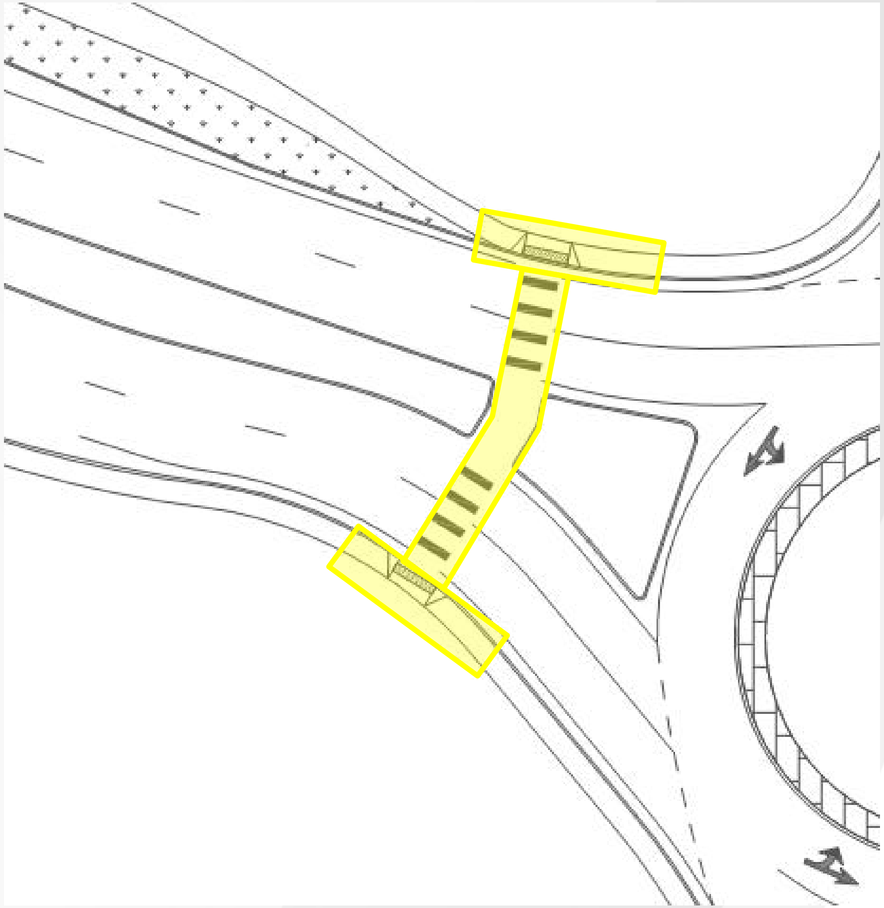
- For this example, we will select one crossing (D-A) and answer each question.
- The exercise would be repeated for the other crossings



Accessible Design for the Blind

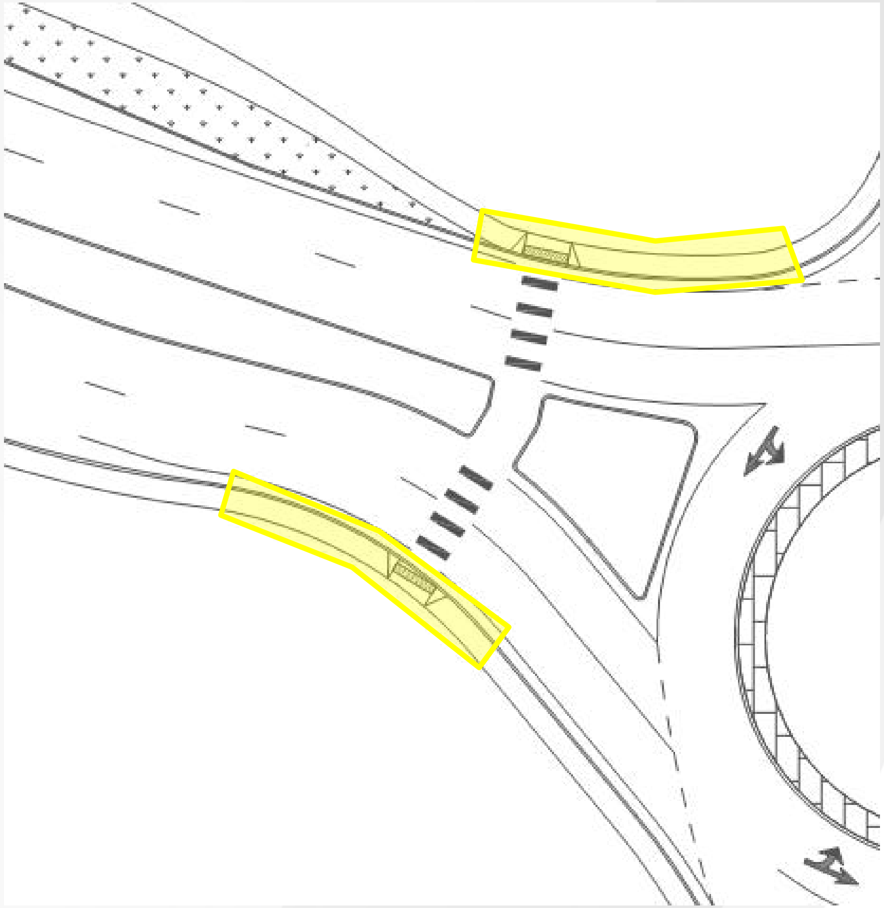
6.1.1 Do sidewalks lead to the crosswalks?

- YES. Sidewalks connect the crosswalks to the surrounding sidewalk network.



6.1.2 Is separation provided between sidewalk and curb?

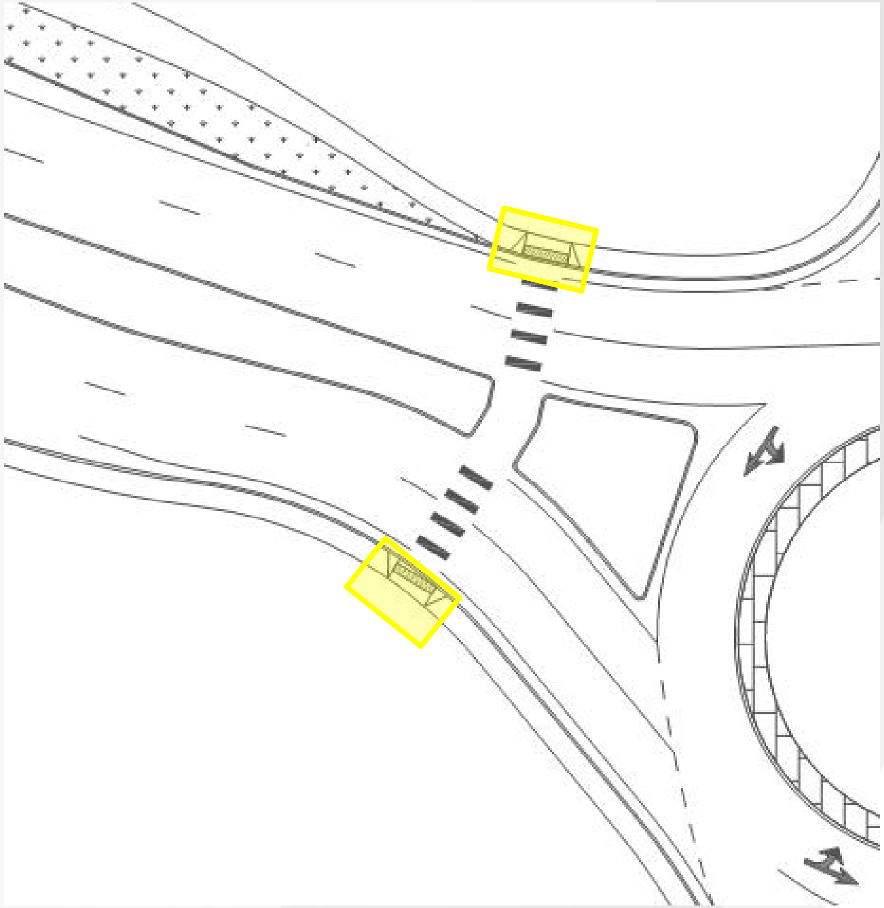
- **NO**. The sidewalk is curb-tight with no detectable buffer between the sidewalk and circulatory roadway.



Accessible Design for the Blind

6.1.3 Is the edge of the street clearly defined (outside edge)?

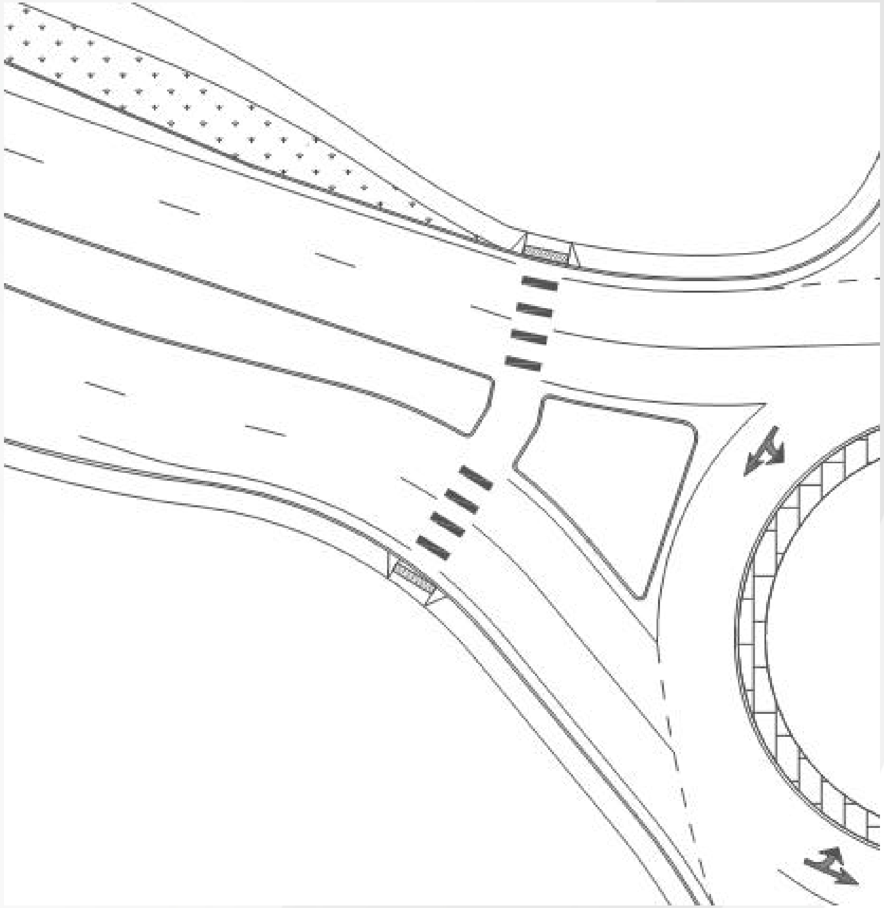
- **YES.** Detectable warnings are properly located at the bottom of the ramp. (The island is covered in 6.4.2.)



Accessible Design for the Blind

6.1.4 If other ramps or driveways are nearby, are they adequately delineated and separated?*

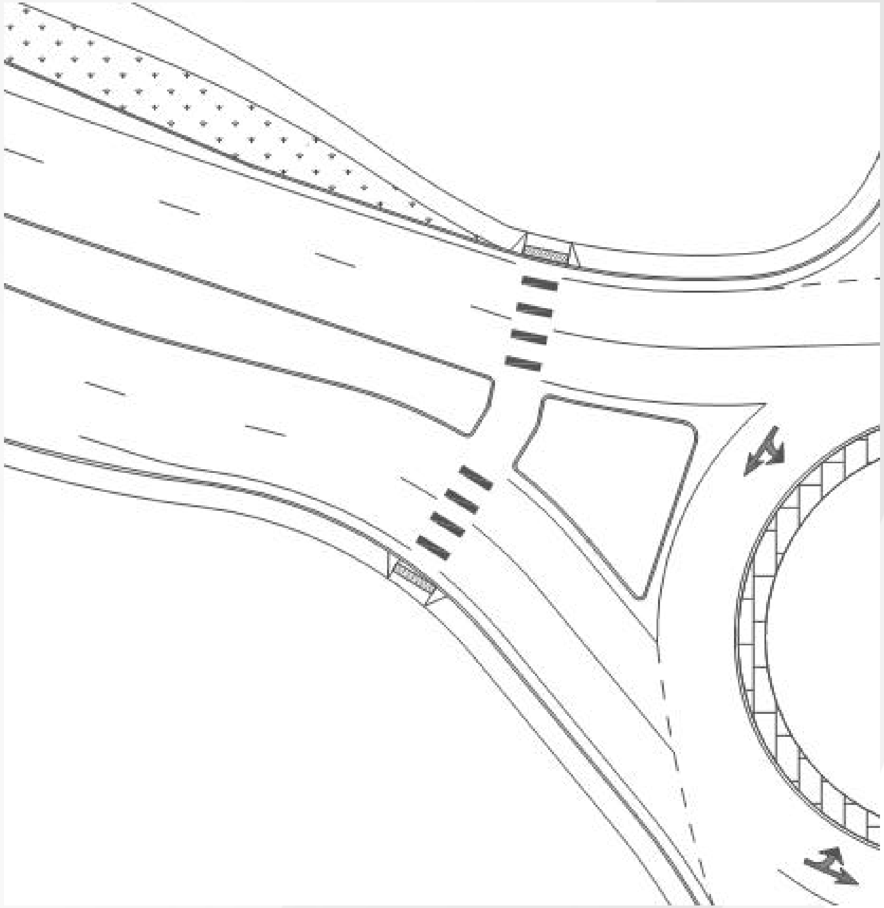
- **N/A**. There are no other ramps in the immediate vicinity that could be mistaken for the crossing location.



Question has been reworded from NCHRP Report 834.

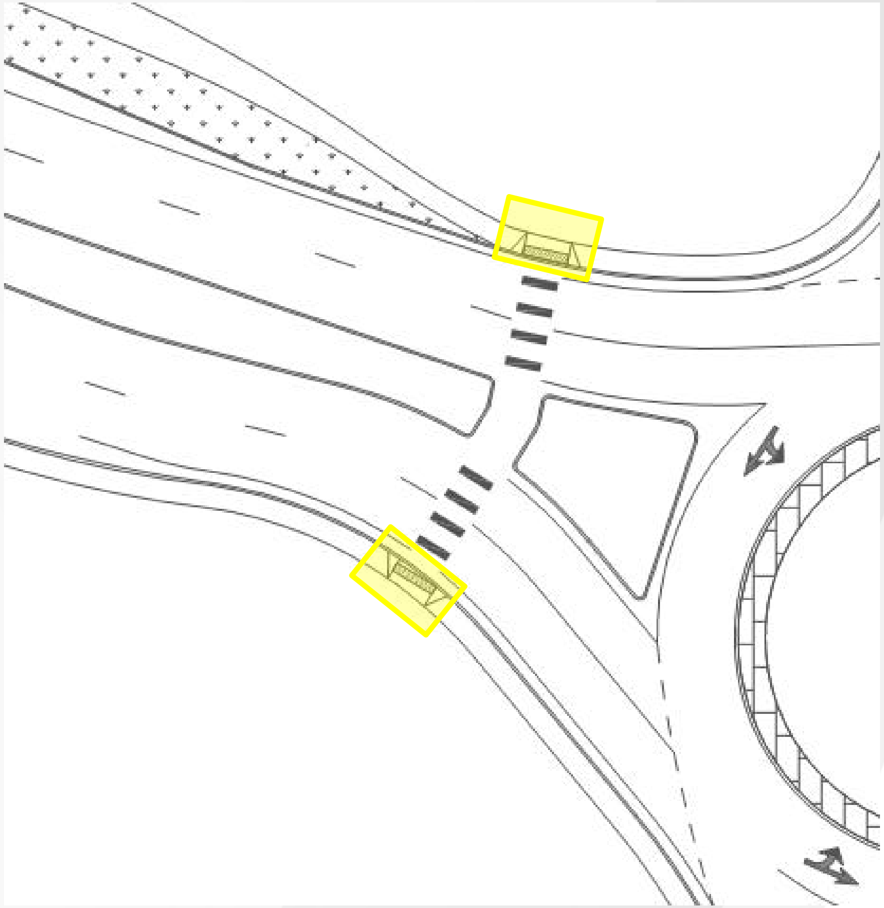
6.1.5 Are traffic control devices accessible?

- UNCLEAR. The provided plans do not indicate traffic control devices other than markings.



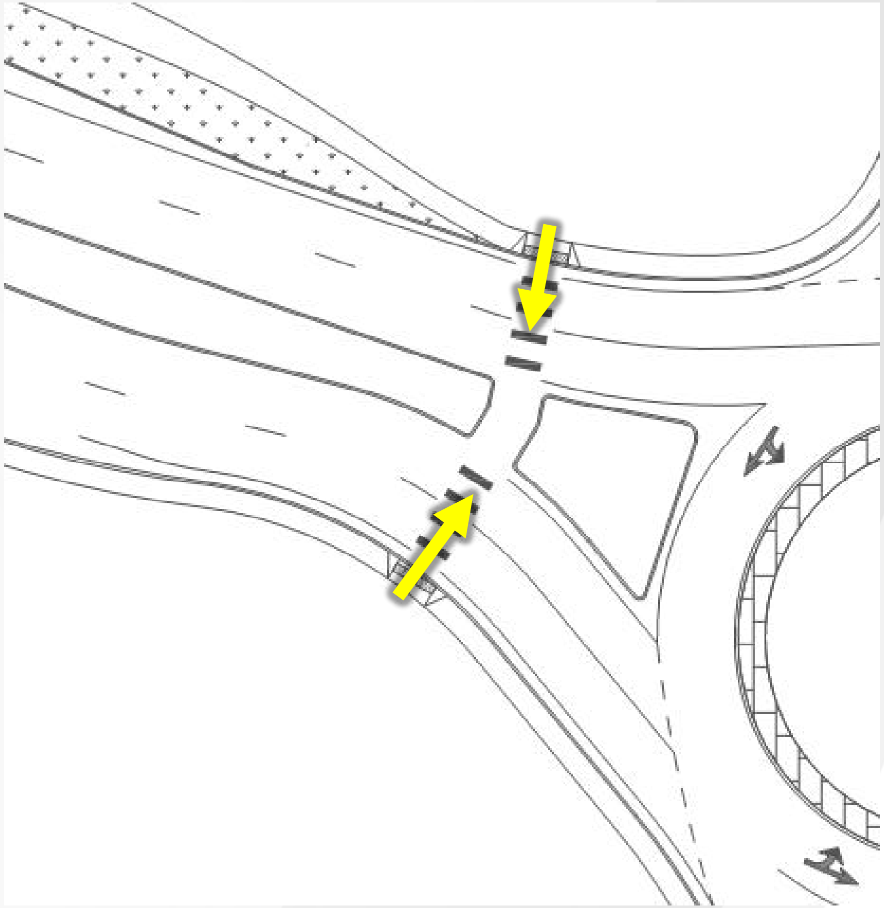
6.2.1 Is curb ramp width the same as crosswalk width?

- YES.



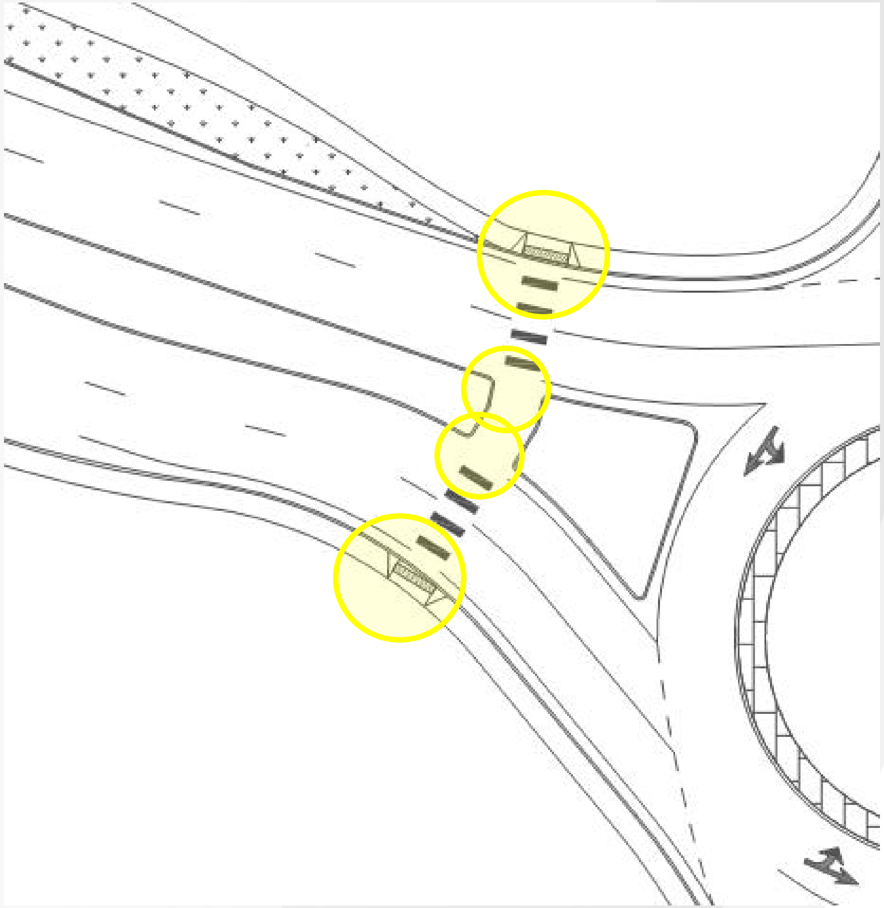
6.2.2 Is curb ramp slope aligned with crossing?

- **YES**. The ramp is aimed directly towards the crossing.



6.2.3 Are ramp edges aligned with crossing?

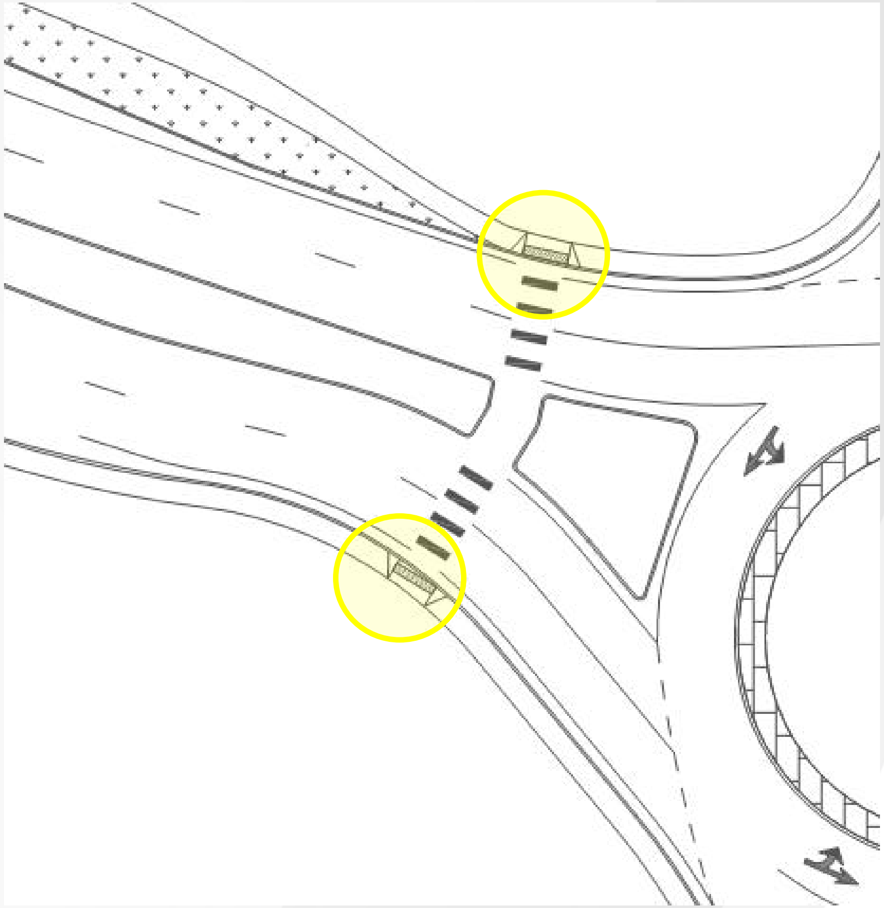
- **YES**.



Accessible Design for the Blind

6.2.4 Is the detectable warning aligned with slope of the curb ramp?

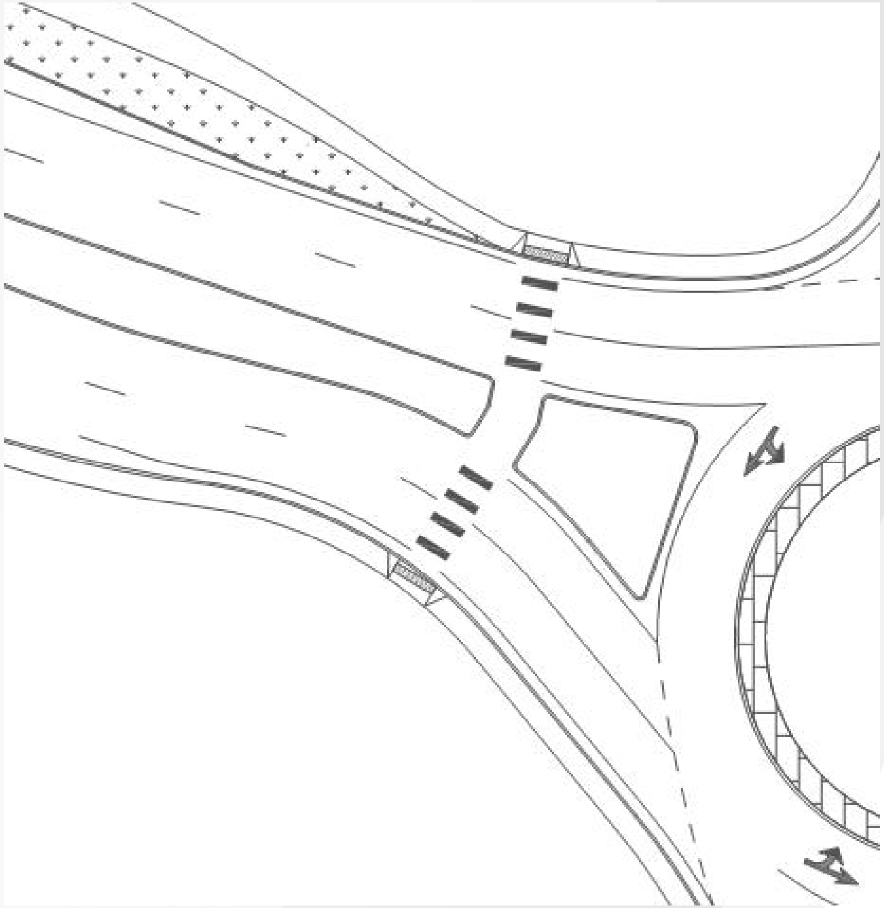
- **YES**.



Accessible Design for the Blind

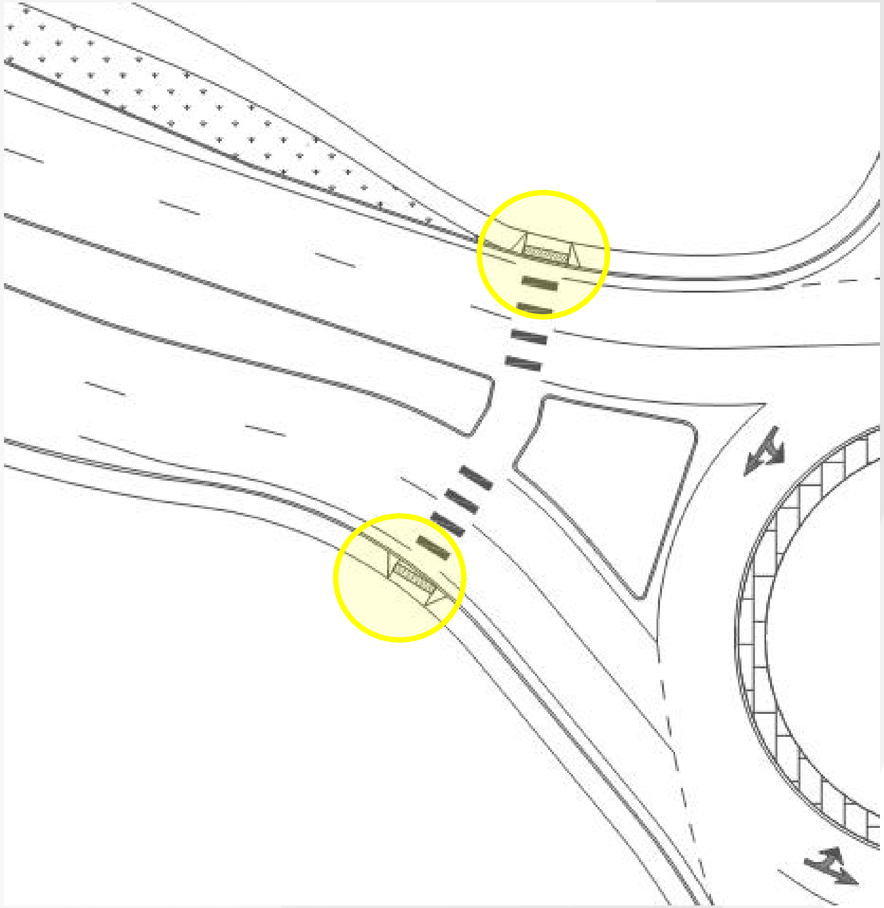
6.2.5 Are pushbuttons in correct location?

- UNCLEAR. The provided plans do not indicate traffic control devices other than markings.



6.2.6 Is there a sufficiently level landing and turning space where the pedestrian is waiting to cross?

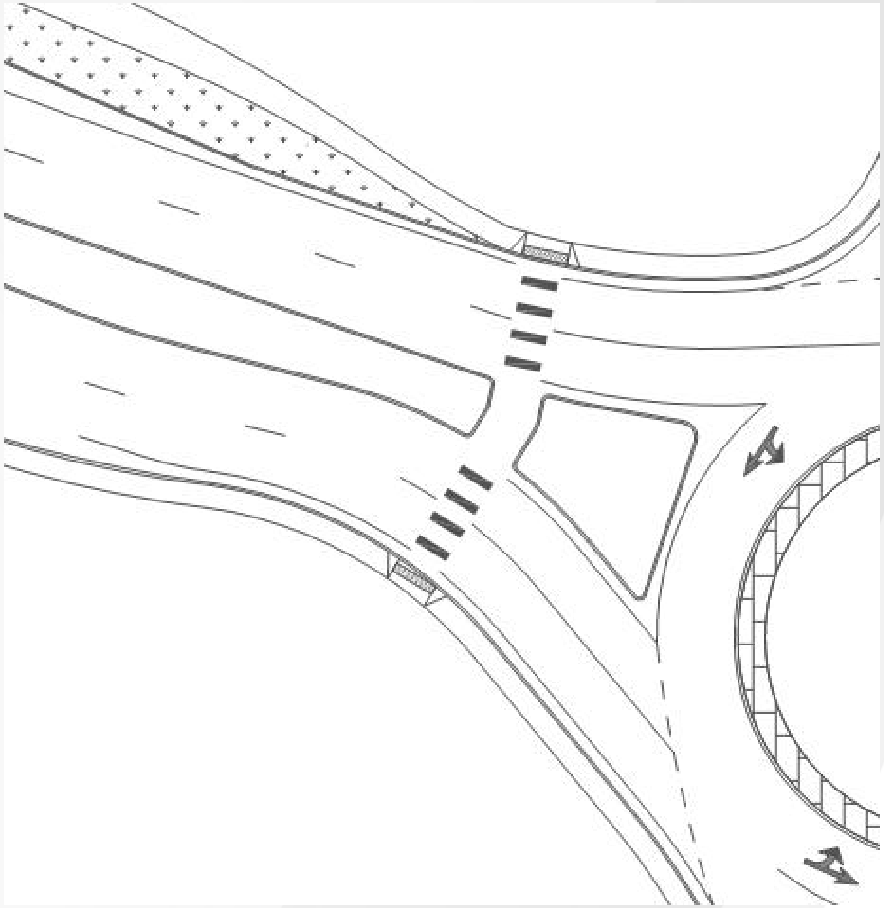
- **NO**. The ramp slope occupies the entire width of the sidewalk and provides no landing area at the top. Either a landing behind the ramp or a depressed (parallel) ramp would provide the necessary landing area.



Accessible Design for the Blind

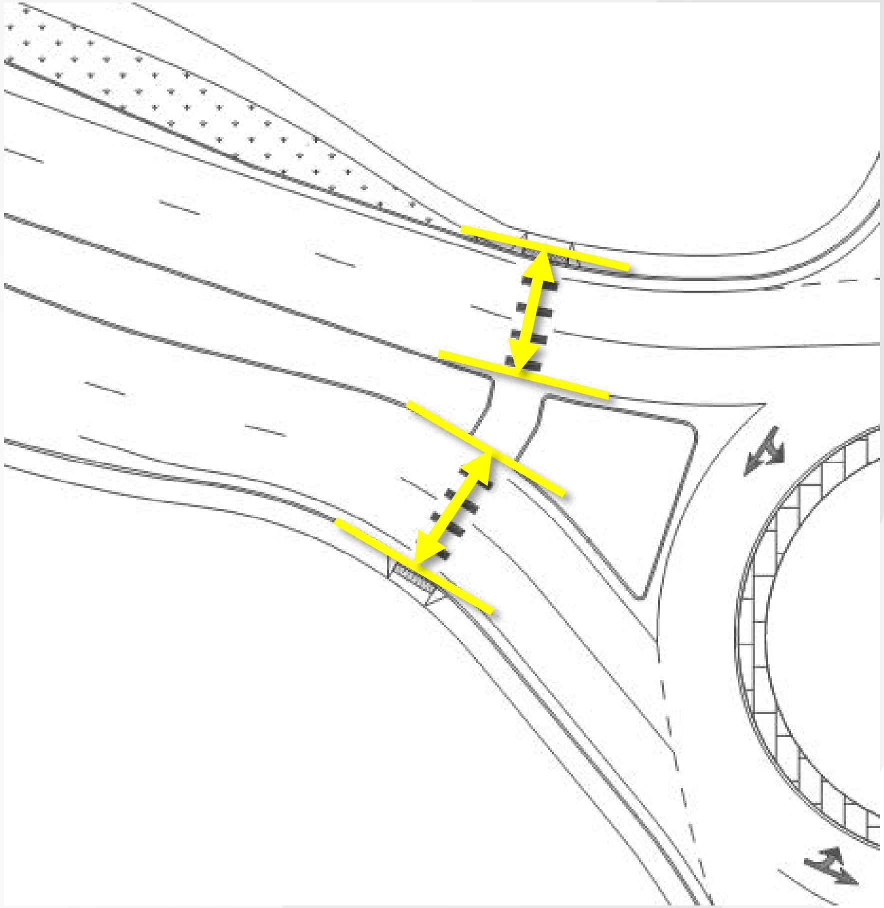
6.3.1 Is the crossing configured at the shortest distance practical?

- **YES**.



6.3.2 Is the crossing aligned perpendicular to the curb and splitter edges?

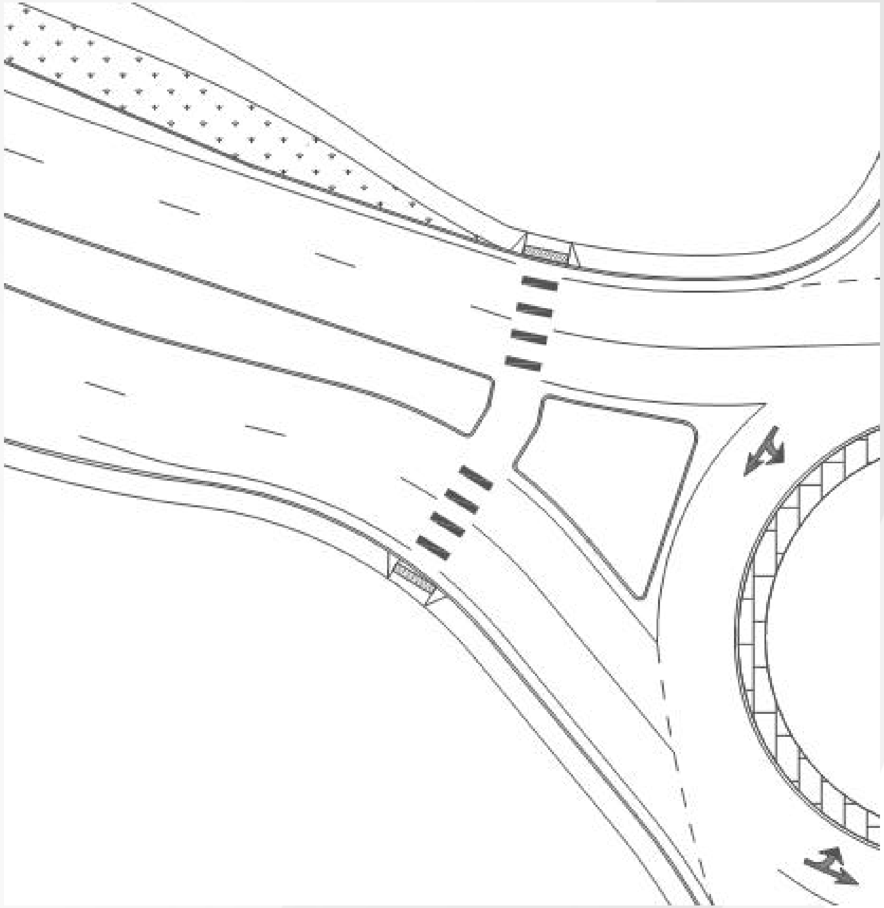
- **YES**.



Accessible Design for the Blind

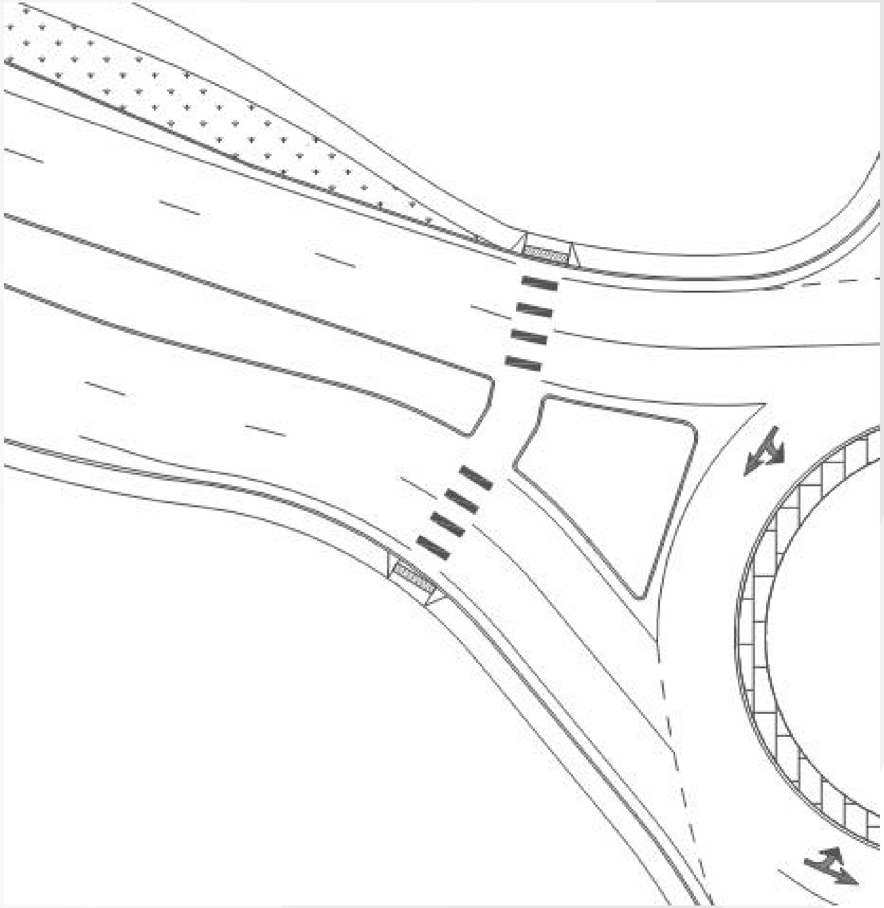
6.3.3 Are markings clearly visible?

- **YES**. High visibility crosswalk markings have been used.



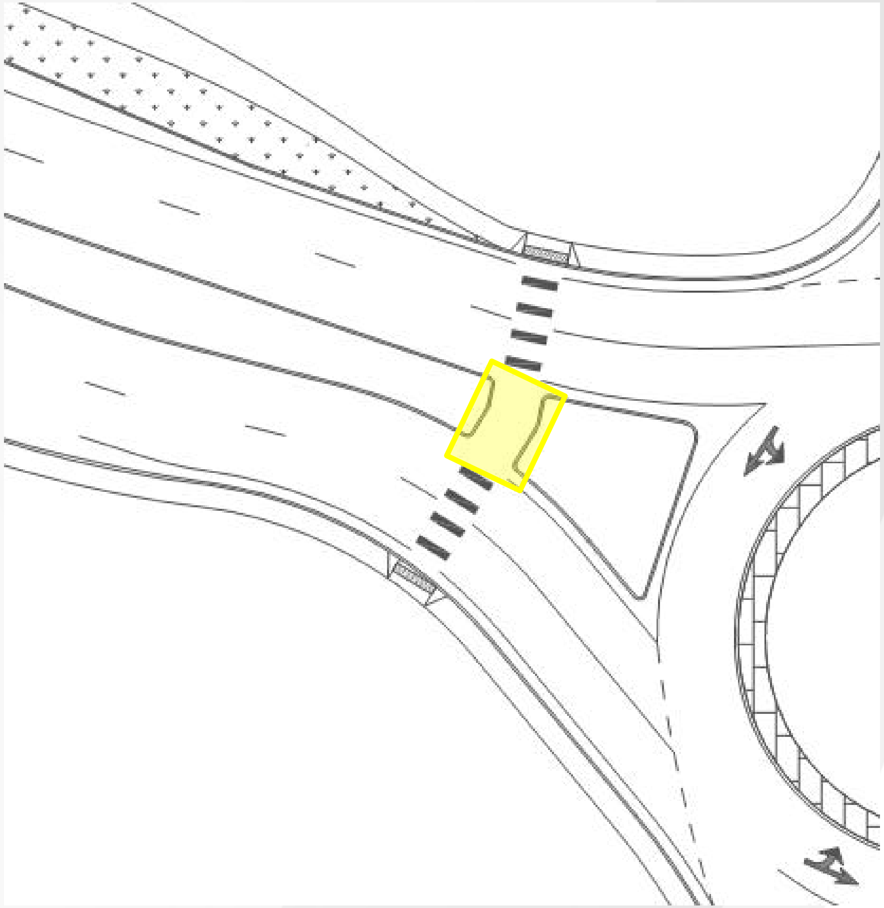
6.4.1 Are islands wide enough to provide safe refuge?

- **YES**.



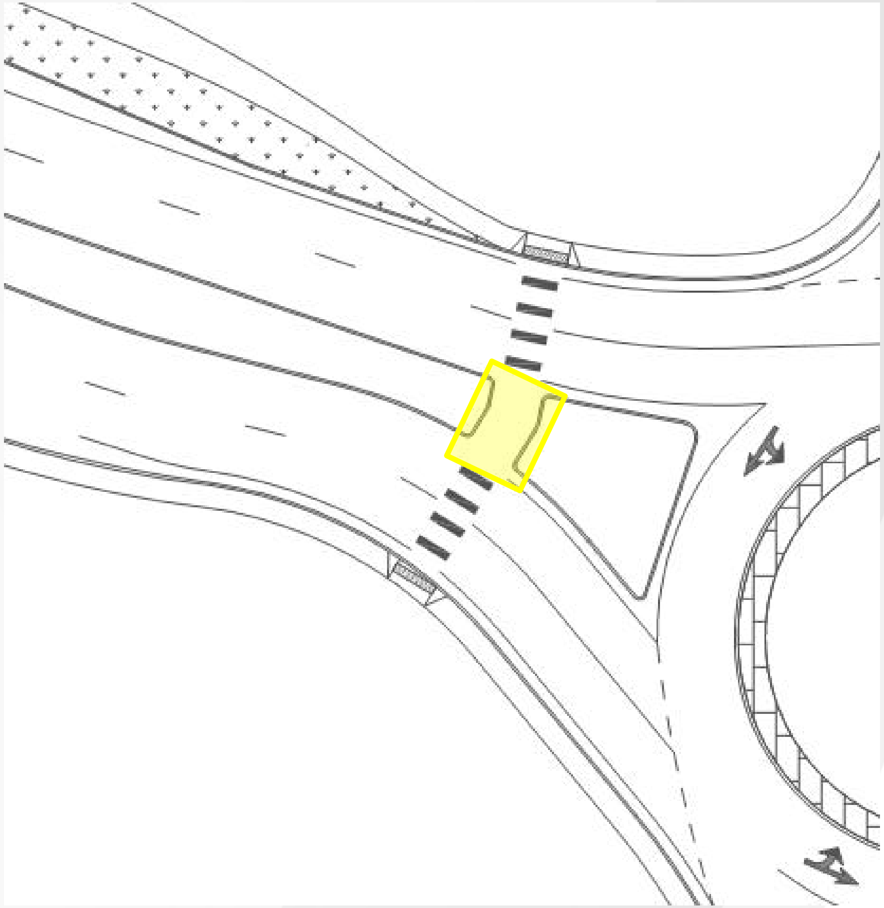
6.4.2 Are transitions to roadway clearly defined (within the island)?

- **NO**. Detectable warnings are not provided at the boundary between the splitter island refuge and the travel lanes.



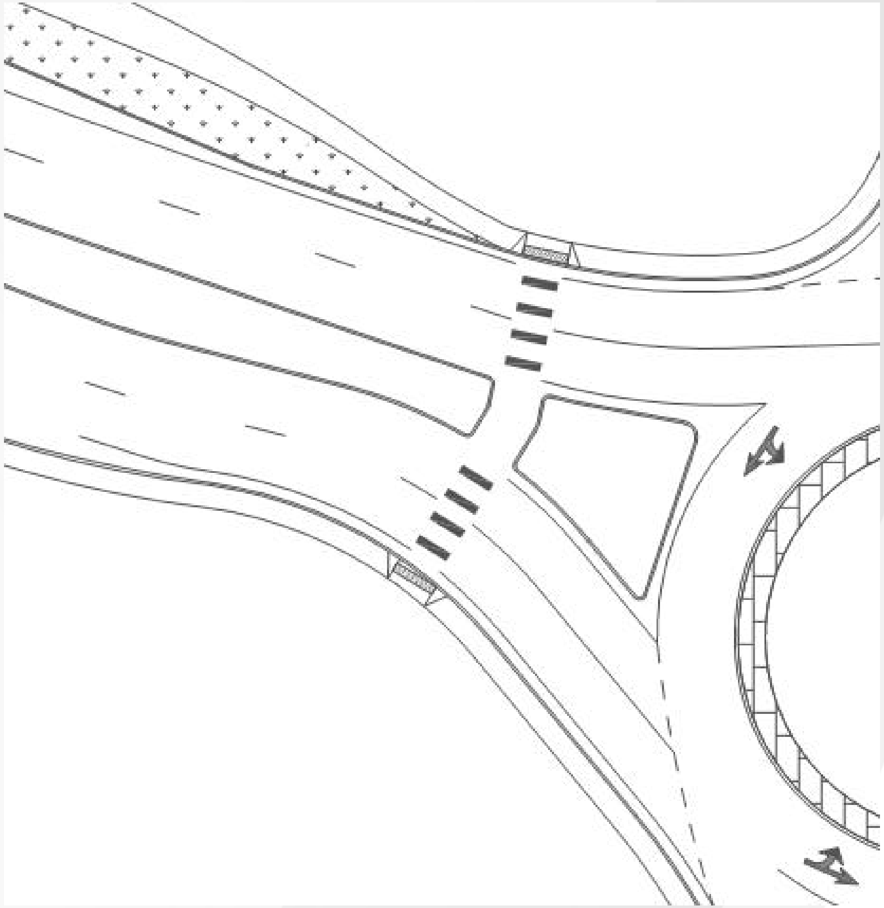
6.4.3 Are paths through island clearly identifiable?

- UNCLEAR. It is unknown what type of material may be proposed for the surface of the island and whether that surface can be distinguished under foot from the intended walking path.



6.4.4 Are pushbuttons accessible?

- **UNCLEAR. The provided plans do not indicate traffic control devices other than markings.**



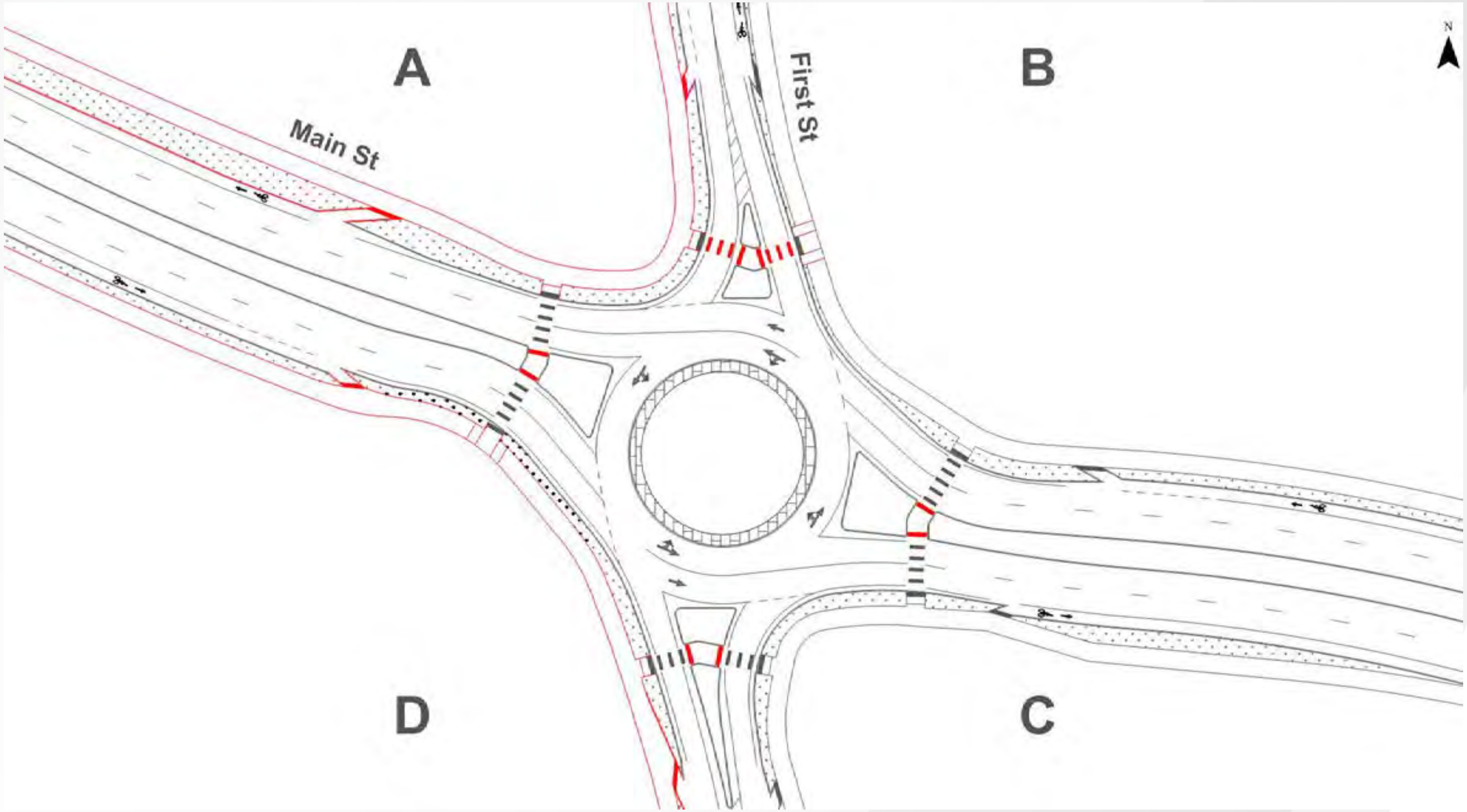
Accessible Design for the Blind

Roundabout Example 1: Main St./First St.

	A-B	B-C	C-D	D-A
6.1.1. Sidewalks lead to crosswalks	YES	YES	YES	YES
6.1.2. Separation between sidewalk and curb	**NO**	YES	YES (C), **NO (D)**	**NO**
6.1.3. Edge of street defined (outside edge)	YES	YES	YES	YES
6.1.4. Other ramps/driveways separated/delineated	N/A (A), YES (B)	**NO**	YES (C), N/A (D)	N/A
6.1.5. TCDs accessible	UNCLEAR	UNCLEAR	UNCLEAR	UNCLEAR
6.2.1. Ramp width = crosswalk width	**NO**	YES	YES	YES
6.2.2. Ramp slope aligned with crossing	**NO**	YES	YES	YES
6.2.3. Ramp edges aligned with crossing	**NO**	YES	YES	YES
6.2.4. DW aligned with ramp slope	YES	YES	YES	YES
6.2.5. PBs in correct location	UNCLEAR	UNCLEAR	UNCLEAR	UNCLEAR
6.2.6. Level landing	**NO**	YES	YES (C), **NO (D)**	**NO**
6.3.1. Crossing shortest distance	YES	YES	YES	YES
6.3.2. Crossing perpendicular to curb	**NO**	YES	YES	YES
6.3.3. Markings visible	YES	YES	YES	YES
6.4.1. Islands wide enough	YES	YES	YES	YES
6.4.2. Transitions to roadway defined (within island)	**NO**	**NO**	**NO**	**NO**
6.4.3. Paths through island identifiable	UNCLEAR	UNCLEAR	UNCLEAR	UNCLEAR
6.4.4. Pushbuttons accessible	UNCLEAR	UNCLEAR	UNCLEAR	UNCLEAR

Roundabout Example 1: Main St./First St.

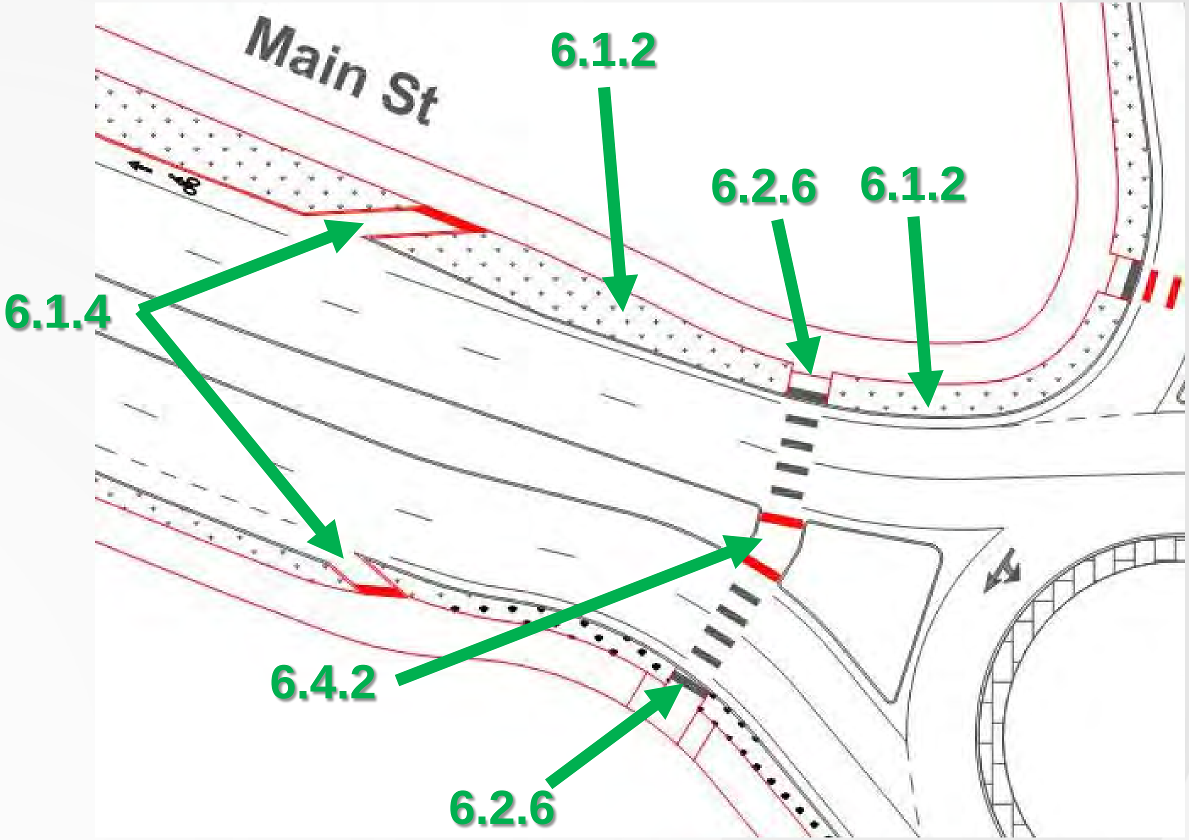
- Possible Solution



Accessible Design for the Blind

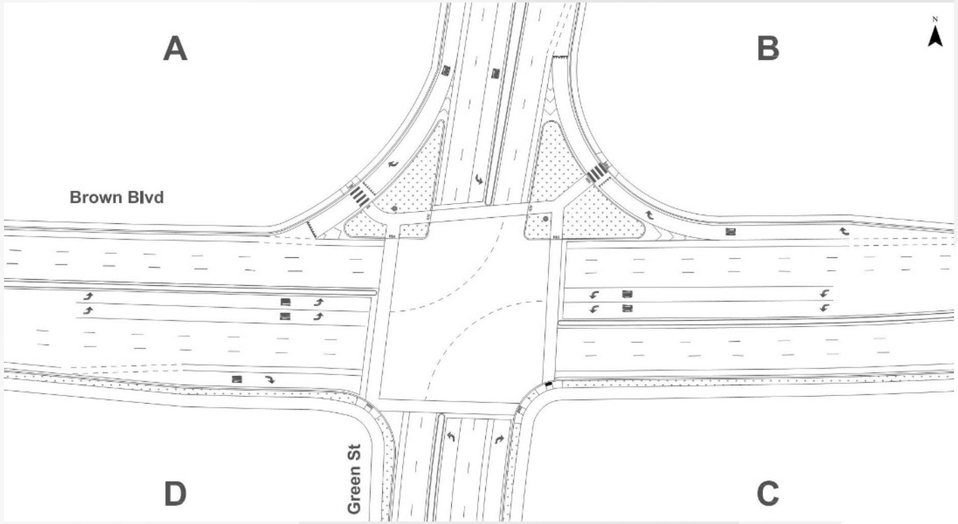
Roundabout Example 1: Main St./First St.

- Possible Solution



Channelized Turn Lane Example 2: Brown Blvd./Green St.

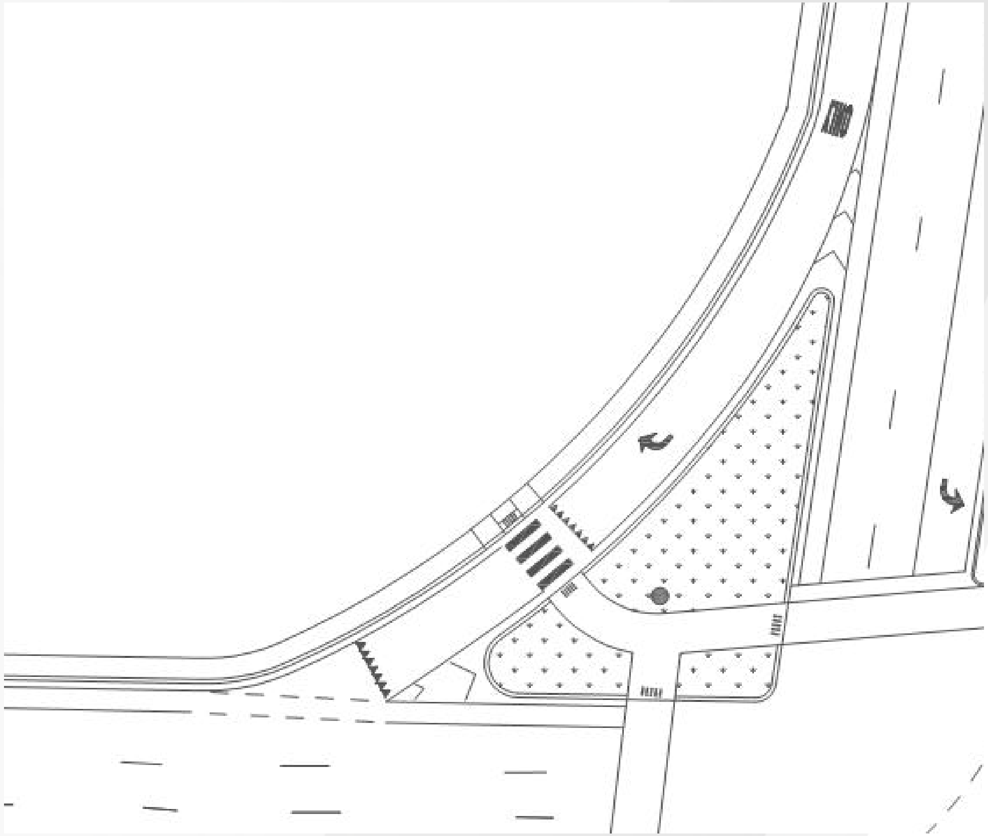
- For this example, we will select one crossing (A) and answer each question.
- The exercise would be repeated for the other crossings



Accessible Design for the Blind

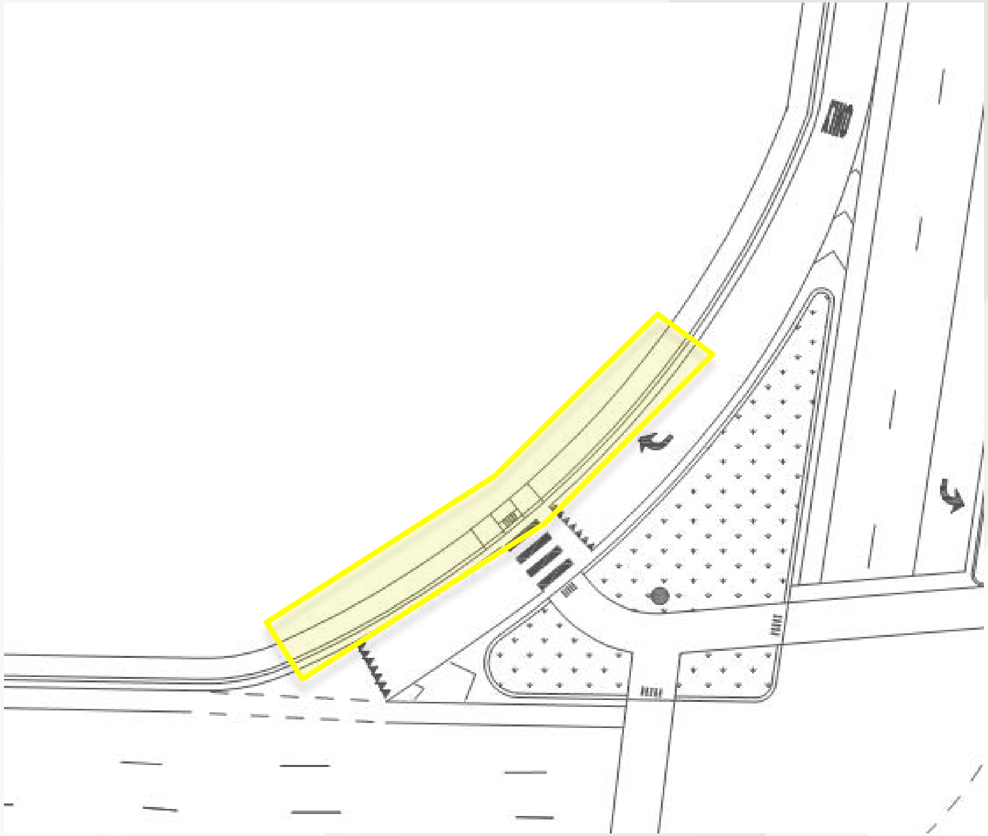
6.1.1 Do sidewalks lead to the crosswalks?

- **YES**. Sidewalks connect the crosswalks to the surrounding sidewalk network.



6.1.2 Is separation provided between sidewalk and curb?

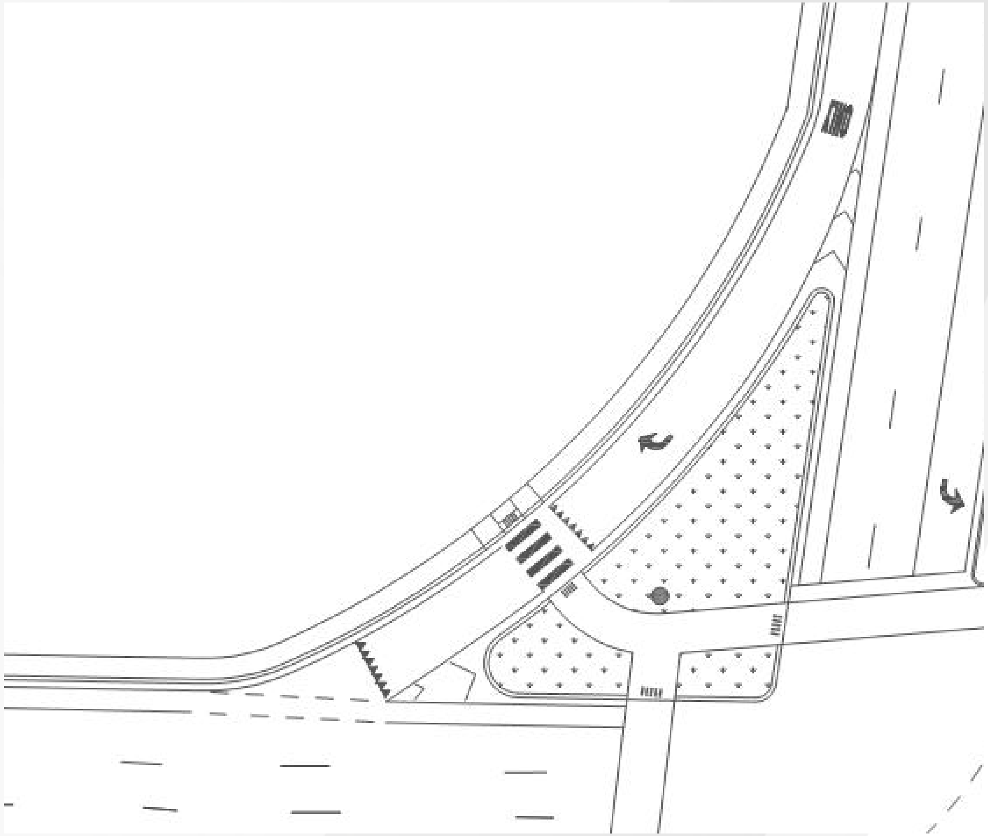
- **NO**. The sidewalk is curb-tight with no detectable buffer between the sidewalk and roadway. While not required by PROWAG for channelized turn lanes, it is still important to finding the crosswalk for blind pedestrians.



Accessible Design for the Blind

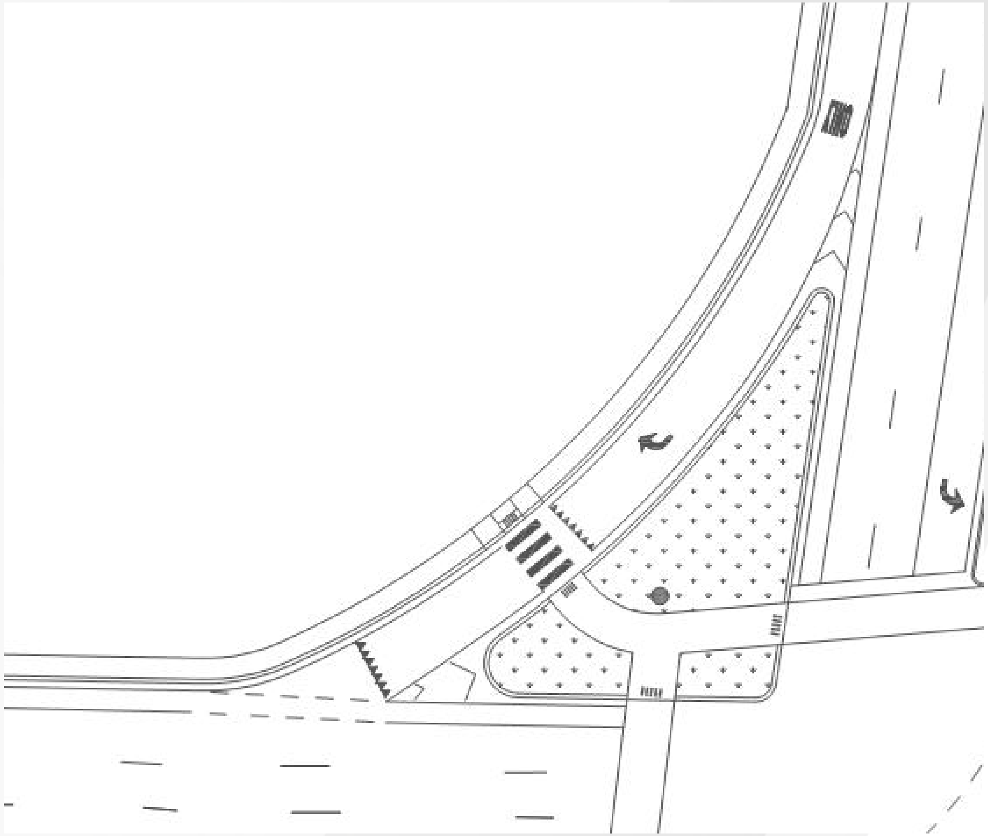
6.1.3 Is the edge of the street clearly defined (outside edge)?

- **NO**. The detectable warnings do not extend across the full width of the ramp.



6.1.4 If other ramps or driveways are nearby, are they adequately delineated and separated?*

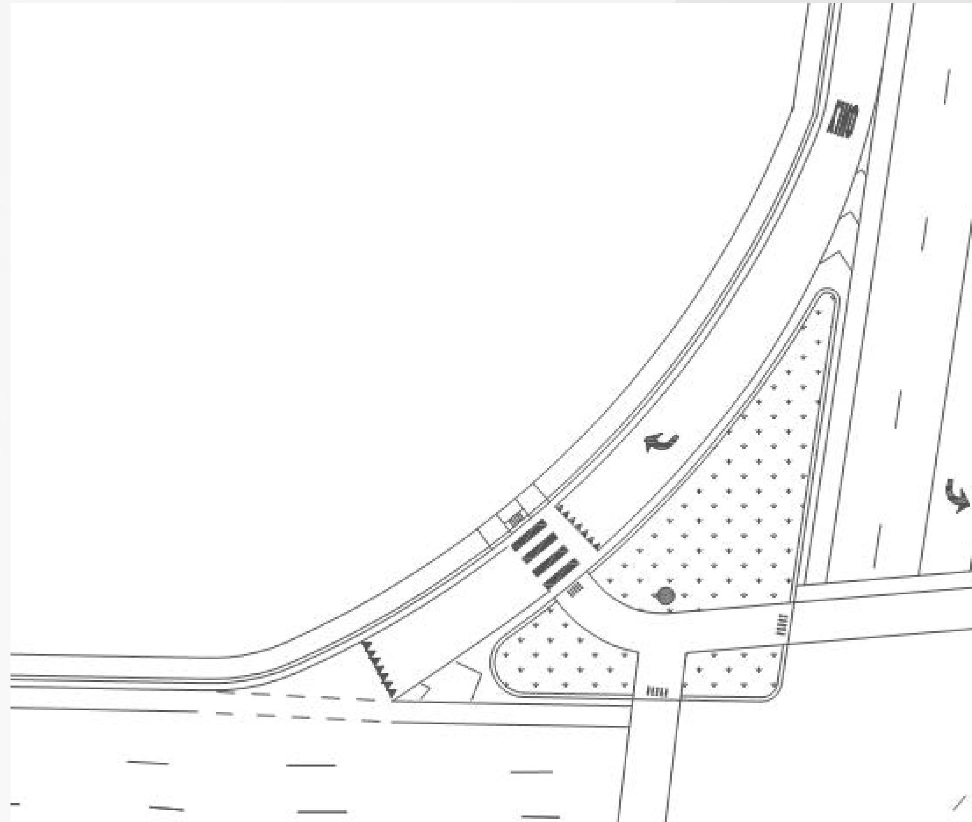
- **N/A**. There are no other ramps in the immediate vicinity that could be mistaken for the crossing location.



*Question has been reworded from NCHRP Report 834.

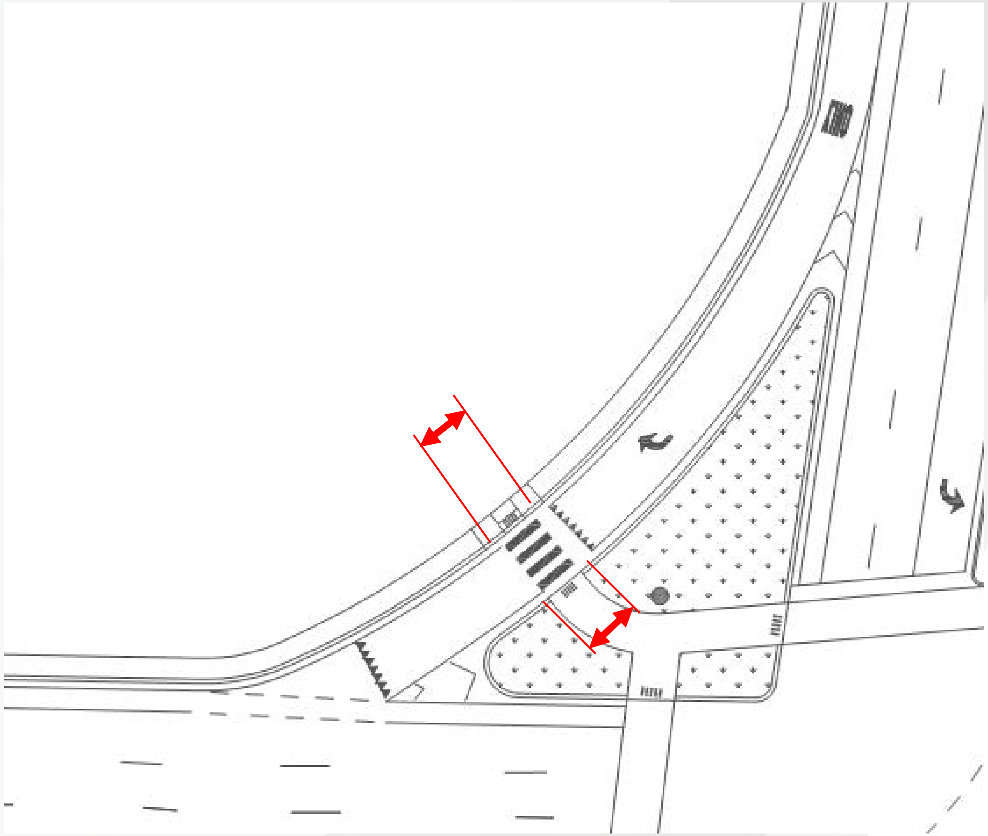
6.1.5 Are traffic control devices accessible?

- **UNCLEAR**. No detail is provided on the type of pedestrian signal and push button.



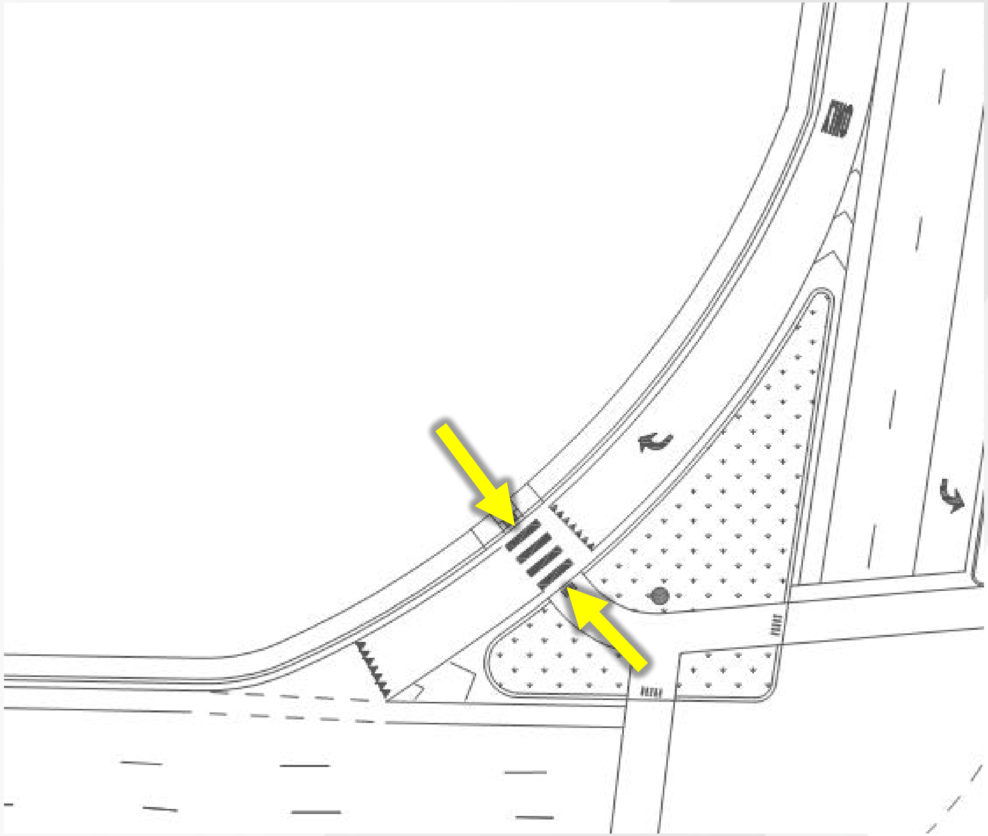
6.2.1 Is curb ramp width the same as crosswalk width?

- **NO**. The curb ramps should be wider to match the width of the crosswalk.



6.2.2 Is curb ramp slope aligned with crossing?

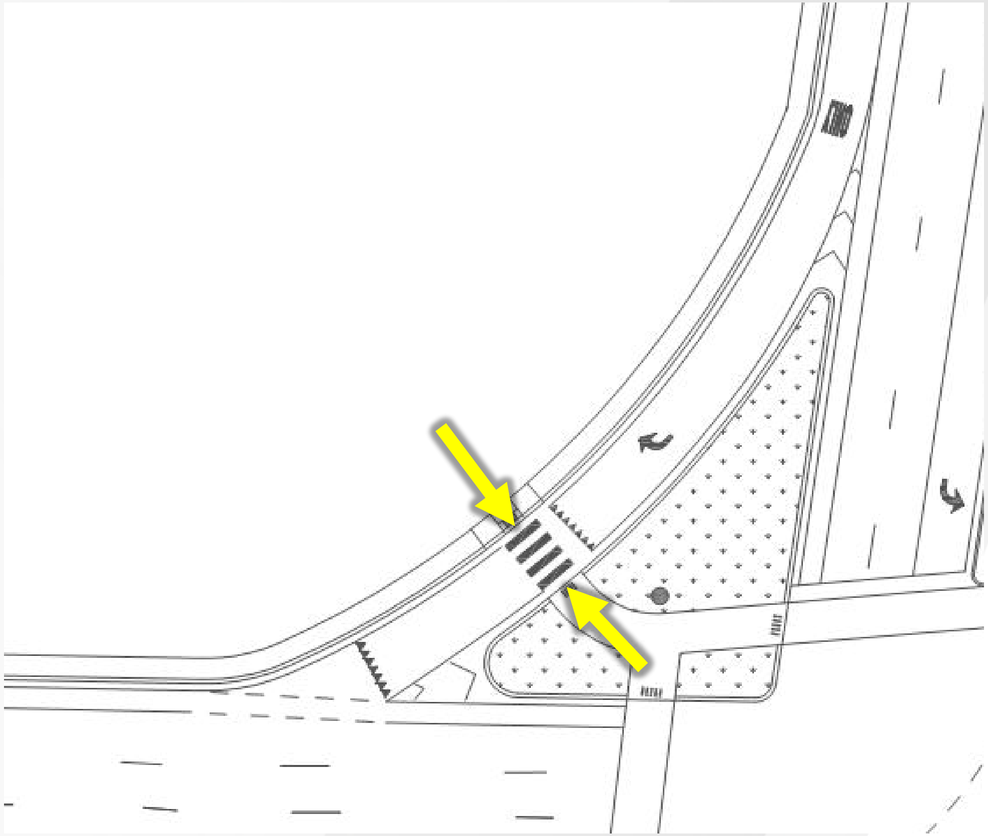
- **YES**.



Accessible Design for the Blind

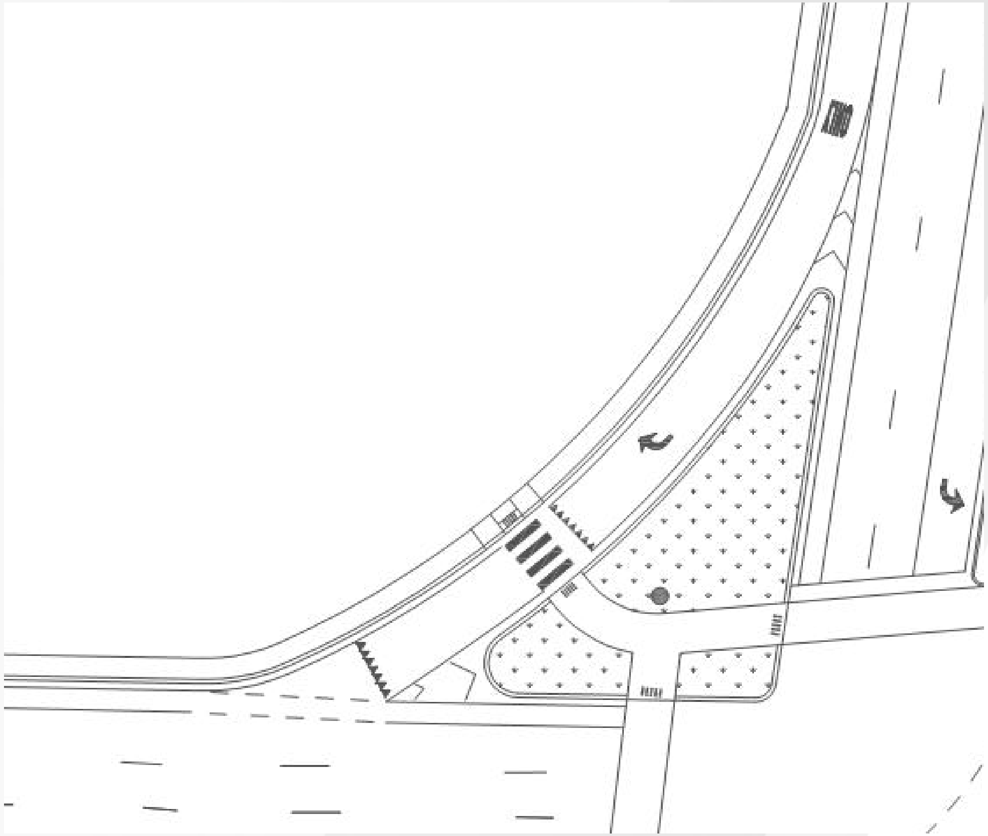
6.2.3 Are ramp edges aligned with crossing?

- **YES**.



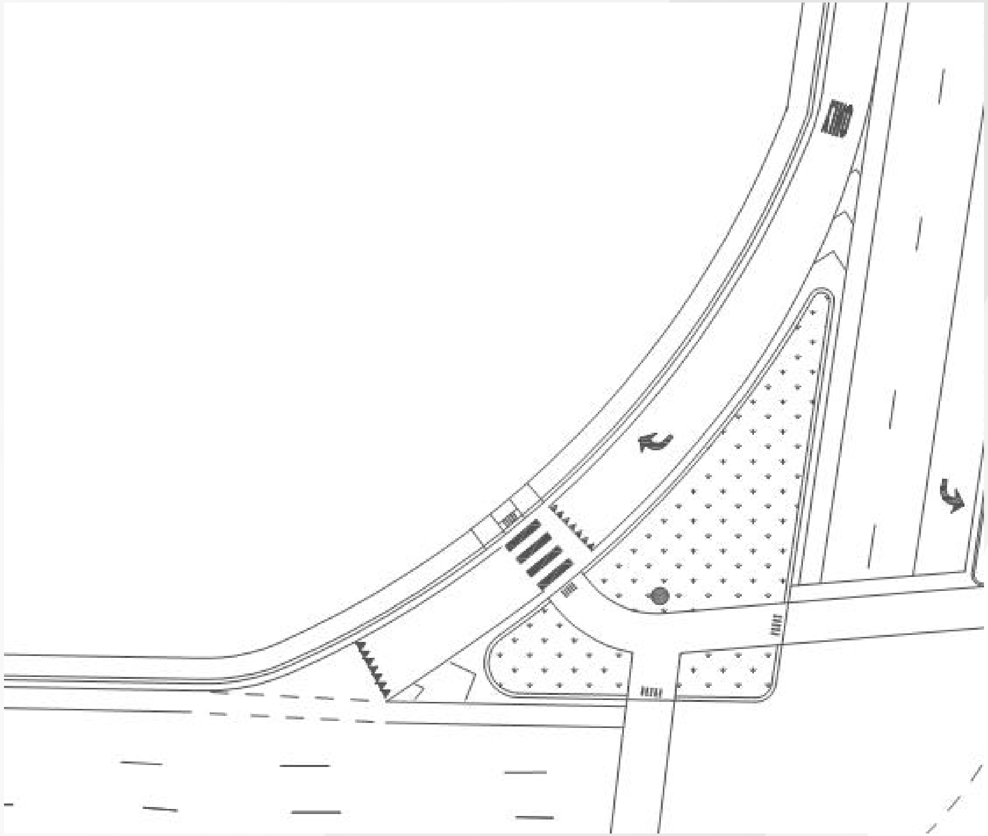
6.2.4 Is the detectable warning aligned with slope of the curb ramp?

- **YES**.



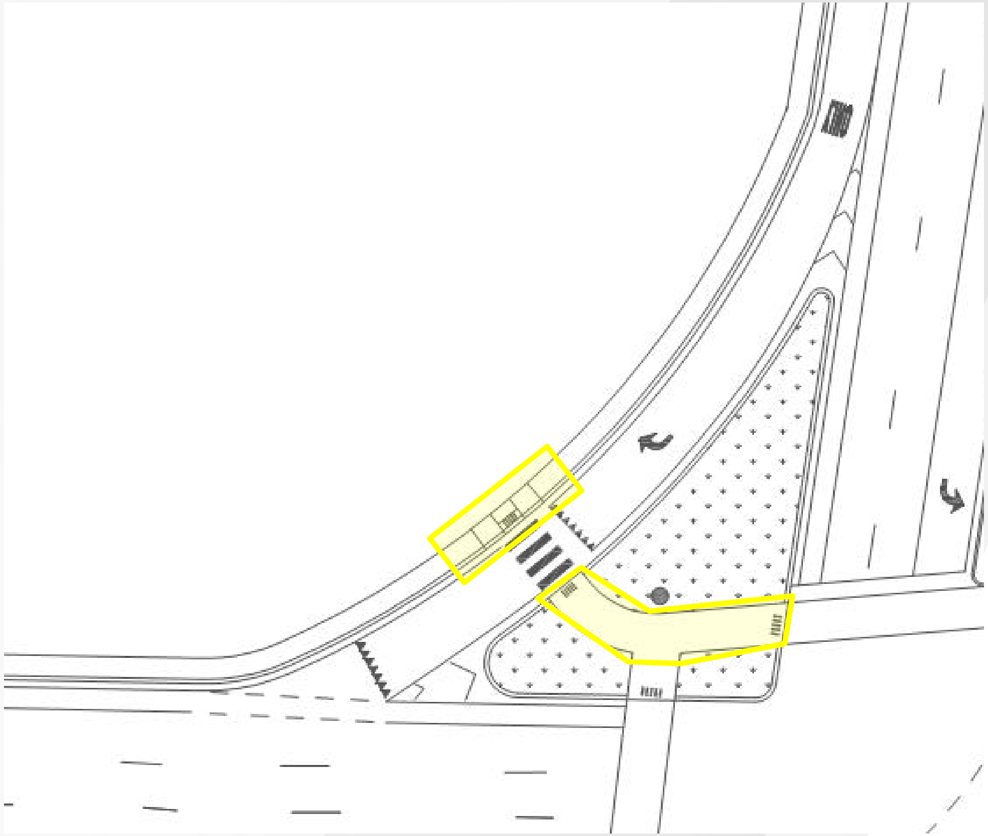
6.2.5 Are pushbuttons in correct location?

- UNCLEAR. No detail is provided on the push button location on the outside curb, and it is unclear whether push buttons are separated from the single signal pole indicated on the island.



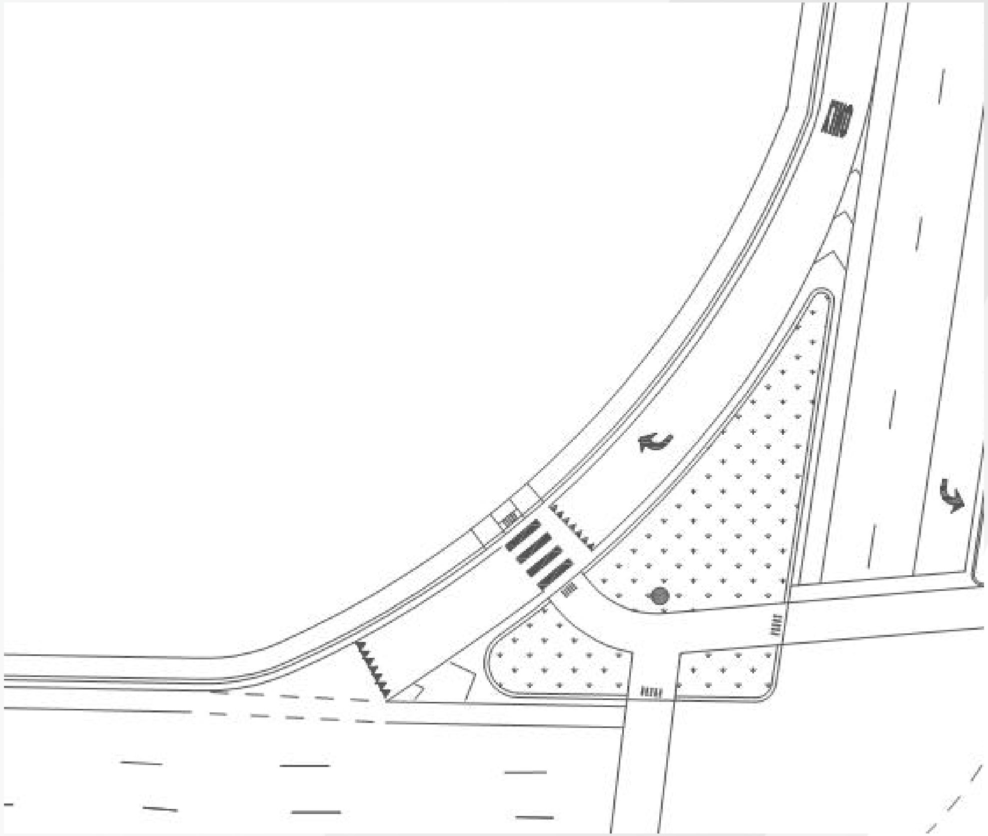
6.2.6 Is there a sufficiently level landing and turning space where the pedestrian is waiting to cross?

- **YES**. A parallel ramp has been used on the outside to provide the landing space, and the island has a sufficient landing area beyond the ramps.



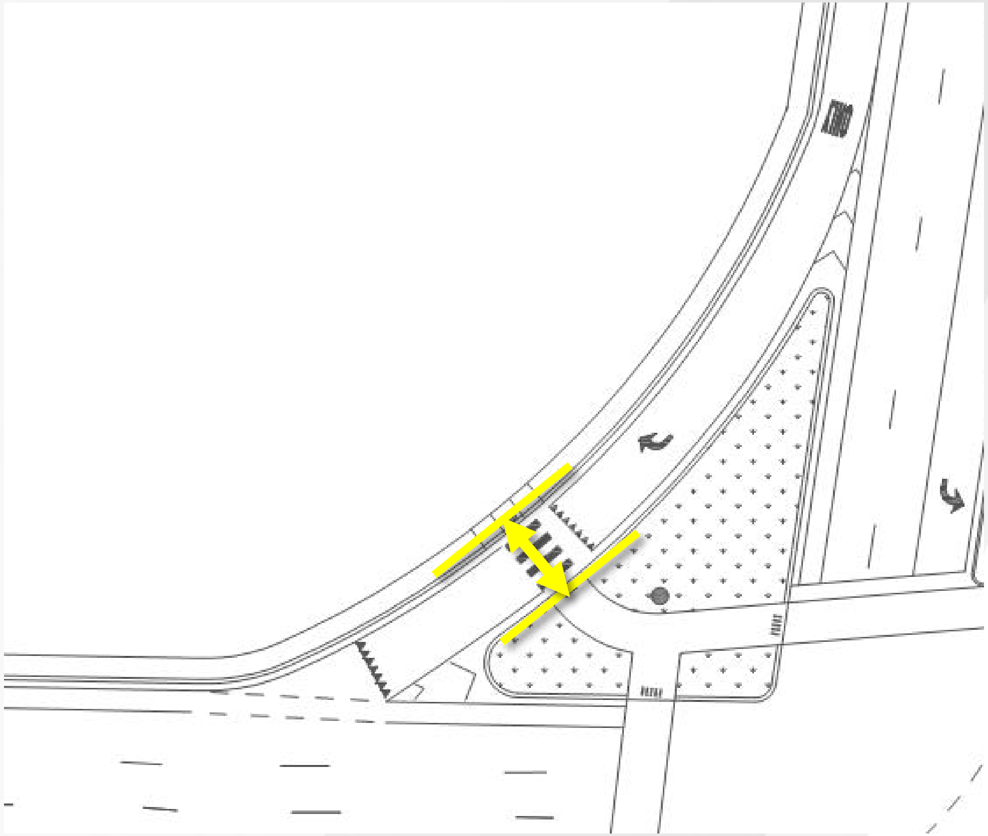
6.3.1 Is the crossing configured at the shortest distance practical?

- YES.



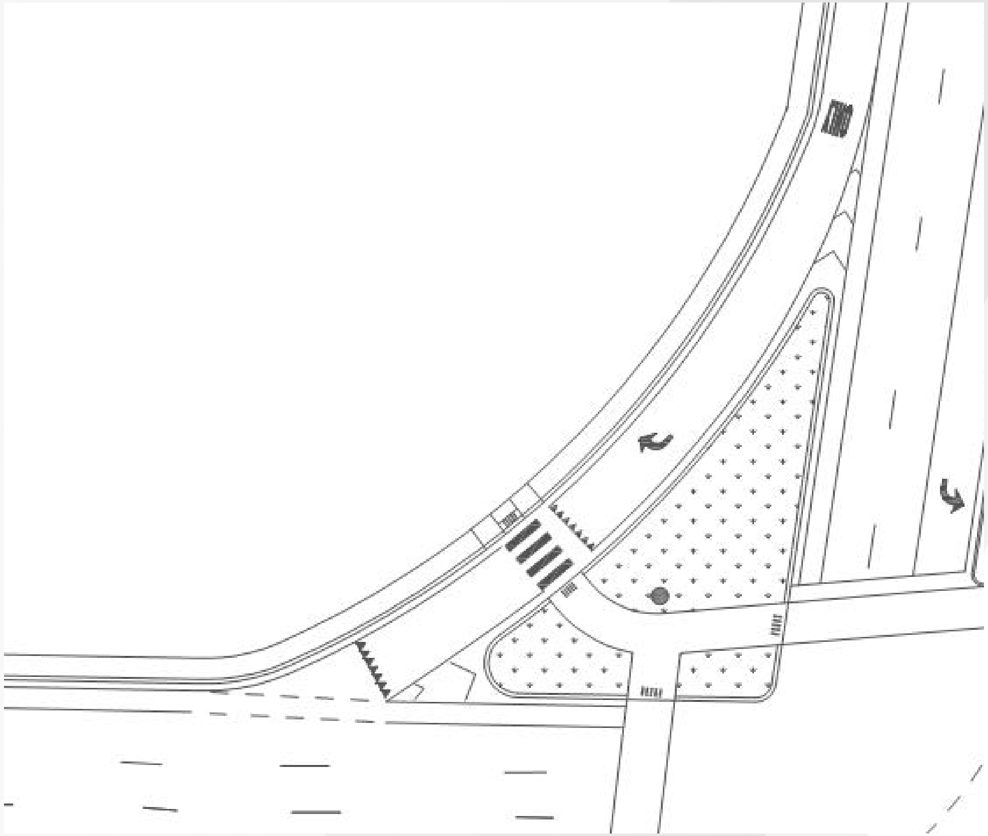
6.3.2 Is the crossing aligned perpendicular to the curb and splitter edges?

- **YES**.



6.3.3 Are markings clearly visible?

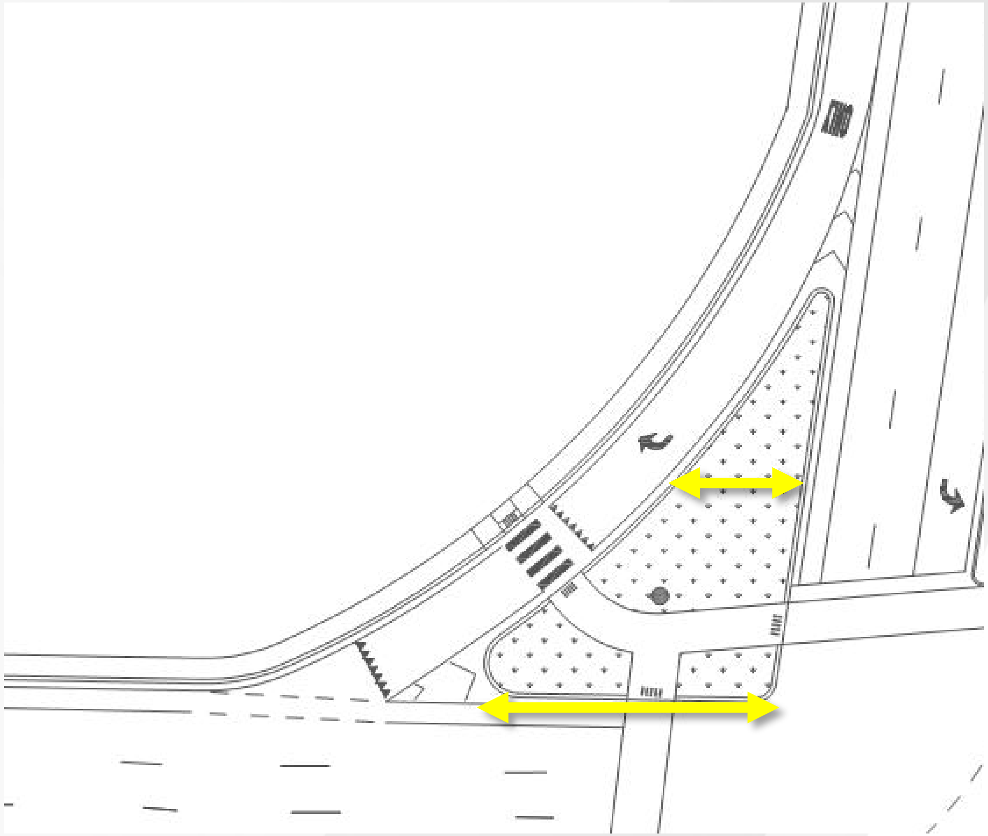
- **YES**. High-visibility crosswalk markings have been used.



Accessible Design for the Blind

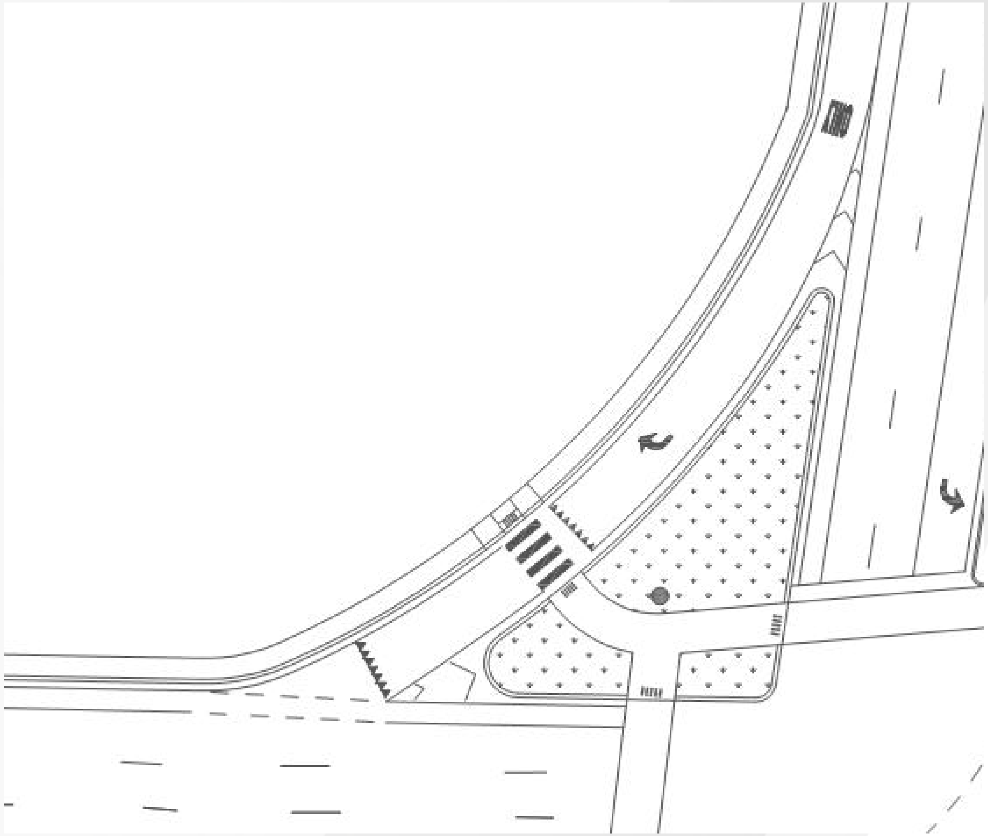
6.4.1 Are islands wide enough to provide safe refuge?

- **YES**.



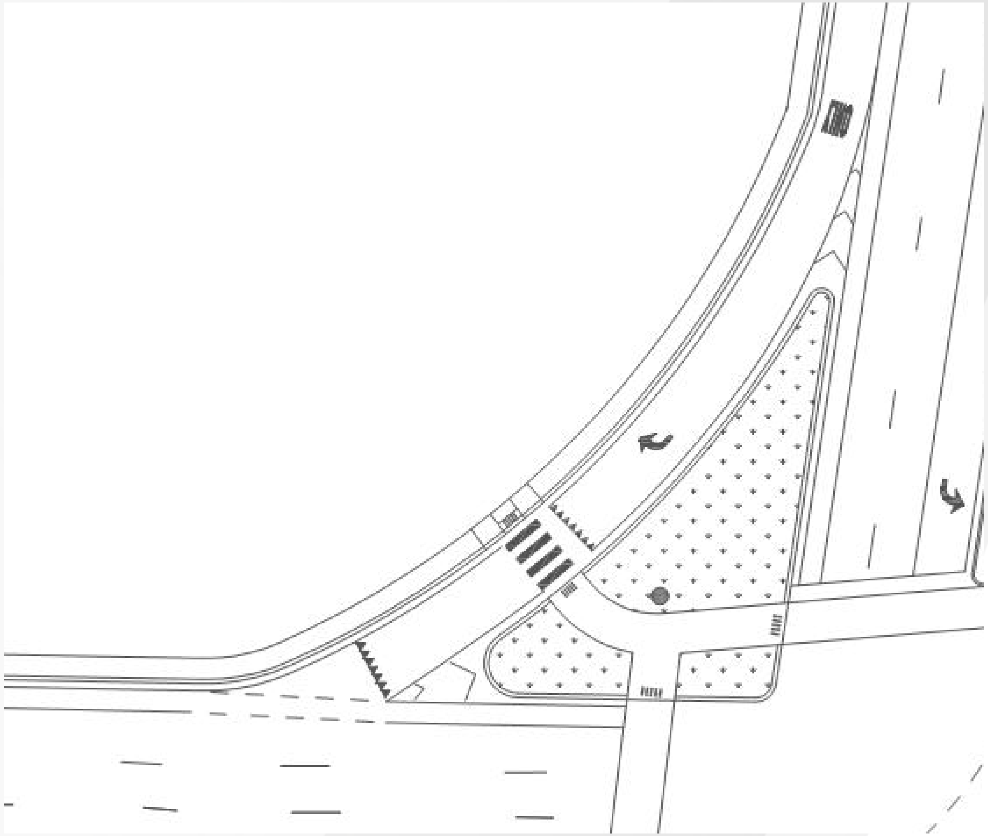
6.4.2 Are transitions to roadway clearly defined (within the island)?

- **NO**. The edges of the detectable warning surfaces on the island should extend to the edges of the walkway.



6.4.3 Are paths through island clearly identifiable?

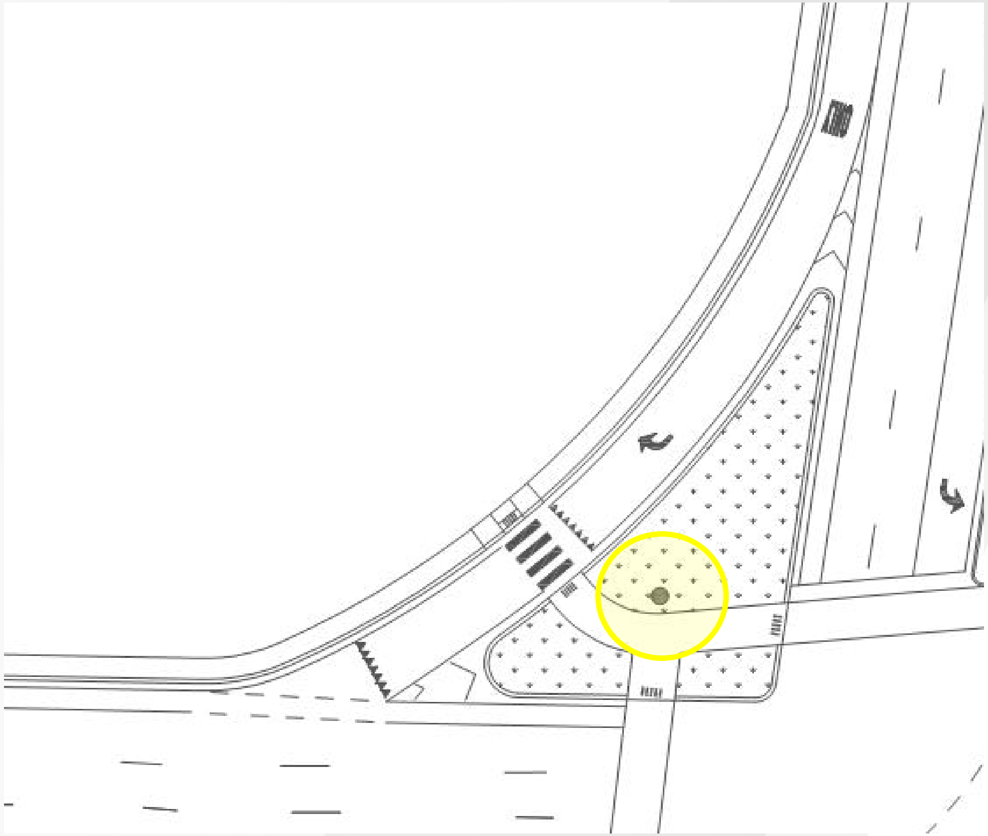
- **YES**. The pathway within the island appears to have a surface that is different enough from the rest of the island (which appears to be grass) to be detectable under foot.



Accessible Design for the Blind

6.4.4 Are pushbuttons accessible?

- **NO**. No poles for accessible pushbuttons are shown near the ramps and crosswalks. There should be two for the crossings from the island to each street, separated from each other by at least 10 feet. It is unclear how the CTL is being served, although the yield line suggests a warning beacon at most.

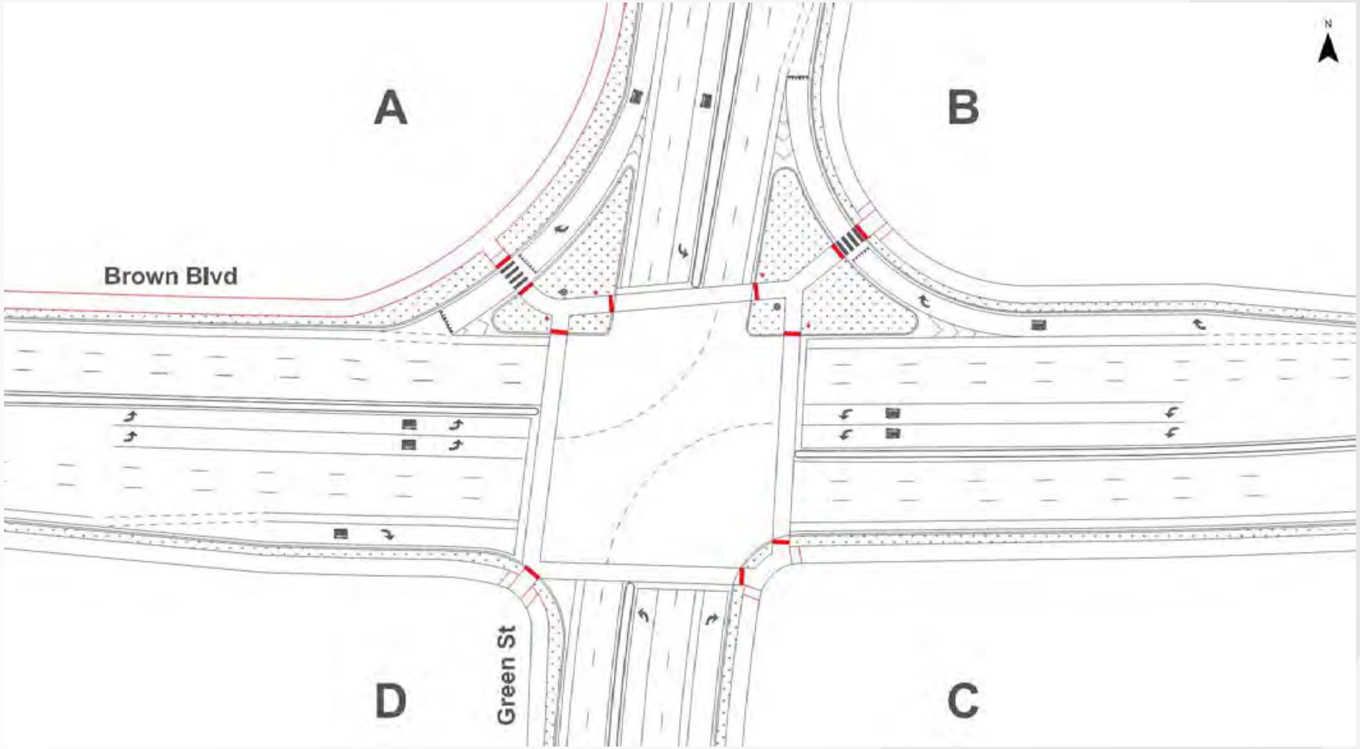


Channelized Turn Lane Example 2: Brown Blvd./Green St.

	A	B
6.1.1. Sidewalks lead to crosswalks	YES	YES
6.1.2. Separation between sidewalk and curb	NO	NO
6.1.3. Edge of street defined (outside edge)	NO	NO
6.1.4. Other ramps/driveways separated/delineated	N/A	N/A
6.1.5. TCDs accessible	UNCLEAR	UNCLEAR
6.2.1. Ramp width = crosswalk width	NO	NO
6.2.2. Ramp slope aligned with crossing	YES	YES
6.2.3. Ramp edges aligned with crossing	YES	YES
6.2.4. DW aligned with ramp slope	YES	YES
6.2.5. PBs in correct location	UNCLEAR	UNCLEAR
6.2.6. Level landing	YES	YES
6.3.1. Crossing shortest distance	YES	YES
6.3.2. Crossing perpendicular to curb	YES	YES
6.3.3. Markings visible	YES	YES
6.4.1. Islands wide enough	YES	YES
6.4.2. Transitions to roadway defined (within island)	NO	NO
6.4.3. Paths through island identifiable	YES	YES
6.4.4. Pushbuttons accessible	NO	NO

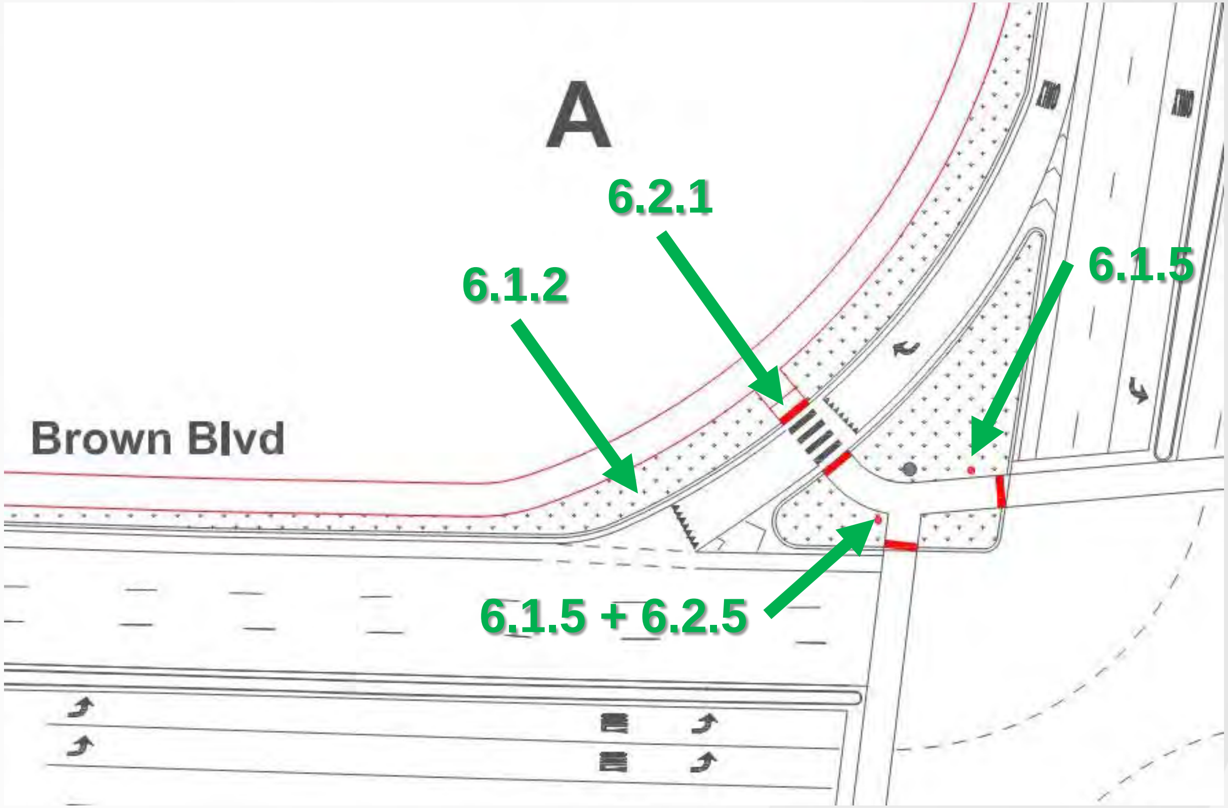
Channelized Turn Lane Example 2: Brown Blvd./Green St.

- Possible Solution



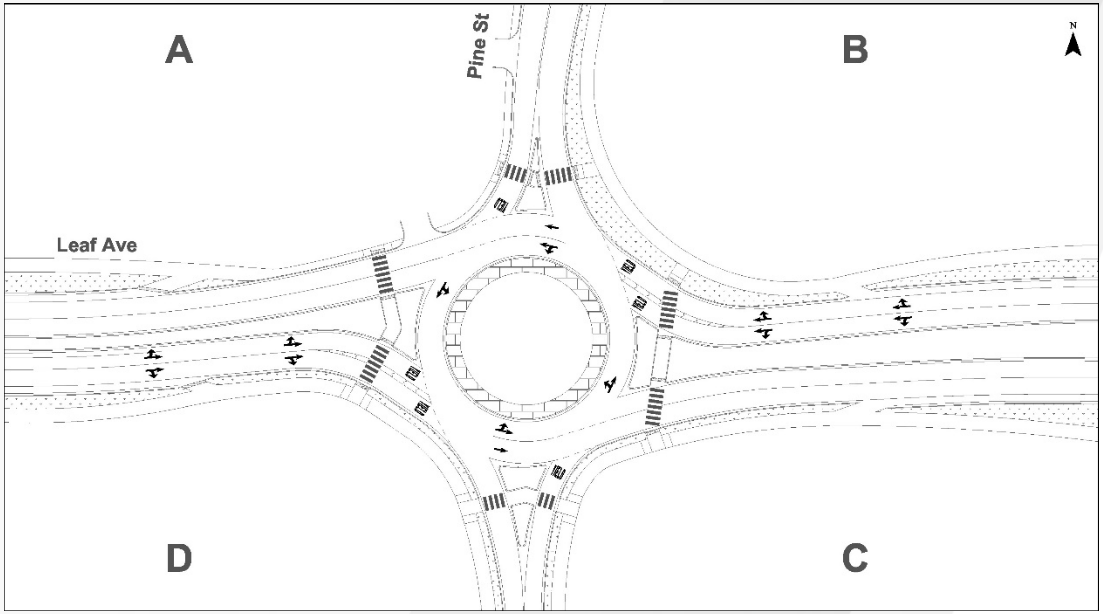
Channelized Turn Lane Example 2: Brown Blvd./Green St.

- Possible Solution



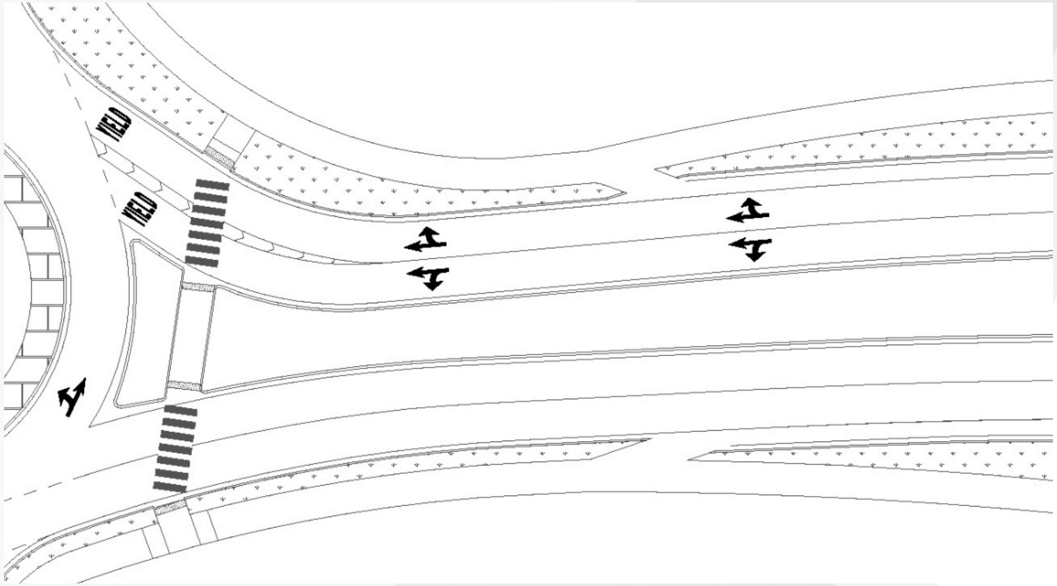
Roundabout Example 3: Leaf Ave./Pine St.

- For this example, we will select one crossing (B-C) and answer each question.
- The exercise would be repeated for the other crossings



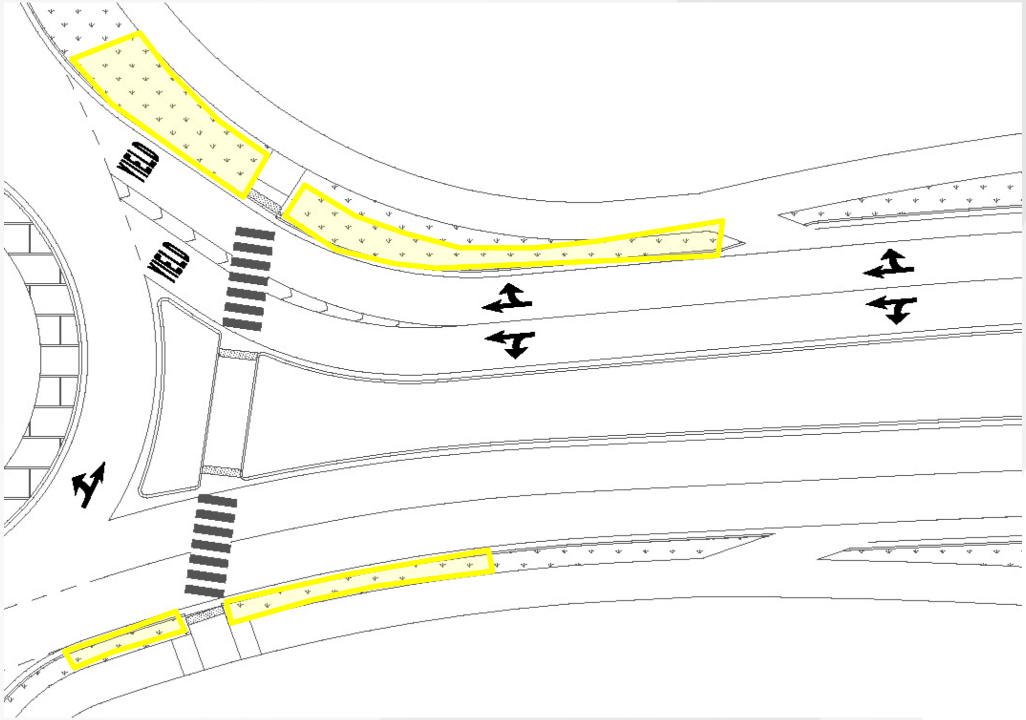
6.1.1 Do sidewalks lead to the crosswalks?

- **YES**.



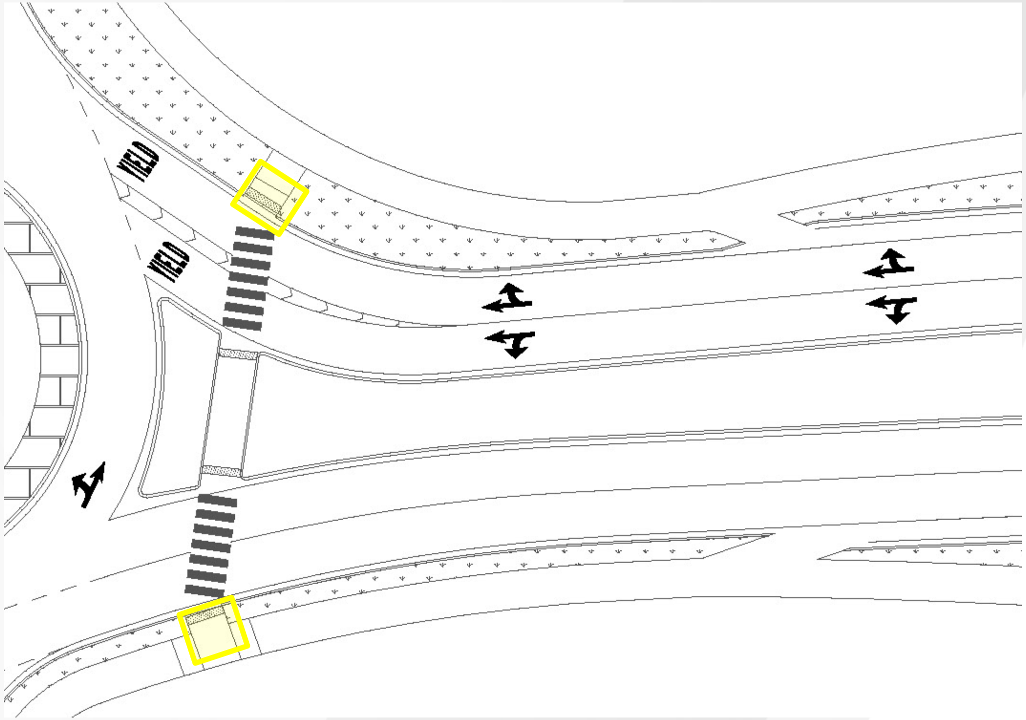
6.1.2 Is separation provided between sidewalk and curb?

- **YES**.



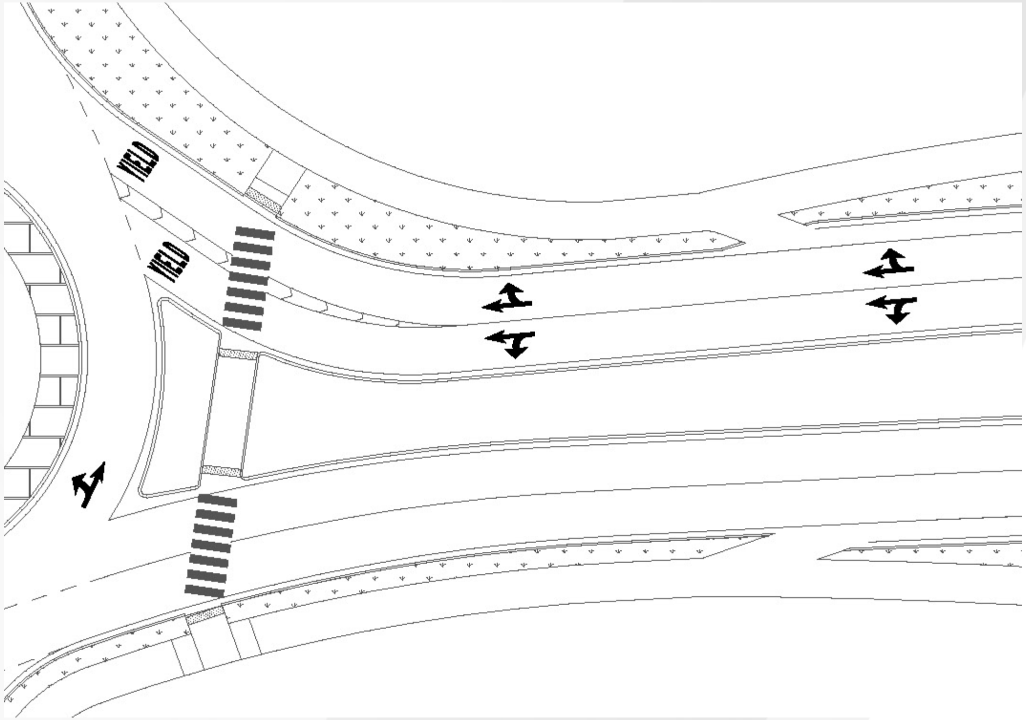
6.1.3 Is the edge of the street clearly defined (outside edge)?

- **YES**. Detectable warnings are provided at the bottom of the ramp.



6.1.4 If other ramps or driveways are nearby, are they adequately delineated and separated?*

- **NO**. The bike ramps are adequately separated but do not have adequate delineation.

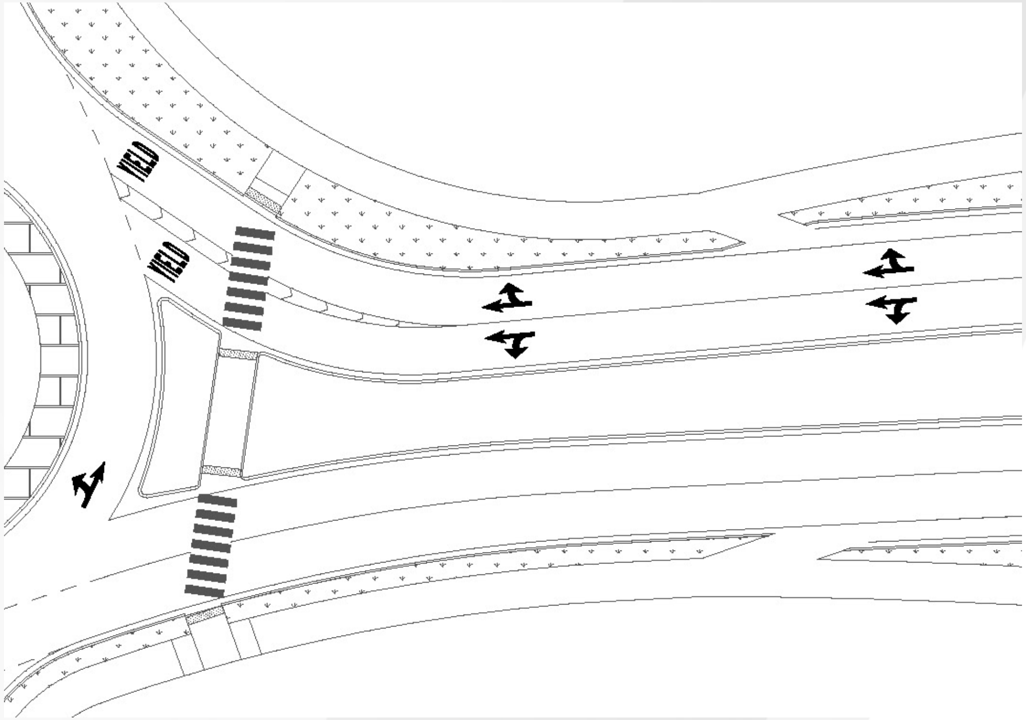


**Question has been reworded from NCHRP Report 834.*

Accessible Design for the Blind

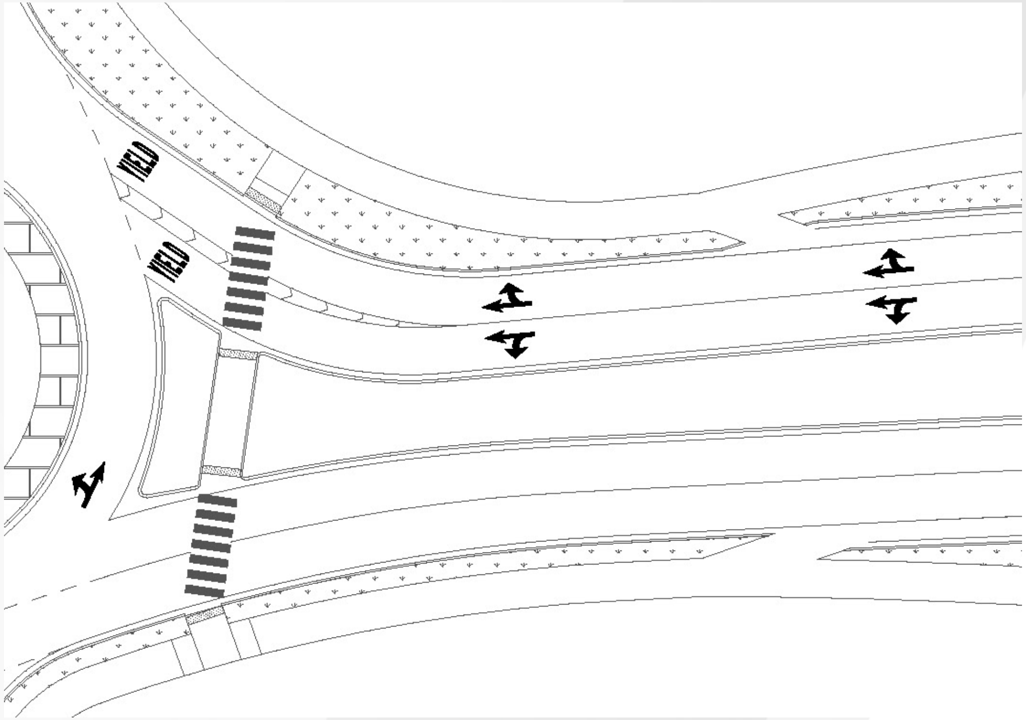
6.1.5 Are traffic control devices accessible?

- **UNCLEAR**. The provided plans do not indicate traffic control devices other than markings.



6.2.1 Is curb ramp width the same as crosswalk width?

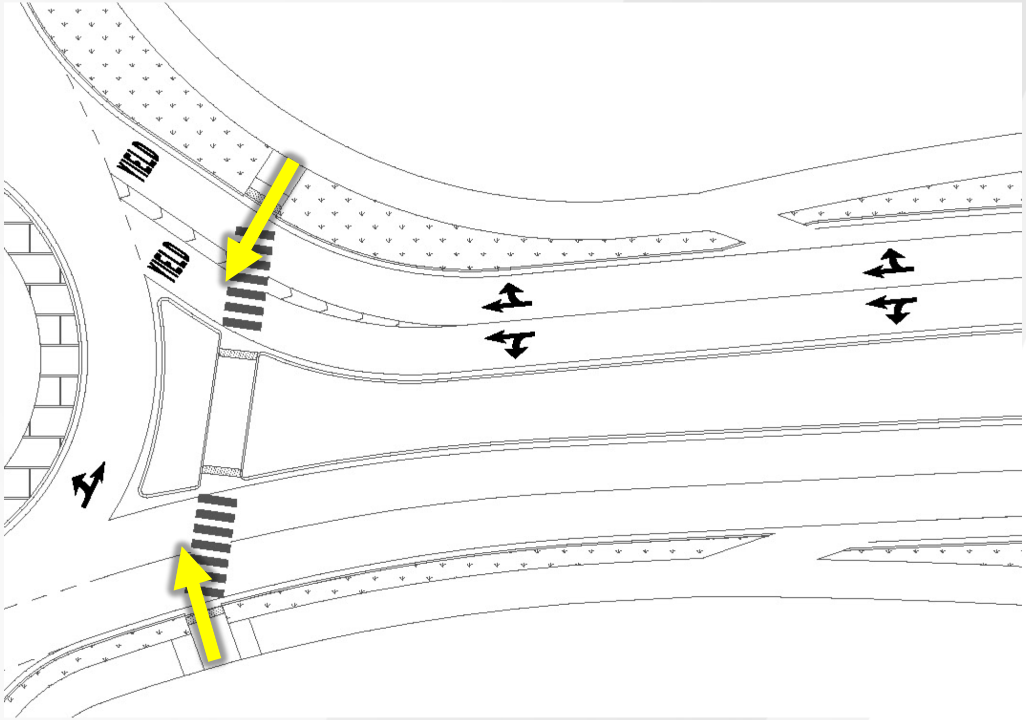
- **YES**.



Accessible Design for the Blind

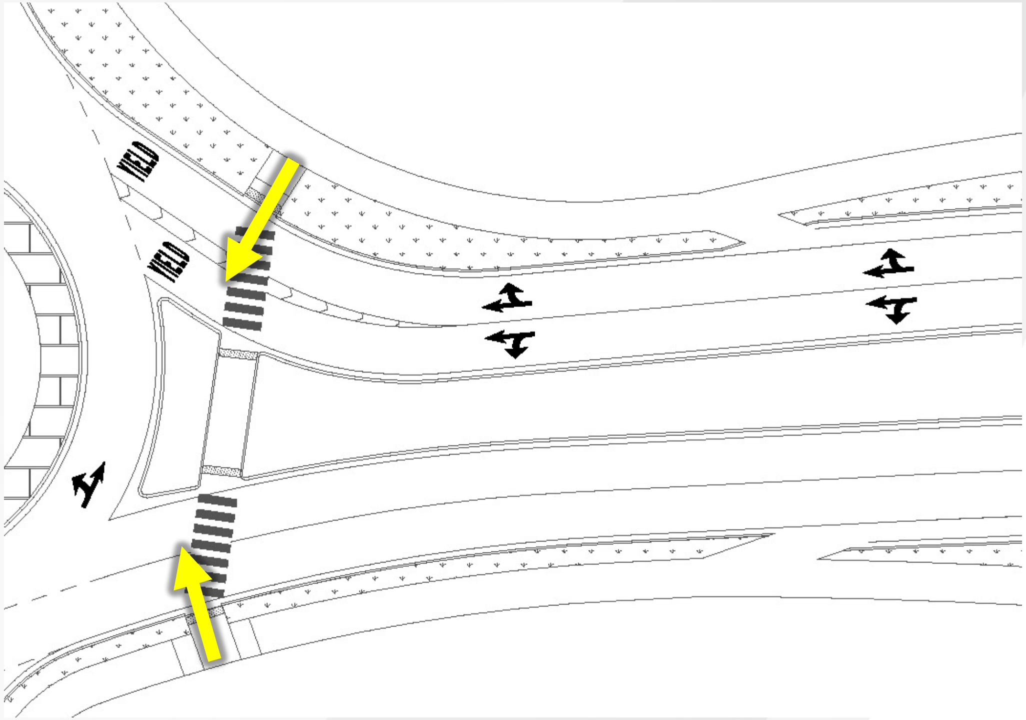
6.2.2 Is curb ramp slope aligned with crossing?

- **NO**. The curb ramp slopes are not aligned with the crossing.



6.2.3 Are ramp edges aligned with crossing?

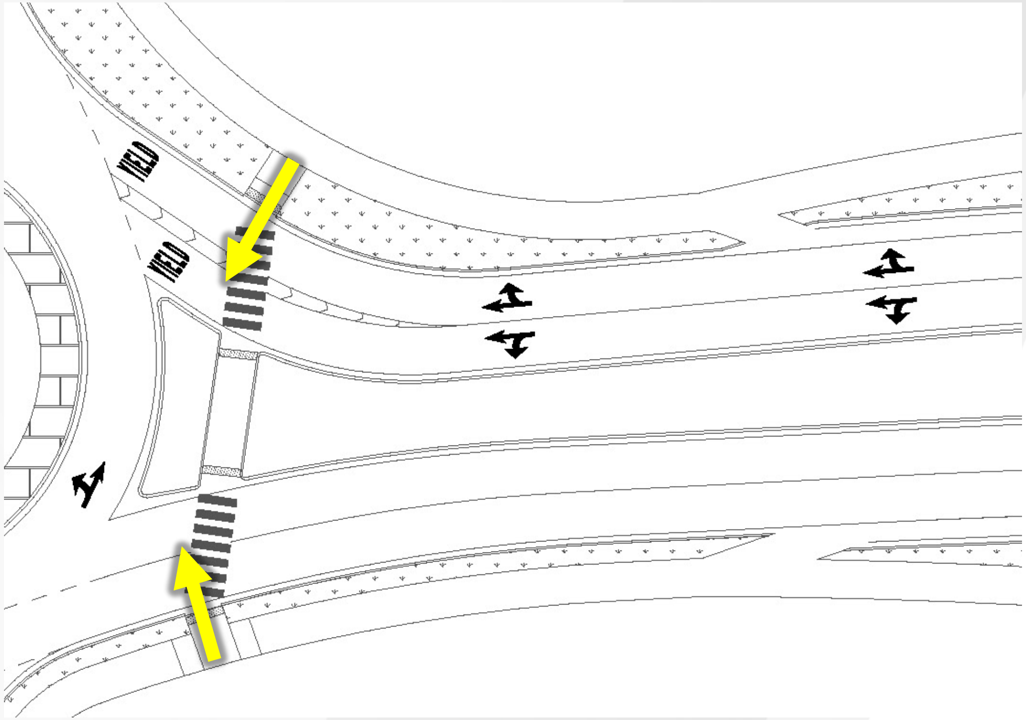
- **NO**. While the ramp edges on the island are aligned with the crossing, the outer curb ramp edges are not aligned with the crossing.



Accessible Design for the Blind

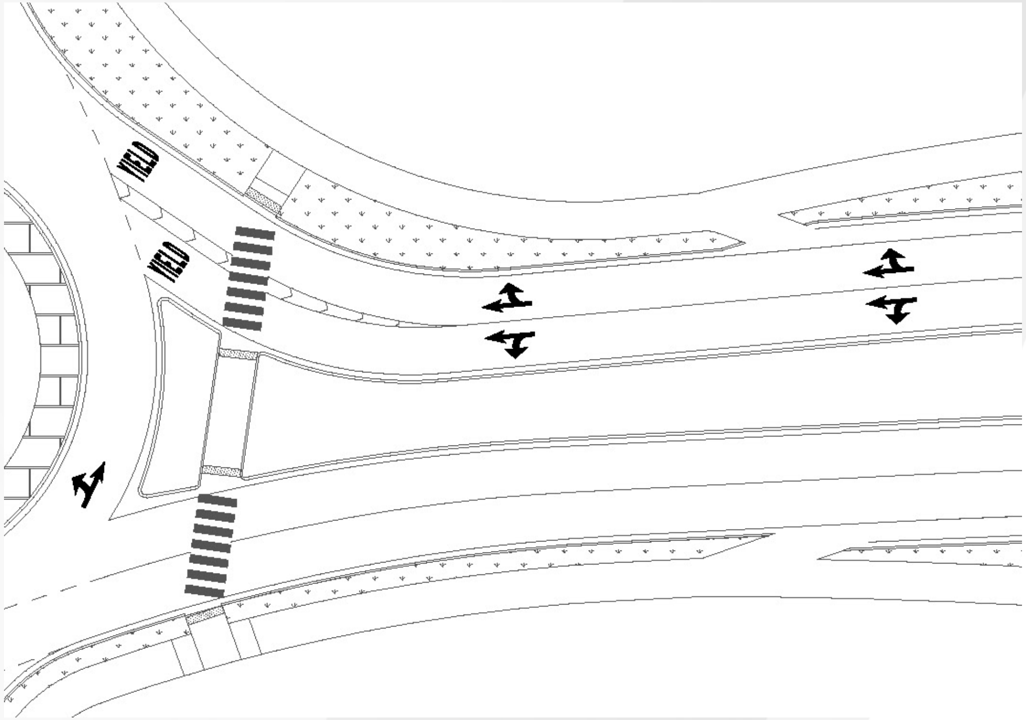
6.2.4 Is the detectable warning aligned with slope of the curb ramp?

- **YES**. The detectable warning is aligned with the ramps.



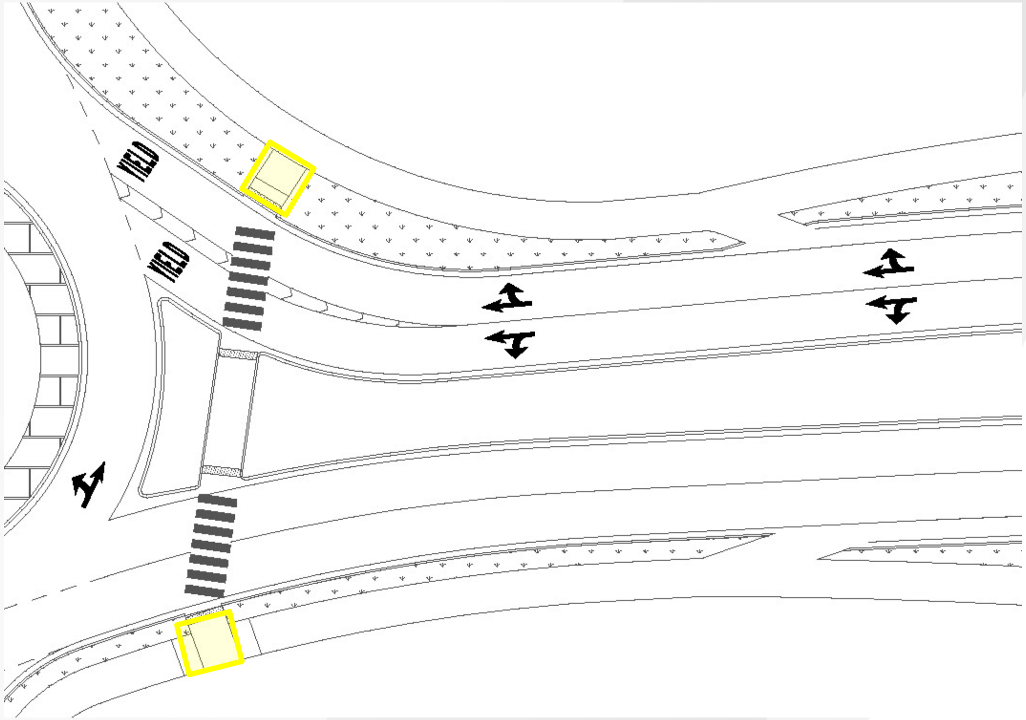
6.2.5 Are pushbuttons in correct location?

- **UNCLEAR. The provided plans do not indicate traffic control devices other than markings.**



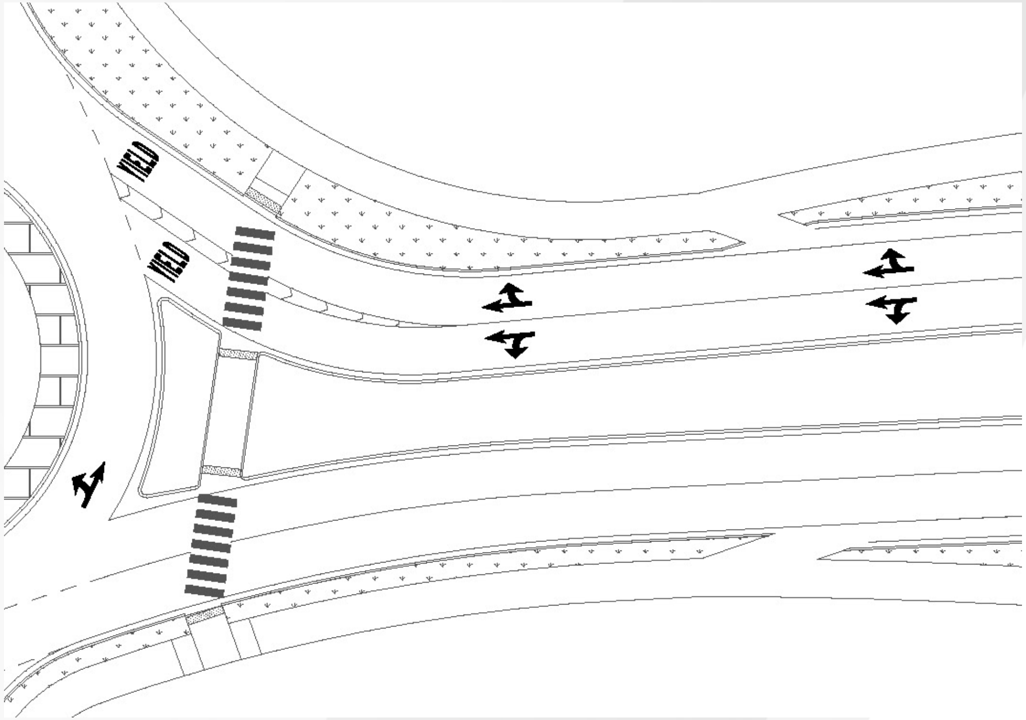
6.2.6 Is there a sufficiently level landing and turning space where the pedestrian is waiting to cross?

- **YES**. The necessary landing area is provided.



6.3.1 Is the crossing configured at the shortest distance practical?

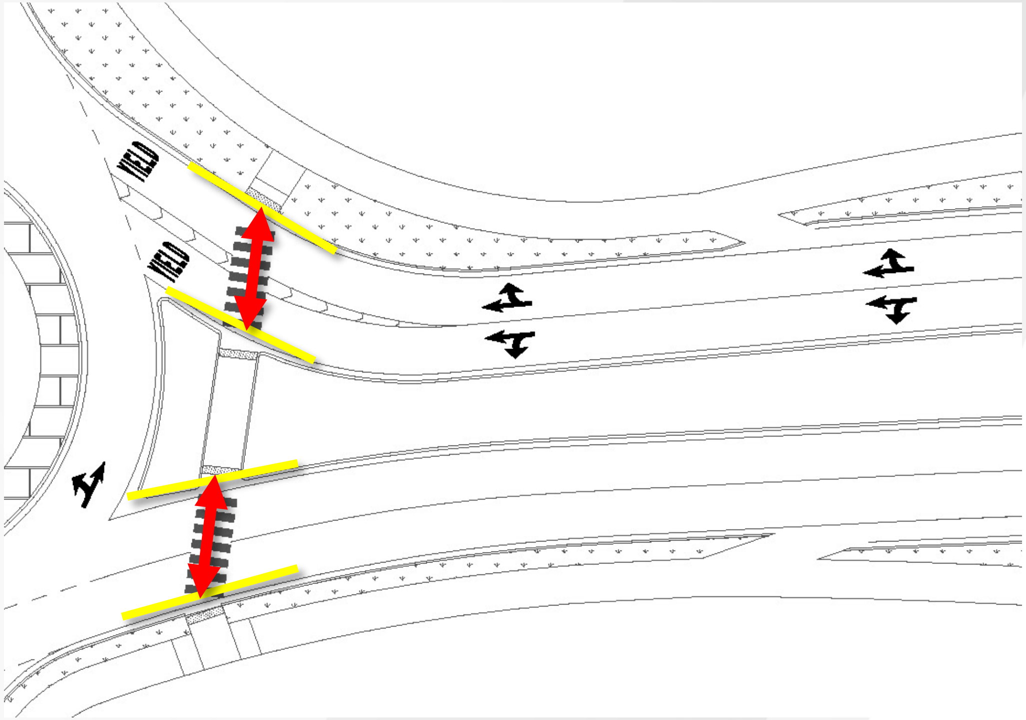
- **NO**. The crossing provided is not the shortest practical crossing distance for the location.




Accessible Design for the Blind

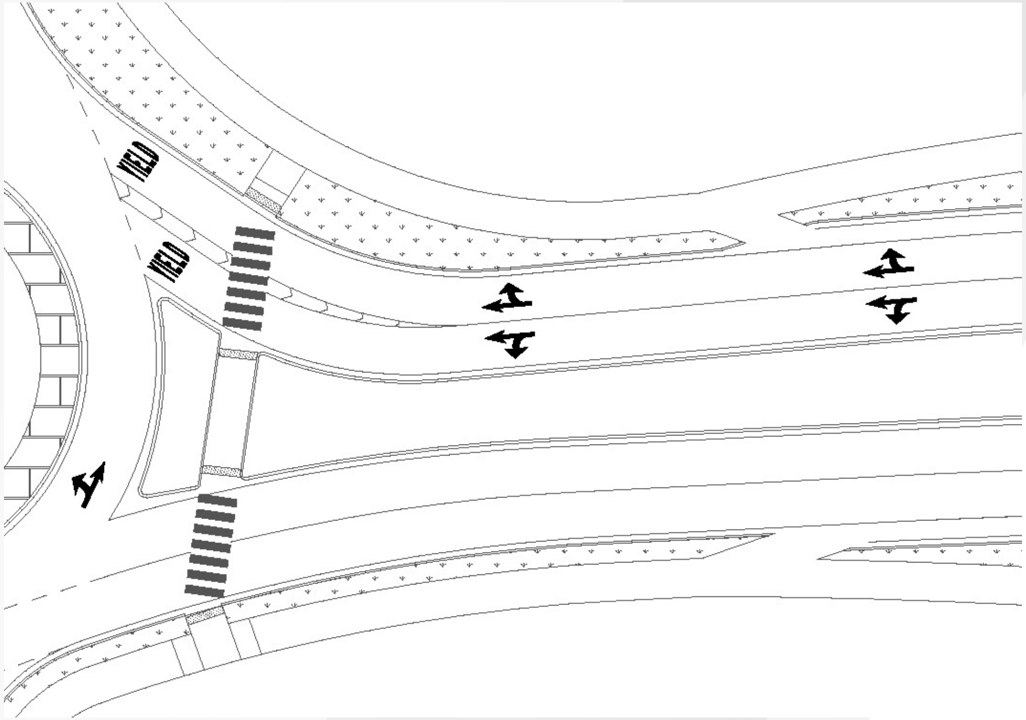
6.3.2 Is the crossing aligned perpendicular to the curb and splitter edges?

- **NO**. The crossing is not perpendicular to the curb or the splitter edge.



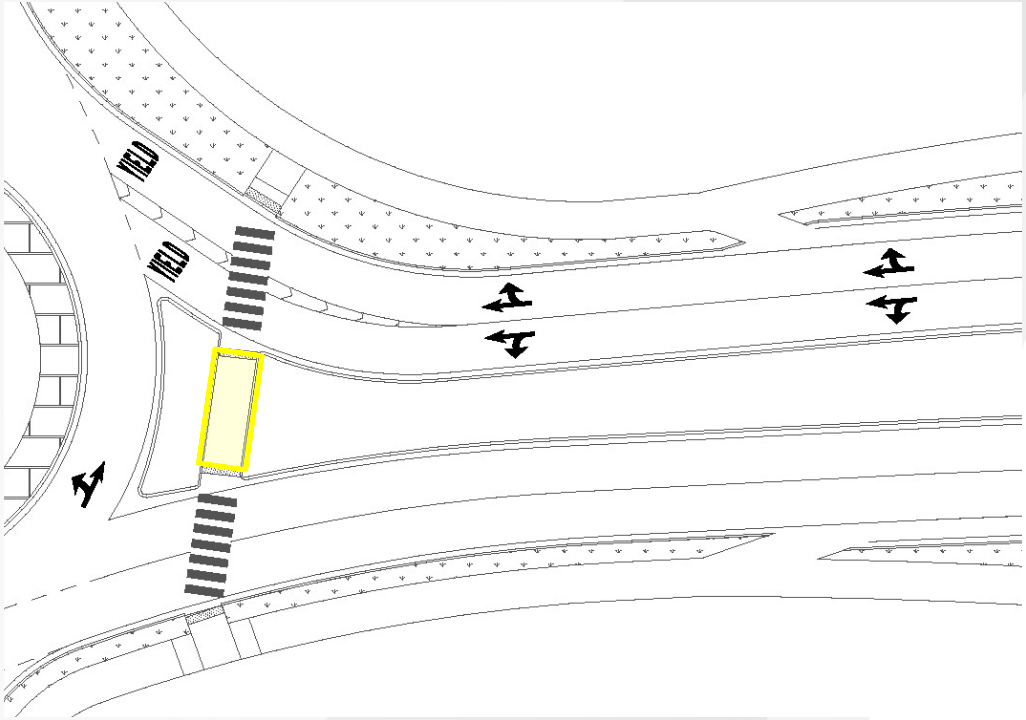
6.3.3 Are markings clearly visible?

- **YES**.



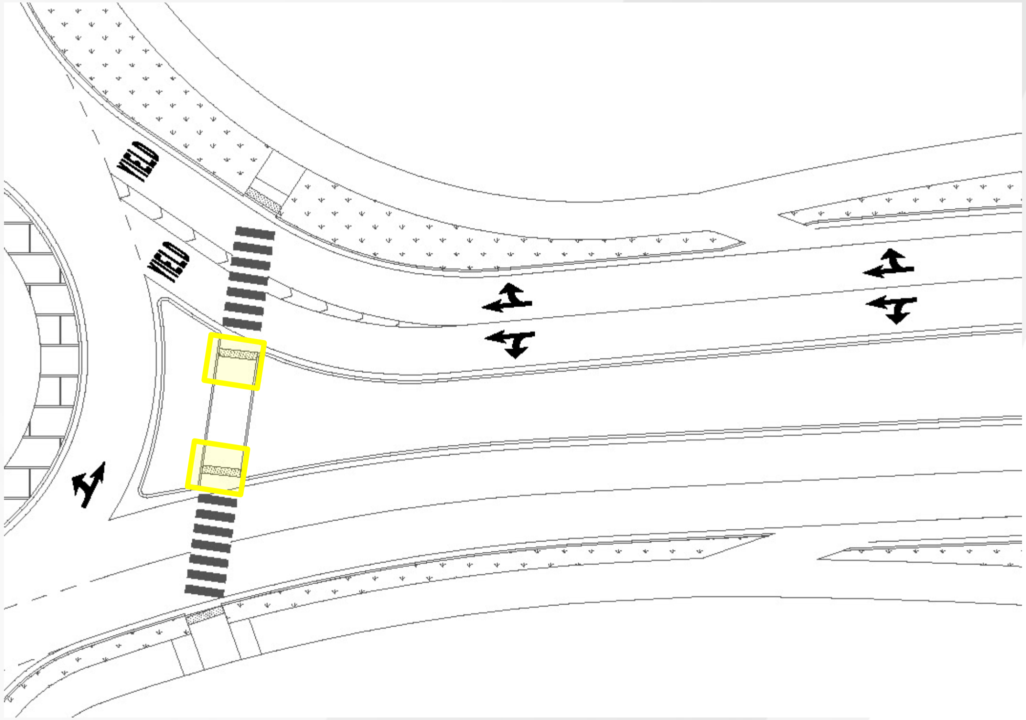
6.4.1 Are islands wide enough to provide safe refuge?

- **YES**.



6.4.2 Are transitions to roadway clearly defined (within the island)?

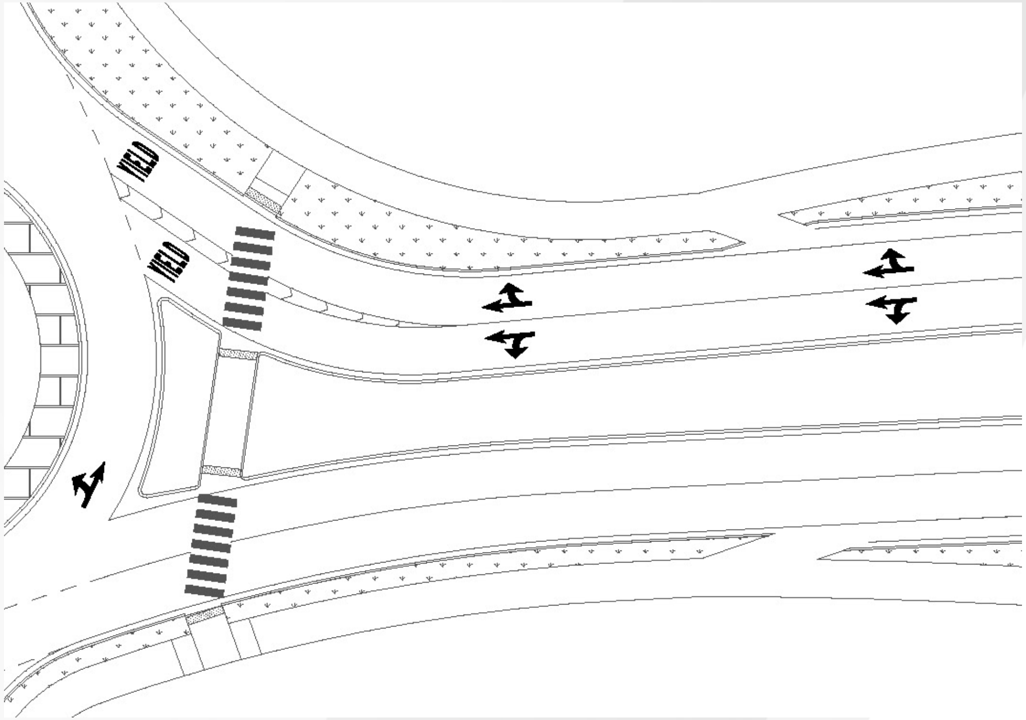
- **YES**. Detectable warnings are provided at the boundary between the splitter island refuge and the travel lanes.



Accessible Design for the Blind

6.4.3 Are paths through island clearly identifiable?

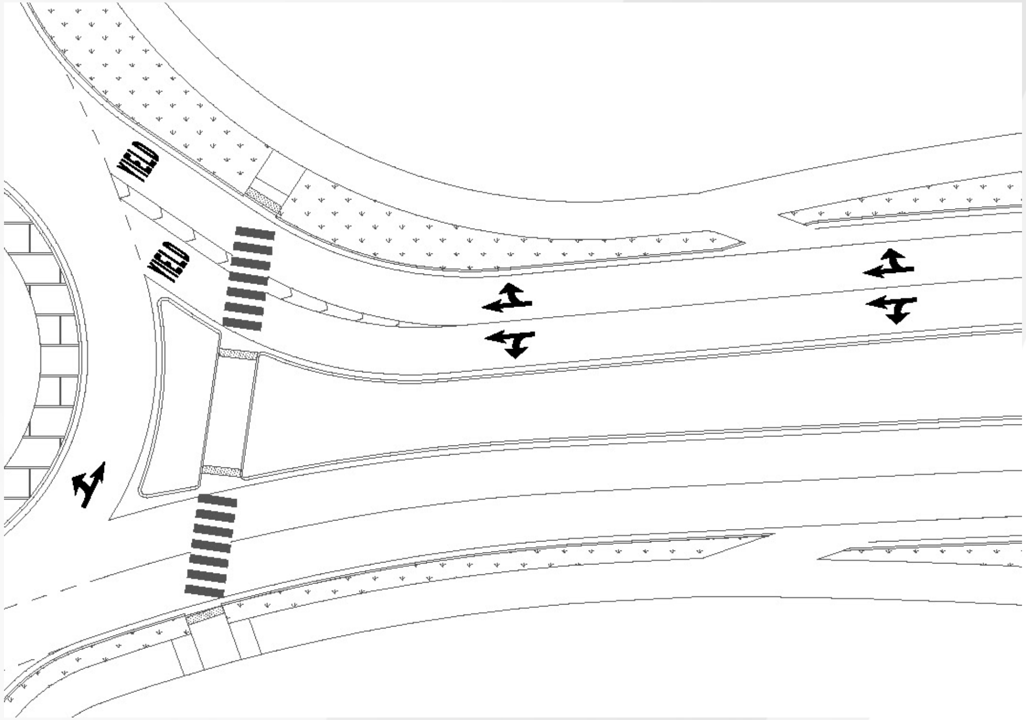
- UNCLEAR. It is unclear whether the pathway within the island has a surface that is different enough from the rest of the island to be detectable under foot.



Accessible Design for the Blind

6.4.4 Are pushbuttons accessible?

- UNCLEAR. The provided plans do not indicate traffic control devices other than markings.



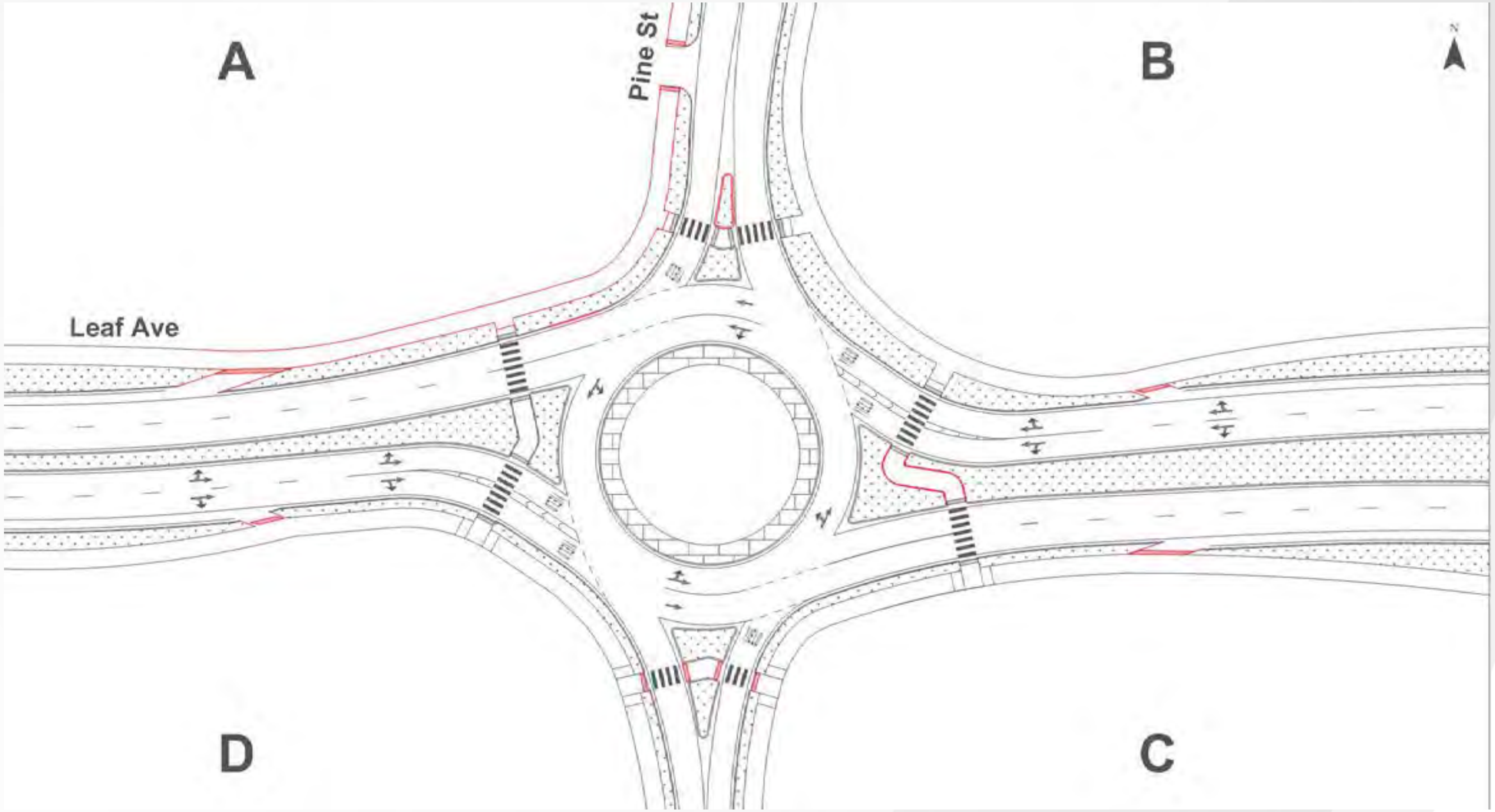
Accessible Design for the Blind

Roundabout Example 3: Leaf Ave./Pine St.

	A-B	B-C	C-D	D-A
6.1.1. Sidewalks lead to crosswalks	YES	YES	YES	YES
6.1.2. Separation between sidewalk and curb	NO (A), YES (B)	YES	YES	YES (D), NO (A)
6.1.3. Edge of street defined (outside edge)	YES	YES	NO	YES
6.1.4. Other ramps/driveways separated/delineated	N/A	NO	N/A	NO
6.1.5. TCDs accessible	UNCLEAR	UNCLEAR	UNCLEAR	UNCLEAR
6.2.1. Ramp width = crosswalk width	YES	YES	YES	YES
6.2.2. Ramp slope aligned with crossing	YES	NO	YES	YES
6.2.3. Ramp edges aligned with crossing	YES	NO	YES	YES
6.2.4. DW aligned with ramp slope	YES	YES	NO	YES
6.2.5. PBs in correct location	UNCLEAR	UNCLEAR	UNCLEAR	UNCLEAR
6.2.6. Level landing	NO	YES	YES	NO
6.3.1. Crossing shortest distance	YES	NO	YES	YES
6.3.2. Crossing perpendicular to curb	YES	NO	YES	YES
6.3.3. Markings visible	YES	YES	YES	YES
6.4.1. Islands wide enough	NO	YES	YES	YES
6.4.2. Transitions to roadway defined (within island)	YES	YES	NO	YES
6.4.3. Paths through island identifiable	UNCLEAR	UNCLEAR	UNCLEAR	UNCLEAR
6.4.4. Pushbuttons accessible	UNCLEAR	UNCLEAR	UNCLEAR	UNCLEAR

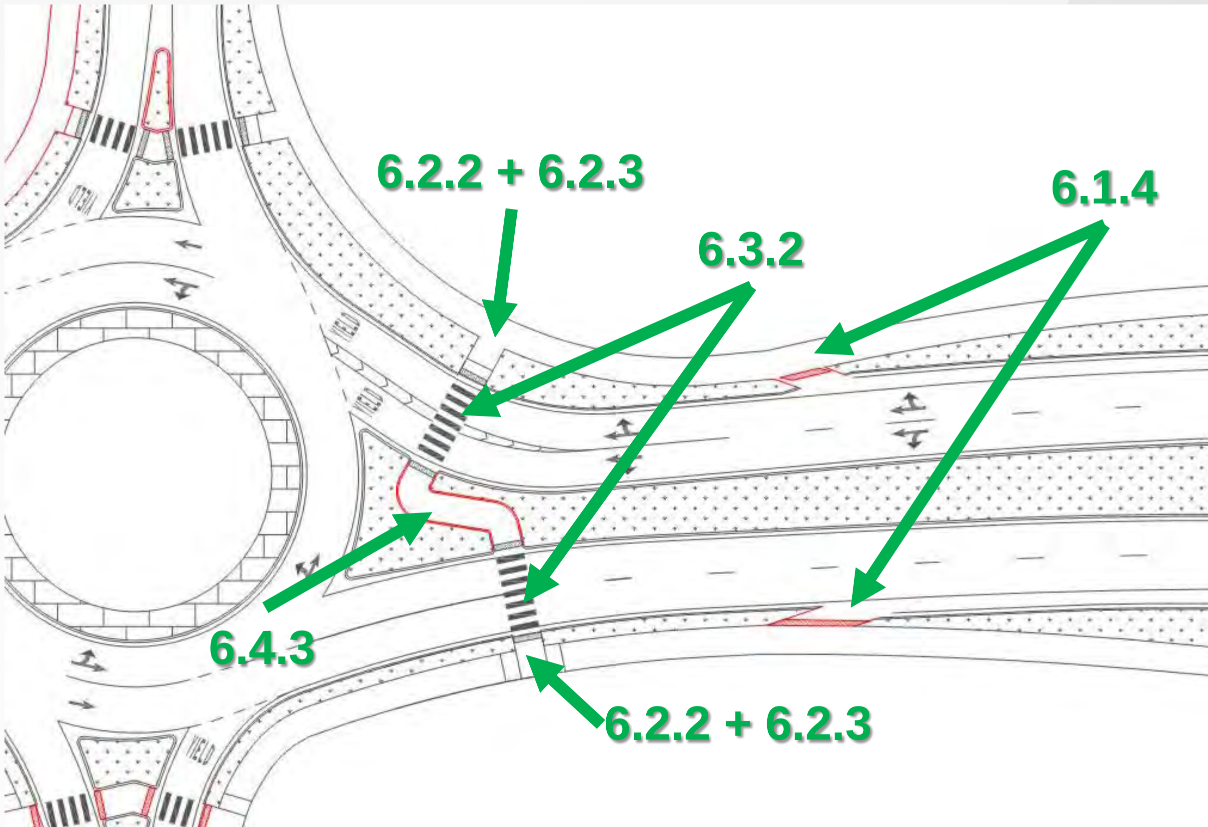
Roundabout Example 3: Leaf Ave./Pine St.

- Possible Solution



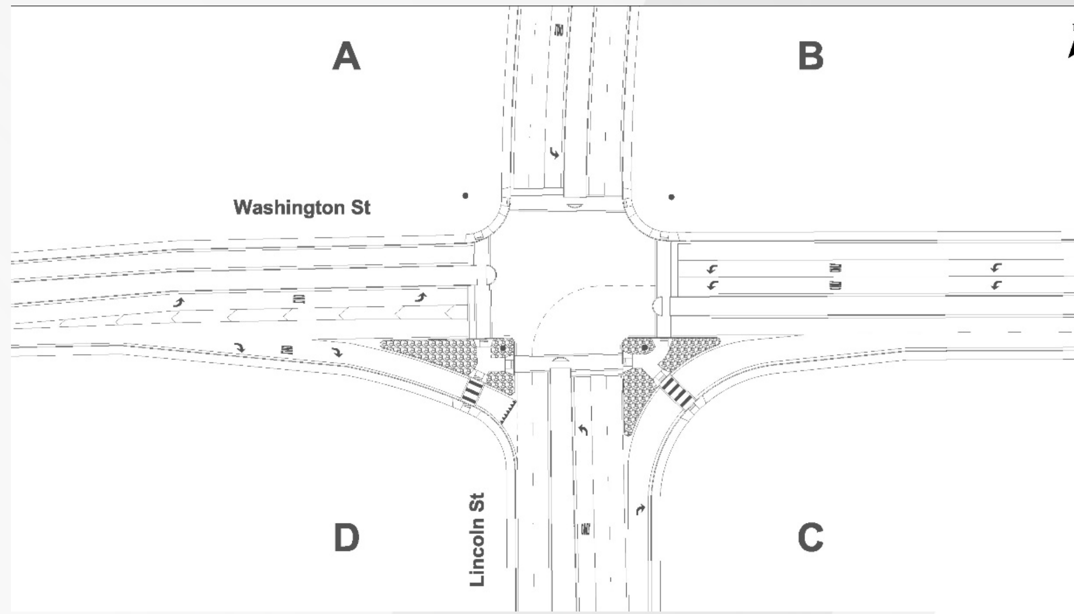
Roundabout Example 3: Leaf Ave./Pine St.

- Possible Solution



Channelized Turn Lane Example 4: Washington St./Lincoln St.

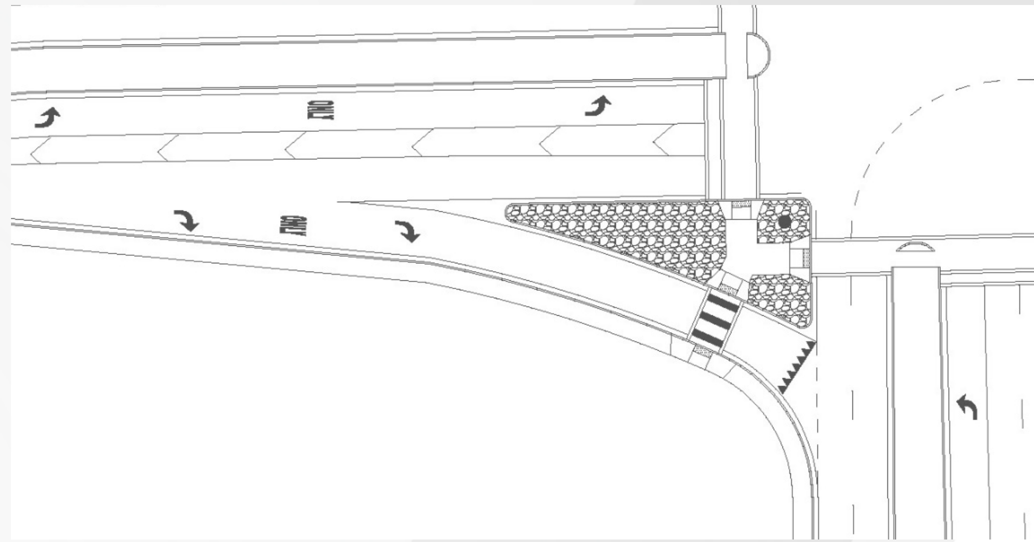
- For this example, we will select one crossing (D) and answer each question.
- The exercise would be repeated for the other crossings



Accessible Design for the Blind

6.1.1 Do sidewalks lead to the crosswalks?

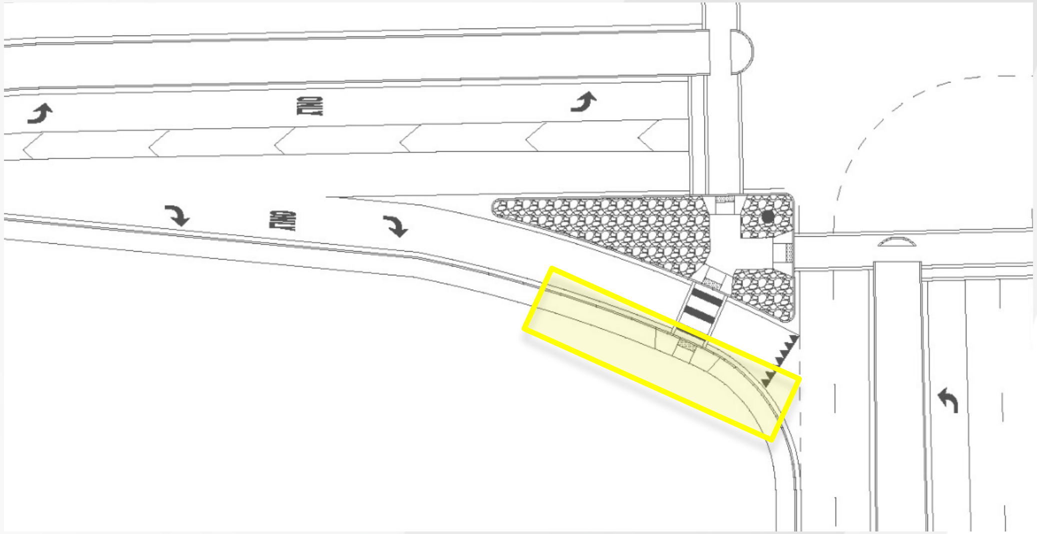
- **YES**.



Accessible Design for the Blind

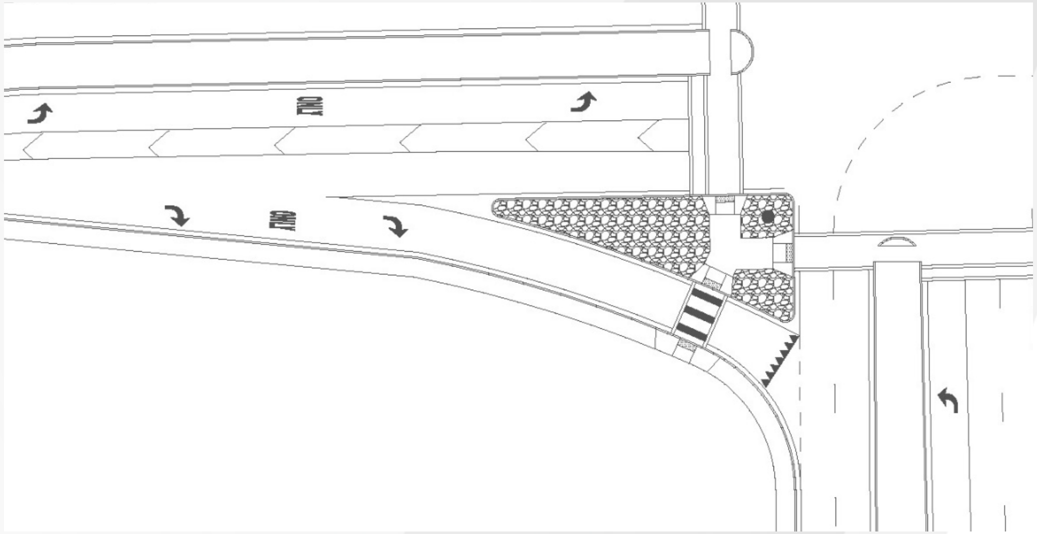
6.1.2 Is separation provided between sidewalk and curb?

- **NO**. A buffer or fence should be provided.



6.1.3 Is the edge of the street clearly defined (outside edge)?

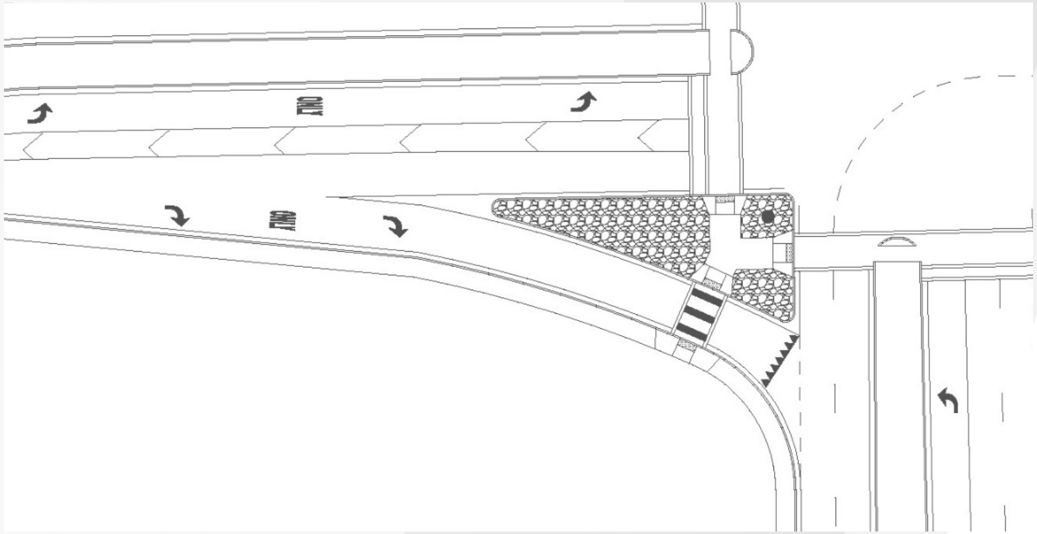
- **YES**. Detectable warnings are provided at the bottom of the ramp.



Accessible Design for the Blind

6.1.4 If other ramps or driveways are nearby, are they adequately delineated and separated?*

- **N/A**.

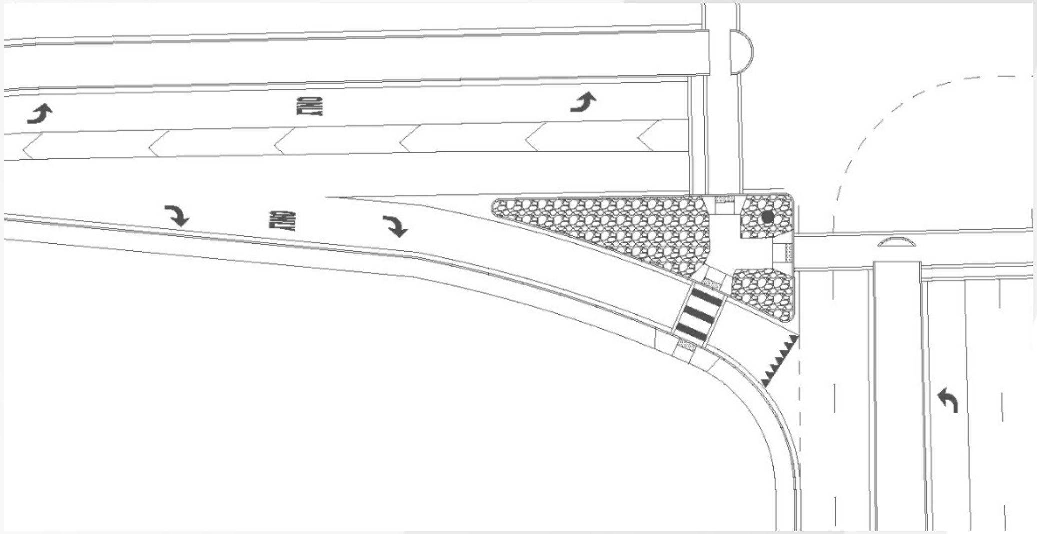


**Question has been reworded from NCHRP Report 834.*

Accessible Design for the Blind

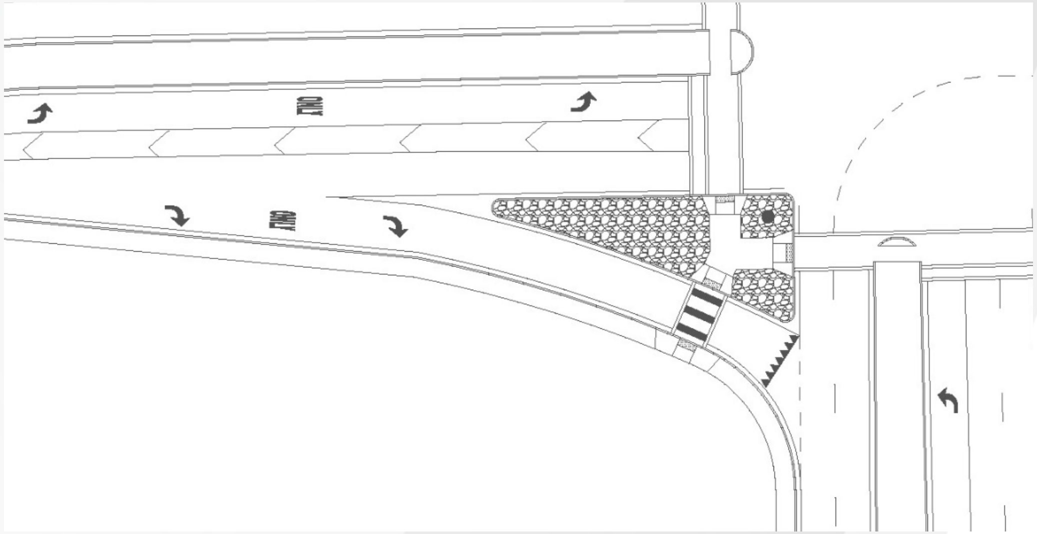
6.1.5 Are traffic control devices accessible?

- **NO. Assuming the pushbuttons are currently located on the main signal pole, pushbuttons should be located closer to each crossing and separated by at least 10 feet for each crossing direction. The control for the CTL is unclear but appears to be uncontrolled.**



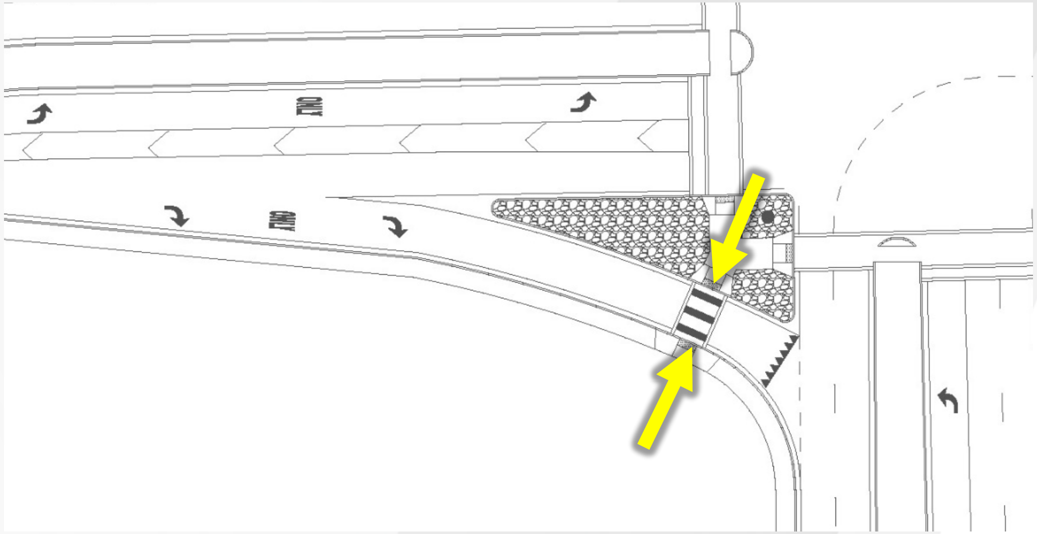
6.2.1 Is curb ramp width the same as crosswalk width?

- **NO**. The curb ramp should be wider and the ramp flares should be located outside of the crosswalk width.



6.2.2 Is curb ramp slope aligned with crossing?

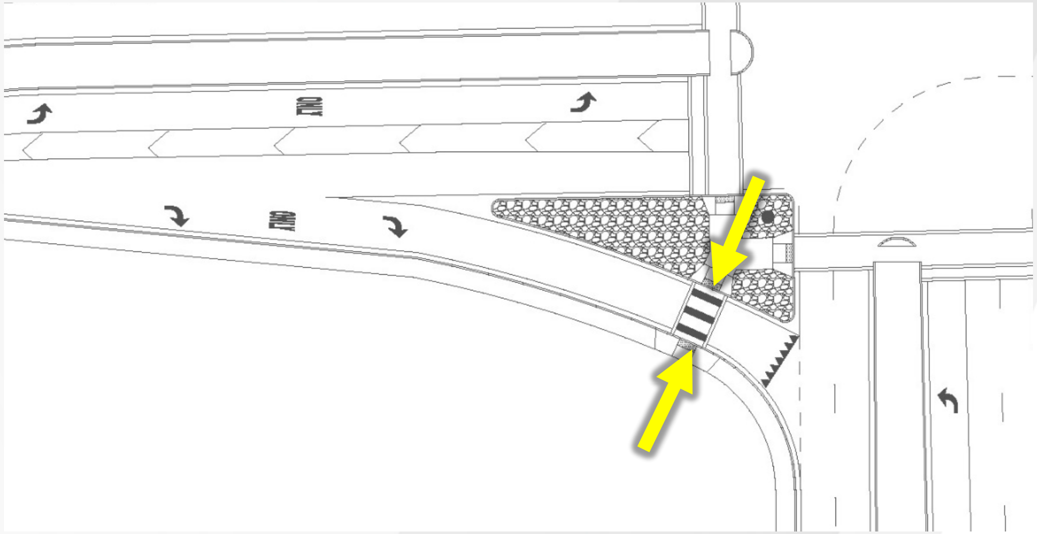
- **YES**.



Accessible Design for the Blind

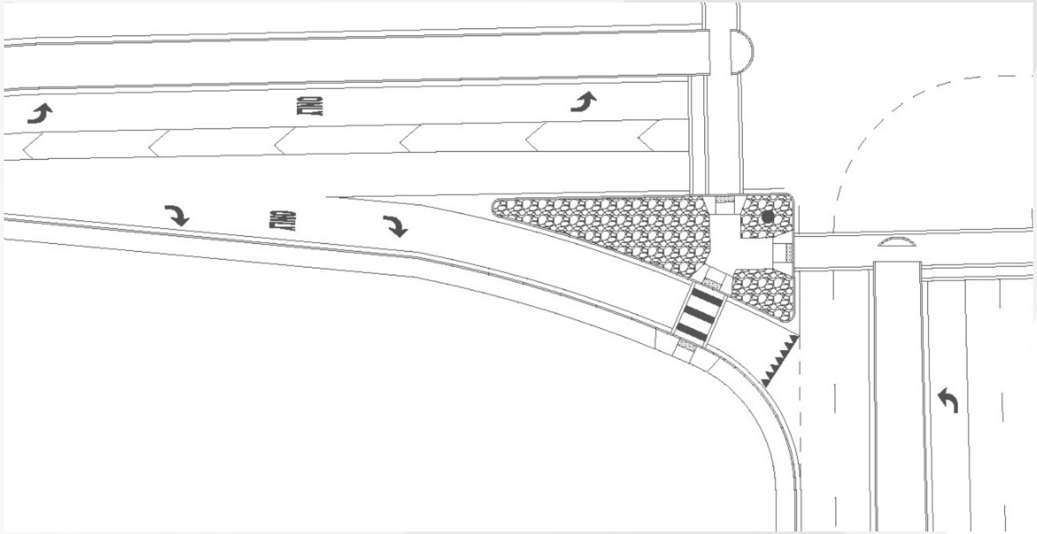
6.2.3 Are ramp edges aligned with crossing?

- **YES**.



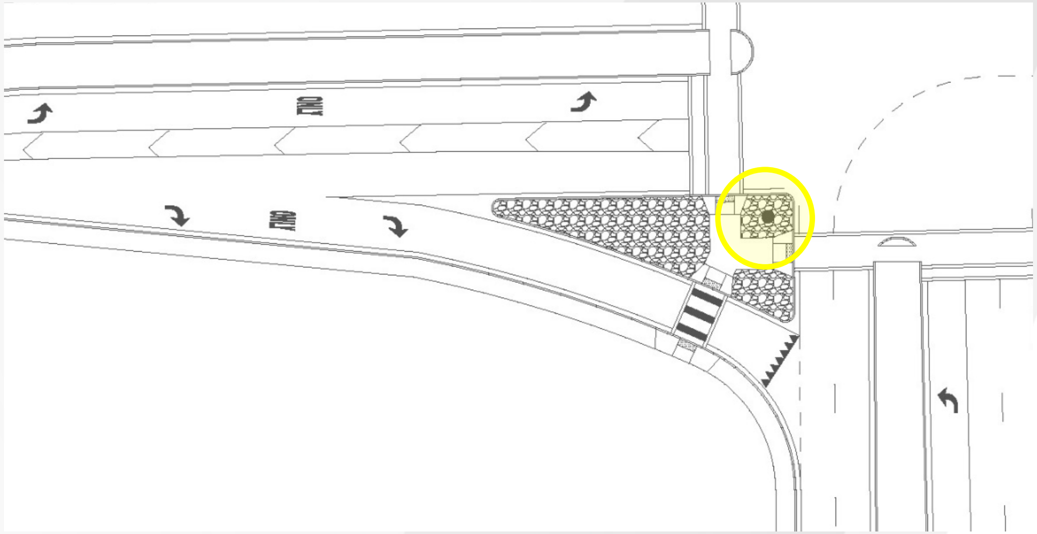
6.2.4 Is the detectable warning aligned with slope of the curb ramp?

- **YES**.



6.2.5 Are pushbuttons in correct location?

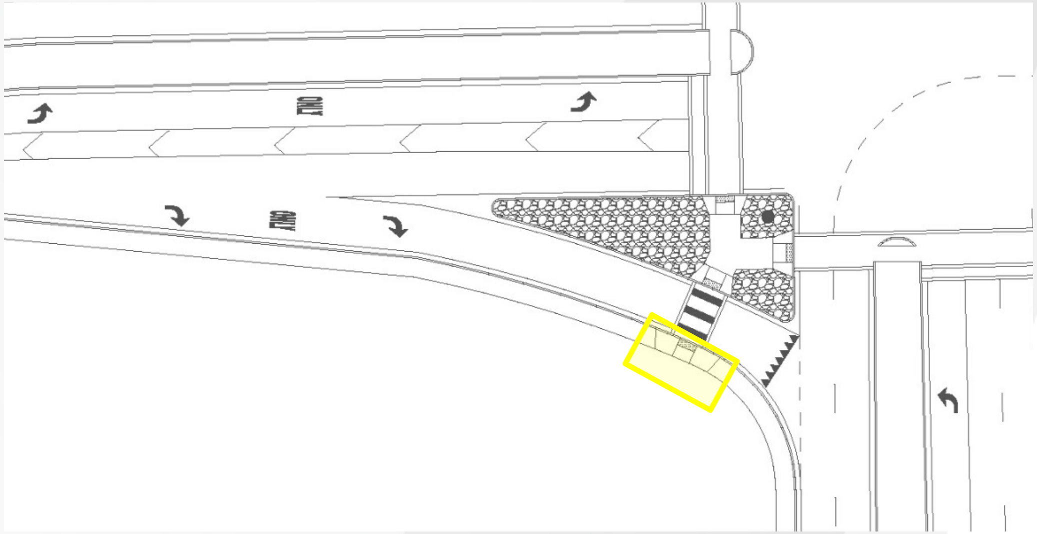
- **NO**. Pushbuttons should be moved closer to the crossing location. Pushbuttons for different directions should be located a minimum of 10 feet apart from each other.



Accessible Design for the Blind

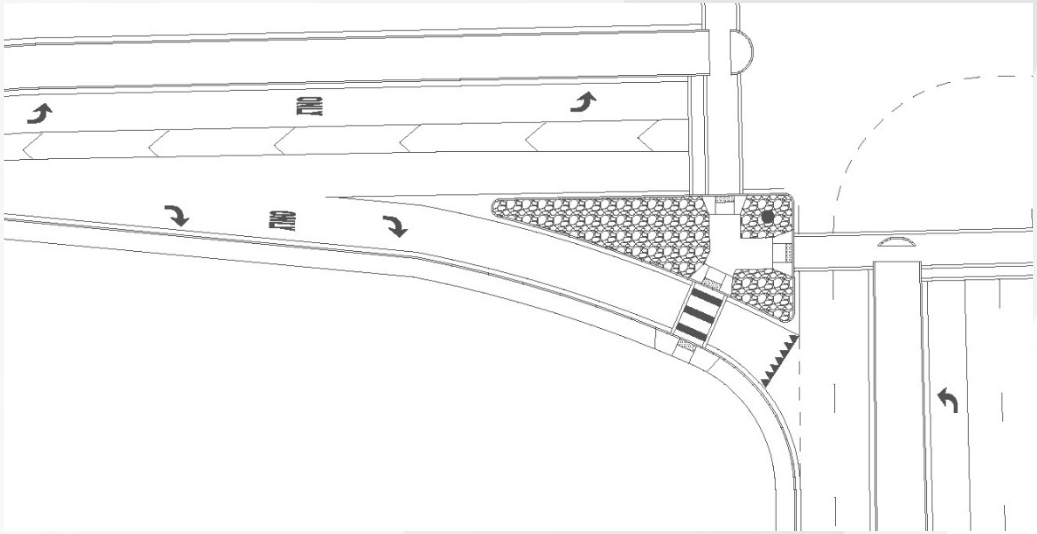
6.2.6 Is there a sufficiently level landing and turning space where the pedestrian is waiting to cross?

- UNCLEAR. If the ramp is a parallel ramp, then a sufficiently level landing is likely available. If it is a sloped ramp similar to those on the island, then a level landing area is not available.



6.3.2 Is the crossing aligned perpendicular to the curb and splitter edges?

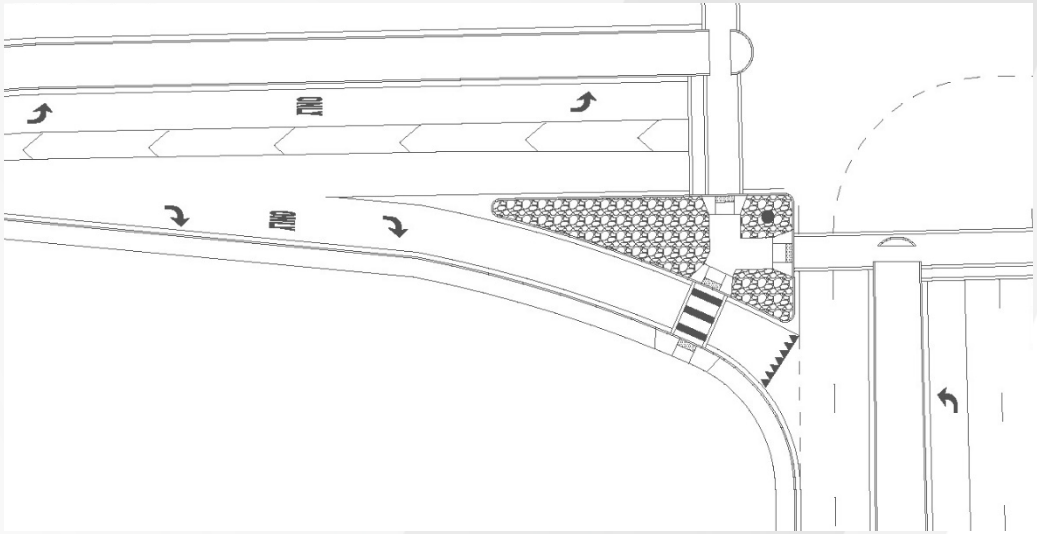
- **YES**.



Accessible Design for the Blind

6.3.3 Are markings clearly visible?

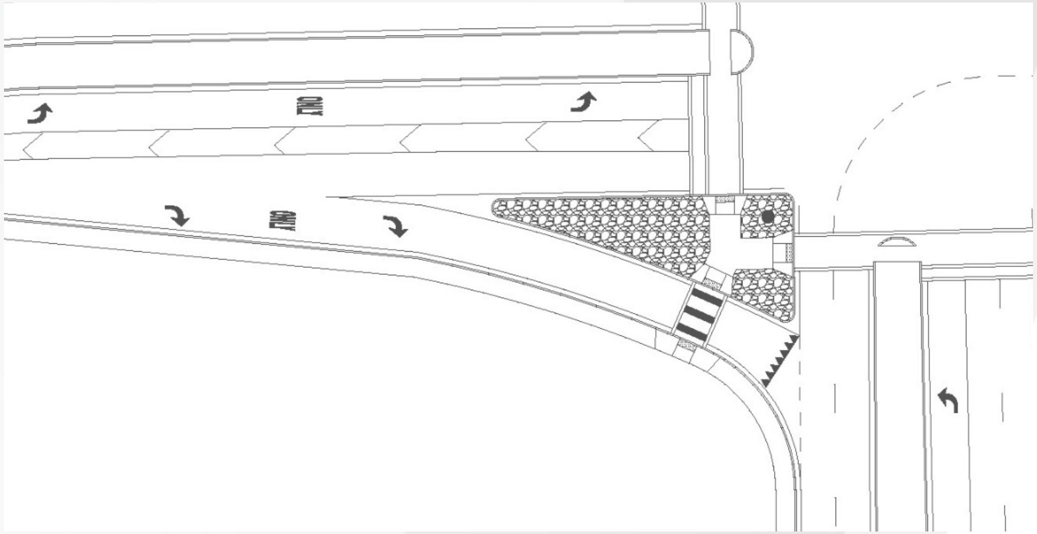
- **YES**. At the channelized turn lane the markings are clearly visible.



Accessible Design for the Blind

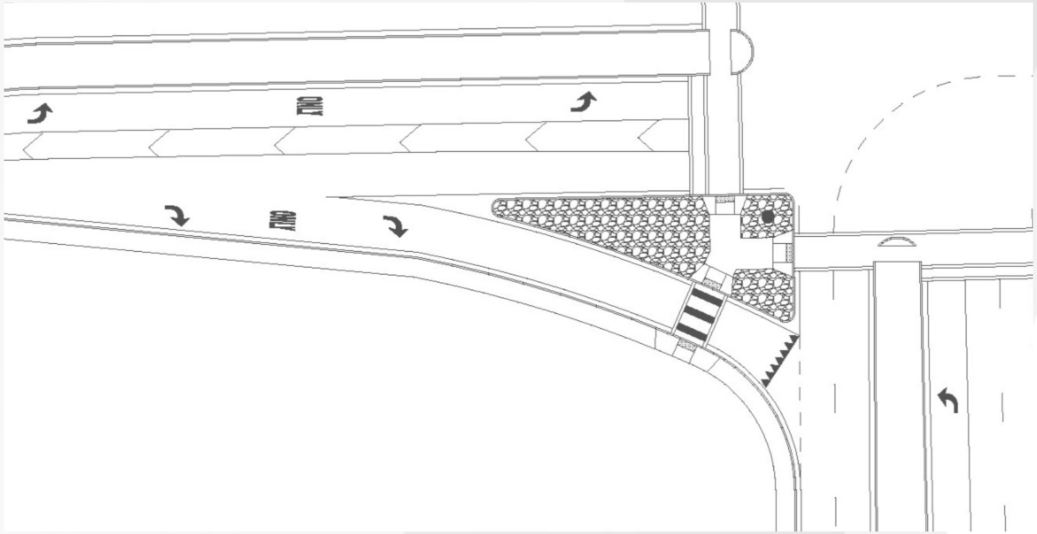
6.4.1 Are islands wide enough to provide safe refuge?

- **YES**.



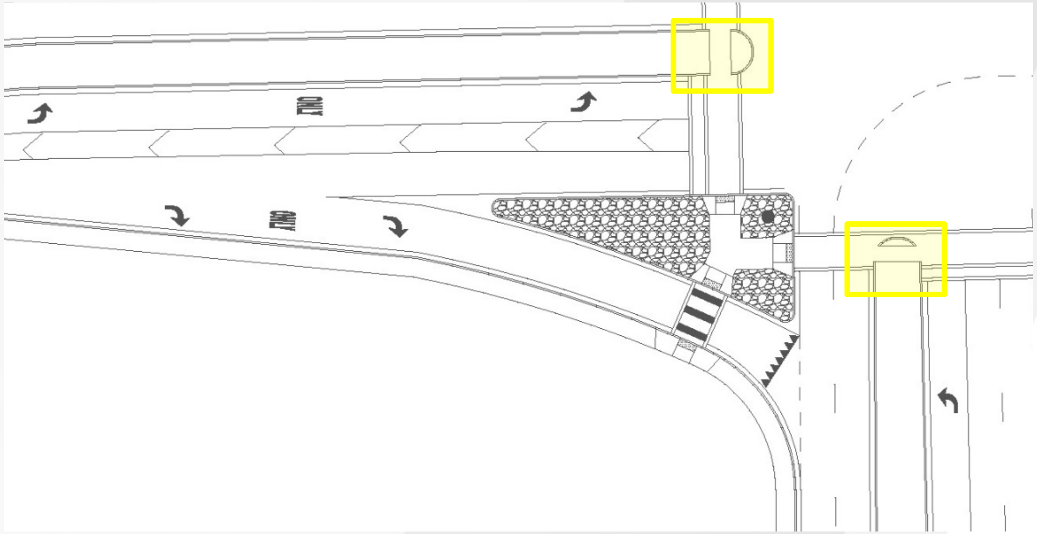
6.4.2 Are transitions to roadway clearly defined (within the island)?

- **YES**.



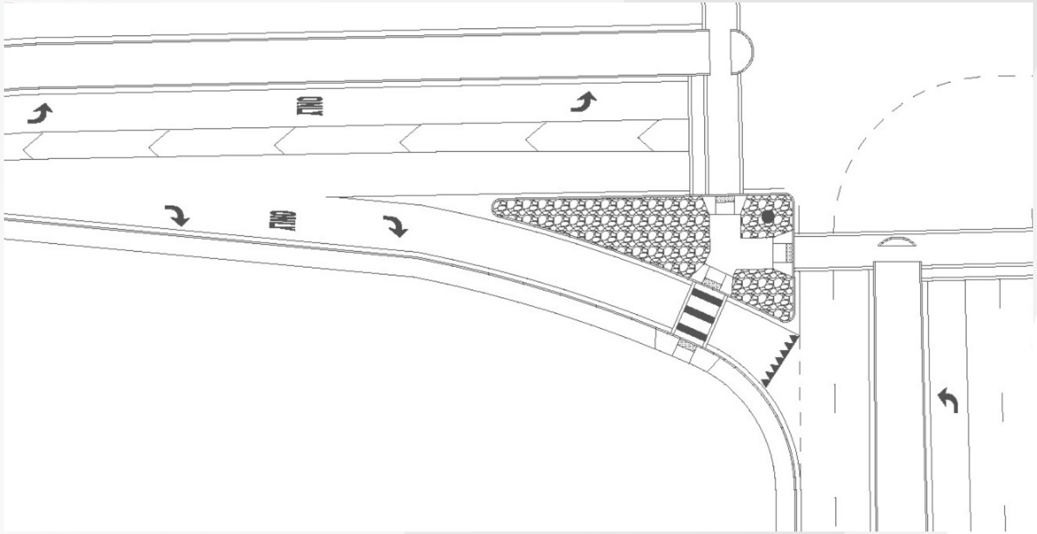
6.4.3 Are paths through island clearly identifiable?

- **NO**. While the path through the corner island is clear, the two main crosswalks have portions of the median island that extend into the crossing.



6.4.4 Are pushbuttons accessible?

- **NO**. Pushbuttons should be moved closer to the crossing location.



Accessible Design for the Blind

Channelized Turn Lane Example 4: Washington St./Lincoln St.

	C	D
6.1.1. Sidewalks lead to crosswalks	YES	YES
6.1.2. Separation between sidewalk and curb	NO	NO
6.1.3. Edge of street defined (outside edge)	YES	YES
6.1.4. Other ramps/driveways separated/delineated	N/A	N/A
6.1.5. TCDs accessible	NO	NO
6.2.1. Ramp width = crosswalk width	NO	NO
6.2.2. Ramp slope aligned with crossing	YES	YES
6.2.3. Ramp edges aligned with crossing	YES	YES
6.2.4. DW aligned with ramp slope	YES	YES
6.2.5. PBs in correct location	NO	NO
6.2.6. Level landing	UNCLEAR	UNCLEAR
6.3.1. Crossing shortest distance	YES	YES
6.3.2. Crossing perpendicular to curb	YES	YES
6.3.3. Markings visible	YES	YES
6.4.1. Islands wide enough	YES	YES
6.4.2. Transitions to roadway defined (within island)	YES	YES
6.4.3. Paths through island identifiable	NO	NO
6.4.4. Pushbuttons accessible	NO	NO

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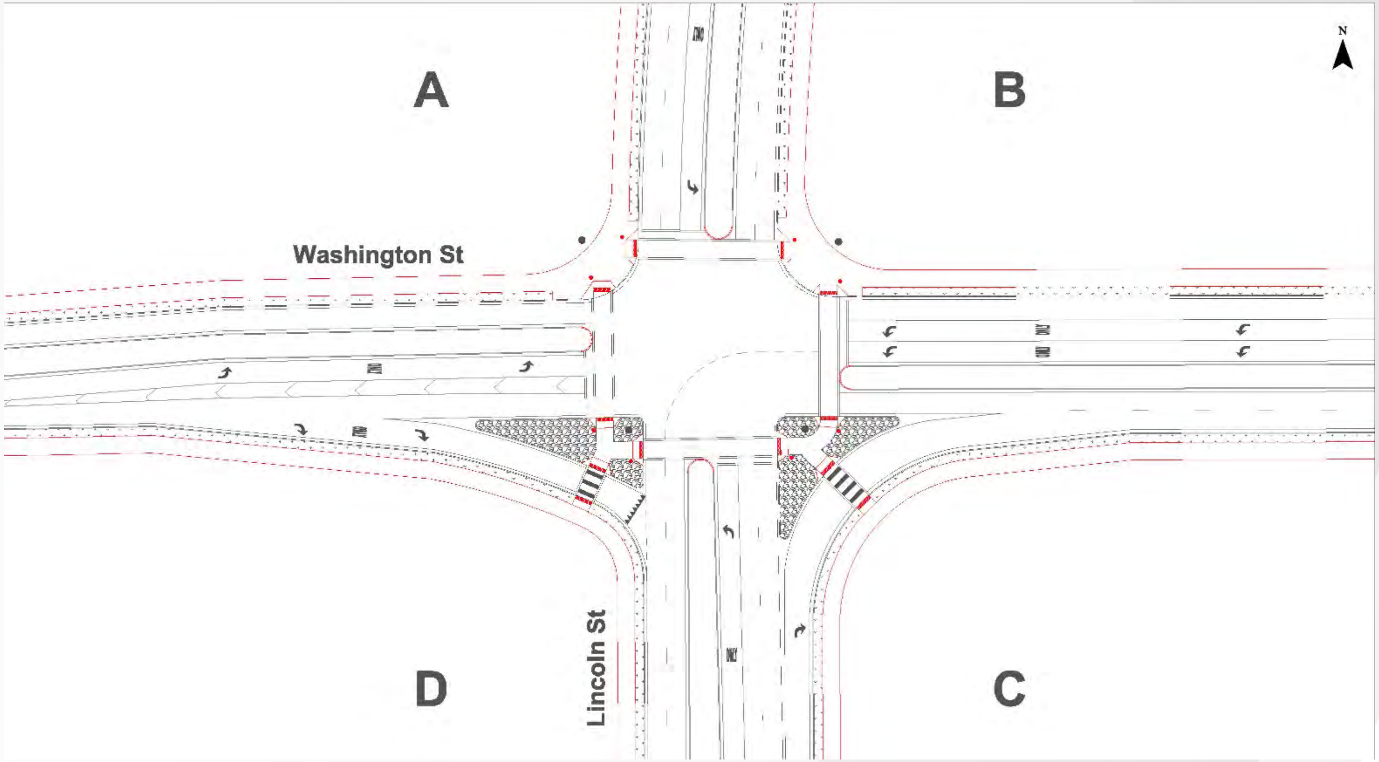
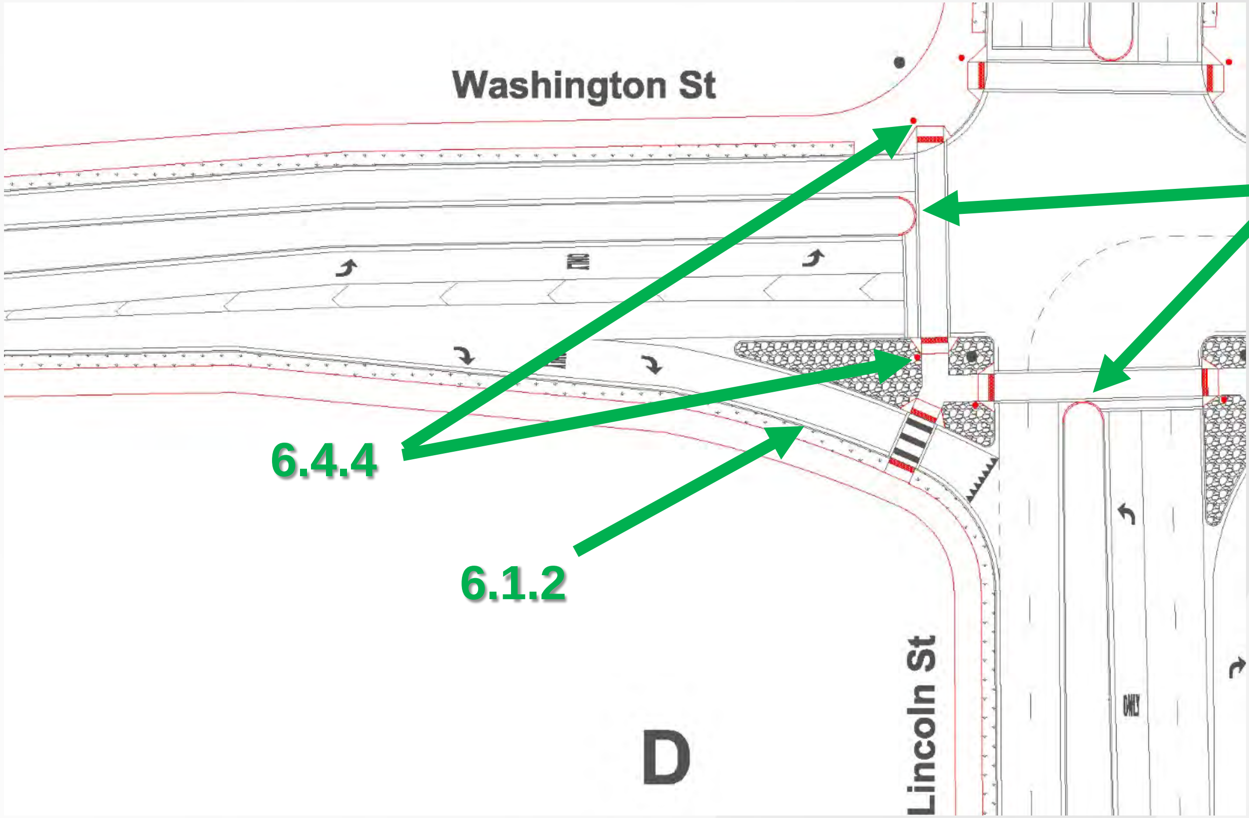
Channelized Turn Lane Example 4: Washington St./Lincoln St.

- Possible Solution



Channelized Turn Lane Example 4: Washington St./Lincoln St.

- Possible Solution



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TRB

Roundabouts and Channelized Turn Lanes: Access for Pedestrians, Particularly Those with Vision Disabilities

Module 5

Crossing Assessment Overview and Treatments

Photo: Lee Rodegerdts

KITTELSON & ASSOCIATES

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INTRODUCTION

Background and Overview of Crossing Assessment Method

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Guidebook Preview

1. Introduction
2. Design Process
3. General Principles for Pedestrian Wayfinding & Crossing Tasks
4. Design Principles for Pedestrian Access to Roundabouts
5. Design Principles for Pedestrian Access to CTLs
6. Wayfinding Assessment
7. **Crossing Assessment**
8. References
9. Appendix A: Discussion of Audible Environment and Noise Effects
10. **Appendix B: Summary of Crossing Treatments**

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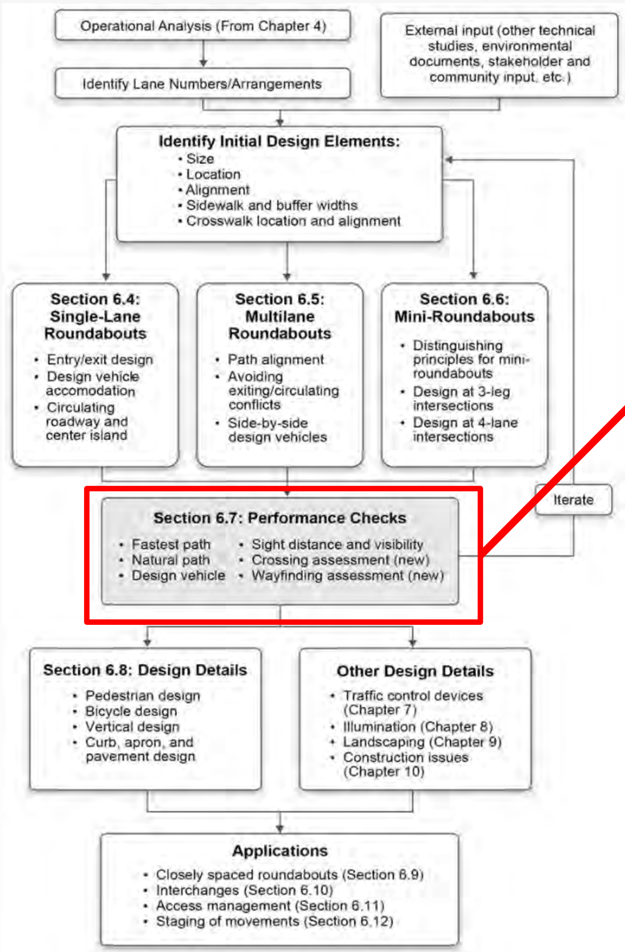
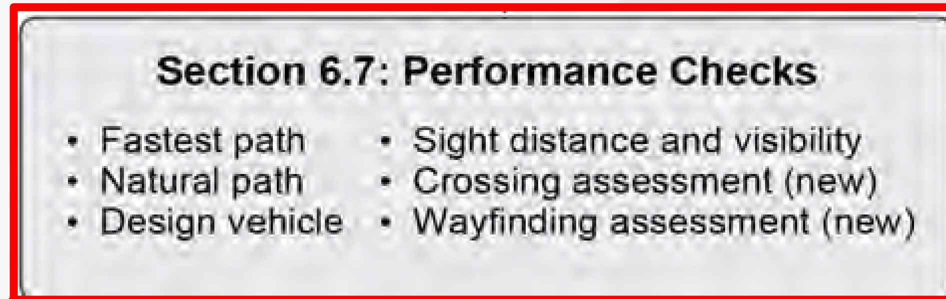
Tying into Existing Roundabout Design Process (NCHRP Report 672 – FHWA Roundabout Guide)





- **New Performance Checks**
  - Wayfinding Assessment
  - **Crossing Assessment**
    - **Crossing Sight Distance**
    - **Pedestrian Delay**
    - **Level of Risk**

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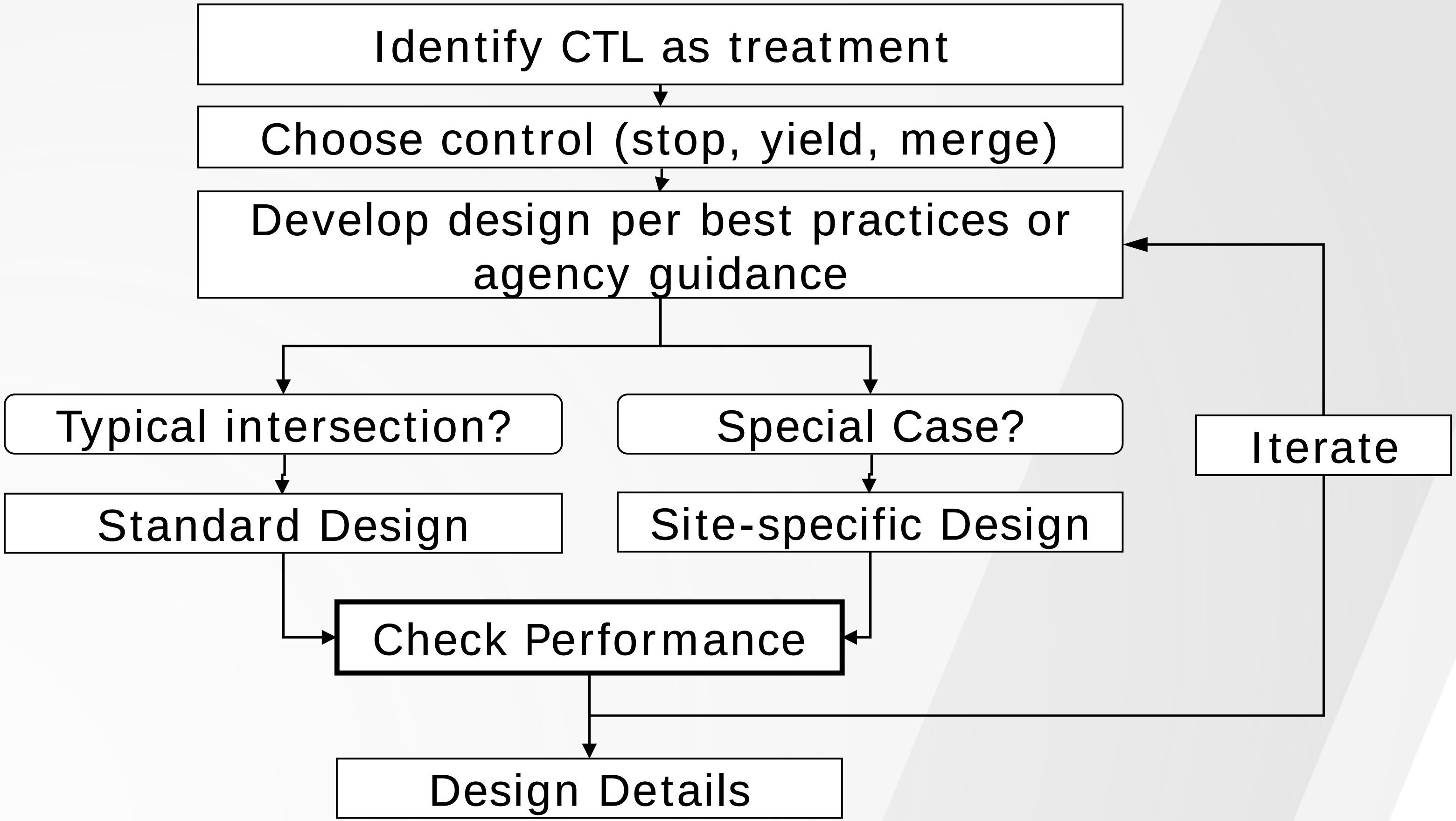
Channelized Turn Lane Design Process (Developed in NCHRP Report 834)



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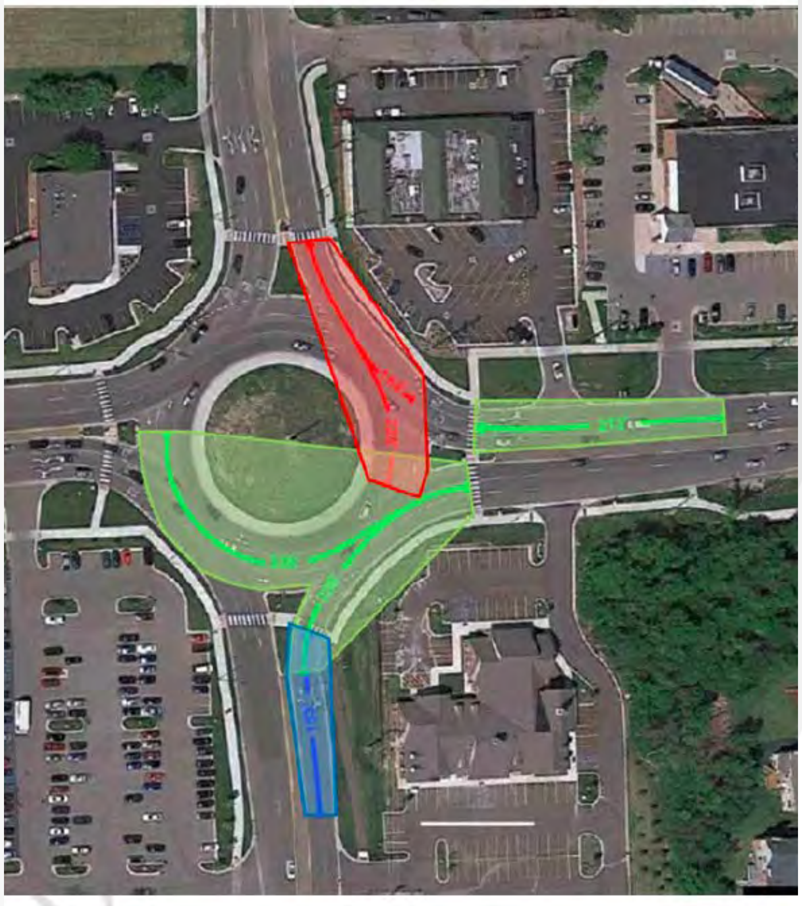
Check 1: Crossing Sight Distance

- **Provide clear lines of sight between the driver and the pedestrian waiting to cross**
  - to provide appropriate reaction and braking time for driver
  - to inform gap acceptance decisions
  - to enhance auditory information at crosswalk



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Check 2: Pedestrian Delay

- Evaluate the level and quality of service
- Provide quantitative performance assessment
- Function of the availability of crossing opportunities and the rate of utilization of these opportunities
  - Crossable gaps
  - Yielding Vehicles
- Models calibrated from field data at roundabouts and channelized turn lanes.

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Check 3: Level of Risk

- Most important performance measure
- Predict rate of expected rate of *interventions* through models calibrated from field data at roundabouts and channelized turn lanes.
- An intervention is an event, in which participants were physically stopped from stepping into the roadway by a Certified Orientation and Mobility Specialist

Setting Performance Targets

- **Through the quantitative nature of the performance checks, it is generally possible to**
  1. conduct a *relative* comparison of two sites, or
  2. conduct a before-and-after assessment of the same site.
- **Guidebook does not provide performance targets or thresholds, which is a policy decision**
  – Agencies may set targets
- **Methods can be used to conduct *relative* accessibility evaluations in the context of PROWAG**

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Value of Direct Field Measurements

- Like any analysis (e.g., HCM or HSM), direct field observations at a given site may give more accurate results than the model estimations from NCHRP Report 834
- NCHRP Web-Only Document 222 provides details on the *Accessibility Audit* data collection protocols used to derive and develop the models contained here

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METHOD OVERVIEW

NCHRP Report 834 Crossing Assessment Method

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Methodology Source

- Updated version of NCHRP Report 834, Chapter 7
- Web-only publication of Revised Chapter 7 anticipated

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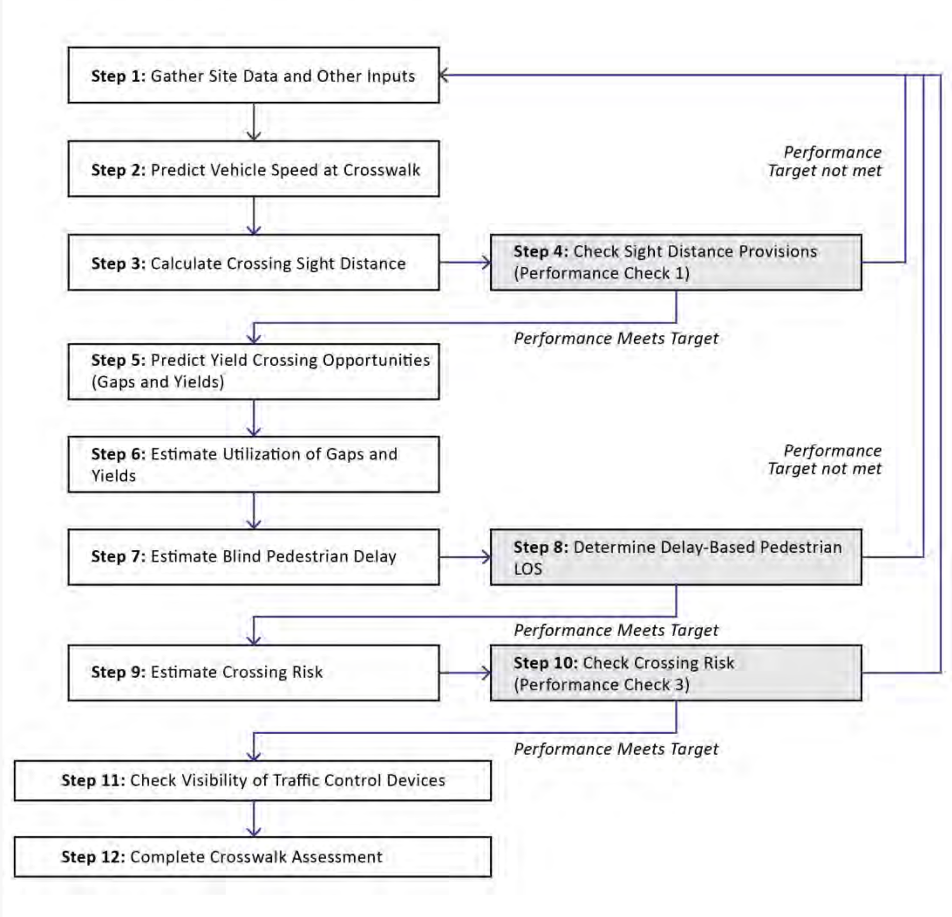
Method Overview

- 12-step methodology
- Iterative procedure until three performance checks are met
- Each step contains models and/or defaults to assist with the estimation



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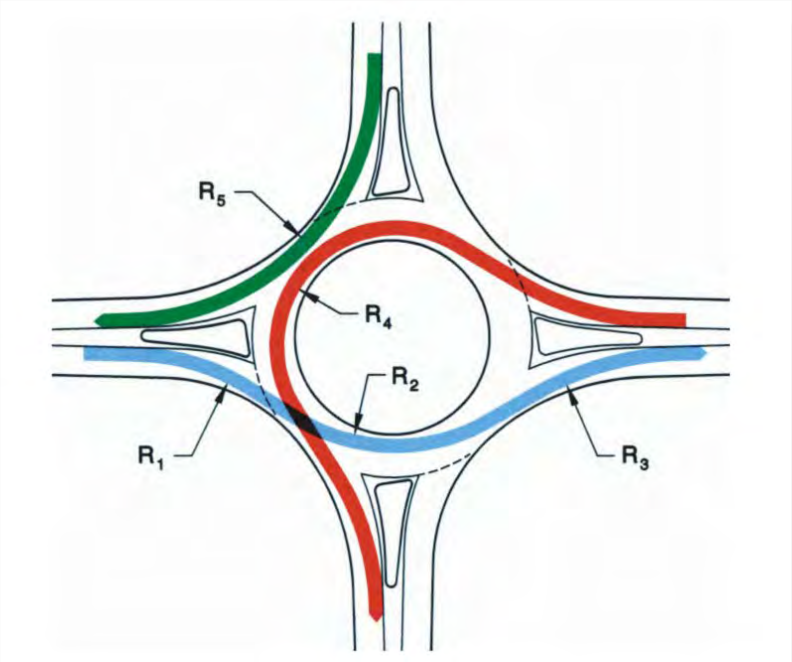
Step 1: Gather Site Data and Other Inputs

Step 2: Predict Vehicle Speed at Crosswalk

- Roundabouts – Use same method/equations in NCHRP Report 672
- CTLs – Use method developed in this project



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Step 2 (cont.): Predict Vehicle Speed at Crosswalk

- **Roundabout entry**

  Eq. 1

  $$V = 3.4415\, R^{0.3861}$$ for e = +0.02

  V = Speed, in mph

  R = Radius, in feet

- The higher of V_1 and V_5 governs
- Site specific features (upstream curvature, raised crosswalks, etc. could result in lower speeds than equation predicts)

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Step 2 (cont.): Predict Vehicle Speed at Crosswalk

- **Roundabout exit**
  Eq. 1 provides V_5 and curvature-based V_3 (V_{3c})
  Eq. 2 provides acceleration-limited V_3 (V_{3a})

$$V_{3a} = \frac{1}{1.47}\sqrt{(1.47\, V_2)^2 + 2a_{23}d_{23}}$$

a_{23} = acceleration along the length between the mid-point of V_2 path and the exit crosswalk. (Estimated 6.9 ft/s^2)

d_{23} = distance between midpoint of V_2 path and exit crosswalk (feet)

- V_3 equals the lower of V_{3a} and V_{3c}
- The higher of V_3 and V_5 is used for the speed at the crosswalk
- Site specific features (downstream curvature, raised crosswalks, etc. could result in lower speeds than equations predict)

Step 2 (cont.): Predict Vehicle Speed at Crosswalk

- **CTL**

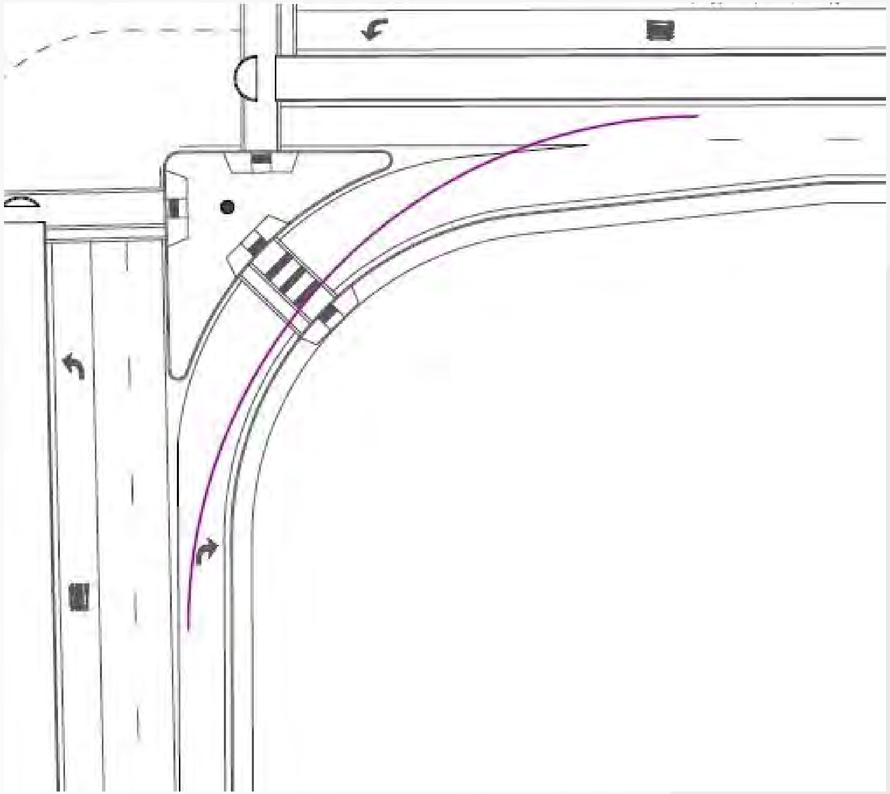
  Draw curve though CTL similar to R_5

  Use Eq. 1 to predict speed

  - Assume vehicles start in deceleration lane/right turn lane
  - Assume vehicles exit into any lane on receiving roadway
  - Keep fastest path 5 feet away from curbs within CTL
  - Fastest path may be single curve or compound curve
  - Speed may be limited by smaller-radius curve at exit of CTL

Step 2 (cont.): Predict Vehicle Speed at Crosswalk

- CTL fastest path curve



Step 3: Calculate Crossing Sight Distance

- **Function of vehicle speed and pedestrian critical gap (crossing time)**
- **Vehicle speed from Step 2**
- **Critical gap from HCM, function of**
  - Crosswalk length
  - Walking speed
  - Clearance time

Once a car comes into view, is there enough time for a pedestrian to cross?

OR

Once a pedestrian comes into a driver's view, is there enough time for them to complete a crossing that is just beginning?

Step 3 (cont.): Calculate Crossing Sight Distance

- **Compute distance**

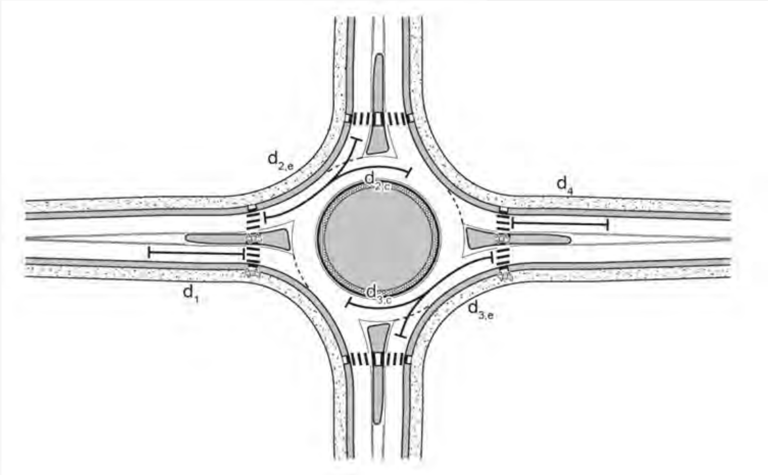
  Eq. 3

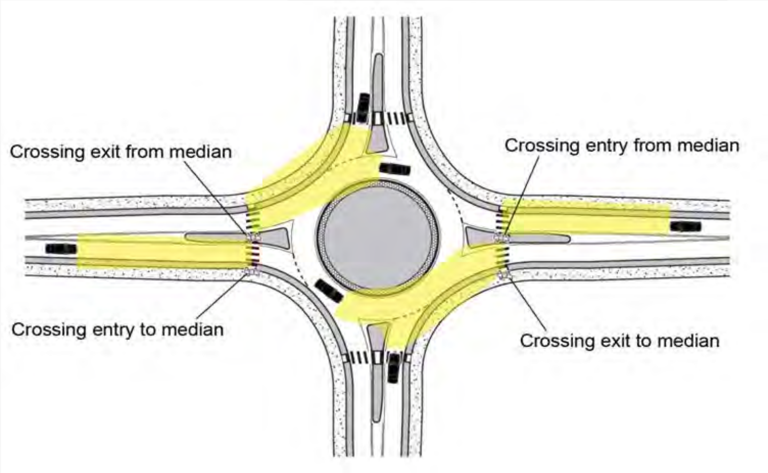
$$d_n = 1.47\, V_n t_{n,c}$$

d_n **=** distance along approach to crosswalk n (measured upstream of the crosswalk), in feet

V_n = Vehicle speed at crosswalk on approach n, in mph

$t_{n,c}$ **=** critical headway required by a pedestrian crossing approach n, in seconds *(see next slide)*





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Step 3 (cont.): Calculate Crossing Sight Distance

- **Compute distance**

Eq. 4

$$t_{n,c} = \frac{L_n}{S_p} + t_s$$

L_n = Crosswalk length for a specific traffic stream, in feet

S_p = Design pedestrian walking speed, in ft/s (default = 3.5 ft/s)

t_s = Pedestrian start-up time and end clearance time, in seconds (default = 2 s)

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Step 4: Check Sight Distance Provisions

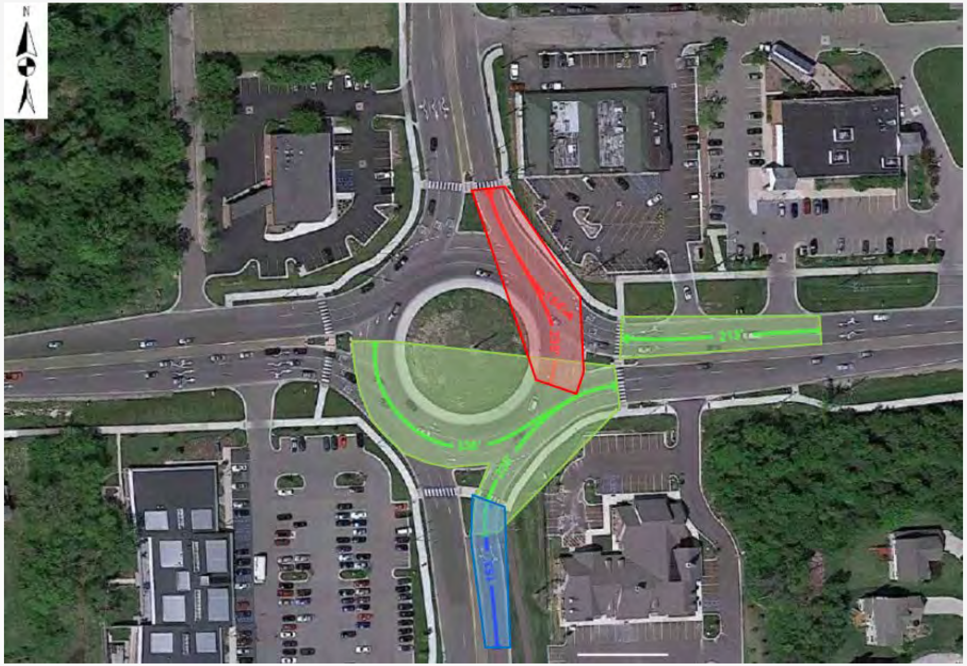

Illustration of Sight Distance for Two-Lane and Three-Lane Roundabout Approaches

Illustration of Sight Distance for CTL with and without raised crosswalk

Step 4 (cont.): Check Sight Distance Provisions

- **Draw sight triangles. Are obstructions present or is sight distance met?**
  - **Performance Check 1: Is Adequate Crossing Sight Distance Available?**

Step 5: Predict Crossing Opportunities (Gaps and Yields)

- **Compute the number of gaps**

  Eq. 5

A pedestrian could cross because no conflicting vehicles are present

$$P_g = e^{\frac{-t_{n,c} * N_{veh}}{3600}}$$

***P_g* =** Probability of a pedestrian encountering a usable gap

***$t_{n,c}$* =** Critical headway for crossable gap on leg *n*, in seconds

N_{veh} = volume (vehicles per hour)

Step 5 (cont.): Predict Crossing Opportunities (Gaps and Yields)

- **Compute the number of yields**

  Single-lane roundabouts and CTLs (Eq. 6):

$$P_Y = (0.6888 - 0.07688 * I_{ex} + 0.62954 * I_{en} + 0.37418 * I_{HC})e^{-0.03465*V}$$

P_Y = Probability of a driver yielding to a pedestrian

I_{ex} = Indicator variable for Exit (1 = Roundabout Exit, 0 = Roundabout Entry or CTL)

I_{en} = Indicator variable for Entry (1 = Roundabout Entry, 0 = Roundabout Exit or CTL)

I_{HC} = Indicator variable for high-compliance region (1 = high compliance, 0 = low)

V = Speed, in mph

A pedestrian could cross if the conflicting vehicle yields to them

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Step 5 (cont.): Predict Crossing Opportunities (Gaps and Yields)

- **Compute the number yields**

  Two-lane roundabouts (Eq. 7):

$$P_Y = (0.7259 + 0.2105 * I_{RRFB} - 0.2574 * I_{ex} + 0.3244 * I_{HC})e^{-0.0129*V}$$

P_Y = Probability of a driver yielding to a pedestrian

I_{RRFB} = Indicator variable for presence of RRFB (note: may not fully represent all pedestrian-actuated beacons)

I_{ex} = Indicator variable for Exit (1=Exit, 0=Entry)

I_{HC} = Indicator variable for high-compliance region

V = Speed, in mph

A pedestrian could cross if the conflicting vehicle yields to them

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Step 5 (cont.): Predict Crossing Opportunities (Gaps and Yields)

- **Driver Compliance**
  - Field data indicates major differences in driver yielding behavior based on environment
    - **Region of country**
    - **Urban vs. suburban**
    - **Campus vs. non-campus**
  - Subjective
  - High/low compliance choice must be made by analyst

Step 5 (cont.): Predict Crossing Opportunities (Gaps and Yields)

- **Compute the number of crossing opportunities**

  Eq. 8

$$P_{YC} = P_Y * (1 - P_G)$$

P_{YC} = The probability of a yield crossing opportunity

Probability of a yield is adjusted to account for the probability that a pedestrian encounters a vehicle that could yield (ignore situations when vehicle not present)

Step 6: Estimate Utilization of Gaps and Yields

- **Acknowledges that many blind travelers will not utilize all crossing opportunities due to**
  - Auditory confusion/clutter
  - Higher risk threshold
  - Personal preferences
- **Default values available from field data**

- **Probability of a blind pedestrian utilizing a gap = P_{UG}**
  - At roundabout crosswalks: 65%
  - At CTL crosswalks: 60%
- **Probability of a blind pedestrian utilizing a yield = P_{UY}**
  - At roundabout crosswalks: 70%
  - At CTL crosswalks: 35%

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Step 7: Estimate Blind Pedestrian Delay

- **Probability of pedestrian crossing each time there is a gap or yield**

  Eq. 9

$$P_C = P_{YC} * P_{UY} + P_G * P_{UG}$$

P_C = Probability that a blind pedestrian crosses at a crosswalk

Blind pedestrians don't use some gaps and yields because they are unaware they exist

Step 7 (cont.): Estimate Blind Pedestrian Delay

- Calculate Pedestrian Delay
- Eq. 10 for CTLs:

$$d_p = 10.75 - 9.95 * ln(P_C)$$

- Eq. 11 for single-lane roundabouts:

$$d_p = 9.37 - 9.78 * ln(P_C)$$

- Eq. 12 for two-lane roundabouts:

$$d_p = 6.14 - 8.53 * ln(P_C)$$

d_p = Pedestrian delay, in seconds

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Step 8: Determine Delay-Based Pedestrian LOS

- Determine LOS based on HCM Table 7-6:
  - **Performance Check 2: Is the Ped LOS within the guidelines for your agency?**

Table 7-6. Pedestrian LOS thresholds for unsignalized intersections from the Highway Capacity Manual.

LOS	Control Delay (s/ped)	Comments
A	0-5	Usually no conflicting traffic
B	5-10	Occasionally some delay due to conflicting traffic
C	10-20	Delay noticeable to pedestrians, but not inconveniencing
D	20-30	Delay noticeable and irritating, increased likelihood of risk-taking
E	30-45	Delay approaches tolerance level, risk-taking behavior likely
F	>45	Delay exceeds tolerance level, high likelihood of pedestrian risk-taking

These thresholds were developed for mid-block crossings and major street crossings at two-way stop-controlled intersections

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Step 9: Estimate Crossing Risk

- **Compute probability of an intervention**
- **Eq. 13**

$$P_I = (0.011895 + 0.008443 * I_{ex} + 0.021915 * I_N - 0.007186 * I_{1L})e^{0.027697 * V}$$

- ***I_{ex}* =** Indicator variable (1 = Exit, 0 = Entry/CTL)
- ***I_N* =** Indicator variable (1= noisy, 0 = low noise)
- ***I_{1L}* =** Indicator variable (1 = one-lane roundabout, 0 = two-lane roundabout/CTL)
- ***V* =** Speed at crosswalk (mph)

This model is not used for PHBs. They are assumed to be accessible.

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Step 9 (cont.): Estimate Crossing Risk

- **Intervention: A physical or audible action taken by a Certified Orientation and Mobility Specialist (COMS) to stop a blind pedestrian from entering a crosswalk because the COMS believed the blind pedestrian would be a risk of getting struck by a vehicle**

Blind pedestrians in field studies were always accompanied by a COMS

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Step 9 (cont.): Estimate Crossing Risk

- **Noise – Regardless of other conditions, high-noise sites without signalization were inaccessible to blind pedestrians. They could not hear gaps and yields. Examples include:**
  – Ramp terminal intersections
  – Sites near freeways
  – Sites with high volumes and heavy vehicle percentages

  – Subjective (except ramp terminal intersections)
  – High/low noise choice must be made by analyst

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Step 10: Check Crossing Risk

- **Performance Check 3: Is probability of an intervention within range allowable by your agency?**

Most important check

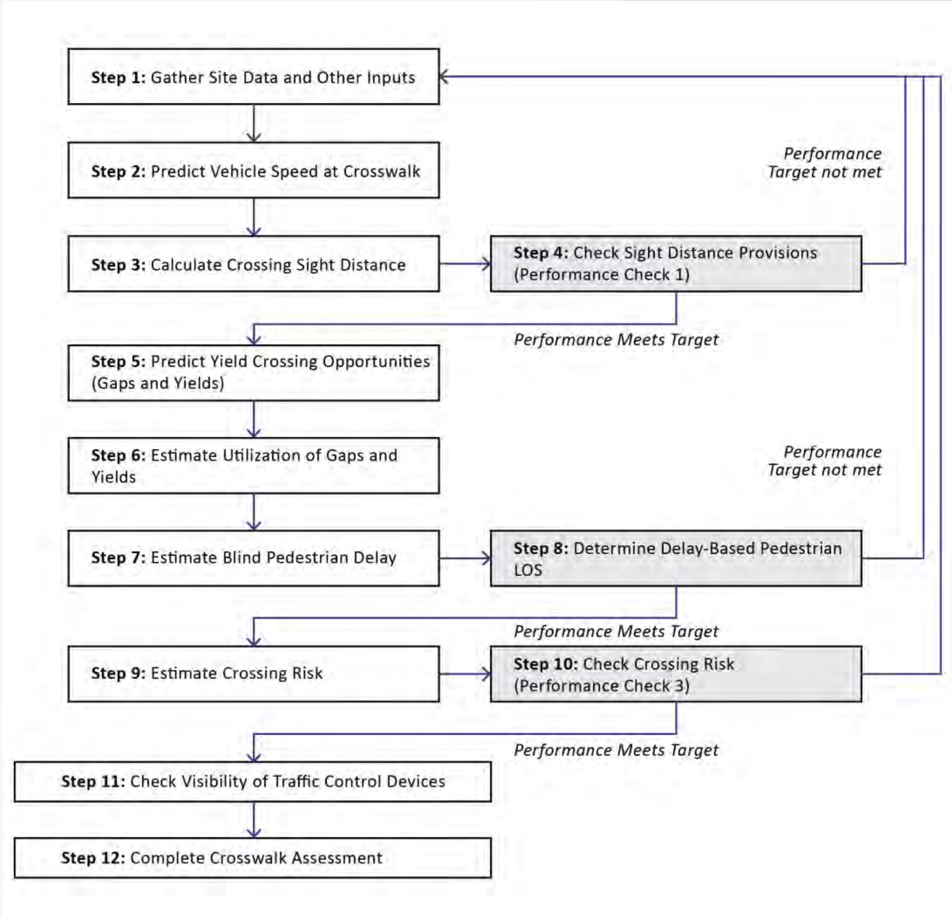
- **Note: PHB and R-Y-G pedestrian signal are assumed to have acceptable crossing risk. Method is used for other potential treatments.**

Step 11: Visibility of Traffic Control Devices

- Determine if Traffic Control Devices are installed properly and meet MUTCD visibility requirements.

Step 12: Complete Crosswalk Assessment

- Assure that all three performance checks are met
- Consider interaction of pedestrian performance checks with other design checks
  - Fastest path
  - Design vehicle
  - …



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What has been observed in field studies?

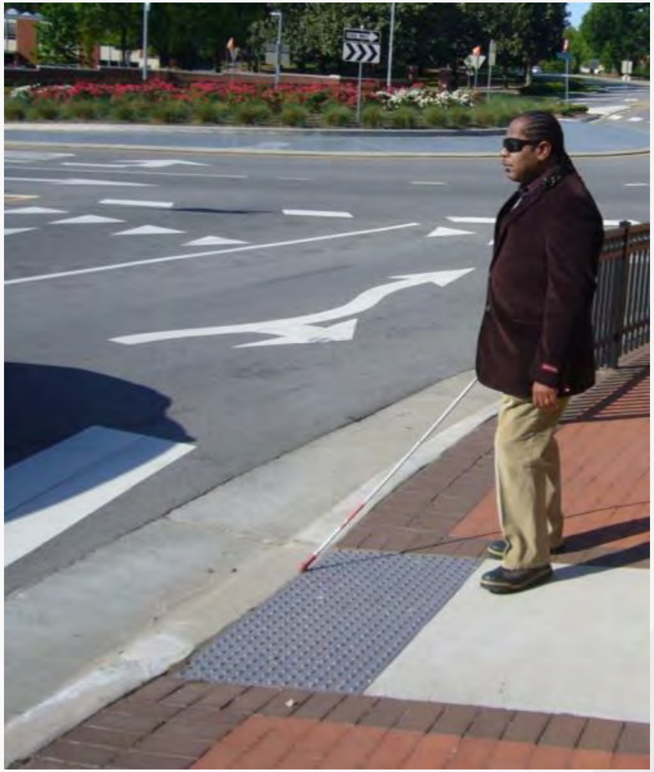

Photo: Janet Barlow

Observed Intervention Rates - Single Lane Roundabouts

Site	City	State	Entry or Exit	Intervention Rate	Yielding Rate	High Noise?	Treatment*
1	Ann Arbor	MI	Entry	0%	82%	No	None
2	Cary	NC	Entry	3%	61%	No	None
3	Greenbelt	MD	Entry	2%	90%	Yes	RCW
4	Ann Arbor	MI	Exit	0%	45%	No	None
5	Cary	NC	Exit	5%	32%	No	None

*RCW = raised crosswalk, RRFB = rectangular rapid flashing beacon

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Observed Intervention Rates - Channelized Turn Lanes

Site	City	State	Intervention Rate	Yielding Rate	High Noise?	Treatment*
1	Boulder	CO	0%	32%	No	RCW
2	Boulder	CO	0%	36%	No	None
3	Boulder	CO	0%	30%	No	None
4	Boulder	CO	8%	40%	Yes	RCW
5	Boulder	CO	8%	66%	No	RCW
6	Boulder	CO	2%	58%	No	None
7	Cary	NC	5%	47%	Yes	None
8	Greenbelt	MD	10%	23%	Yes	None
9	Tucson	AZ	0%	68%	No	RCW
10	Tucson	AZ	2%	50%	No	RCW
11	Tucson	AZ	0%	47%	No	None
12	Tucson	AZ	2%	89%	No	None

*RCW = raised crosswalk, RRFB = rectangular rapid flashing beacon

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Observed Intervention Rates - Multilane Roundabout Entries

Site	City	State	Intervention Rate	Yielding Rate	High Noise?	Treatment*
1	Olympia1	WA	6%	100%	No	RRFB
2	Olympia1	WA	3%	90%	No	RRFB
3	Olympia2	WA	2%	94%	Yes	RRFB
4	Greenbelt	MD	2%	42%	No	RCW
5	Hilliard	OH	2%	58%	No	None
6	Hilliard	OH	2%	64%	No	None
7	Carmel	IN	4%	60%	No	RRFB
8	Ann Arbor	MI	0%	78%	No	None
9	Albany	NY	14%	36%	Yes	RRFB
10	Albany	NY	2%	39%	Yes	RRFB
11	Davidson	NC	4%	96%	No	RRFB
12	Davidson	NC	0%	100%	No	RRFB

*RCW = raised crosswalk, RRFB = rectangular rapid flashing beacon

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Observed Intervention Rates - Multilane Roundabout Entries

Site	City	State	Intervention Rate	Yielding Rate	High Noise?	Treatment*
13	Oshkosh	WI	2%	45%	No	RRFB
14	Oshkosh	WI	0%	83%	No	RRFB
15	Novi	MI	0%	91%	No	RCW
16	Novi	MI	0%	65%	No	RCW
17	Springfield	OR	7%	100%	No	RRFB
18	Springfield	OR	4%	90%	No	RRFB
19	Novi	MI	0%	91%	No	RCW, RRFB

*RCW = raised crosswalk, RRFB = rectangular rapid flashing beacon

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Observed Intervention Rates - Multilane Roundabout Exits

Site	City	State	Intervention Rate	Yielding Rate	High Noise?	Treatment*
1	Olympia1	WA	3%	38%	No	RRFB
2	Olympia1	WA	2%	95%	No	RRFB
3	Olympia2	WA	10%	94%	Yes	RRFB
4	Greenbelt	MD	4%	14%	No	RCW
5	Hilliard	OH	7%	23%	No	None
6	Hilliard	OH	14%	21%	No	None
7	Carmel	IN	4%	61%	No	RRFB
8	Ann Arbor	MI	3%	8%	No	None
9	Albany	NY	22%	0%	Yes	RRFB
10	Albany	NY	13%	11%	Yes	RRFB
11	Davidson	NC	0%	80%	No	RRFB
12	Davidson	NC	8%	96%	No	RRFB

*RCW = raised crosswalk, RRFB = rectangular rapid flashing beacon

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Observed Intervention Rates - Multilane Roundabout Exits

Site	City	State	Intervention Rate	Yielding Rate	High Noise?	Treatment*
13	Oshkosh	WI	16%	90%	Yes	RRFB
14	Oshkosh	WI	15%	20%	Yes	RRFB
15	Novi	MI	0%	54%	No	RCW
16	Novi	MI	7%	65%	No	RCW
17	Springfield	OR	11%	100%	No	RRFB
18	Springfield	OR	12%	64%	No	RRFB
19	Novi	MI	7%	50%	No	RCW, RRFB

*RCW = raised crosswalk, RRFB = rectangular rapid flashing beacon

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Implications for Practice

- **Treatment of all modes holistically is necessary**
  - Assessment of pedestrian (and bicycle) performance should done simultaneously with motor vehicle performance
- **Design decisions create trade-offs**
  - No one correct answer that works in all situations
  - Site-specific design is necessary
- **Performance-based design allows assessment of these trade-offs**
- **The accessibility tools from NCHRP Project 03-78b/Report 834 add to our ability to make these assessments**

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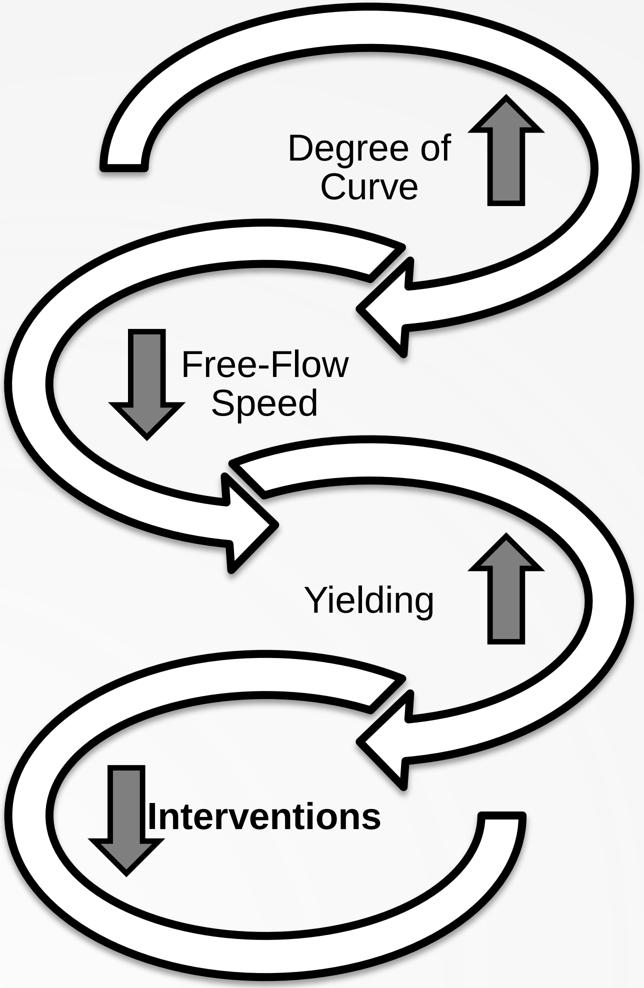


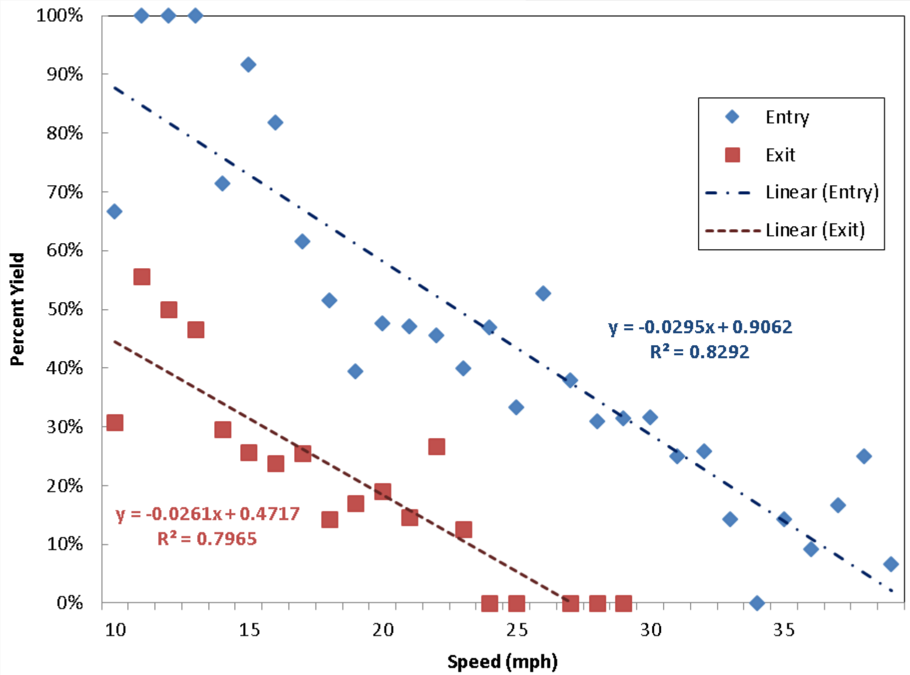
Conceptual Relationship between Interventions and Other Factors (SOURCE: FHWA TOPR34 Task 2)

Selection of Treatments

- **Performance-based process**
- **Understand the implications of each design decision**
- **Examples:**
  - Reduce radius of curvature
  - Install raised crosswalk
  - Install pedestrian-actuated flashing beacon
  - Install pedestrian hybrid beacon

Treatment Example 1: Geometric Modification

- Reduce radius of curvature
  - Reduce vehicular speed
  - Increase driver yielding
  - Reduce sight distance requirements
  - Increase yield opportunities
  - Reduce pedestrian delay
  - Reduce risk



Impact of Speed on Driver Yielding at Two-Lane Roundabouts from 6 sites in 4 states (Source: Geruschat, Salamati and Schroeder, in press)

Treatment Example 2: Raised Crosswalk

- **Reduce vehicular speed**
  - General safety benefit
  - Increase driver yielding
  - Reduce sight distance requirements
  - Increase yield opportunities
  - Reduce pedestrian delay
  - Reduce risk

Speed Impacts Due to Traffic Calming Measures (Adapted from ITE)

Traffic Calming Measure	Sample Size	85th Percentile Speed after Calming in mi/h (Std. Dev.)	Average Change in Speed after Calming in mi/h (Std. Dev.)	Average Percentage Change (Std. Dev.)
12-foot hump	179	27.4 (4.0)	-7.6 (3.5)	-22% (9%)
14-foot hump	15	25.6 (2.1)	-7.7 (2.1)	-23% (6%)
22-foot table	58	30.1 (2.7)	-6.6 (3.2)	-18% (8%)
Longer tables	10	31.6 (2.8)	-3.2 (2.4)	-9% (7%)

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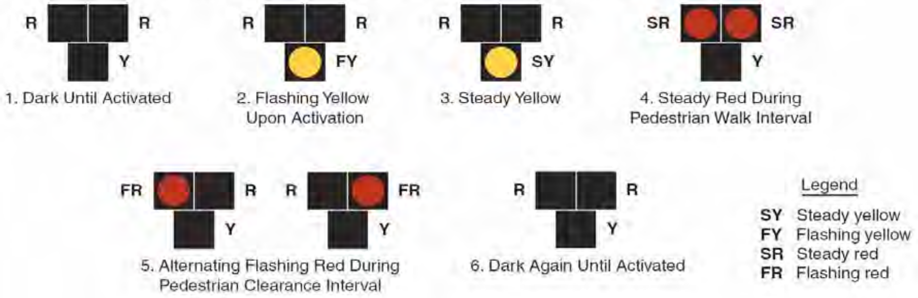
Treatment Example 3: Pedestrian-actuated flashing beacon

- **Increase driver yielding**
  - Increase yield opportunities
  - Reduce pedestrian delay

Treatment Example 4: Pedestrian Hybrid Beacon

- **Stop vehicles at red indication**
  - Increase crossing opportunities
  - Increase opportunity utilization (with APS)
  - Reduce speed (during red)
  - Reduce pedestrian delay
  - Reduce risk

Figure 4F-3. Sequence for a Pedestrian Hybrid Signal



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Questions and Discussion

Photo: Bastian Schroeder

RRFB in Olympia, WA

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TRB

Roundabouts and Channelized Turn Lanes: Access for Pedestrians, Particularly Those with Vision Disabilities

Module 6

Fastest Path Overview

Photo: Lee Rodegerdts

KITTELSON & ASSOCIATES

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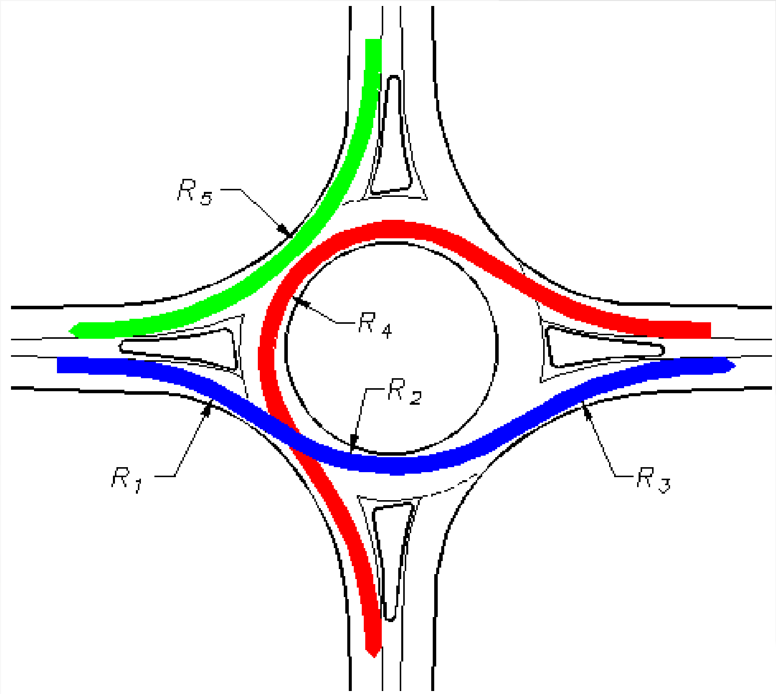
Fastest Path Overview and Exercises

- <u>**What's familiar: NCHRP Report 672 method**</u>
  - Drawing fastest path alignments
  - Measuring radii at key points along the path
  - Estimating speeds from those radii
  - Comparing entry speeds to design thresholds
- **What's new: NCHRP Report 834 method**
  - Renewed focus on estimating exit speeds
  - Determining critical speed over crosswalks
  - Comparable method for channelized turn lanes

Vehicle Path Radii

- Vehicle path definitions
  - R1: entry path radius
  - R2: circulating path radius
  - R3: exit path radius
  - R4: left turn path radius
  - R5: right turn path radius

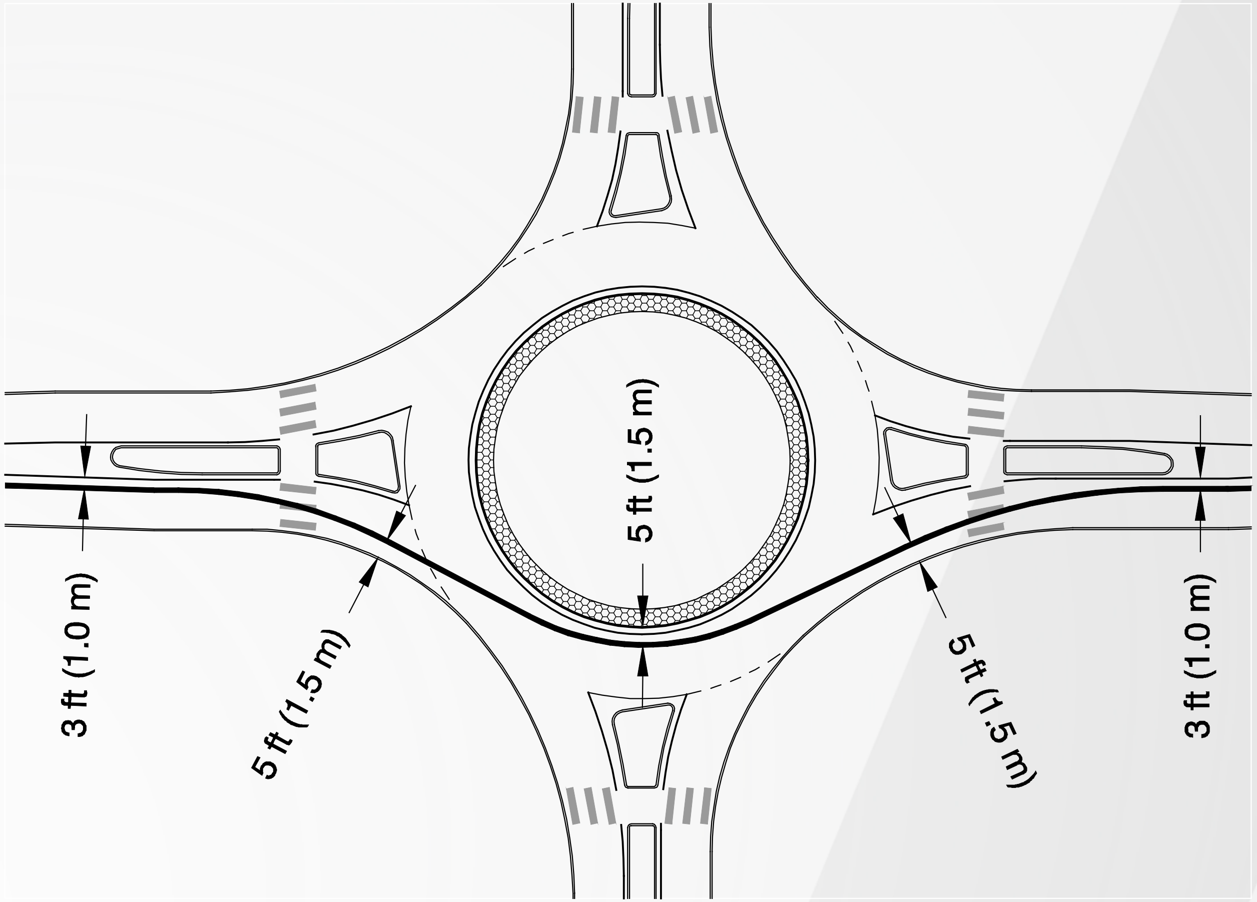


NCHRP Report 672 Exhibit 6-46

Vehicle Path Radii: How to determine them?

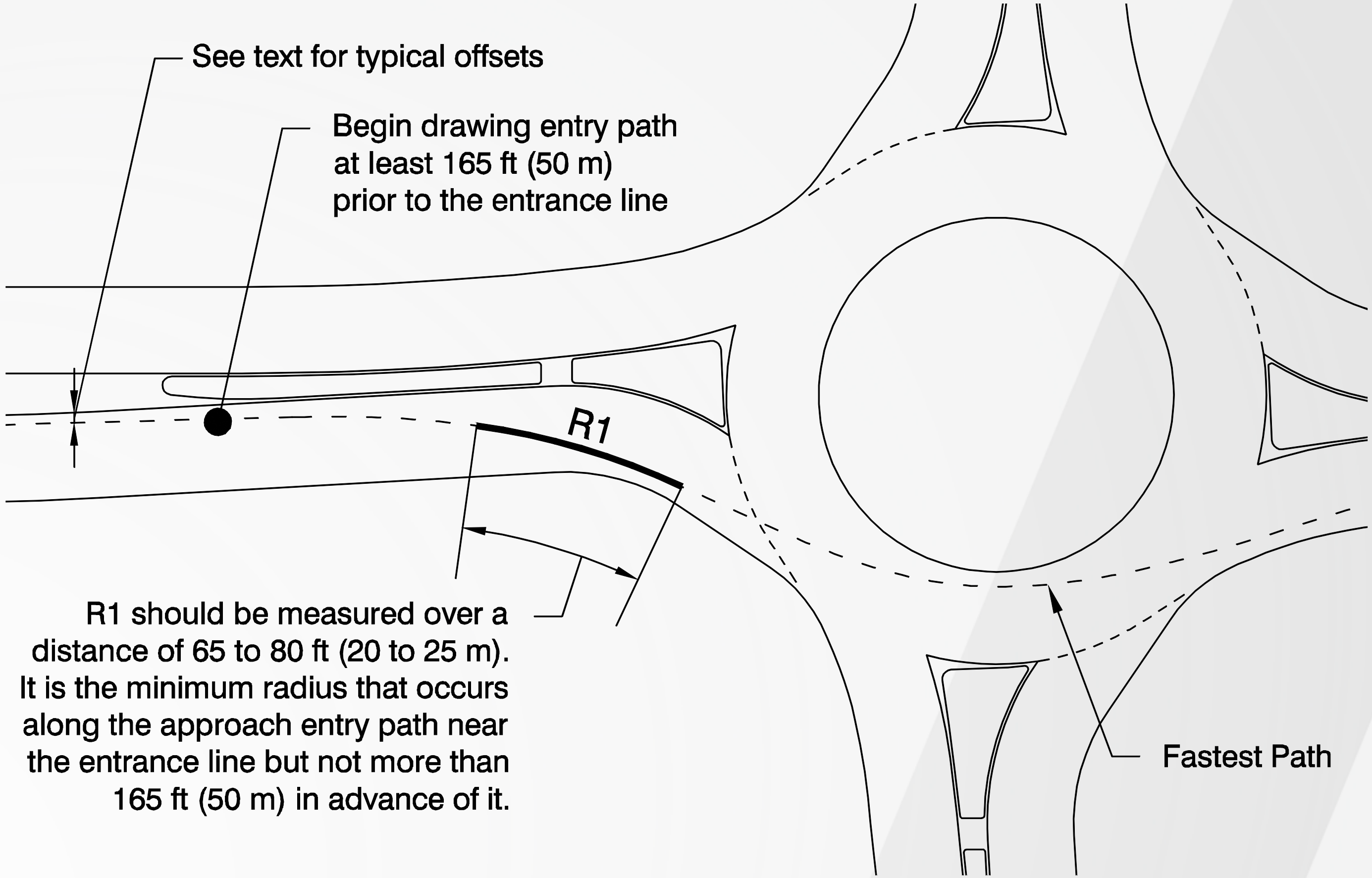
- **Vehicle Path**
  - Fastest path allowed by the geometry
  - Assumes absence of other traffic and ignores lane markings
- **Centerline drawn as follows**
  - 5 ft (1.5 m) from a concrete curb
  - 5 ft (1.5 m) from a painted line separating opposing traffic (e.g., roadway centerline)
  - 3 ft (1.0 m) from all other painted edge lines (except where a curb would govern)

Fastest Path: Single-Lane Roundabout



NCHRP Report 672 Exhibit 6-48

Fastest Path: Measurement of Entry Path Radius



NCHRP Report 672 Exhibit 6-51

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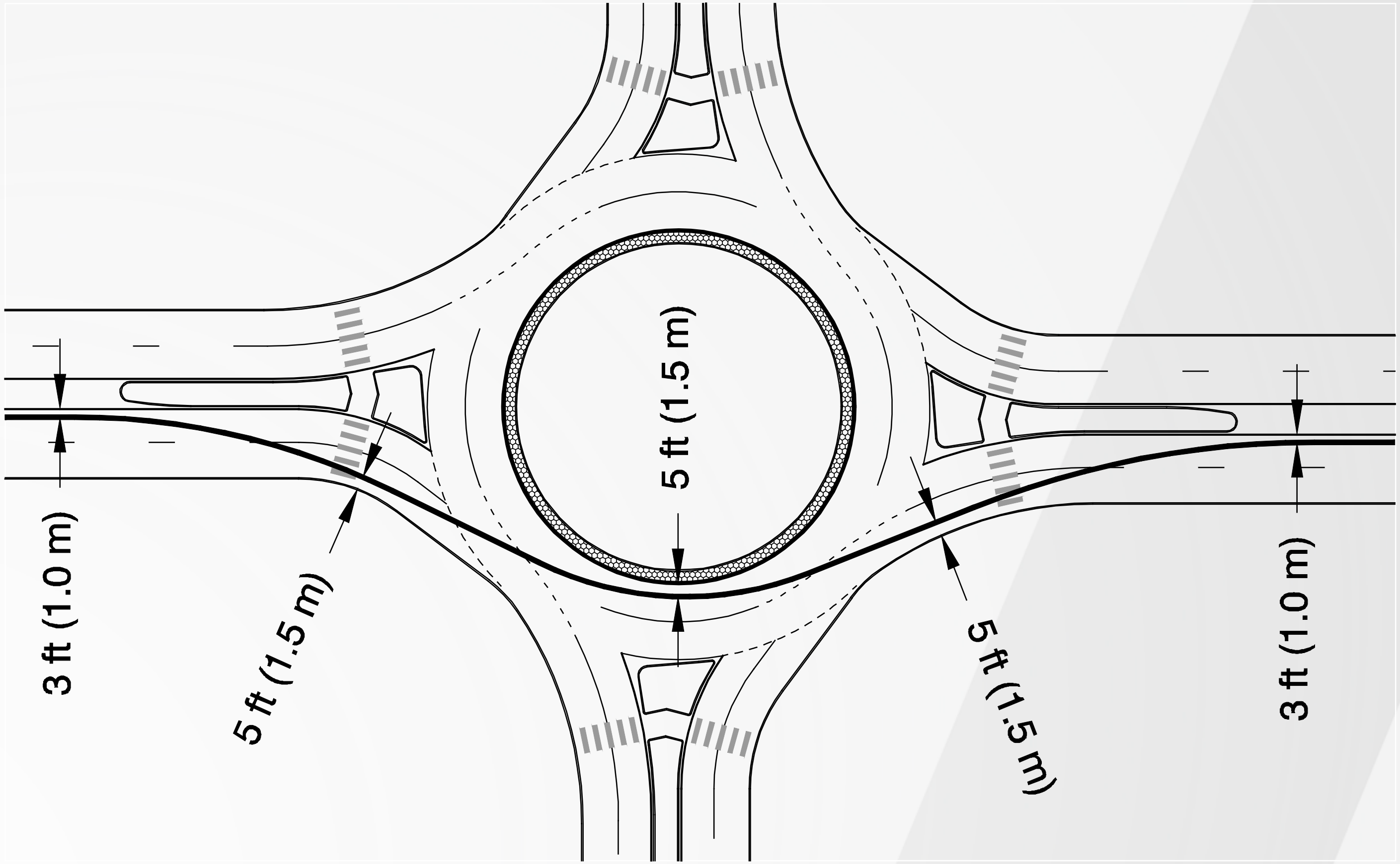
Fastest Path: Double-Lane Roundabout



NCHRP Report 672 Exhibit 6-49

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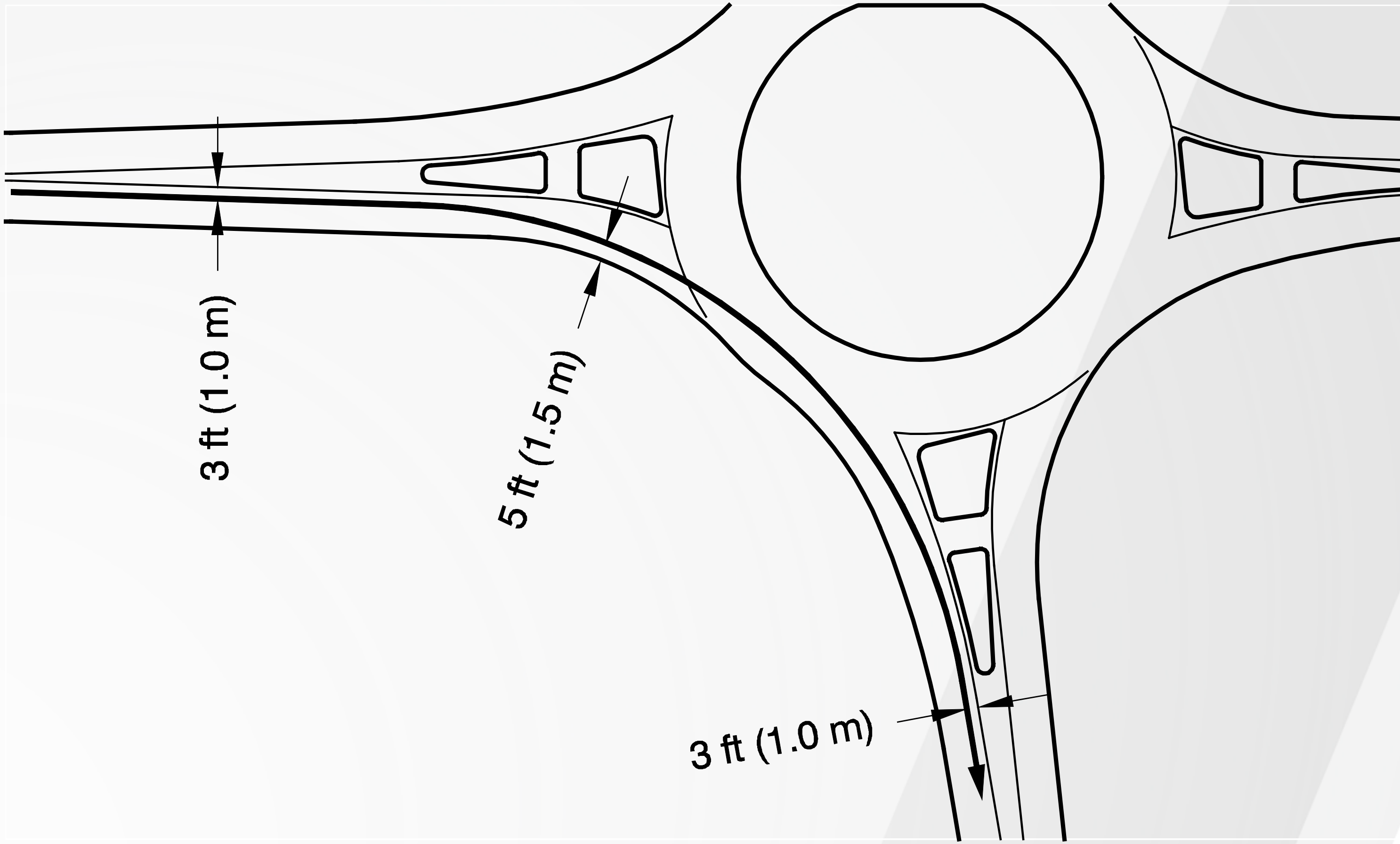
Critical Right-Turn Path (R5)



NCHRP Report 672 Exhibit 6-50

Speed – Curve Relationship

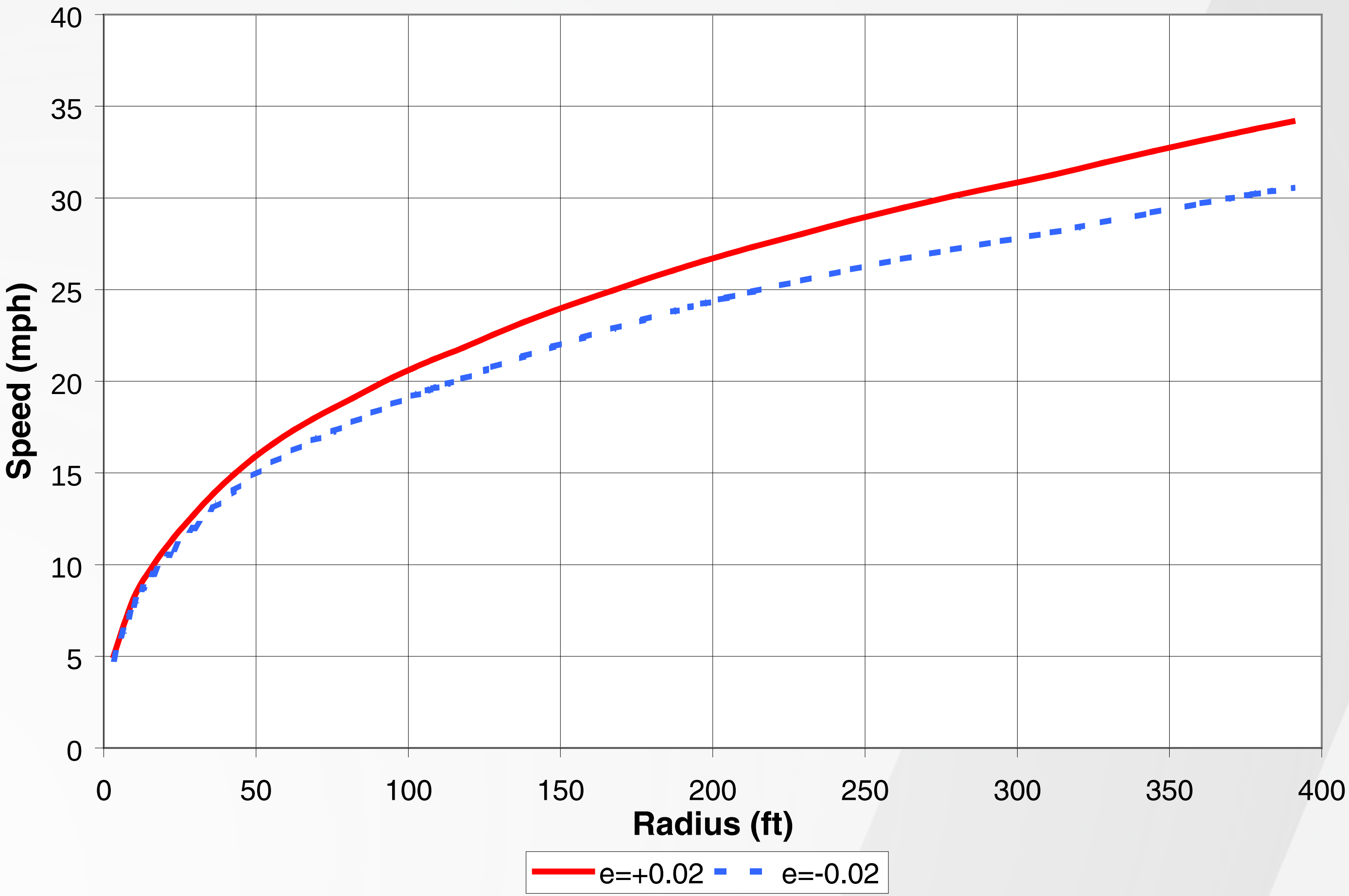
- Based on AASHTO Green Book

$$V = \sqrt{15R(e + f)}$$

where:

V = Design speed, mph
R = Radius, ft
e = superelevation, ft/ft
f = side friction factor

Speed-radius relationship (US units).



NCHRP Report 672 Exhibit 6-52

Entry Design Speeds

- Low speeds through the roundabout
- Research shows that entry-circulating crashes increase at entering speeds > 30 mph

Site Category	Recommended Maximum Theoretical Entry Design Speed
Mini-Roundabout	20 mph (30 km/h)
Single Lane	25 mph (40 km/h)
Multilane	25 to 30 mph (40 to 50 km/h)

NCHRP Report 672 Exhibit 6-47

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Calculate Exit Speed, V3

- **Exit speed limited by one of two factors:**
  - Exit path radius alone, R_3 (resulting in V_{3base})
  - Circulating speed and acceleration distance
    - a_{23} **= 6.9 ft/s²**
    - d_{23} **= distance from midpoint of** R_2 **curve and crosswalk**

$$V_3 = \min \begin{cases} V_{3base} \\ \dfrac{1}{1.47}\sqrt{(1.47V_2)^2 + 2a_{23}d_{23}} \end{cases}$$

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Determine Critical Vehicle Speed at Crosswalk (1/2)

- **Entry: maximum of through and right-turn entry speeds**
  - $V_{entry} = \max(V_1, V_5)$
- **Exceptions or special circumstances:**
  - No right-turn movement: only use V_1
  - If channelized right-turn movement, assess the two crossings separately (V_1 for entry, V_5 for right-turn)
  - If treatments that limit speeds are present (e.g. raised crosswalks), reduce speeds accordingly
  - If features upstream of crosswalk limit speeds (e.g., upstream curvature, origination from parking lot, etc.), use of lower V than predicted by this method is appropriate
  - For existing site, field-measured 85^{th}-percentile speeds may be used

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Determine Critical Vehicle Speed at Crosswalk (2/2)

- **Exit: maximum of through and right-turn exit speeds**
  - $V_{exit} = \max(V_3, V_5)$
- **Exceptions or special circumstances:**
  - No right-turn movement: only use V_3
  - If channelized right-turn movement, assess the two crossings separately (V_3 for exit, V_5 for right-turn)
  - If treatments that limit speeds are present (e.g. raised crosswalks), reduce speeds accordingly
  - If features downstream of crosswalk limit speeds (e.g., speed limit, stop sign, downstream curvature, termination into parking lot, etc.), use of lower V than predicted by this method is appropriate
  - For existing site, field-measured 85^{th}-percentile speeds may be used

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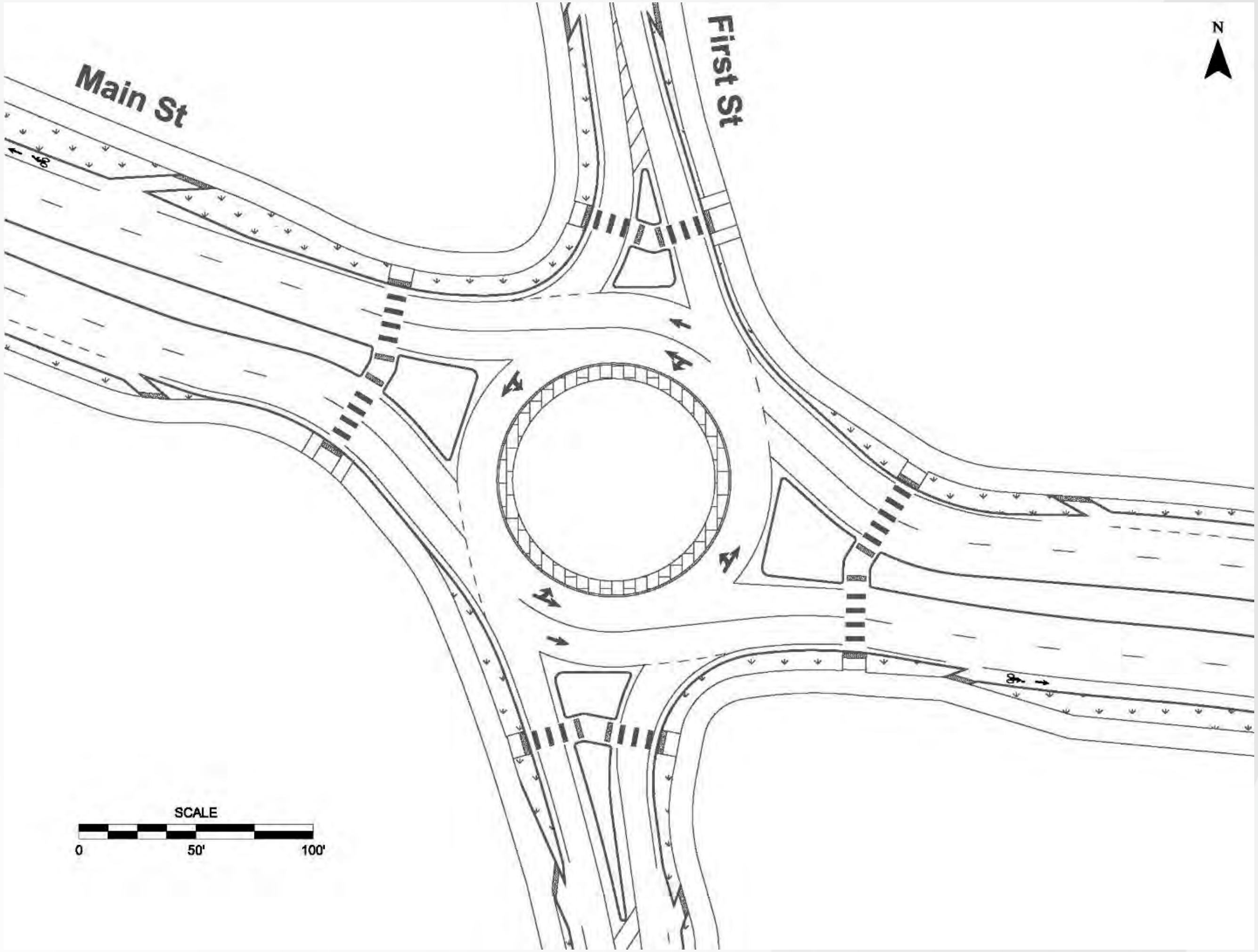
Channelized Turn Lane

- Use similar method as for roundabout right-turn movement
- Start path in right-turn lane
- Finish path ignoring striping on exit

Examples

- **Look at the following Roundabout and CTL**
  - What are the fastest paths?
  - What is the critical vehicle speed at the crosswalk?
- **Your binder has full page, scaled versions of these drawings**

2x1 Hybrid Roundabout Example



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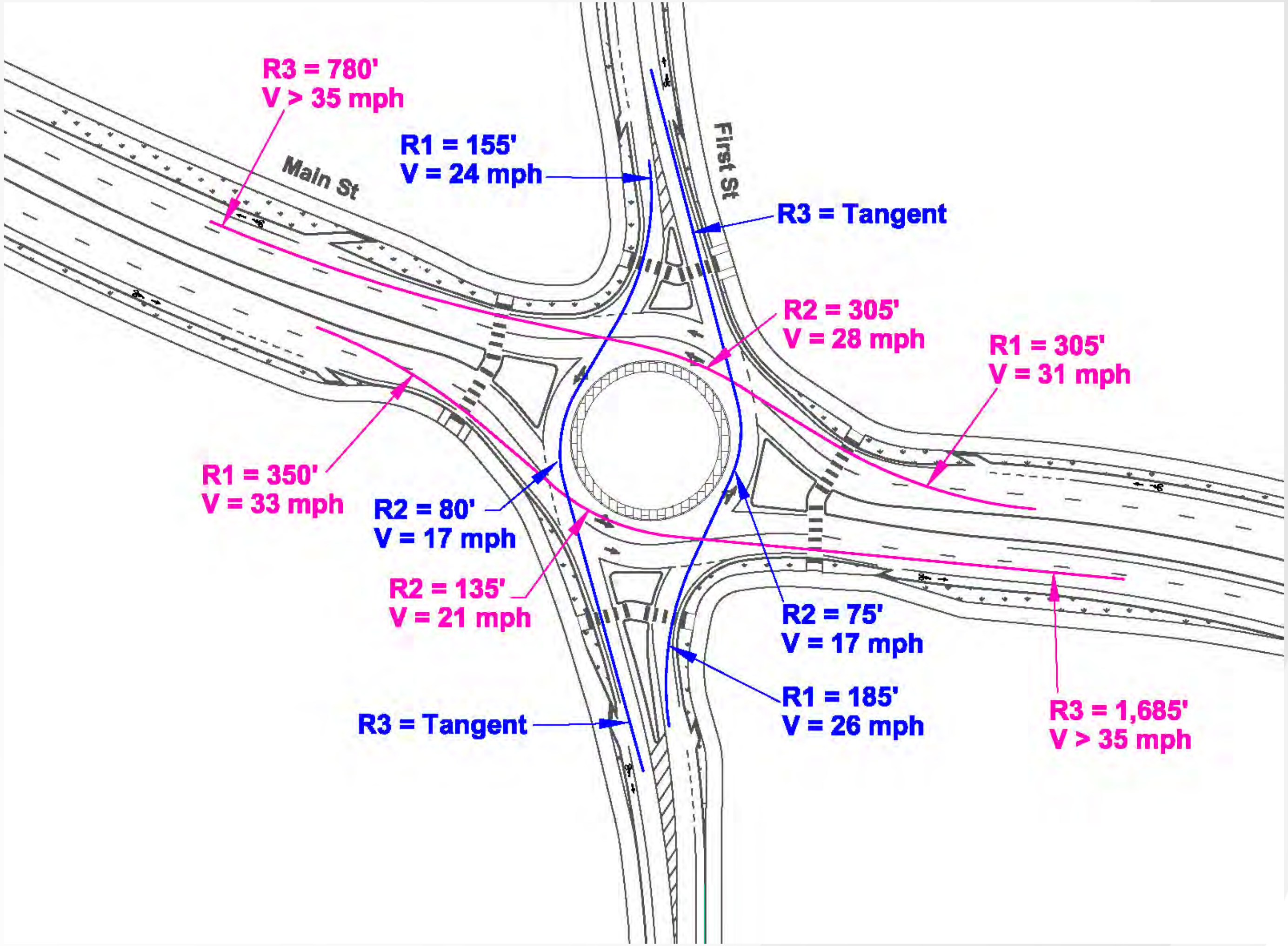
R1, R2, and R3 (radius-based) fastest paths



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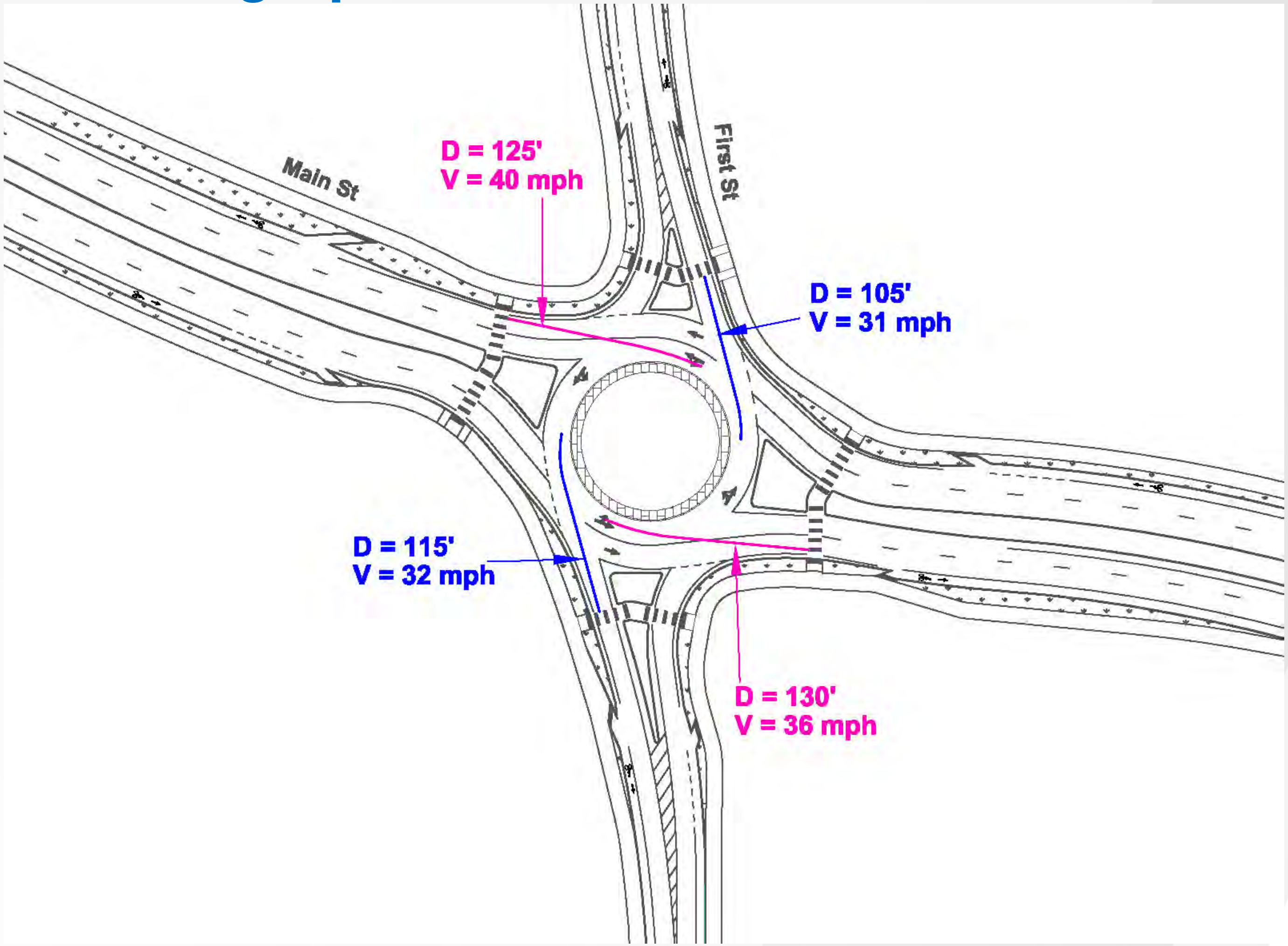
R3 – Circulating Speed and Acceleration



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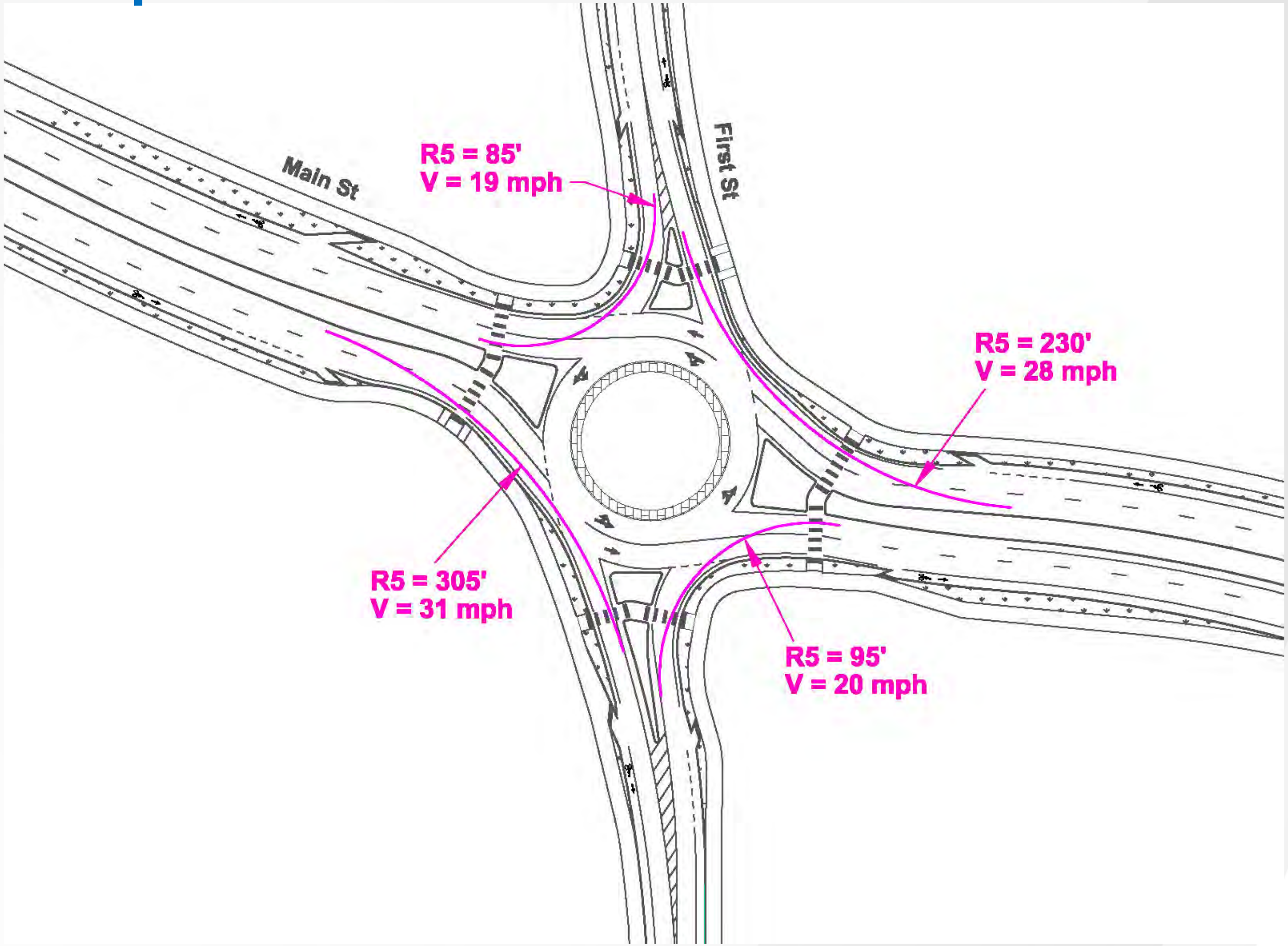
R5 fastest paths



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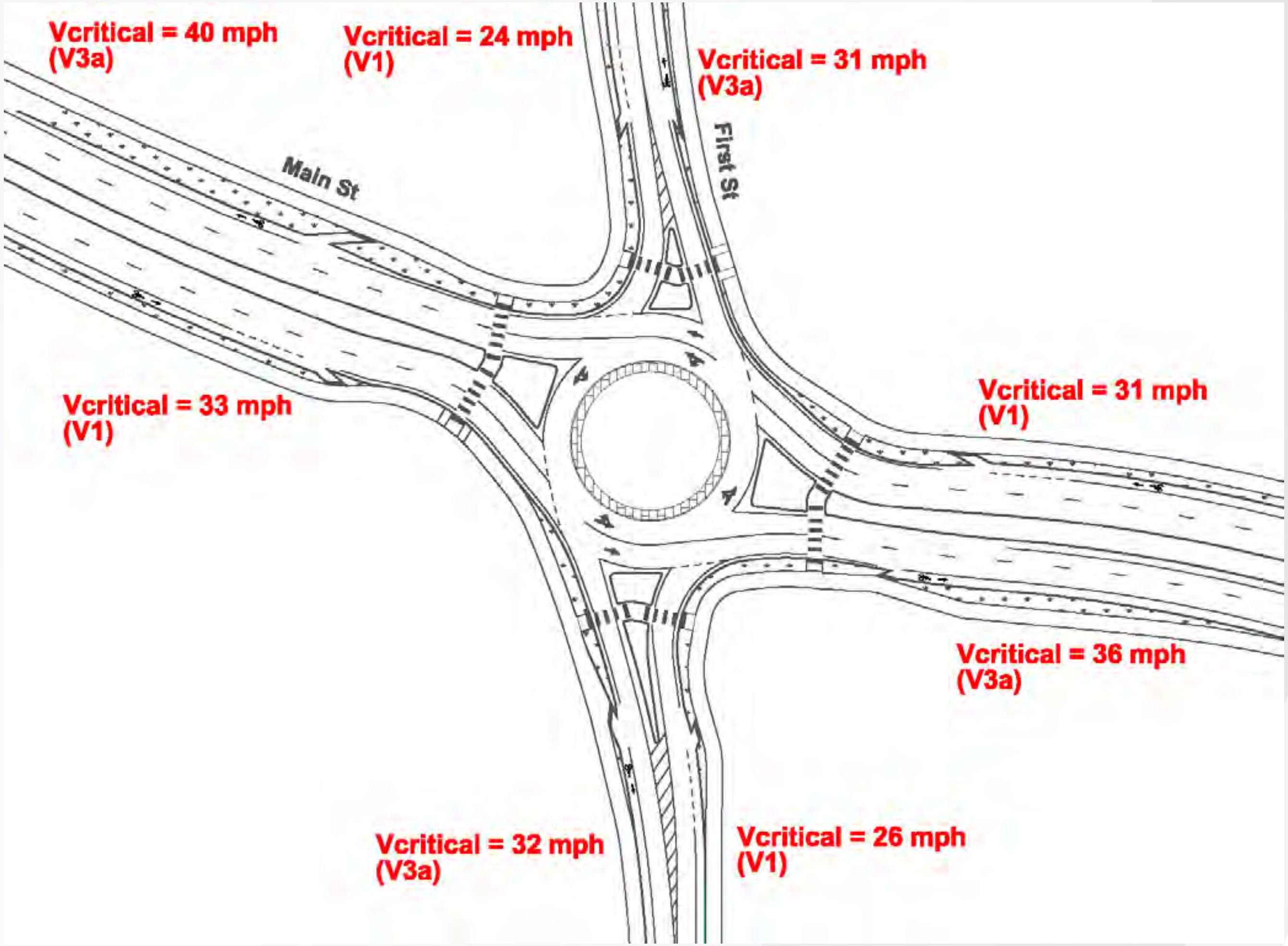
Putting it together – what is the critical vehicle speed at each crosswalk?



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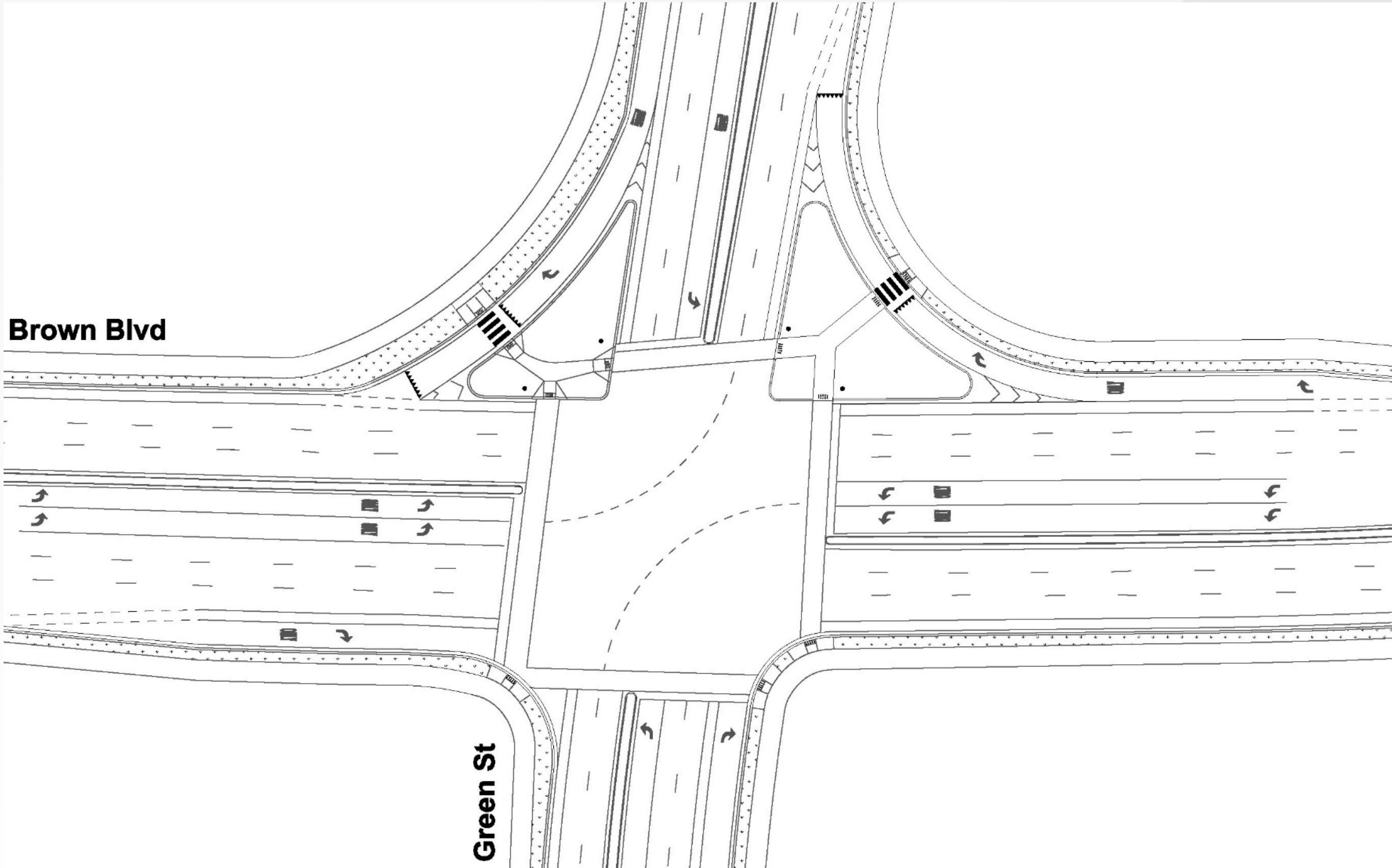
CTL Example



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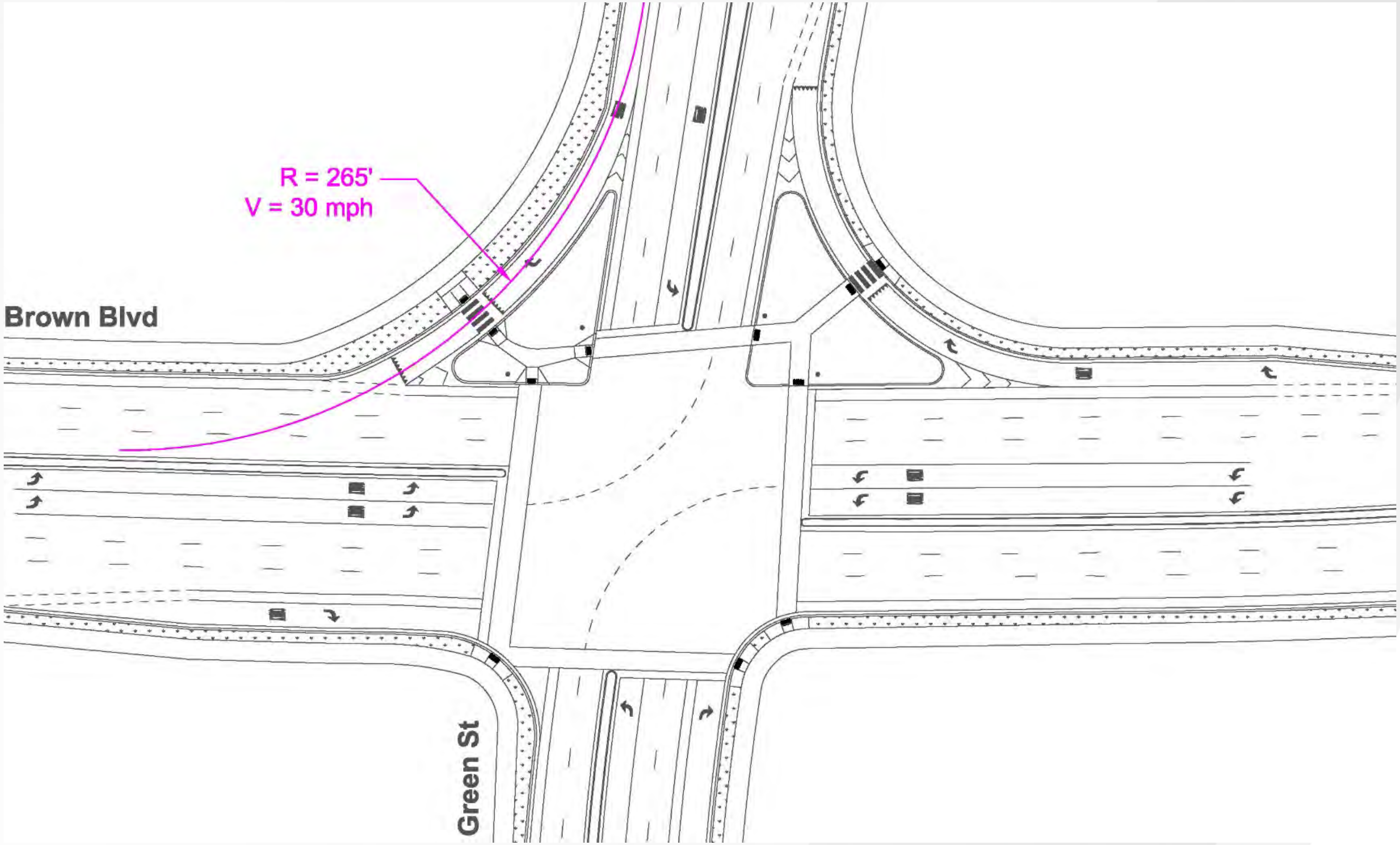
CTL fastest path/critical vehicle speed



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Roundabouts and Channelized Turn Lanes: Access for Pedestrians, Particularly Those with Vision Disabilities

Module 7

Crossing Assessment Exercises

Photo: Lee Rodegerdts

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CROSSING ASSESSMENT EXERCISE

Case Study Problem 1

Hands on by participants

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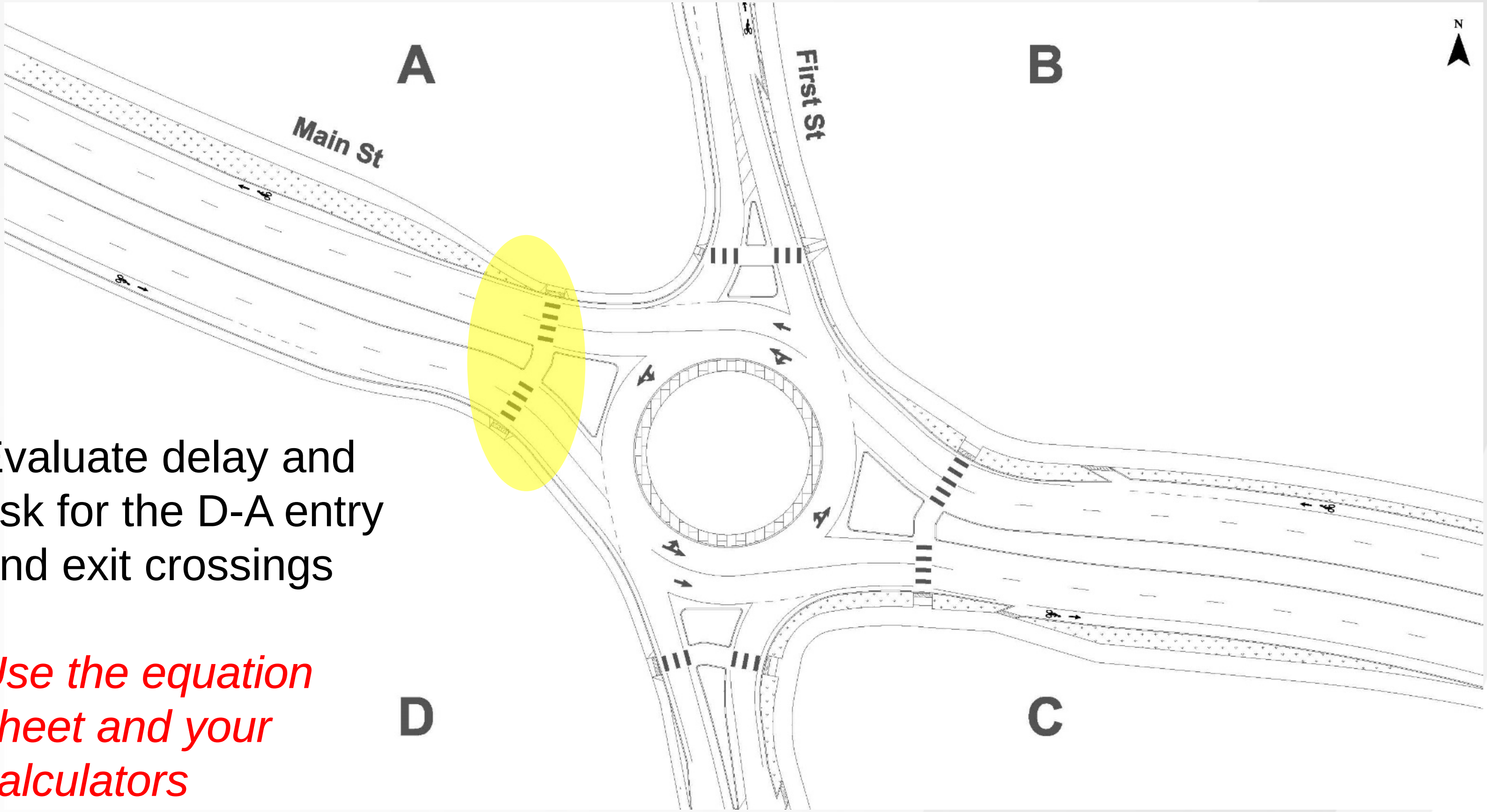
Problem 1 Inputs

	A-B Entry	A-B Exit	B-C Entry	B-C Exit	C-D Entry	C-D Exit	D-A Entry	D-A Exit
Speed at Crosswalk (mph)	24	31	31	36	26	32	33	40
Crosswalk Length (ft)	19	18	30	27	19	18	30	28
Volume (vph)	160	110	700	590	50	260	950	900

Assume: high yield compliance, low noise environment

Problem 1



Evaluate delay and risk for the D-A entry and exit crossings

Use the equation sheet and your calculators

Problem 1 (cont.)

- **Additional scenarios (full group with spreadsheet):**
  - What is the delay and risk on A-B, B-C, and C-D crossings?
  - How would the interventions change if this were in a high noise environment instead of a low noise environment?

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CROSSING ASSESSMENT EXERCISE

Case Study Problem 2

Instructor leads with spreadsheet

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Problem 2 Inputs

- **Quadrant A**
  - Speed at crosswalk = 24 mph
  - Length of crosswalk = 18 ft
  - Volume at crosswalk = 280 vph

- **Quadrant B**
  - Speed at crosswalk = 31 mph
  - Length of crosswalk = 16 ft
  - Volume at crosswalk = 350 vph

Assume: high yield compliance, low noise environment

CROSSING ASSESSMENT EXERCISE

Case Study Problem 3

Instructor leads with spreadsheet

Problem 3 Inputs

	A-B Entry	A-B Exit	B-C Entry	B-C Exit	C-D Entry	C-D Exit	D-A Entry	D-A Exit
Speed at Crosswalk (mph)	30	34	32	35	30	32	32	38
Crosswalk Length (ft)	18	21	33	30	15	23	33	29
Volume (vph)	240	170	440	780	170	140	450	320

Assume: high yield compliance, low noise environment

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CROSSING ASSESSMENT EXERCISE

Case Study Problem 4

Instructor leads with spreadsheet

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Problem 4 Inputs

- **Quadrant C**
  - Speed at crosswalk = 24 mph
  - Length of crosswalk = 26 ft
  - Volume at crosswalk = 130 vph

- **Quadrant D**
  - Speed at crosswalk = 22 mph
  - Length of crosswalk = 18 ft
  - Volume at crosswalk = 390 vph

Assume: high yield compliance, low noise environment

APPENDIX C – UPDATED CHAPTER 6 ON WAYFINDING ASSESSMENT

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NCHRP Project 03-78b

Guidebook for the Application of Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities

Revised Chapter 6

Prepared for:
National Cooperative Highway Research Program
Transportation Research Board
National Research Council

Kittelson & Associates, Inc.
ITRE at N.C. State University
Accessible Design for the Blind

December 2018

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6.0 WAYFINDING ASSESSMENT

This chapter provides a methodology for assessing wayfinding and alignment challenges for pedestrians who are blind. The most important underlying principle in the design of pedestrian crosswalks is that the design should be intuitive for its users. Many pedestrians who are blind or who have low vision have received orientation and mobility instruction and training for independent travel, but their training may not have covered roundabouts and intersections with CTLs, particularly if they received training several years ago. Furthermore, pedestrians likely did not receive training at the specific location they may be trying to cross. An intuitive design of the crosswalk therefore is critical to make sure pedestrians understand the purpose of the crosswalk and the rules governing the interaction between pedestrians and drivers.

As discussed in Chapter 3, pedestrians who are blind or who have low vision may not be aware of the presence of a roundabout where two roads intersect or of a CTL at the intersection. If the design and wayfinding features of the sidewalk do not guide them to the correct crossing location, or provide cues to the proper crosswalk heading, they may cross at a location where crossing is not intended, or they may veer out of the crosswalk and possibly along the vehicular travel lanes or into the roundabout circulatory roadway. It is important to evaluate each crossing from each approach direction and with respect to the three wayfinding tasks outlined in chapter 3: determining the crossing location (or locating the crossing), aligning to cross, and maintaining correct heading while crossing. This assessment is one of the added performance checks to be integrated into the overall design processes discussed in Chapter 2.

There may be cases where additional treatments beyond those identified in the questions below may be beneficial to help a blind pedestrian correctly locate and align with the crossing. Bar tiles or guidance tiles are used in other countries to notify pedestrians of the location and alignment of the crosswalk at roundabouts and CTLs. These types of surfaces provide information about the crosswalk location to pedestrians who use dog guides or to cane users who are not trailing the edge of the sidewalk with their canes. Pilot research suggested that bar tiles placed perpendicular to the crosswalk direction may work well to address concerns of wheelchair users while helping pedestrians who are blind locate crosswalks and align to cross. There is a need for more research on the appropriate placement of such surfaces and potential effect on wheelchair users.

Similarly, maintaining alignment while crossing may be assisted by raised crosswalks, which provide additional cues to assist blind pedestrians in staying within the crosswalk if they recognize the slope on the edges of the crosswalk. Detection is dependent on the steepness of that slope but slight changes in cross slope are detectable by many pedestrians who are blind. Likewise, the pushbutton locator tone of an APS or audible information device may provide a cue to the end of the crosswalk and heading direction.

6.1 Determining the Crossing Location

The first task of the pedestrian is to determine the appropriate crossing location or to locate the crosswalk. Sidewalks, curb ramps, and other features should guide pedestrians to the point where the designer wants them to cross the roadway and discourage or prevent pedestrians from crossing at other locations. This should also be considered in the design of islands.

As shown in Figure 6-1 and Figure 6-2 below, the zone discussed is on the approach to the roundabout or CTL as pedestrians walk towards the crossing location from either direction along the sidewalk.

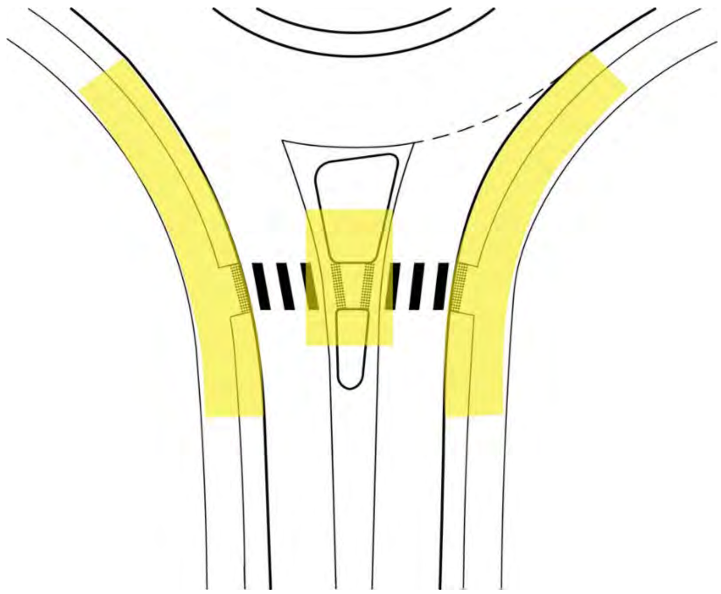

Figure 6-1: Illustration of Zone to Determine Crossing Location at Roundabout

This figure shows a drawing of a single-lane roundabout. A yellow shaded zone is shown on the sidewalk approaching the crosswalk on both entry and exit sides, denoting the region where wayfinding features to assist in determining the crossing location should be considered.

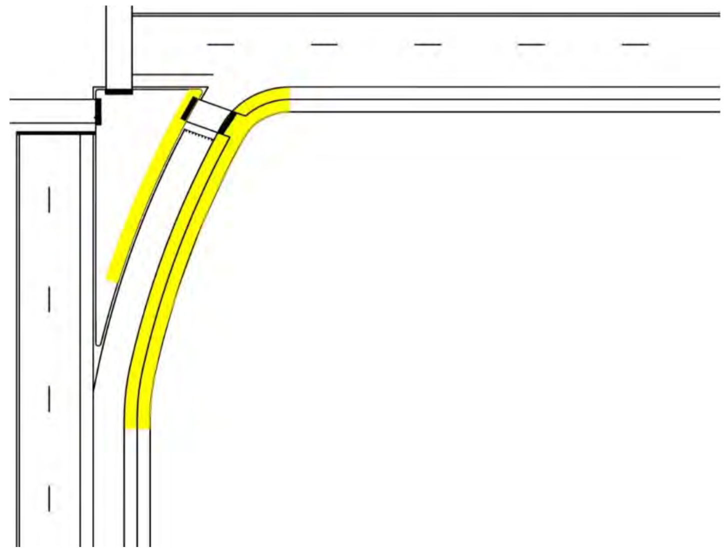

Figure 6-2: Illustration of Zone to Determine Crossing Location at CTL

This figure shows a drawing of a CTL. A yellow shaded zone is shown on the sidewalk approaching the crosswalk on the curb side, denoting the region where wayfinding features to assist in determining the crossing location should be considered.

In evaluating wayfinding features for the task of determining the crossing location, six basic questions should be considered by designers, as presented in Table 6-1. Each is discussed further below, with additional details and graphics provided in referenced sections of Chapters 4 and 5.

Table 6-1: Considerations for Determining the Crossing Location

Question	Notes
1. Do sidewalks lead to the crosswalks?	• See Section 4.1 and 5.1 for details
2. Is separation provided between sidewalk and curb?	• See Section 4.1 and 5.1 for details • Required by PROWAG-NPRM at roundabouts; good practice at CTLs
3. Is the edge of the street clearly defined by detectable warning surfaces?	• See Section 4.1 and 5.1 for details • Required by Department of Transportation ADA regulations and PROWAG-NPRM
4. If other ramps or driveways are nearby, are they adequately delineated and separated?	• See Section 4.1 and 5.1 for details
5. Are traffic control devices accessible?	• See Section 4.2 and 5.2 for details • Required by PROWAG-NPRM • Specifications in MUTCD 4E
~~6. Are there other treatments needed or desired to assist with locating the crosswalk?~~	• ~~See Section 4.2 and 5.2 for details~~

6.1.1 Do sidewalks lead to the crosswalks?

Sidewalks should lead to the crosswalk, particularly in designs where the sidewalk is not beside the roadway. On islands, the walkway should be defined to give clear guidance to all pedestrians to the appropriate crossing location (see Section 6.5).

6.1.2 Is separation provided between sidewalk and curb (as required in PROWAG-NPRM)?

Sidewalks should be separated from the curb by a landscape strip, except at the crosswalks. A landscape strip at least 2 feet wide should be provided between the sidewalk and curb on each side of the curb ramp and should be a surface that is detectable under foot, such as grass, gravel, pebbles or small shrubs. Bricks, cobblestone type pavers, or colored paved surfaces do not provide a sufficiently detectable cue to prevent blind pedestrians from crossing into the circulatory roadway. This should be provided on the approach to the crosswalk from either direction (see zone in Figure 6-1)

If there is insufficient right of way to provide a landscape strip as described above, fencing, or bollards and chain, should be provided on either side of crosswalks to prevent crossing into the circulatory roadway. PROWAG-NPRM requires a lower edge or chain that is not more than 15 inches above the walking surface; a higher chain or fence may be needed to avoid tripping by sighted pedestrians. If bollards are used, they must be connected by chains or other material to prevent pedestrians from walking between them.

6.1.3 Is the edge of the street clearly defined (outside edge) (as required by Department of Transportation ADA standards and in *PROWAG NPRM*)?

A detectable warning surface (truncated domes) should be provided for the width of the ramp, or for the area that is level with the street. The surface must be a minimum of two feet deep in the direction of pedestrian travel covering the entire area that is level with the street so a pedestrian cannot easily step over or around the surface. When a raised crosswalk is installed that brings the crosswalk up to sidewalk level, the detectable warning surface is the only indication of the street/sidewalk boundary to a blind pedestrian. This question applies to the boundary between the sidewalk and the crosswalk; a separate question in 6.4.2 applies to the boundaries within islands.

6.1.4 If other ramps or driveways are nearby, are they adequately delineated and separated? ~~there other features that could be mistaken for curb ramps~~?

If bike ramps are planned, they must be carefully designed to avoid misleading pedestrians. The ramp should be angled at a more than 45-degree angle toward the roadway rather than parallel to the sidewalk. Detectable warning surfaces should be installed at the top of the ramp, at the junction with the sidewalk and aligned with the edge of the sidewalk to alert the blind pedestrian to the presence of the ramp.

6.1.5 Are traffic control devices accessible (as required in *PROWAG-NPRM, with specifications in MUTCD 4.E*)?

If a pedestrian signal is present, an Accessible Pedestrian Signal (APS) with an appropriate audible pushbutton locator tone has to be provided. Pedestrians need to be able to locate and use a pedestrian pushbutton without having to deviate far from the path of travel or the crosswalk. Audible indications, including a pushbutton locator tone to assist blind pedestrians in locating a pushbutton, should be provided, even on devices such as RRFBs, which do not provide a walk indication. The sound of the pushbutton locator tone can also provide information about the location of the crosswalk.

~~6.1.6 Are other treatments needed or desired to assist with locating the crosswalk?~~

~~Bar tiles or guidance tiles are used in other countries to notify pedestrians of the location of the crosswalk at roundabouts and CTLs. These types of surfaces provide information about the crosswalk location to pedestrians who use dog guides or to cane users who are not trailing the edge of the sidewalk with their canes. Pilot research suggested that bar tiles may work well to address concerns of wheelchair users while helping pedestrians who are blind locate crosswalks and align to cross.~~

6.2 Aligning to Cross and Establishing a Correct Heading

Aligning to cross is the necessary task after finding the crosswalk. The technique most commonly used by blind pedestrians at a typical intersection is aligning with traffic traveling parallel to the crosswalk. At roundabouts and CTLs this technique is generally not available since there is no parallel traffic. Blind pedestrians must use a combination of sidewalk and curb ramp features and the movement of traffic perpendicular to their path as primary cues to the direction of travel on the crosswalk. A mistake in alignment may put the pedestrian who is blind outside the crosswalk area, or headed toward the circulatory roadway, and could be a dangerous, as well as confusing, mistake. The graphic below shows the areas where this task takes place and where the designer needs to focus in considering alignment cues.

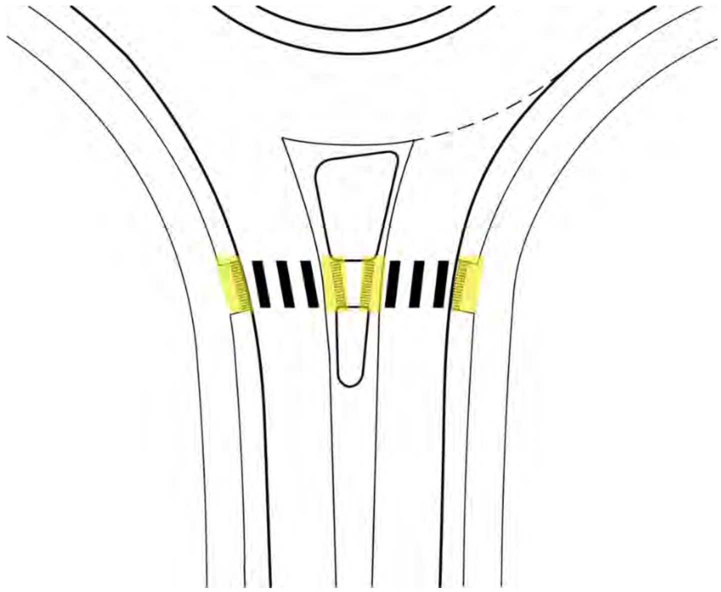

Figure 6-3: Illustration of Zone for Aligning to Cross at Roundabout

> *This figure shows a drawing of a single-lane roundabout. A yellow shaded zone is shown on the crosswalk landing on both entry and exit sides, as well as on the curb and island. The shaded areas denote the regions where wayfinding features to assist in aligning to cross should be considered.*

In evaluating wayfinding features for the task of aligning to cross and for establishing the correct heading, six basic questions should be considered by designers, as presented in Table 6-2. Each is discussed further below, with details provided in Chapters 4 and 5 as referenced.

Table 6-2: Considerations for Aligning to Cross and Establishing a Correct Heading

Question	Notes
1. Is curb ramp width the same as crosswalk width?	• See Section 4.1 and 5.1 for details
2. Is curb ramp slope aligned with crossing?	• See Section 4.1 and 5.1 for details
3. Are ramp edges aligned with crossing?	• See Section 4.1 and 5.1 for details
4. Is detectable warning aligned with the slope of the curb ramp?	• See Section 4.1 and 5.1 for details • ~~Required by PROWAG NPRM~~
5. Are pushbuttons in correct location?	• See Section 4.2 and 5.2 for details
6. Is there a sufficiently level landing and turning space where the pedestrian is waiting to cross?	• Required by PROWAG NPRM
~~6. Is there a need for additional treatments?~~	• ~~See Section 4.2 and 5.2 for details~~

6.2.1 Is curb ramp width the same as crosswalk width?

The curb ramp and sidewalk width leading to the crosswalk should be the same width as the crosswalk. If the sidewalk on either end of the crosswalk is wider than the crosswalk, pedestrians who are blind may cross outside the crosswalk area. If the ramp or cut-through area is narrower than the crosswalk, the curb can be a tripping hazard and cause confusion as the pedestrians who are blind may think they have veered outside the crosswalk when they have not. Detectable warning surface must also be the full width of the area that is level with the street so it also must be the full width of the crosswalk.

6.2.2 Is curb ramp slope aligned with crossing?

All curb ramps should be oriented so that the running slope is in the same direction as direction of travel on the crosswalk. The slope of the ramp can influence the direction of travel of blind pedestrians on the crosswalk, so it should align with the direction of the crosswalk. The greater the slope, the more potential influence there is. In addition, it can be difficult for wheelchair users to make a turn at the base of the curb ramp and stay within the crosswalk; at best, it slows them and distracts them as they enter the street.

Curb ramps and crosswalks should further be aligned perpendicular to the curb, gutter, and the travel lanes. To prevent tipping problems for wheelchair users, it is essential that the base of the ramp be square to the gutter or grade break at the base of the ramp. Pedestrians who are blind also tend to use the gutter and/or curb line as an alignment cue and will often travel across the roadway on a path that is perpendicular to the curb line.

On islands, both at roundabouts and CTLs, when the island is not cut-through, the curb ramp slope can provide help with the detecting the crossing location and with alignment for the crossing. See Section 6.5 below for more discussion of this.

6.2.3 Are ramp edges aligned with crossing?

Returned edges on the curb ramp should be aligned with the crosswalk direction. If there are returned edges on the curb ramps, they may serve as a cue to blind pedestrians and should be in line with the crosswalk. Returned curbs should not be used in locations without landscaping or other features where they may be a tripping hazard to pedestrians walking across the ramp area.

Flares (sloped areas beside the ramp) are not needed where there is landscaping beside the ramp. The ramp should be the width of the entire crosswalk and the flares, if needed, can be outside the crosswalk area.

6.2.4 Is detectable warning aligned with slope of the curb ramp?

While not a requirement of PROWAG, the domes of the detectable warning surface desirably should be aligned with the slope of the ramp. This is to make it easier for wheelchair users to travel between the domes on the slope of the ramp. The alignment of the detectable warning surface is not intended to be a cue for the direction of travel on the crosswalk, but some pedestrians who are blind will try to align with it, nonetheless. It is not possible for most people who are blind to accurately align with the truncated dome surface. Nonetheless, aligning the detectable warning surface edges, the curb/gutter, and the ramp slope with the direction of travel on the crosswalk can provide consistency that can lead to better alignment.

6.2.5 Are pushbuttons in correct location?

When a pedestrian pushbutton is used, either with a pedestrian signal, a PHB or a RRFB, it should be next to the crossing and beside a level area to allow access for wheelchair users. Most pushbutton devices include a tactile arrow that must be aligned with the direction of travel on the crosswalk. That arrow must be located within 5 feet of the crosswalk line and should be no further than 6 feet from the curb, if possible. Audible devices, either APS or audible information devices, provide a pushbutton locator tone and that tone may be audible across a short crossing and may help with alignment and maintaining the correct heading when crossing. The pushbutton locator tone is supposed to be audible no more than 12 feet from the pushbutton, so it may not provide alignment help on longer crossings.

6.2.6 Is there a sufficiently level landing and turning space where the pedestrian is waiting to cross?

Level landings and turning spaces are not a feature required by pedestrians who are blind, but they are a required feature for usability of a curb ramp by those who use wheelchairs or other mobility devices (e.g., PROWAG R304.2.1). When considering the wayfinding questions here, it is essential also provide the appropriate landing (turning space) at the top of perpendicular curb ramps and at the base of parallel ramps.

~~6.2.7 Is there a need for additional treatments?~~

~~For approaches that do not meet the above criteria, additional treatments may be needed to assure that a blind pedestrian is able to correctly align with the crossing. A tactile bar tile type surface perpendicular to the direction of travel on the crosswalk was found in pilot research to lead to better initial alignment. There is a need for more research on the appropriate placement of such surfaces and potential effect on wheelchair users.~~

6.3 Maintaining Correct Heading while Crossing (Staying within the Crosswalk)

Staying within the crosswalk area while crossing can be critical to safety, driver expectation and orientation. Critical zones for this task are the area of the crosswalk within the street as shown in the Figure 6-4 below.

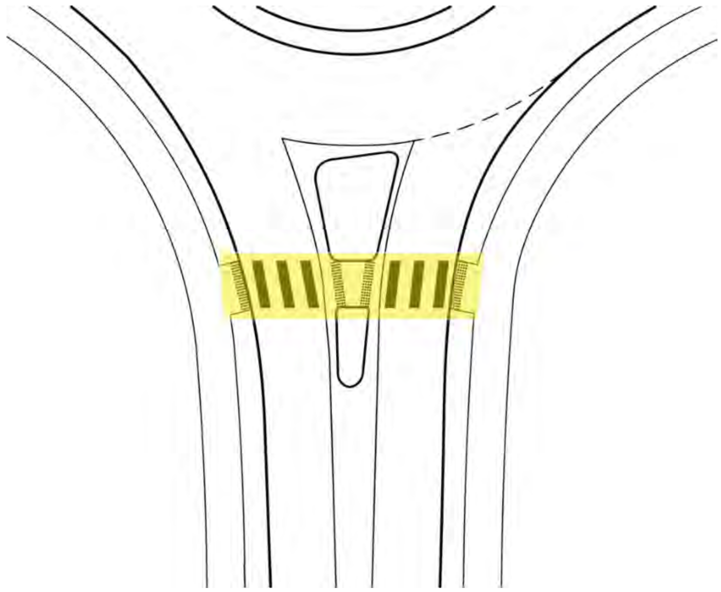

Figure 6-4: Illustration of Zone for Maintaining Correct Heading at Roundabout

> *This figure shows a drawing of a single-lane roundabout. A yellow shaded zone is shown across the entire crosswalk for both entry and exit sides, denoting the region where wayfinding features to assist in maintaining the correct heading should be considered.*

In evaluating wayfinding features for the task of maintaining the correct heading while crossing and staying within the crosswalk, four basic questions should be considered by designers, as presented in Table 6-3. Each is discussed further below, with details provided in Chapters 4 and 5 as referenced.

Table 6-3: Considerations for Maintaining Correct Heading while Crossing and Staying Within the Crosswalk

Question	Notes
1. Is the crossing configured at the shortest distance practical?	• See Section 4.1 and 5.1 for details
2.Is the crossing aligned perpendicular to the curb and splitter edges?	• See Section 4.1 and 5.1 for details
3. Are markings clearly visible?	• See Section 4.1 and 5.1 for details
~~4. Is there need for additional treatments?~~	• ~~See Section 4.2 and 5.2 for details~~ ~~Required by PROWAG NPRM~~

6.3.1 Is the crossing configured at the shortest distance practical?

The shorter the crossing, the less exposure and less opportunity there is for the pedestrian to veer outside the crosswalk area.

6.3.2 Is the crossing aligned perpendicular to the curb and splitter edges?

Good initial alignment makes it more likely that blind pedestrians will complete their crossing within the crosswalk. As noted in the alignment discussion, the crossing and crosswalk needs to be aligned with the edge of the street.

6.3.3 Are markings clearly visible?

For low vision pedestrians, crosswalk markings provide critical information to assist them in staying within the crosswalk. Ladder markings with both longitudinal and transverse lines are preferred by individuals with low vision.

~~6.3.4 Is there a need for additional treatments?~~

~~For approaches that do not meet the above criteria, additional treatments may be needed to assure that a blind pedestrian is able to maintain correct heading during crossing. Raised crosswalks provide additional cues to assist blind pedestrians in staying within the crosswalk if they recognize the slope on the edges of the crosswalk. Detection is dependent on the steepness of that slope but slight changes in cross slope are detectable by many pedestrians who are blind. As a pedestrian is crossing, the pushbutton locator tone of an APS or audible information device may provide a cue to the end of the crosswalk and heading direction.~~

~~Tactile guide strips are used in some countries and have been experimented with in the US to provide guidance, particularly if the crossing is more than two lanes.~~

6.4 Crossings from Channelization and Splitter Islands

Crossing from triangular islands at CTLs or splitter islands of roundabouts can be problematic if the island does not provide crossing and alignment cues as noted above. Additional principles also need to be considered for the island environment. Figure 6-5 and Figure 6-6 show the channelization island zone for a roundabout and a CTL, respectively.

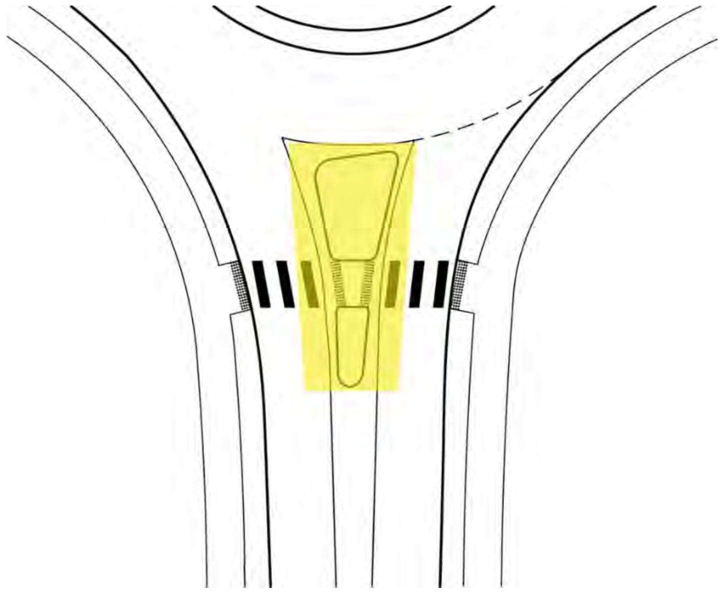

Figure 6-5: Illustration of Zone for Island Crossings at Roundabout

This figure shows a drawing of a single-lane roundabout. A yellow shaded zone is shown covering the island, denoting the region where wayfinding features to assist in navigating the splitter island should be considered.

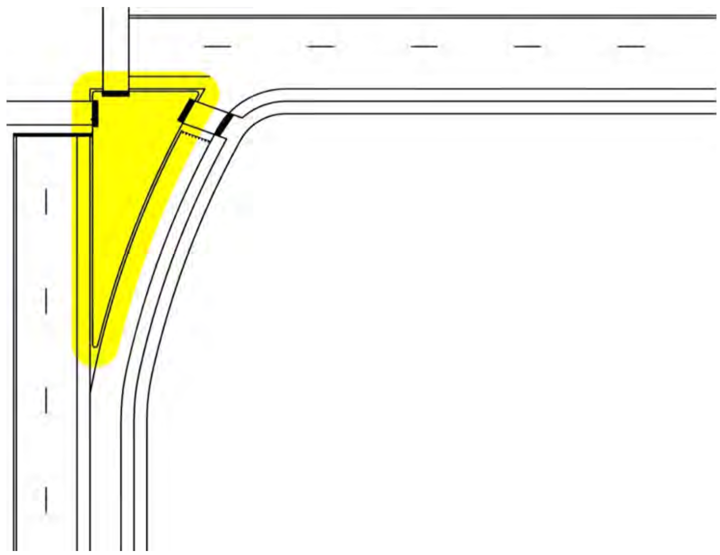

Figure 6-6: Illustration of Zone for Island Crossings at Channelized Turn Lane

This figure shows a drawing of an intersection with a channelized right turn lane. A yellow shaded zone is shown covering the island, denoting the region where wayfinding features to assist in navigating the splitter island should be considered.

In general, the same wayfinding features that were discussed in the previous sections also apply to channelization islands. In addition, the following four questions should be considered by designers, as presented in Table 6-4. Each is discussed further below, with details provided in Chapters 4 and 5 as referenced.

Table 6-4: Considerations for Crossings from Channelization and Splitter Islands

Question	Notes
1. Are islands wide-enough to provide safe refuge?	• See Section 4.1 and 5.1 for details
2. Are transitions to roadway clearly defined?	• See Section 4.1 and 5.1 for details
3. Are paths through islands clearly defined?	• See Section 4.1 and 5.1 for details
4. Are push-buttons accessible?	• See Section 4.2 and 5.2 for details

6.4.1 Are islands wide enough to provide safe refuge?

The minimum width of an island (length in direction of pedestrian travel) should be six feet. The minimum width of cut-through areas should also be six feet (or the same width as the crosswalk if the crosswalk is wider than six feet). For areas with heavier pedestrian traffic (greenways, shared use paths, etc.), consider larger islands to provide adequate storage. In addition, a level landing (turning space) is required at the top of any ramps (see Section 6.2.6).

6.4.2 Are transitions to roadway clearly defined (within the island) (as required by Department of Transportation ADA standards and in *PROWAG NPRM*)?

Detectable warning surfaces that denote street/sidewalk boundaries are needed on all edges of the islands where it is level with the street. All islands should be raised to clearly separate them from the vehicular right-of-way. Painted islands are inaccessible (not detectable) to blind users and should not be used. The island size should be large-enough to be visible to approaching drivers, and as recommended by AASHTO.

6.4.3 Are paths through island clearly identifiable?

To define the path through the island and prevent disorientation, if a blind pedestrian veers from the crosswalk on approach to the island, it is most desirable to have landscaping outside of the walkway that is detectable under foot such as gravel, grass, or shrubs. Even at cut-through islands, detectable landscaping clearly directs pedestrians to stay on the planned path through the island rather than take a different path or shortcut. Completely paved islands, even with rough pavers or bricks can result in confusion and disorientation for pedestrians who are blind.

If the island is cut-through, the approach to the curb line of cut-through areas needs to be aligned with the direction of travel on the crosswalk. If islands are not cut-through, attention should be paid to alignment of curb ramps, detectable warnings and gutters to provide alignment cues.

6.4.4 Are pushbuttons accessible?

There are somewhat different location needs for APS at signalized intersection than there are for audible information devices at unsignalized crosswalks. MUTCD 4E.08 requires pushbuttons and APS to be installed within 5 feet of the crosswalk line furthest from the center of the intersection. There are no specific requirements in the MUTCD for audible information devices, such as those installed at RRFBs, however, it is desirable for the device to be close to the crosswalk and to be downstream from the crosswalk to avoid having the device sounds between blind pedestrians and the vehicles they need to hear. In addition, devices also must be separated by at least 10 feet to allow pedestrians to distinguish which one is sounding. On small islands, that can be challenging to design and may require additional stub poles.

Pushbutton information messages, a type of speech message provided when the pushbutton is held for more than one second, can be configured to provide street name information. This could be a very helpful orientation aid on islands at channelized turn lanes to differentiate the main street crossings.

6.5 Wayfinding Assessment Worksheet

Each of the Wayfinding Assessment steps described in this chapter can be captured in a formal worksheet, shown in Figure 6-7. To use the worksheet, the user should proceed through the questions in Sections 6.1 through 6.4 for each crossing. A larger version of this worksheet is included in Appendix E.

Question	Crossing A-B	Crossing B-C	Crossing C-D	Crossing D-A	Notes
6.1 Determining the Crossing Location					
6.1.1 Do sidewalks lead to the crosswalks?					
6.1.2 Is separation provided between sidewalk and curb?					
6.1.3 Is the edge of the street clearly defined (outside edge)?					
6.1.4 If other ramps or driveways are nearby, are they adequately delineated and separated?*					
6.1.5 Are traffic control devices accessible?					
6.2 Aligning to Cross and Establishing a Correct Heading					
6.2.1 Is curb ramp width the same as crosswalk width?					
6.2.2 Is curb ramp slope aligned with crossing?					
6.2.3 Are ramp edges aligned with crossing?					
6.2.4 Are detectable warnings aligned with the slope of the curb ramp?					
6.2.5 Are the pushbuttons in correct location?					
6.2.6 Is there a sufficiently level landing and turning space where the pedestrian is waiting to cross?*					
6.3 Maintaining Correct Heading while Crossing (Staying within the Crosswalk)					
6.3.1 Is the crossing configured at the shortest distance practical?					
6.3.2 Is the crossing aligned perpendicular to the curb and splitter edges?					
6.3.3 Are markings clearly visible?					
6.4 Crossings from Channelization and Splitter Islands					
6.4.1 Are islands wide enough to provide safe refuge?					
6.4.2 Are transitions to roadway clearly defined (within the island)?					
6.4.3 Are paths through island clearly identifiable?					
6.4.4 Are pushbuttons accessible?					

Notes:

Bold lettering indicates particular item is required by PROWAG-NPRM.
*Question has been reworded from Report 834.
Some questions have been added to or removed from this list.

Figure 6-7: Wayfinding Assessment Worksheet

APPENDIX D – UPDATED CHAPTER 7 ON CROSSING ASSESSMENT

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NCHRP Project 03-78c

Guidebook for the Application of Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities

Revised Chapter 7

Prepared for:

National Cooperative Highway Research Program
Transportation Research Board
National Research Council

Kittelson & Associates, Inc.
ITRE at N.C. State University
Accessible Design for the Blind

December 2018

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7 CROSSING ASSESSMENT

7.1 Introduction

This chapter provides a method for the assessment of a pedestrian crossing at a roundabout or intersection with CTLs. The method is divided into twelve principal steps geared at quantifying the performance of a given site. The method is based on *input variables* available to the analyst, including site geometry, traffic volumes, etc. These inputs are used to estimate *operational characteristics*, including vehicle speed, driver yielding, gap availability, and utilization rates of crossable yields and gaps.

These operational characteristics feed into three *performance checks* that are integrated into the overall design processes for roundabouts and CTLs discussed in Chapter 2. These new performance checks for pedestrian accessibility are: (1) Crossing Sight Distance, (2) Pedestrian Delay, and (3) Level of Risk.

Many of the models and interim steps used to predict these performance measures are sensitive to the effects of crossing treatments and can be used to predict performance for new and existing sites.

This chapter provides the overall methodology used for crossing assessment, while details for the various models are given in the NCHRP Project 03-78b final report.

7.2 Crossing Performance Checks

The crossing assessment method is geared at estimating three key performance checks, which jointly attempt to describe the accessibility of a site. These performance measures are (1) the crossing sight distance, (2) the estimated level of crossing delay, and (3) the expected level of risk for blind travelers. These measures, combined with other performance checks on wayfinding presented in Chapter 6, allow for an overall accessibility evaluation of a site.

The first performance check, *crossing sight distance*, is a design parameter used to provide clear lines of sight between the driver and the pedestrian to provide appropriate reaction and braking time. A driver with adequate time to see the pedestrian can make adequate decisions about yielding; more generally, the driver has sufficient time to react should the pedestrian step into the roadway. For a sighted pedestrian, adequate sight distance is directly linked to their ability to make gap acceptance decisions. But even for blind pedestrians, having a clear line of sight is critically linked to the amount and quality of audible information that is available to make crossing decisions. Crossing sight distance is determined from the design of the roundabout and CTL, and is a function of the approaching vehicle speed, the crossing width, and the walking speed for pedestrians. In general, faster vehicle speed, longer crossings, and slower walking speed result in an increase in crossing sight distance requirements.

The second performance check, *pedestrian delay*, is one commonly used by transportation analysts to evaluate the level and quality of service of pedestrian facilities for sighted pedestrians. In the context of this method, the delay is focused on that expected to be experienced by a pedestrian who is blind. Crossing delay is a direct function of the availability of crossing opportunities in the form of crossable gaps and yields. With more crossing opportunities, delay is expected to decrease. Differences in delay between sighted and blind pedestrians may be associated with differences in the rate of utilization of the crossing opportunities. The utilization rates are in turn related to attributes of the vehicle stream, the auditory environment, and ultimately the individual making the decision. It is noted here that in many of the crossing trials performed in this and prior research, the experienced delay did not seem to be as important to blind study participants as the level of risk. Accordingly, the relative weight of delay is conceptually less important than the weight of the risk score. Nonetheless, extraordinarily high delays are considered an impediment to accessibility, which is why the measure is included in this methodology. Extraordinary delays may also lead to acceptance of risky crossing opportunities.

The last performance check, *level of risk*, is arguably the most important performance measure for any crossing, as it estimates the likelihood of a poor crossing decision given attributes of the site. For the field studies that form the empirical basis of this research, risk was estimated through *intervention* events (participants being physically stopped from stepping into the roadway by a Certified Orientation and Mobility Specialist), through expert ratings of crossing risk, and through measurements of time-to-contact (TTC) – a measure of time between a pedestrian decision and the next vehicle arrival. All three metrics are *surrogate safety measures*, as no actual crash data are available for this analysis. However, all three metrics are documented in the literature as valid measurements of pedestrian risk and have been previously used in accessibility assessment studies.

Together, the three performance checks (as well as the various operational characteristics used as inputs in their calculation) are intended to provide a multifaceted look at the expected crossing performance of the studied crosswalk. As with any performance measure, their usefulness is limited by their ability to be measured objectively and predicted from available data.

7.2.1 Setting Performance Targets

The three performance checks are intended to enable a quantitative assessment of the accessibility of a crosswalk at a roundabout or a crosswalk at a CTL at an intersection. Through the quantitative nature of the performance checks, it is generally possible to 1) conduct a *relative* comparison of two sites or 2) conduct a before-and-after assessment of the same site. Regardless of the type of assessment, the performance targets should yield evidence as to which site or treatment results in better *relative* accessibility performance.

It is much more challenging to use these checks to conduct an *absolute* assessment of accessibility. In other words, once a crossing assessment has been completed, and once estimates for risk, delay, and confidence score performance measures have been obtained, can a given site be classified as being "accessible?"

The question of whether a performance level is acceptable is ultimately a policy decision by the appropriate agency. As an example, for general pedestrian delay, the Highway Capacity Manual (TRB, 2016) provides a letter-grade assessment of the *Levels of Service (LOS)* of a pedestrian crossing based on the estimated average pedestrian delay. Pedestrian delay at two-way stop-controlled intersections less than 5 seconds per pedestrian is considered LOS A, while a delay greater than 45 seconds is considered LOS F. For signalized intersections, LOS thresholds are based on a user-perception score, which incorporates delay as one of several factors. However, even with the letter-grade LOS being determined by HCM methodologies, the decision of what LOS is acceptable is an agency decision. In other words, the performance target for pedestrian LOS is an agency policy decision.

In the context of this research, the performance target for accessibility also lies with the appropriate implementing agency or agencies. The performance checks and prediction tools presented in this document are intended to support these policy decisions through quantitative metrics, but as a research publication, this document does not set the standard. Minimum standards for accessibility, as a civil rights issue in the United States, are set by the U.S. Access Board and adopted by other agencies.

7.2.2 Limitations of the Methodology

It is important to emphasize the limitations of the crossing assessment method and the performance checks presented in this chapter. The predictive models and performance estimation methods are based on a limited number of study sites that are believed to be representative, but nonetheless describe only a small subset of all roundabouts and CTLs that exist around the country. Further, all field studies showed high variability of performance across participants.

The field-measured performance is thus only a snapshot of the true complexity of pedestrian decision-making, especially for pedestrians who are blind. The methods put forth in this chapter are intended to provide an approximation of the expected performance to aid engineers and planners in evaluating design alternatives and assist in the selection of crossing treatments to enhance accessibility of a given or proposed site.

The limitations of the methodology are primarily due to two factors: a) variability in the geometry, signing, marking, and other features of roundabouts and CTLs chosen for the study; and b) high variability of performance across participants.

Variability in the geometry of studied sites may affect the range of observed vehicle speed, conflicting traffic volume, and local and regional differences of driver behavior. These site attributes may in turn affect yielding rate and gap availability, which are key inputs in the performance estimation. Variability in participant behavior and skill level may in turn affect yield and gap utilization rate, which are also critically linked to the performance measures.

The analyst is encouraged to check for these limitations by comparing local data to the field measurements presented in this research, and details published in the NCHRP Project 03-78b final report. For example, results from a region with general high driver yield compliance and frequent pedestrian activity are likely not transferable to areas with low compliance and low expectancy of a driver encountering a pedestrian - and vice versa.

7.2.3 Value of Direct Field Measurements

The procedures and models presented in this chapter present a way to estimate the expected accessibility of a new intersection based on available geometric and traffic operational input variables. However, in some instances, an analyst may be interested in evaluating the accessibility of an existing site and in identifying treatments that may enhance the accessibility performance of such sites. For existing sites, direct field measurements of accessibility may represent a viable and preferred alternative to predicting performance.

The clear benefit of direct field measurements is that any bias and error from applying national models to a local site are avoided. In that sense, driver behavioral difference, driving culture, and local context are uniquely tied to the site in question; this can be a big advantage. Given local context, participants may be accustomed to crossing at single-lane roundabouts due to frequent use of this intersection form in the local area. Similarly, certain treatments may be very effective in an area, where such treatments are used routinely at other intersection forms. In short, locally observed accessibility performance data is likely to be more accurate and representative of the “true” accessibility of a site in question.

On the other hand, a field accessibility assessment is resource intensive, requires trained staff, and may involve the use of human subjects, which requires approval from an Institutional Review Board (IRB). As such, a full-scale *accessibility audit* may be out of scope for many sites in question. The final report for NCHRP Project 03-78b provides detailed field protocols for conducting this accessibility audit using the methods that also form the basis of this report.

As an alternative to a full accessibility audit, an agency may select a subset of studies, as permitted by the available resources, to calibrate for local context. For example, if a crossing indicator study with blind participants is not possible due to resource constraints or IRB approval requirements, one or more of the input variables may be measured directly in the field. A field study of driver yielding behavior is generally very feasible and requires minimal resources. Similarly, a local study of gap availability is generally feasible. In some cases, a local gap study may even be desirable if conditions at adjacent intersections (such as an upstream signal) are expected to affect the gap availability distribution.

As general guidance, direct measurements of driver and pedestrian behavior under local operating conditions are expected to provide a better accessibility assessment than national-scale predictive models, provided that the local studies are executed by trained and qualified staff and follow the study protocols put forth in the final project report (or comparable).

7.3 Overview of Methodology

The crossing assessment methodology consists of twelve principal steps that are evaluated sequentially. The methodology obtains key input and performance targets from the overall site design process described in Chapter 2. A key characteristic of the method is that it is iterative. Should a performance check fail to meet a specified performance target, it may require changes to the design and recalculation of the performance checks as described in Chapter 2. The methodology flow chart is shown in Figure 7-1 and discussed in detail in the following sections.

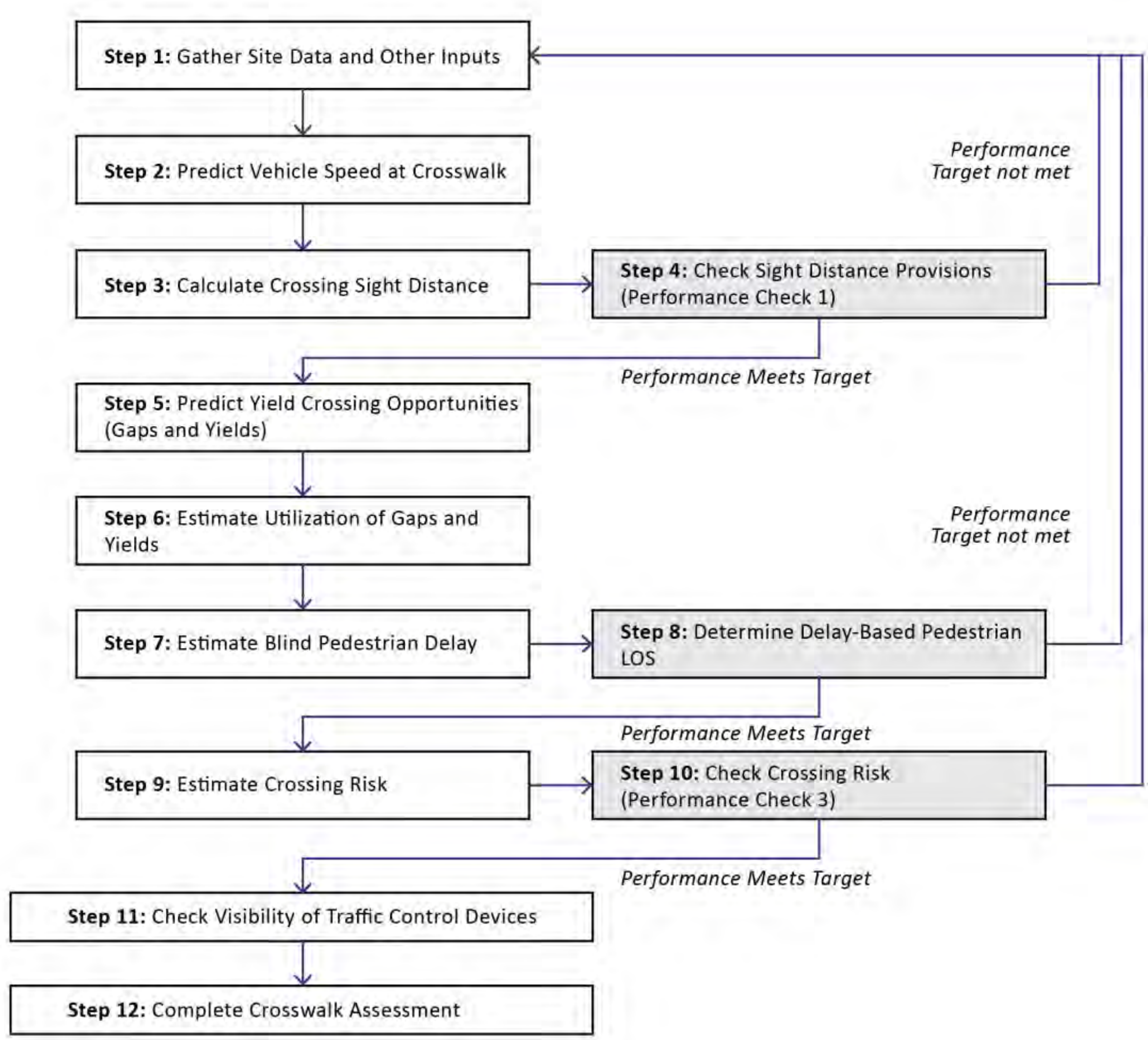

Figure 7-1: Methodology Flow Chart

This is a figure showing a thirteen-step methodology for assessing crossing performance. Step Zero obtains design data from the overall process described in Chapter 2, as well as performance targets set by the agency. The twelve principal steps of the methodology are as follows: ~~(0) obtain geometry inputs,~~ (1) gather site data and other inputs; (2) predict vehicle speed at crosswalk; (3) calculate crossing sight distance; (4) check sight distance provision, (5) predict crossing opportunities in the form of gaps and yields, (6) estimate utilization of gaps and yields, (7) estimate pedestrian delay, (8) check pedestrian delay, (9) estimate crossing risk; (10) check crossing risk; (11) check visibility of traffic control devices, and (12) complete crosswalk assessment. The analysis sequence is linear, with potential for iteration after each of the three performance checks.

To use the crossing assessment methodology, initial site-related data need to be gathered. The data are entered into various models developed as part of crossing assessment and eventually the model results are used for final crossing assessment performance measures. A summary of required input data and their application in each of the crossing models is shown in Table 7-1.

Table 7-1: Required Inputs for Crossing Assessment Method

Step	Equation/Table	Required User Input
Step 2: Predict speed at crosswalk	Equation 7-1 Equation 7-2 Table 7-2	Fastest path radius Treatment effect
Step 3: Calculate crossing sight distance	Equation 7-3 Equation 7-4	Vehicle speed at crosswalk (from Step 2) Approach geometry Pedestrian walking speed
Step 4: Check Sight Distance Provisions	Expert judgment	CAD drawing Crossing sight distance (from Step 3)
Step 5: Calculate crossing opportunity (gaps and yields)	Equation 7-5 through Equation 7-8	Approach geometry and treatment Gap acceptance parameters Pedestrian walking speed Traffic volume on approach Vehicle speed at crosswalk (from Step 2)
Step 6: Estimate utilization of gaps and yields	Table 7-3 Table 7-4	Approach geometry
Step 7: Evaluate audible environment and noise effect	Expert judgment Appendix A	Local observation Surrounding land uses
Steps 8 and 9: Estimate pedestrian delay	Equation 7-9 through Equation 7-12 Table 7-5	Gap and yield opportunities (from Step 5) Gap and yield utilization (from Step 6)
Steps 10 and 11: Estimate crossing risk	Equation 7-13	Vehicle speed at crosswalk (from Step 2) Noise (from Step 7) Sight distance (from Step 4)

7.4 Methodological Steps

In this section, each of the steps shown in Figure 7-1 is described in more detail. For steps with significant computations, only the key equations are shown here, with additional information on model derivation provided in the NCHRP Project 03-78b final report. The methodology is applied to each approach of the roundabout, and separately to entry and exit legs, as well as to CTLs.

Before embarking on the steps, the analyst needs to obtain geometry inputs and performance targets. In the overall design process described in Chapter 2, the analyst defines the candidate design and crossing configuration of the roundabout or CTL to be evaluated for accessibility. The initial design should contain sufficient detail to specify the number of lanes, design radii, crosswalk location, and other geometric details. The initial design may be obtained from an engineering design project at approximately the 10-25 percent completion level. At this stage, the design is expected to provide sufficient geometric and operational detail, while still allowing flexibility for design adjustments and treatment provision as needed. Key design elements needed for the crossing assessment include the number of lanes, lane widths, crosswalk location, and treatment details, and design radii for the intersection itself. The initial design should also be sensitive to other performance elements that are specified in various guidelines or standards (e.g., design vehicle). The initial design may or may not include specialized treatments intended to enhance the accessibility of the site.

Before starting with the principal procedure, the analyst reviews and notes performance targets for the three accessibility performance checks based on agency guidelines or standards. Pedestrian accessibility performance objectives based on federal guidelines and previously conducted studies can serve as target values, but the specification of target standards is the responsibility of the agency conducting the assessment. This report intends to provide the quantitative assessment methodology to estimate the performance measures needed in those standards.

7.4.1 Step 1: Gather Site Data and Other Inputs

The analyst gathers engineering inputs or selects default conditions specified by the methodology. These inputs include traffic conditions and roadway factors, as well as geometric details of the roundabout or CTL in question. The overall design of the roundabout or CTL in question was transferred to the crossing assessment in step 0. In this step, design details necessary for the crossing assessment are extracted, along with other traffic operational factors. See Table 7-1 for a listing of required input data.

7.4.2 Step 2: Predict Vehicle Speed at Crosswalk

Vehicular speed has been identified as a key measure affecting pedestrian accessibility. This step predicts the free-flow speeds under low volume conditions that can be expected in the vicinity of the crosswalk. The analyst may obtain speed estimates through field measurements at comparable sites or use speed prediction equations presented below.

Speed prediction is required for computing other aspects of accessibility in steps to follow, namely in calculating required crossing sight distance, driver yielding rate at the crosswalk, and in prediction of rate of intervention and risks events.

A suggested model for predicting vehicular speed at the crosswalk is the theoretical fastest path speed method described in NCHRP Report 672 for roundabouts. It was found to also apply to vehicle free-flow speeds through CTLs. In all cases considered in this methodology, field-measured speeds may be used in place of computed speeds when evaluating existing sites.

The vehicle speed model in Equation 7-1 estimates the free-flow speed at the crosswalk, V, as a function of the fastest path radius, R, for a curve with positive superelevation $e = +0.02$ (drainage towards the outside, which is most common).

Equation 7-1: Fastest path radius calculation for vehicle speed

$$V = 3.4415\ R^{0.3861}, \qquad \text{for } e = +0.02$$

The equation predicts the 85th percentile free-flow speed expected at the crosswalk as a function of *fastest path radius* (in feet) that is believed to control the speed at the crosswalk. At a roundabout entry, this speed is principally a function of the maximum of the R_1 and R_5 radii shown in Figure 7-2. If no right-turn movement exists, or if the right turn cannot be accomplished with a single curve, then only R_1 applies.

If a channelized right-turn movement is present at the roundabout, then the through movement and right-turn crossings should be analyzed separately, considering R_1 for the through movement and R_5 for the right-turn movement.

If speed-limiting features, such as mainline roadway curvature or origination from a parking lot, are present on an approach upstream of the crosswalk, then the use of lower V values than predicted by R_1 or R_5 may be appropriate.

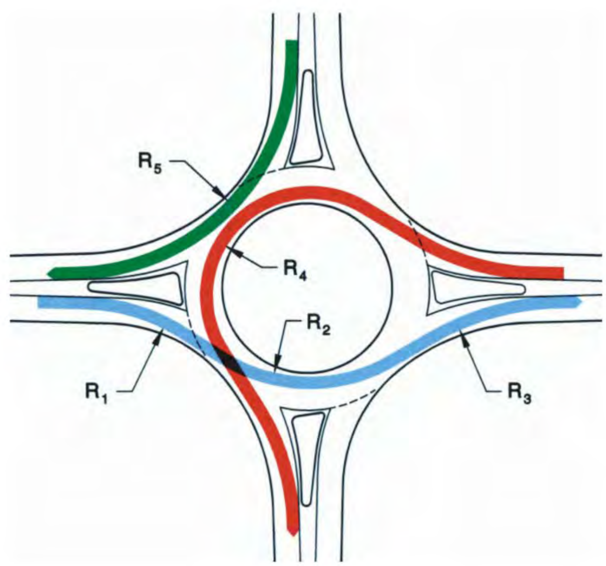

Figure 7-2: Roundabout Vehicle Path Radii (Source: NCHRP Report 672)

For exiting vehicles, speeds are dependent upon both roadway curvature and acceleration. First, the analyst should compute the speeds at the exit crosswalk associated with through and right-turn movements using the measured R_3 and R_5 radii and Equation 7-1. These result in the through exiting speed due to curvature, V_{3c}, and the right turn speed at the crosswalk, V_5, respectively. Then the through-movement speed due to acceleration is calculated using Equation 7-2.

Equation 7-2: Through-movement exiting speed due to acceleration

$$V_{3a} = \frac{1}{1.47}\sqrt{(1.47V_2)^2 + 2a_{23}d_{23}}$$

where,

V_{3a} = speed constrained by acceleration, a (mph)

a_{23} = acceleration along the length between the midpoint of the R_2 path and the exit crosswalk, estimated to be 6.9 (ft/s^2), and

d_{23} = distance between the midpoint of the R_2 path and the exit crosswalk (ft)

V_3 is then taken as the minimum of the two through exit speed values, V_{3a} and V_{3c}. The speed at the exit crosswalk is then taken as the greater of the through and right turn speeds, V_3 and V_5. If no right-turn movement exists, then only V_3 should be considered. If R_5 is a compound curve, then the speed in the larger radius portion of the curve at the exit crosswalk will be limited by the speed in an upstream, smaller radius portion of the curve with acceleration, and a calculation similar to the one presented in Equation 7-2 should be used.

If a channelized right-turn movement is present at the roundabout, then the through movement and right-turn crossings should be analyzed separately, considering R_3 for the through movement and R_5 for the right-turn movement.

If speed-limiting features, such as mainline roadway curvature, traffic control (e.g. a stop sign) or entry into a parking lot, are present downstream of the crosswalk, then the use of lower V values than predicted by R_3 or R_5 may be appropriate.

At a CTL, the fastest path should be drawn similarly to the R_5 for a roundabout. Upstream of the crosswalk, assume that vehicles begin their turn from the deceleration lane/right turn lane, if present (i.e., vehicles are assumed to not sweep across multiple lanes). Downstream, assume that vehicles will exit into any of the lanes on the receiving roadway and may not remain in the rightmost lane or acceleration lane, if present (i.e., vehicles are assumed to sweep across multiple lanes). Equation 7-1 should be used to compute the V_5 speed similar to a roundabout.

If the CTL contains a compound curve, then the smallest radius within the curve controls the speed, and it should be used for calculations. If speed-limiting features, such as mainline roadway curvature, traffic control (e.g. a stop sign) or entry/exit into a parking lot, are present upstream or downstream of the crosswalk, then the use of a lower V_5 value than predicted by R_5 may be appropriate.

For roundabouts and CTLs, the free-flow speed at the crosswalk can also be impacted by certain treatments that are installed specifically with the goal of reducing vehicle speeds. Several sites were evaluated in prior research with various forms of raised crosswalks or speed tables installed to slow traffic, and some sites even had speed humps in advance of the crosswalk with a similar goal. ITE provides some guidance for estimating the speed-reducing effects of traffic calming measure as shown in Table 7-2.

Table 7-2: Speed Impacts Due to Traffic Calming Measures (Adapted from ITE)

Traffic Calming Measure	Sample Size	85th Percentile Speed after Calming in mi/h (Std. Dev.)	Average Change in Speed after Calming in mi/h (Std. Dev.)	Average Percentage Change (Std. Dev.)
12-foot hump	179	27.4 (4.0)	-7.6 (3.5)	-22% (9%)
14-foot hump	15	25.6 (2.1)	-7.7 (2.1)	-23% (6%)
22-foot table	58	30.1 (2.7)	-6.6 (3.2)	-18% (8%)
Longer tables	10	31.6 (2.8)	-3.2 (2.4)	-9% (7%)

The specific design attributes of the traffic calming measure (e.g. the height of the speed hump or speed table, as well as the transition slope) are not reflected in the ITE guidance. Further, the ITE data refer to "standard" intersections and do not consider the speed-reducing impacts of roundabout or CTL geometry. As such, it is advisable to use the average reduction or percentage reduction in speed as an approximation of the effect, rather than the absolute measured speed.

7.4.3 Step 3: Calculate Crossing Sight Distance

Crossing sight distance corresponds to the distance required by pedestrians to recognize the presence of conflicting vehicular traffic and determine crossing opportunities at intersections and roundabouts. The distance is established through sight triangles that allow a pedestrian to evaluate potential conflicts with approaching vehicles. Similarly, the resulting sight triangles also assure that the driver has a clear view of a pedestrian waiting to cross or approaching the crosswalk. For pedestrians who are blind, the crossing sight distance applies in that any visual obstructions are also expected to impact the audible environment at the crosswalk and the ability to hear approaching vehicles without sound obstructions or deflections.

The methodology developed to determine crossing sight distance adequacy at a roundabout or CTL has been adapted from the sight distance performance check for vehicles at roundabouts from NCHRP Report 672, Roundabouts: An Informational Guide, Second Edition (Rodegerdts et al., 2010), calculations and definitions from the AASHTO "Green Book" (AASHTO, 2011), and the pedestrian mode methodology in Chapter 19 of the Highway Capacity Manual 2010 (TRB, 2010).

The four pedestrian movements at a roundabout crosswalk—crossing from curb to splitter island at entry, crossing from splitter island to curb at entry, crossing from curb to splitter island at exit, crossing from splitter island to curb at exit—are all different for several reasons, including:

- Traffic is approaching from the left when crossing from the curb, but from the right when crossing from the splitter island;
- Traffic is moving only in front of the pedestrian when crossing from the curb (quiet behind the pedestrian), while it is moving both in front of and behind the pedestrian when crossing from the splitter island; and
- Entering traffic is decelerating in approach of the yield line, while exiting traffic is accelerating as drivers exit the roundabout.

Since traffic patterns at each conflicting approach are judged independently, there are sight distances and sight triangles associated with each location and its conflicting approaches. The entry crossing locations have one potential conflict with vehicles entering the roundabout. The exit crossing locations are subject to two conflicting movements with different trajectories: traffic from the immediate upstream entry approach (right turns), and traffic circulating from other upstream approaches (through and left turn movements).

The sight distance (d_n) is calculated as a function of the conflicting vehicle speed (V) and the pedestrian critical headway (t_c)

Equation 7-3: Crossing Sight Distance Calculation

$$d_n = (1.47)\ (V_n)\ (t_{n,c})$$

where,

d_n = distance along approach leg n upstream of the crosswalk for crossing, ft;

V_n = free-flow speed of conflicting vehicle movement on approach n, mph; and

$t_{n,c}$ = critical headway required by a pedestrian crossing approach n.

The critical headway, $t_{n,c}$, describes the minimum amount of time necessary for a pedestrian to cross the roadway. The critical headway calculation is directly derived from the pedestrian analysis method covered in the two-way stop-controlled intersection methodology of the Highway Capacity Manual 6th Edition (TRB, 2016).

Equation 7-4: Estimating Pedestrian Critical Headway

$$t_{n,c} = (L_n\ /\ S_p) + t_s$$

where,

L_n = crosswalk length for a specific traffic stream, ft;

S_p = average pedestrian walking speed, ft/s (default=3.5 ft/s);

t_s = pedestrian start-up time and end clearance time, s (default = 2 s).

The vehicle speed parameter is the same as was estimated in Step 2. At a roundabout entry, this speed is principally a function of the R_1 radius shown in Figure 7-2. For exiting vehicles, the analyst uses the controlling radius for the particular movement from radii R_2, R_4, and R_5 depending on whether the conflicting movement is a right-turning, through, or left-turning vehicle. For all exit-leg movements, the actual speed is adjusted to account for the vehicle's ability to accelerate before reaching the crosswalk using the calculation in Equation 7-2.

Once the minimum distance, *d*, is determined for all possible conflicting movements, the designer should plot the distance along the centerline of the direction of travel. Figure 7-3 shows the necessary sight distance, *d*, for each crossing location at the entry and exit of a roundabout. The length of each *d* may be longer or shorter than shown relative to the roundabout geometry, depending on the speed and critical headway times used in the calculation.

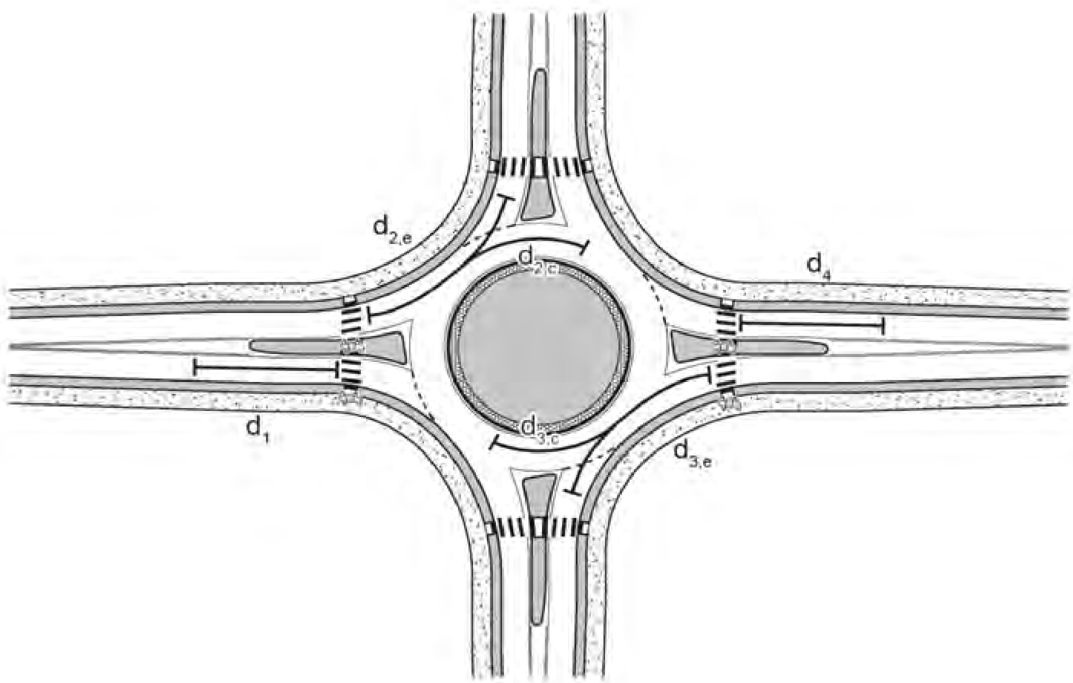

Figure 7-3: Minimum Sight Distance along the Actual Vehicle Path for Roundabouts

This figure shows a schematic of a roundabout with calculated sight distances drawn for entry and exit legs, and for both crossings from the curb and crossings from the splitter island.

After plotting the distance from the pedestrian location, the sight triangle is determined as shown in Figure 7-4. Any sight obstruction should be eliminated from the sight triangles for better pedestrian visibility. The figure focuses on showing examples for just two of the crosswalks. But just like the rest of the crossing assessment method, the evaluation needs to be performed for each crosswalk, entry and exit, and both for crossings originating from the island and those originating from the curb.

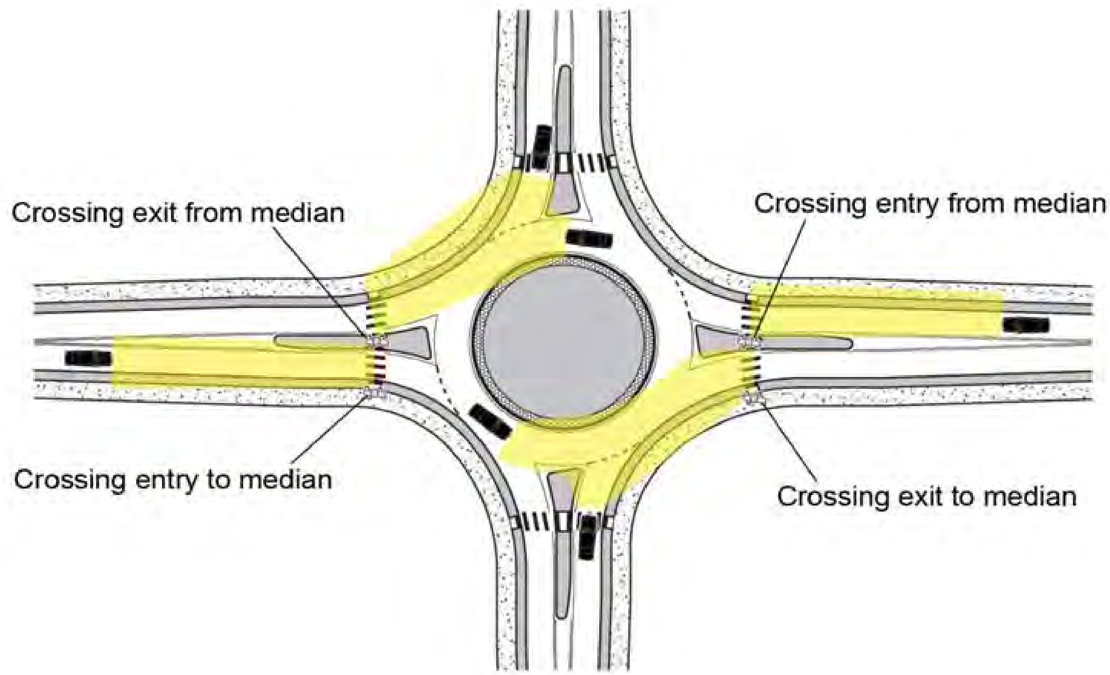

Figure 7-4: Pedestrian Sight Triangles for Each Crossing Location

> *This figure shows a schematic of a roundabout with estimated sight triangles drawn based on the calculated sight distances. Sight triangles are drawn for entry and exit legs, and for both crossings from the curb and crossings from the splitter island.*

7.4.4 Step 4: Check Sight Distance Provisions

In this step, performance check #1 is evaluated:

Performance Check #1 – Is Adequate Crossing Sight Distance Available?

If high-height objects are present in sight triangles, no

If not, yes – performance check is satisfied.

The calculated required crossing sight distance is checked against the design of the roundabout or CTL to check if sufficient sight distance is provided. The required length of sight distance is measured along the center of the approaching roadway in advance of the crosswalk. Figure 7-5 illustrates this for a roundabout for both entry and exit legs. The figure includes a two-lane entry (south entry, shown in blue), a two-lane exit (north exit, shown in red), and a three-lane entry and exit (east entry and exit, shown in green). Sight distances are shown based on the field-measured vehicle speed at the crosswalk, which were approximately 13-15 mi/h due to raised crosswalks installed on the tested approaches. Without this treatment, the sight distance requirements would have been significantly longer. The figure further shows the resulting sight "triangles" drawn relative from the respective waiting positions (on both curb and island) for a pedestrian to the end of the measured sight distance.

It is evident from this example that the three-lane crossings result in longer required sight distance (336 feet for traffic exiting from circle, 236 feet for traffic exiting from south-to-east right turn, and 213 feet for entering) relative to two-lane crossings (235, 164, and 153 feet for the corresponding distances). This is intuitive, as the required crossing time for pedestrians (exposure time in the street) is longer for a three-lane crossing, thereby increasing the sight distance requirements.

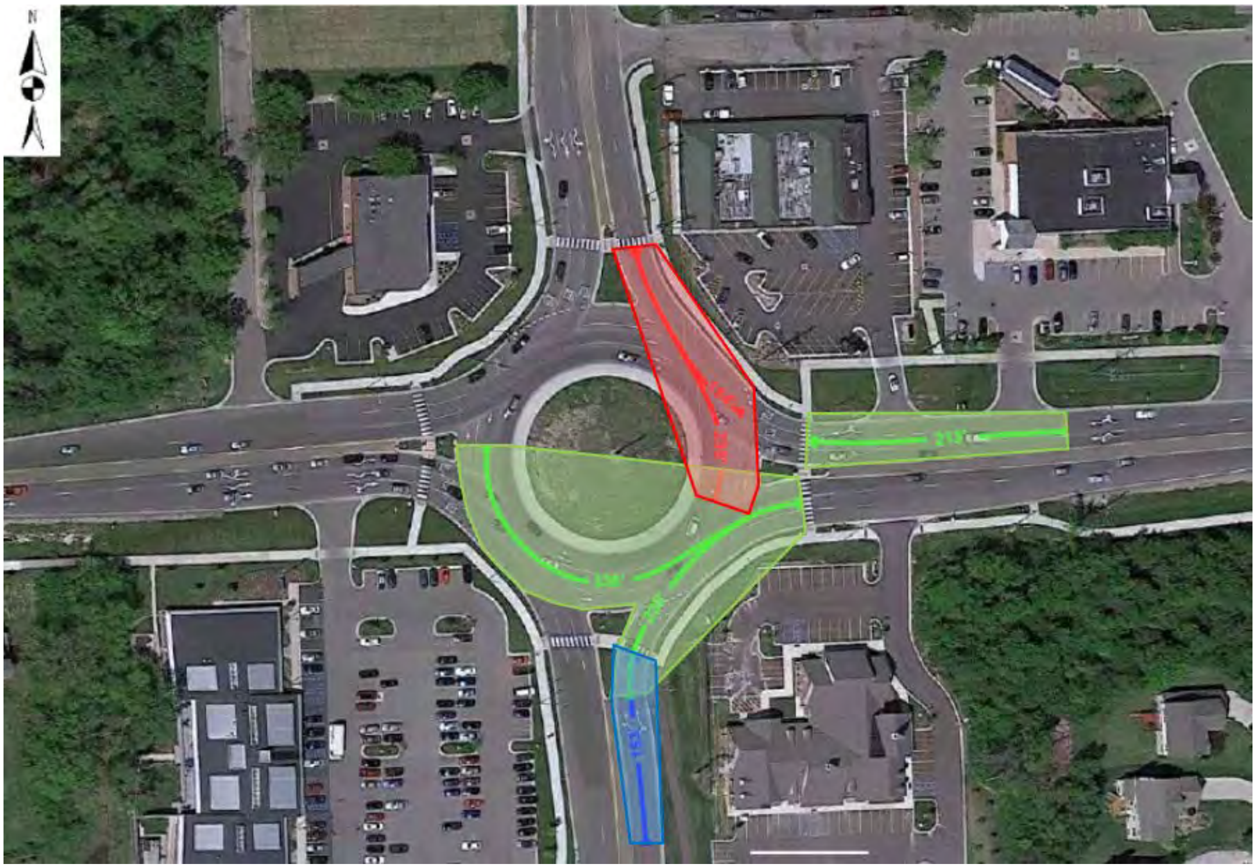

Figure 7-5: Illustration of Sight Distance for Two-Lane and Three-Lane Roundabout Approaches

The figure shows an example application of the sight distance calculations for a two-lane entry (south entry, shown in blue), a two-lane exit (north exit, shown in red), and a three-lane entry and exit (east entry and exit, shown in green). Sight distances are shown as arrows based on the field-measured vehicle speed at the crosswalk, which were approximately 13-15 mi/h due to raised crosswalks installed on the tested approaches. The figure further shows the resulting sight "triangles" drawn relative from the respective waiting positions (on both curb and island) for a pedestrian to the end of the measured sight distance.

The sight triangles between the pedestrian crosswalk landing and the end of the measured sight distance should be clear of obstacles and obstruction, including tall bushes, signal controller cabinets, walls, or buildings. If the crossing sight distance is not provided, pedestrians will not be able to see (and presumably hear) far enough to be able to accept a sufficiently large gap in traffic. Similarly, drivers may not be able to see a pedestrian waiting to cross or beginning to cross, which is expected to impact their propensity to yield as well as ability to react in time to avoid a potential collision.

Increased vehicle speeds, longer crossing distances, and slower pedestrian walking speeds all contribute to longer sight distance requirements. If the sight distance check fails, the designer has the choice of modifying the design to reduce the sight distance requirements (e.g., through tighter radii, fewer lanes, or a raised crosswalk to reduce speeds), or may decide to move the crosswalk (e.g., further from the circulating lane for an exit crossing).

As an illustration of these effects, Figure 7-5 illustrates the effect of crossing distance for a roundabout with two-lane and three-lane crossings. Figure 7-6 shows two CTL approaches to a signalized intersection. The east approach has a required crossing sight distance of 203 feet for a single-lane crossing. For the north approach, the presence of a raised crosswalk reduces vehicle speeds and thereby the sight distance to 129 feet.

Figure 7-6: Illustration of Sight Distance for CTL with and without raised crosswalk

The figure shows an example application of the sight distance calculations a CTL Sight distances are shown as arrows and the resulting sight "triangles" drawn relative from the respective waiting positions (on both curb and island) for a pedestrian to the end of the measured sight distance.

7.4.5 Step 5: Predict Crossing Opportunities (Gaps and Yields)

This step predicts the availability of crossing opportunities in the form of crossable gaps between moving vehicles, as well as vehicle yields.

The availability of crossable gaps can be estimated from traffic flow relationships by accounting for platooning or bunching effects that may result from signals upstream of the crosswalk in question. A predictive equation for gap opportunities is presented below.

The probability of a pedestrian encountering a usable gap, P_G, is predicted with Equation 7-5 as a function of *critical headway for crossable gap* (t_c) and *average headway* (t_{avg}), which is defined as 3,600 over the vehicular flow rate in veh/h. The equation shows the equation that can be used to estimate the probability of encountering a gap greater than the critical gap.

Equation 7-5: Estimating P(CG-Opp) from Traffic Flow Theory (May 1990)

$$P_G = e^{-\left(\frac{t_c}{t_{avg}}\right)} = e^{-\left(\frac{t_c N_{veh}}{3600}\right)}$$

where,

t_c = critical headway for crossable gap (sec.), previously computed with Equation 7-4

N_{veh} = volume (number of vehicles per hour)

In addition to crossable gaps, driver yielding events also present crossing opportunities. Equations 7-6 and 7-7 provide an estimation of the probability of a driver yielding to a pedestrian, P_Y, at single-lane roundabouts/CTLs or two-lane roundabouts, respectively, as a function of geometry and other prevailing traffic conditions.

Equation 7-6: Estimating Probability of Yielding for a Single-Lane Roundabout or CTL

$$P_Y = (0.6888 - 0.07688 * I_{ex} + 0.62954 * I_{en} + 0.37418 * I_{HC}) * e^{(-0.03465)*V}$$

where,

I_{ex} = Indicator variable for Exit (1 = roundabout exit, 0 = roundabout entry or CTL)

I_{en} = Indicator variable for Entry (1 = roundabout entry, 0 = roundabout exit or CTL)

I_{HC} = Indicator variable for high-compliance region

V = Speed, in mph

Equation 7-7: Estimating Probability of Yielding for a Two-Lane Roundabout

$$P_Y = (0.7259 + 0.2105*I_{RRFB} - 0.2574*I_{ex} + 0.3244*I_{HC})*e^{(-0.0129)*V}$$

where,

I_{RRFB} = Indicator variable for presence of RRFB

and other variables are as previously defined.

The equations above are not sensitive to the presence of a raised crosswalk. The analyst may apply judgment or consult other studies and literature to estimate the percentage of yielding for a raised crosswalk or other treatment.

The probability of yield crossing opportunity, P_{YC}, is different than the probability of driver yielding, P_Y. The term P_{YC} is calculated on the basis of all encountered vehicles, and it is a better representation of the rate of encountered yields that a pedestrian is likely to experience.

A reasonable approach for estimating P_{YC} from P_Y is to subtract the probability of crossable gaps from the total number of vehicle events (see Equation 7-8):

Equation 7-8: Estimating Yield Opportunities from Yield Probabilities

$$P_{YC} = P_Y * (1 - P_G)$$

This approach assures that the sum of P_{YC} and P_G is less than or equal to 1.0 as is required by definition.

7.4.6 Step 6: Estimate Utilization of Gaps and Yields

In this step the analyst estimates the rate of utilization of gap and yield crossing opportunities. The utilization rate of gaps is calculated as the ratio of the number of crossings a blind pedestrian is expected to take in a gap over the total estimated number of gap crossing opportunities available. Yield utilization is similarly calculated as the ratio of the number of yields utilized or accepted over the total number of yields available.

The gap utilization rate of pedestrians who are blind is generally more conservative than that of sighted pedestrians, with the biggest differences being additional latency time after a vehicle passes the crosswalk until a decision to cross is made. Sighted pedestrians will often visually identify a gap in traffic approaching the crosswalk and initiate crossing as soon as the gap opens in front of them. Research has generally shown that a blind pedestrian requires additional time for the noise of the vehicle to subside before choosing to cross in a gap. That additional decision latency time results in blind travelers rejecting gaps that a sighted person may have utilized.

Gap opportunity utilization is estimated from the average gap opportunity utilizations observed at study locations in NCHRP Project 03-78b and are shown in Table 7-3. There is presently insufficient data in the literature to derive more sophisticated gap utilization models, but analysts are encouraged to use local data or estimates should those be available.

Table 7-3 Estimated Average Gap Utilization for Blind Pedestrians

Approach	Average Gap Utilization
Roundabout	65%
CTL	60%

Similar to the concept of gap utilization, not all yield events may result in a utilized crossing. Pedestrians who are blind may not utilize a yield crossing opportunity because of high ambient noise, quiet vehicles, uncertainty of driver intent, or other reasons that result in not having confidence in their judgment. A non-utilized yield is not necessarily an event "missed" by the pedestrian, as the decision to reject the yield may be made consciously.

Yield opportunity utilization is estimated from the average yield opportunity utilizations observed at study locations and is shown in Table 7-4. There is presently insufficient data in the literature to derive more sophisticated yield utilization models, but analysts are encouraged to use local data or estimates should those be available.

Table 7-4 Estimated Average Yield Utilization for Blind Pedestrians

Approach	Average Yield Utilization
Roundabout	70%
CTL	35%

7.4.7 Step 7: Estimate Blind Pedestrian Delay

The second accessibility performance check is pedestrian delay. NCHRP Report 674 showed a link between pedestrian delay and the probability of crossing at a crosswalk. The probability of crossing at a crosswalk, P_C, is described in Equation 7-9 as a function of the probability of yield opportunities, P_{YC}, the probability of yield utilization, P_{UY}, the probability of encountering a crossable gap, P_G, and the probability of utilizing that crossable gap, P_{UG}:

Equation 7-9: Estimating the Probability of Crossing, P(Cross)

$$P_C = P_{YC} * P_{UY} + P_G * P_{UG}$$

The components of P_C were all estimated in previous steps. This research developed models to predict pedestrian delay at roundabouts and intersections with CTLs as a function of P_C. These models allow analysts to estimate pedestrian delay for new sites if the input variables are known. Since the models are sensitive to the utilization measures, the delay estimation can distinguish between blind and sighted pedestrians, who may be presented with the same gap and yield opportunities but have different rates of utilizing these opportunities.

Separate models were developed for single-lane CTL approaches, single-lane roundabout approaches, and two-lane roundabout approaches. Pedestrian delay for single-lane CTL approaches is predicted as shown in Equation 7-10 as a function of P_C.

Equation 7-10: Calculating Pedestrian Delay for Single-Lane CTL Approaches

$$d_p = 10.75 - 9.95 * LN(P_C)$$

Pedestrian delay for single-lane roundabouts is predicted as shown in Equation 7-11 as a function of P_C.

Equation 7-11: Calculating Pedestrian Delay for Single-Lane RBT Approaches

$$d_p = 9.37 - 9.78 * LN(P_C)$$

Pedestrian delay for two-lane approaches (two-lane roundabouts) is predicted as shown in Equation 7-12 as a function of P_C.

Equation 7-12: Calculating Pedestrian Delay for Two-Lane RBT Approaches

$$d_p = 6.14 - 8.53 * LN(P_C)$$

The delay term, d_p, in Equations 7-11 through 7-13 is measured in seconds per pedestrian. The equations are applied separately to each portion of the crossing, which in the case of a roundabout means the total delay is the sum of delay for the entry and exit legs.

The quantity increases with a decreasing probability of crossing, P_C, which in turn decreases with reduced availability and utilization of gaps and yields. As such, a low-volume site (i.e., with lots of gaps) or a high-yielding site are expected to result in low delay, provided that utilization of crossing opportunities is adequate. As traffic volumes increase (reducing the availability of gaps), and as vehicle speeds increase (reducing the number of yields), the delay per pedestrian is expected to increase.

As an alternative to this pedestrian delay methodology, the analyst may choose to refer to the method in the Highway Capacity Manual, or conduct a simulation study. However, it is emphasized here that the HCM method does not account for opportunity utilization of less than 100%. For simulation, a method for considering varying gap and yield availability and utilization distributions is described in Schroeder and Rouphail (2012).

7.4.8 Step 8: Check Pedestrian Delay

The calculated pedestrian delay can be compared to the agency performance target to determine whether it is acceptable. The HCM defines pedestrian level of service (LOS) for unsignalized intersections on the basis of the average delay per pedestrian, although these performance thresholds are not calibrated for blind travelers. Table 7-5 shows the HCM thresholds for delay.

Table 7-5: Pedestrian LOS Thresholds for Unsignalized Intersections from HCM

LOS	Control Delay (s/ped)	Comments
A	0-5	Usually no conflicting traffic
B	5-10	Occasionally some delay due to conflicting traffic
C	10-20	Delay noticeable to pedestrians, but not inconveniencing
D	20-30	Delay noticeable and irritating, increased likelihood of risk taking
E	30-45	Delay approaches tolerance level, risk-taking behavior likely
F	>45	Delay exceeds tolerance level, high likelihood of pedestrian risk taking

The LOS in Table 7-5 is defined on a per approach basis. In the case of a roundabout, this means that the entry and exit leg delays should be added together before applying the thresholds. For a CTL, the total crossing delay should be considered, which adds whatever delay the pedestrian experiences crossing one or more of the intersecting streets to the calculated CTL delay. The analyst may use the HCM methodology for signalized intersections to estimate the pedestrian delay of the full crossing.

In Table 7-5, it is further shown that the likelihood of risk taking increases significantly with longer wait times. While this refers primarily to sighted pedestrians (no studies with blind travelers have been conducted to date), high delay times are nonetheless cause for concern and should be avoided. The agency may thus choose to adopt stricter performance thresholds than those shown in the table.

> **Performance Check #2 – Is the Pedestrian LOS at or below the acceptable value established by your agency?**
>
> **If so, yes**

If not, no.

7.4.9 Step 9: Estimate Crossing Risk

The third, and arguably most critical, accessibility performance check is the expected level of pedestrian risk. The level of risk is determined in field studies from COMS intervention events, observer ratings, time-to-contact measurements, and video observations. These risk assessment factors are correlated to characteristics of the studied crosswalk to arrive at a risk prediction model. The model predicts the likelihood of a risky decision as a function of different variables.

The intervention model in Equation 7-13 predicts the likelihood that a blind pedestrian makes crossing decisions which would have resulted in a COMS intervention, P_I.

Equation 7-13: Estimating the Probability of Interventions, P_I

$$P_I = (0.011895 + 0.008443*I_{ex} + 0.021915*I_N - 0.007186*I_{1L})e^{0.027697*V}$$

where,

I_{ex} = Indicator variable (1 = Exit, 0 = Entry/CTL)

I_N = Indicator variable (1= noisy, 0 = low noise)

I_{1L} = Indicator variable (1 = one-lane roundabout, 0 = two-lane roundabout/CTL)

V = Speed at crosswalk (mph)

Research has linked the accessibility of a site for a pedestrian who is blind to the availability of adequate audible cues. This is intuitive, as a blind traveler relies on hearing to navigate and make crossing decisions. An adequate audible environment is therefore critical to assure that a blind traveler can independently and safely navigate a crossing. In this step, the analyst should identify and flag any concerns about the audible environment. The outcome is a yes/no check on whether audibility is likely to be compromised at the site. To date, no quantitative method exists to accomplish this, but some guidance is provided below, as well as in Appendix A.

The availability of audible cues is related to the presence of noise sources in the vicinity of the site, as well as obstacles that may interfere with the ability to clearly hear approaching vehicles. Such obstacles may include signs, poles, or landscaping that may impact audibility in a matter similar to their impact on sight distance. The principal question is whether the person can adequately hear the approaching vehicle (referred to as the *signal* in human factors research) over the background *noise*. Having an adequate *signal-to-noise ratio* is critical to assure that the conflicting vehicle can be heard and distinguished from other noise sources.

In evaluating the audible environment, the first and foremost audibility consideration is the location of the crosswalk relative to sources of noise. In the case of a CTL, most traffic noise is generated at the main intersection. It is generally expected that smaller radius CTLs result in smaller channelization islands, which in turn place the pedestrian closer to that noise source. In a similar fashion, crossing from the channelization island to the curb is expected to have higher levels of interfering noise (from behind the pedestrian) than crossings from the curb to that island.

For roundabouts, the separation between the crosswalk and the circulatory roadway affects the level of noise at the crosswalk. Noise levels are further expected to be different between entry legs (quiet traffic slowing down in approach of the roundabout) and exit legs (louder traffic accelerating away from the roundabout, combined with a more continuous source of circulating traffic noise coming from the same direction as the exiting vehicle). Similar to the islands at CTLs, the splitter island is expected to have the highest levels of noise, with traffic traversing in front of and behind the waiting pedestrian. Landscaping has the potential to minimize the noise behind the waiting pedestrian when installed on the splitter island but may limit lines of sight from the driver to the pedestrian.

Other noise sources may exist in the vicinity of the site that have a high impact on the blind person's ability to hear conflicting traffic and distinguish it from background noise. Common examples of this include nearby freeways (especially at interchanges), work zones or construction activity, or general industrial activity. Noise levels are also often amplified in locations with a high percentage of trucks and other heavy vehicles.

7.4.10 Step 10: Check Crossing Risk

Performance Check #3 – Is the probability of an intervention, as determined in Step 9, within the range allowable by your agency?

If so, the crossing is accessible

If not, the crossing is not accessible. A PHB or full signal with APS is needed.

The calculated crossing risk can be compared to the agency performance target to determine whether it is acceptable. There is presently no standardized guidance for what level of risk or what rate of interventions is acceptable. Clearly, an intervention rate of zero would be desirable to reduce the risk as much as possible. In the language of the ADA legislation, however, a crossing should provide *equivalent access* to persons with and without a disability. To date, no comprehensive study exists comparing the rate of interventions between blind and sighted pedestrians; therefore, guidance is limited.

Based on research conducted for FHWA at two-lane roundabouts (Schroeder et. al, 2015), researchers concluded that an intervention rate of 3 percent or less is similar to the rate of interventions at single-lane roundabouts and may be considered accessible in many cases. Rates of intervention above 5 percent were considered as likely present a significant barrier for blind travelers crossing at these locations, and intervention rates above 10 percent were considered as representing a challenging and risky crossing environment.

It is emphasized here that these thresholds are not based on any formal guidance available, nor should they be used as the basis for policy and categorization of roundabouts. The thresholds are merely introduced to help distinguish and categorize sites for the purpose of analysis and discussion. An agency should set its own thresholds for purpose of evaluating sites and deciding on the need for further treatments.

7.4.11 Step 11: Visibility of Traffic Control Devices

The accessibility framework and method presented in this chapter may result in the provision of treatments intended to enhance accessibility of pedestrians who are blind at roundabouts and CTLs. These treatments encompass a range of geometric and design changes to the roundabouts, as well as installation of traffic control devices in the form of traffic signals, beacons, signs, and markings. Traffic control devices on roads open to public travel have important functions in providing guidance and information to road users. The visibility of such physical aids is especially important for motorists, bicyclists, and pedestrians navigating complex roundabouts and intersections with CTLs.

The basic question in this context of visibility is whether traffic control devices can be seen by drivers as they approach the crosswalk, and similarly whether pedestrians can see or hear the device. An underlying consideration of whether traffic control devices are understood by drivers and pedestrians also plays into the question of visibility. Note that the key difference between visibility and sight distance (discussed in the another step of the crossing assessment method) is that crossing sight distance is strictly tied to physical obstructions and line of sight between drivers and the pedestrian, while visibility considers whether drivers and pedestrians can see (and properly interpret) traffic control devices.

The principles underlying the visibility performance checks presented in this section are compiled from the Manual on Uniform Traffic Control Devices for Streets and Highways (FHWA, 2011), the ITE Traffic Control Devices Handbook (ITE, 2013), NCHRP Report 672 – Roundabouts: An Informational Guide (Rodegerdts et al. 2010), and other sources.

7.4.11.1 Visibility Considerations for Signs and Markings

Traffic signs and pavement markings are designed and placed in a way that they are legible to the road user for whom it is intended. Proper visibility of these traffic control devices assures that they are understandable in time to provide information for a proper decision. This decision can be for the purpose of navigation, warning, guidance, or advisory purposes. Important aspects include, but are not limited to, consistent design, daytime and nighttime visibility, proper size, and correct placement.

Two key considerations exist for signage and markings, both of which test for adequate separation of traffic control devices at the crosswalk with the traffic control devices controlling the downstream merge point at the CTL or with the entry at a roundabout.

1. The first consideration is whether there is sufficient separation between the crosswalk markings and the markings for the yield-line or stop-bar downstream of the crosswalk at the roundabout entry or the CTL merge point. The two sets of markings should be separated by at least one vehicle length. This assures a visual separation and distinction of the two sets of markings. It also provides one-vehicle length of storage between the yield-line or stop-line and the crosswalk, so that a waiting vehicle does not obstruct the crosswalk. Any subsequent vehicles can then queue upstream of the crosswalk, leaving the crossing area free (in principle). As such, separating the crosswalk and the yield/stop-line markings too far may result in the second or third vehicle in the queue blocking the crosswalk. As such, a separation in multiples of vehicle lengths (i.e. 20 feet, 40 feet, 60 feet, etc.) is desirable.
2. The second consideration whether there is appropriate separation of signs at the crosswalk from signs at the yield or stop line. In addition to checking for separation, the designer should also check for potential occlusion effects with a sign blocking one or more downstream signs. Visual obstruction may also affect the visibility of the pedestrian, but that aspect should have been identified in the crossing sight distance step above.

7.4.11.2 Visibility Considerations for Signals and Beacons

Six considerations exist for signal and beacon installations at roundabouts and CTLs, as follows:

1. Are signals visible to an approaching driver to provide adequate stopping sight distance per MUTCD requirements? Stopping sight distance is calculated from the approaching vehicle speed and assumed driver reaction times and deceleration rates. If stopping sight distance is not adequate, a supplemental (upstream) signal head may be needed. This visibility concern is especially important at CTLs and roundabout exit leg signals, where the roadway curvature upstream of the signal may limit its visibility.
2. Are mounting heights correct? Overhead traffic signals need to be mounted at a sufficient height to allow large design vehicles (trucks) to pass underneath them. The general mounting height of overhead mounted signals is 15 feet. In addition, side-mounted signals need to be mounted at least 8 feet high to assure proper visibility, and to not act as a potential obstacle for pedestrian traffic.
3. Is the stop bar set back enough? The MUTCD requires a separation between the vehicle stop bar and any overhead signal to assure that a driver stopped at the

stop bar can comfortably see the signal display (without having to lean forward in their seat). This setback requirement may result in the need for full or partial crosswalk relocation at roundabouts to meet this criterion at the exit leg.

4. Is the stop bar located upstream of the crosswalk? Pedestrians should cross downstream of the stop bar where vehicles wait for a red signal. For multilane crossings, where there is a high potential for multiple threat situation, an additional set-back distance from the crosswalk is desirable. A stop bar downstream of the crosswalk would result in vehicles queuing onto the crosswalk, which is undesirable. It is noted here that this is a principle between signalized and unsignalized crosswalks and their position relative to the vehicular stop bar or yield line, respectively.
5. Is the signal or beacon control separated from other traffic control devices? Both roundabouts and CTLs have additional traffic control devices that control yielding and merging behavior at the roundabout entry and the downstream end of the CTL. Any signals or beacons at the crosswalk need to be visibly separated to avoid driver confusion. For example, a green vehicle signal at a roundabout entry crosswalk may be misunderstood by drivers as providing a protected movement into the circulating lane, unless the signal is sufficiently separated from the circulatory roadway.
6. Are audible messages provided and sufficiently separated? Any pedestrian signal or beacon installation requires the use of accessible pedestrian signals (APS) or other audible devices that convey the presence and functionality of the traffic control device to a pedestrian who is blind. These devices should be installed immediately adjacent to the crosswalk, aligned with the crossing direction, and downstream of the approaching vehicles. Any audible devices further need to be separated from each other by at least 10 feet, or must have special speech messages, to uniquely tie the audible message to a crossing point. This is especially critical on the splitter or channelization islands, which exist for both roundabout and CTLs. In some cases, larger island designs may be required to assure a separation of entry and exit devices, or of devices controlling the CTL versus the main intersection. Additional discussion on audibility considerations at both facility types is given in the next section.

7.4.12 Step 12: Complete Crosswalk Assessment

When the candidate design satisfies the performance targets, the design can be finalized and the treatments can be implemented as applicable. As part of this assessment, the analyst conducted three explicit performance checks and compared estimates to the performance targets established by the agency to evaluate whether or not the candidate design meets the desired level of accessibility. The result of the crosswalk assessment is iterative by definition and will prompt the analyst to accept, reject, or modify the candidate design. Depending on the outcome of the performance checks, the analyst may complete the crosswalk assessment or may repeat the process with a modified design after appropriate iterations.

While not explicitly called for, an assessment of vehicle impacts may be considered in this step. Chapter 2 of this guidebook presents the context of the accessibility evaluation within the broader intersection design process, which considers the expected operational and safety performance of each mode. By conducting that assessment in this step, the analyst may check for these impacts within the accessibility assessment.

7.2 Crossing Assessment Worksheet

Each of the Crossing Assessment steps described in this chapter can be captured in a formal worksheet, shown in Figure 7-7. A two-page version of this worksheet is included in Appendix E.

Crossing Assessment Worksheet			Quadrant A for CTL or		Quadrant B for CTL or		Quadrant C for CTL or		Quadrant D for CTL or	
Task	Default Values	Units	Crossing A-B Entry	Crossing A-B Exit	Crossing B-C Entry	Crossing B-C Exit	Crossing C-D Entry	Crossing C-D Exit	Crossing D-A Entry	Crossing D-A Exit
Step 1. Gather Site Data and Other Inputs										
Step 2. Predict Vehicle Speed at Crosswalk										
Speed at crosswalk, $V_{critical}$	(none)	[mph]								
Step 3. Calculate Crossing Sight Distance										
Crosswalk length, L_n	(none)	[ft]								
Design ped walking speed, S_p	3.5	[ft/s]								
Ped start-up time and end clearance time, t_s	2	[s]								
Critical headway, $t_{n,c} = \frac{L_n}{S_p} + t_s$	(none)	[s]								
Crossing sight distance, $d_n = 1.47\ V_n t_{n,c}$	(none)	[ft]								
Step 4. Checking Sight Distance Provisions										
Performance Check 1: Is Adequate Sight Distance Available?										
Step 5. Predict Crossing Opportunities (Gaps and Yields)										
Volume, N_{veh}	(none)	[veh]								
Crossing type	1L, 2L, CTL	[]								
Probability of encountering usable gap, $P_g = e^{\frac{-t_{n,c} * N_{veh}}{3600}}$	(none)	[]								
Single-lane crossing/CTL crossing										
Indicator variable for exit, I_{ex}	1 = exit, 0 = entry/CTL	[]								
Indicator variable for entry, I_{en}	1 = entry, 0=exit/CTL	[]								
Indicator variable for high compliance region, I_{HC}	1=high, 0=low	[]								
Prob. of yields, single-lane roundabout/CTL, $P_Y = (0.6888 - 0.07688 * I_{ex} + 0.62954 * I_{en} + 0.37418 * I_{HC})e^{-0.03465 * V}$	(none)	[]								
Two-lane crossing										
Indicator variable for RRFB, I_{RRFB}	1=yes, 0=no	[]								
Indicator variable for exit, I_{ex}	1=exit, 0=entry	[]								
Indicator variable for high compliance region, I_{HC}	1=high, 0=low	[]								
Prob. of yields, two-lane roundabout, $P_Y = (0.7259 + 0.2105 * I_{RRFB} - 0.2574 * I_{ex} + 0.3244 * I_{HC})e^{-0.0129 * V}$	(none)	[]								
Probability of yields, P_Y (select row based on 1L/2L/CTL)	(none)	[]								
Probability of yield crossing opportunities, $P_{YC} = P_Y * (1 - P_G)$	(none)	[]								
Step 6. Estimate Utilization of Gaps and Yields										
Probability of using a gap, P_{UG} (default for roundabouts = 65%)	Rbt = 0.65, CTL = 0.60	[]								
Probability of using a yield, P_{UY} (default for roundabouts = 70%)	Rbt = 0.70, CTL = 0.35	[]								
Step 7. Estimate Blind Pedestrian Delay										
Probability of crossing, $P_C = P_{YC} * P_{UY} + P_G * P_{UG}$	(none)	[]								
Delay, single-lane crossing, $d_p = 9.37\ - 9.78\ * ln(P_C)$	(none)	[s/veh]								
Delay, two-lane crossing, $d_p = 6.14\ - 8.53\ * ln(P_C)$	(none)	[s/veh]								
Delay, CTL, $d_p = 10.75\ - 9.95\ * ln(P_C)$	(none)	[s/veh]								
Delay, d_p (select row based on 1L/2L/CTL)	(none)	[s/veh]								
Step 8. Determine Delay-Based Pedestrian LOS										
Performance Check 2: Is the Pedestrian LOS within the guidelines for your agency?										
Step 9. Estimate Crossing Risk										
Indicator variable for entry/exit, I_{ex}	1=exit, 0=entry/CTL	[]								
Indicator variable for noise, I_N	1=noisy, 0=low noise	[]								
Indicator variable for number of lanes, I_{1L}	1=1L or CTL, 0=2L	[]								
Probability of intervention, $P_I = (0.011895 + 0.008443 * I_{ex} + 0.021915 * I_N - 0.007186 * I_{1L})e^{0.027697 * V}$	(none)	[]								
Step 10. Check Crossing Risk										
Performance Check 3: Is probability of an intervention within range allowable by your agency?										
Step 11. Visibility of Traffic Control Devices										
Step 12. Complete Crosswalk Assessment										

Figure 7-7: Crossing Assessment Worksheet

APPENDIX E – WAYFINDING AND CROSSING ASSESSMENT WORKSHEETS TO SUPPLEMENT CHAPTERS 6 AND 7

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Question	Crossing A-B	Crossing B-C	Crossing C-D	Crossing D-A	Notes
6.1 Determining the Crossing Location					
6.1.1 Do sidewalks lead to the crosswalks?					
6.1.2 Is separation provided between sidewalk and curb?					
6.1.3 Is the edge of the street clearly defined (outside edge)?					
6.1.4 If other ramps or driveways are nearby, are they adequately delineated and separated?*					
6.1.5 Are traffic control devices accessible?					
6.2 Aligning to Cross and Establishing a Correct Heading					
6.2.1 Is curb ramp width the same as crosswalk width?					
6.2.2 Is curb ramp slope aligned with crossing?					
6.2.3 Are ramp edges aligned with crossing?					
6.2.4 Are detectable warnings aligned with the slope of the curb ramp?					
6.2.5 Are the pushbuttons in correct location?					
6.2.6 Is there a sufficiently level landing and turning space where the pedestrian is waiting to cross?*					
6.3 Maintaining Correct Heading while Crossing (Staying within the Crosswalk)					
6.3.1 Is the crossing configured at the shortest distance practical?					
6.3.2 Is the crossing aligned perpendicular to the curb and splitter edges?					
6.3.3 Are markings clearly visible?					
6.4 Crossings from Channelization and Splitter Islands					
6.4.1 Are islands wide enough to provide safe refuge?					
6.4.2 Are transitions to roadway clearly defined (within the island)?					
6.4.3 Are paths through island clearly identifiable?					
6.4.4 Are pushbuttons accessible?					

Notes:

Bold lettering indicates particular item is required by PROWAG-NPRM.
*Question has been reworded from Report 834.
Some questions have been added to or removed from this list.

Crossing Assessment Worksheet

Task	Default Values	Units	Quadrant A for CTL or Crossing A-B Entry	Crossing A-B Exit	Quadrant B for CTL or Crossing B-C Entry	Crossing B-C Exit	Quadrant C for CTL or Crossing C-D Entry	Crossing C-D Exit	Quadrant D for CTL or Crossing D-A Entry	Crossing D-A Exit
Step 1. Gather Site Data and Other Inputs										
Step 2. Predict Vehicle Speed at Crosswalk										
Speed at crosswalk, $V_{critical}$	(none)	[mph]								
Step 3. Calculate Crossing Sight Distance										
Crosswalk length, L_n	(none)	[ft]								
Design ped walking speed, S_p	3.5	[ft/s]								
Ped start-up time and end clearance time, t_s	2	[s]								
Critical headway, $t_{n,c} = \frac{L_n}{S_p} + t_s$	(none)	[s]								
Crossing sight distance, $d_n = 1.47\ V_n t_{n,c}$	(none)	[ft]								
Step 4. Checking Sight Distance Provisions										
Performance Check 1: Is Adequate Sight Distance Available?										
Step 5. Predict Crossing Opportunities (Gaps and Yields)										
Volume, N_{veh}	(none)	[veh]								
Crossing type	1L, 2L, CTL	[]								
Probability of encountering usable gap, $P_g = e^{\frac{-t_{n,c} * N_{veh}}{3600}}$	(none)	[]								
Single-lane crossing/CTL crossing										
Indicator variable for exit, I_{ex}	1 = exit, 0 = entry/CTL	[]								
Indicator variable for entry, I_{en}	1 = entry, 0=exit/CTL	[]								
Indicator variable for high compliance region, I_{HC}	1=high, 0=low	[]								
Prob. of yields, single-lane roundabout/CTL, $P_Y = (0.6888 - 0.07688 * I_{ex} + 0.62954 * I_{en} + 0.37418 * I_{HC})e^{-0.03465 * V}$	(none)	[]								
Two-lane crossing										
Indicator variable for RRFB, I_{RRFB}	1=yes, 0=no	[]								
Indicator variable for exit, I_{ex}	1=exit, 0=entry	[]								

Crossing Assessment Worksheet Task	Default Values	Units	Quadrant A for CTL or Crossing A-B Entry	Crossing A-B Exit	Quadrant B for CTL or Crossing B-C Entry	Crossing B-C Exit	Quadrant C for CTL or Crossing C-D Entry	Crossing C-D Exit	Quadrant D for CTL or Crossing D-A Entry	Crossing D-A Exit
Indicator variable for high compliance region, I_{HC}	1=high, 0=low	[]								
Prob. of yields, two-lane roundabout, $P_Y = (0.7259 + 0.2105 * I_{RRFB} - 0.2574 * I_{ex} + 0.3244 * I_{HC})e^{-0.0129*V}$	(none)	[]								
Probability of yields, P_Y (select row based on 1L/2L/CTL)	(none)	[]								
Probability of yield crossing opportunities, $P_{YC} = P_Y * (1 - P_G)$	(none)	[]								
Step 6. Estimate Utilization of Gaps and Yields										
Probability of using a gap, P_{UG} (default for roundabouts = 65%)	Rbt = 0.65, CTL = 0.60	[]								
Probability of using a yield, P_{UY} (default for roundabouts = 70%)	Rbt = 0.70, CTL = 0.35	[]								
Step 7. Estimate Blind Pedestrian Delay										
Probability of crossing, $P_C = P_{YC} * P_{UY} + P_G * P_{UG}$	(none)	[]								
Delay, single-lane crossing, $d_p = 9.37 - 9.78 * ln(P_C)$	(none)	[s/veh]								
Delay, two-lane crossing, $d_p = 6.14 - 8.53 * ln(P_C)$	(none)	[s/veh]								
Delay, CTL, $d_p = 10.75 - 9.95 * ln(P_C)$	(none)	[s/veh]								
Delay, d_p (select row based on 1L/2L/CTL)	(none)	[s/veh]								
Step 8. Determine Delay-Based Pedestrian LOS										
Performance Check 2: Is the Pedestrian LOS within the guidelines for your agency?										
Step 9. Estimate Crossing Risk										
Indicator variable for entry/exit, I_{ex}	1=exit, 0=entry/CTL	[]								
Indicator variable for noise, I_N	1=noisy, 0=low noise	[]								
Indicator variable for number of lanes, I_{1L}	1=1L or CTL, 0=2L	[]								
Probability of intervention, $P_I = (0.011895 + 0.008443 * I_{ex} + 0.021915 * I_N - 0.007186 * I_{1L})e^{0.027697*V}$	(none)	[]								
Step 10. Check Crossing Risk										
Performance Check 3: Is probability of an intervention within range allowable by your agency?										
Step 11. Visibility of Traffic Control Devices										
Step 12. Complete Crosswalk Assessment										

APPENDIX F – CASE STUDY DESIGNS AND SOLUTIONS FOR TRAINING COURSE

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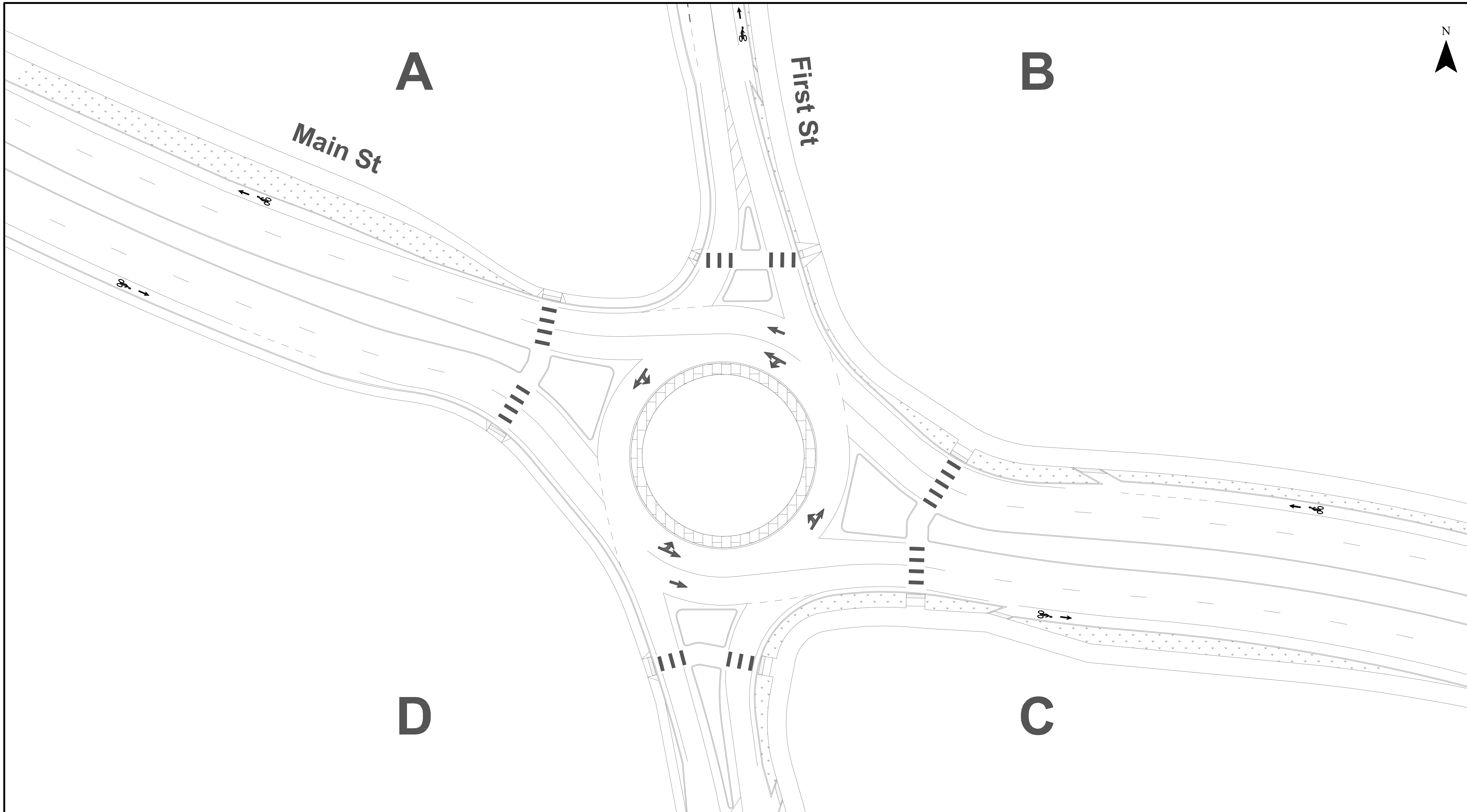

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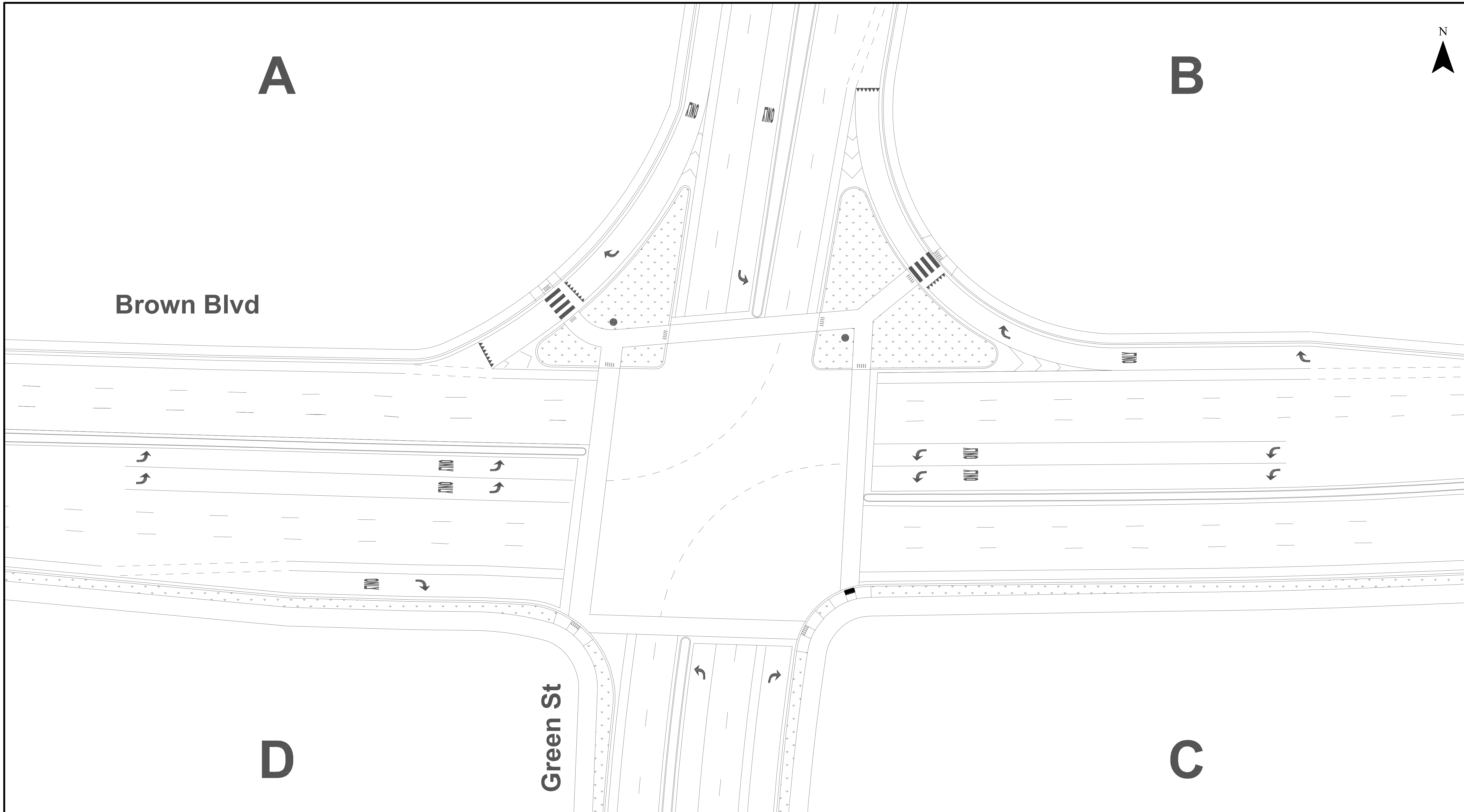
Main Street / First Street

Problem
1



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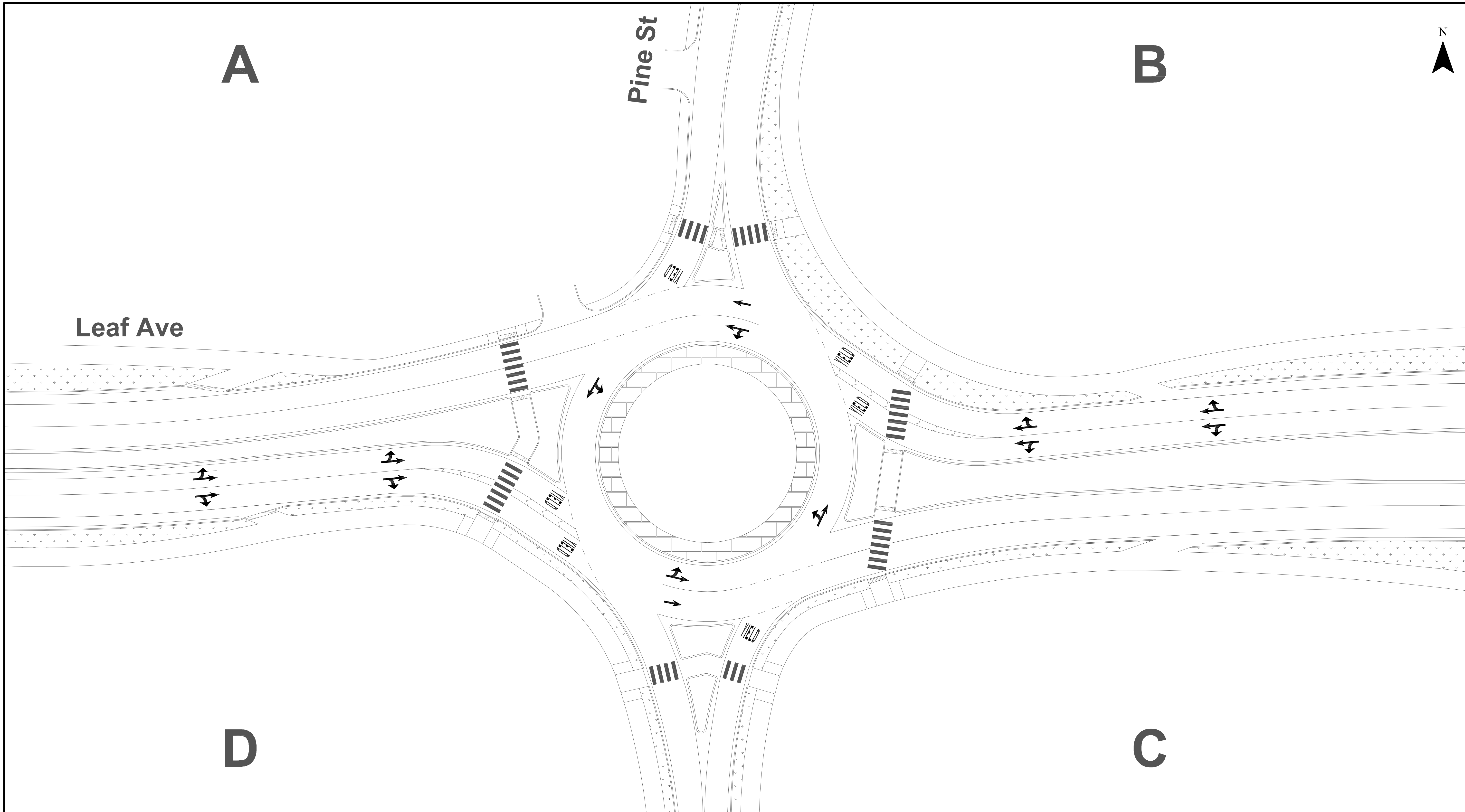
Brown Boulevard / Green Street

Problem
2



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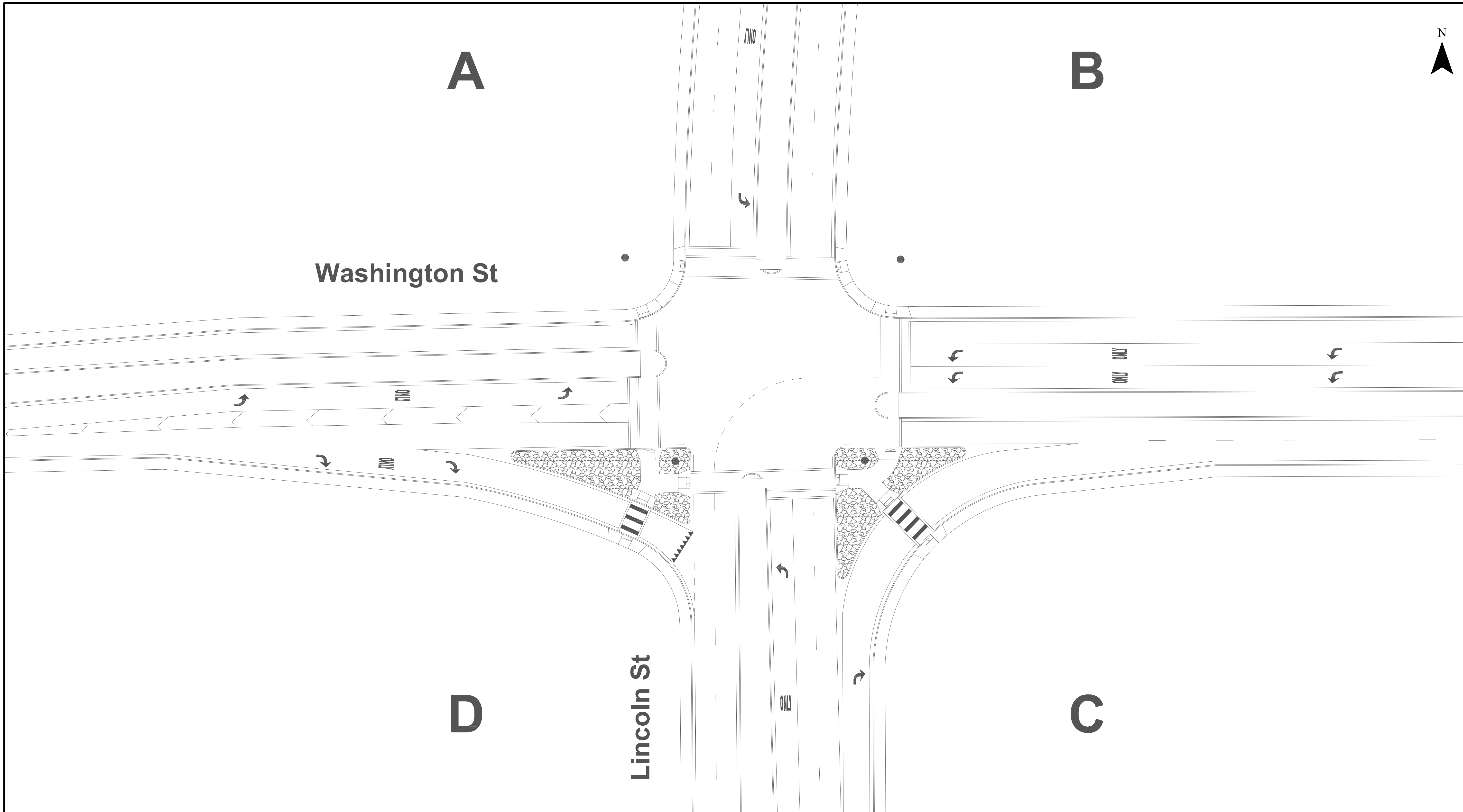
Leaf Avenue / Pine Street

Problem
3



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Washington Street / Lincoln Street

Problem
4

K:\H_Projects\19\19542 - NCHRP 03-78c Training and Tech Transfer\Task 3 - Develop Training Materials\Case Studies\CAD\problems\Problem 4_v2.dwg May 13, 2018 - 2:40pm - zbugg Layout Tab: Layout1

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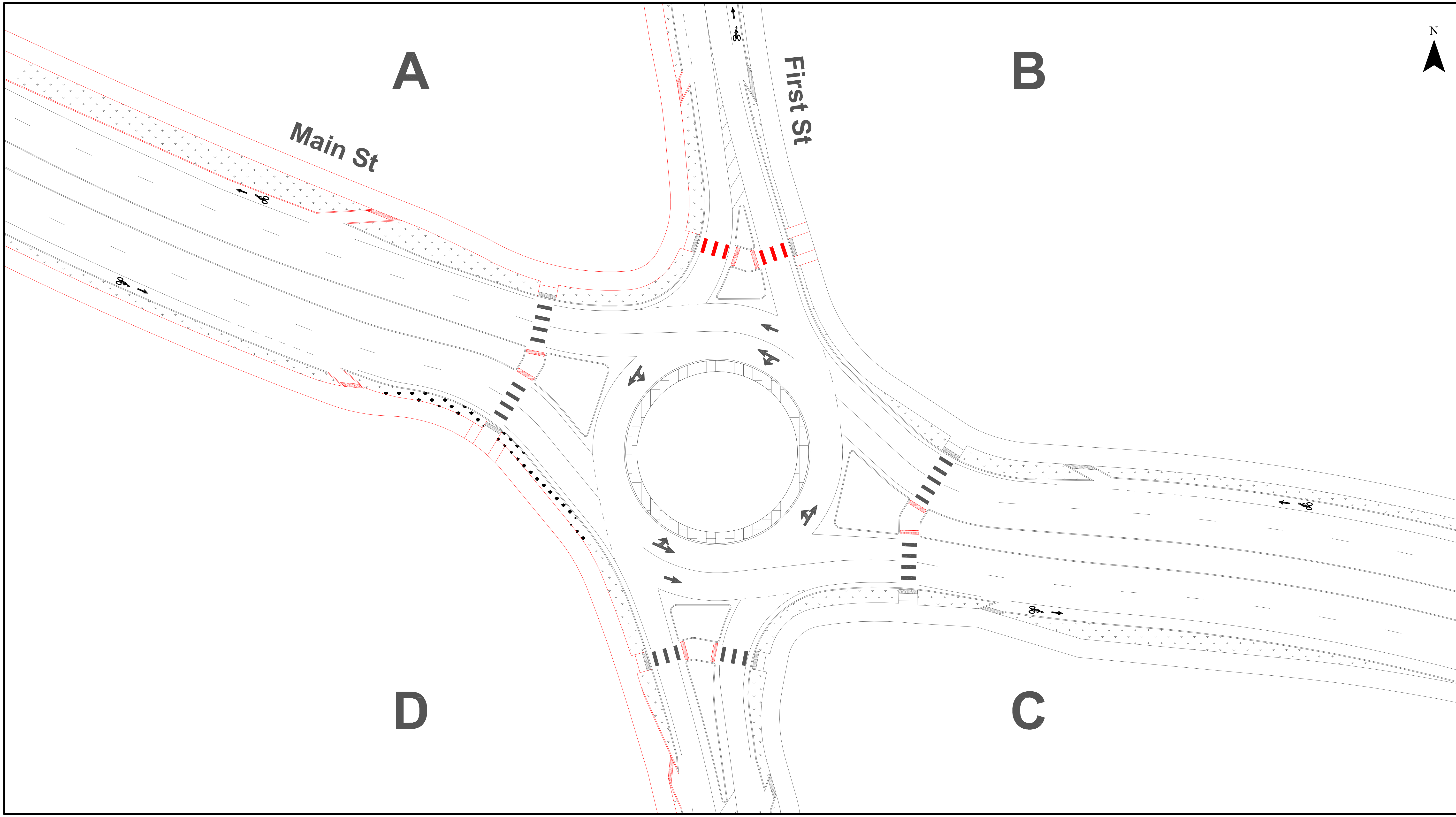
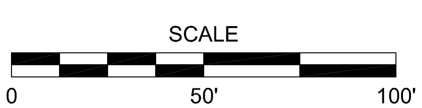
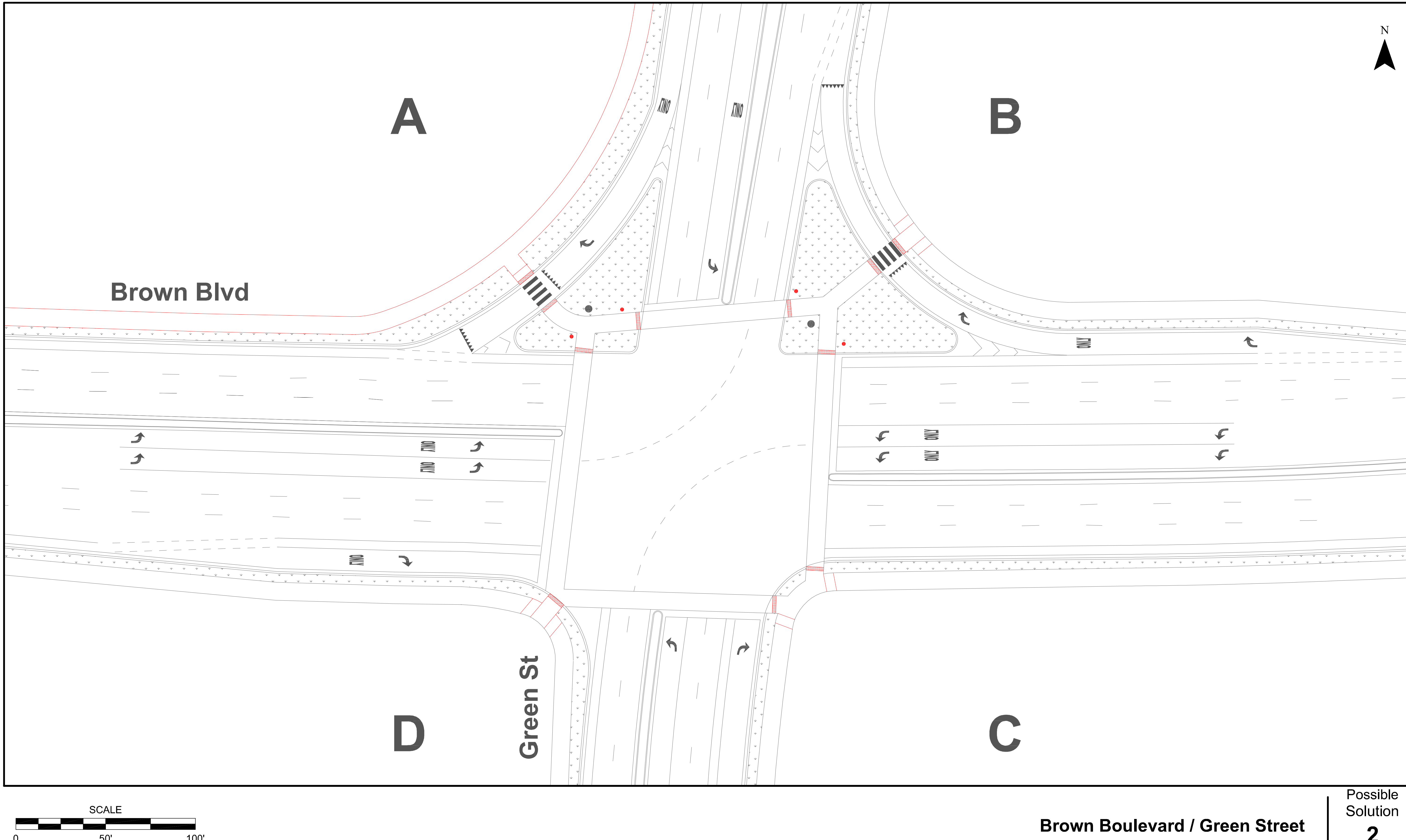




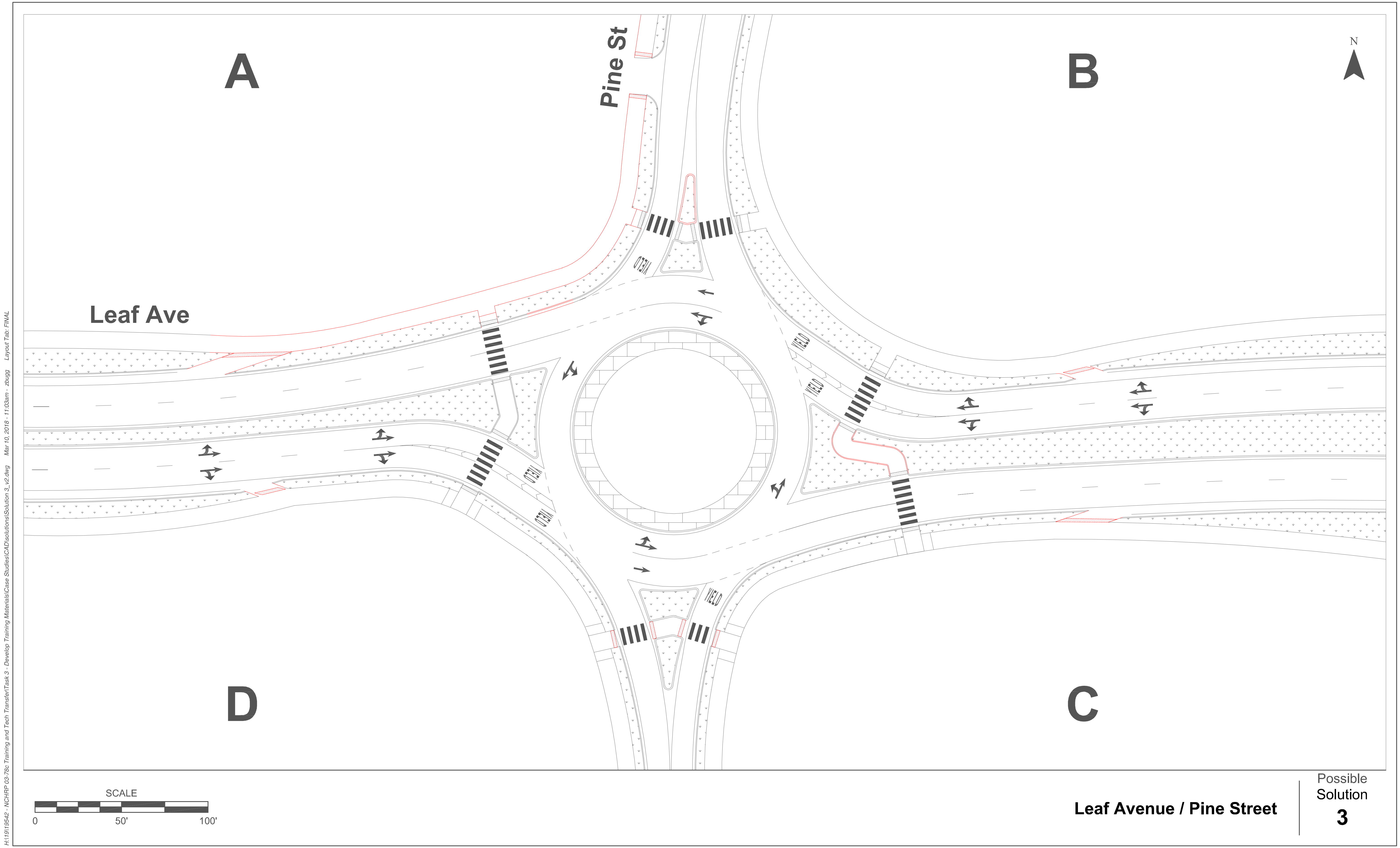
Main Street / First Street

Possible Solution
1



Brown Boulevard / Green Street

Possible Solution 2



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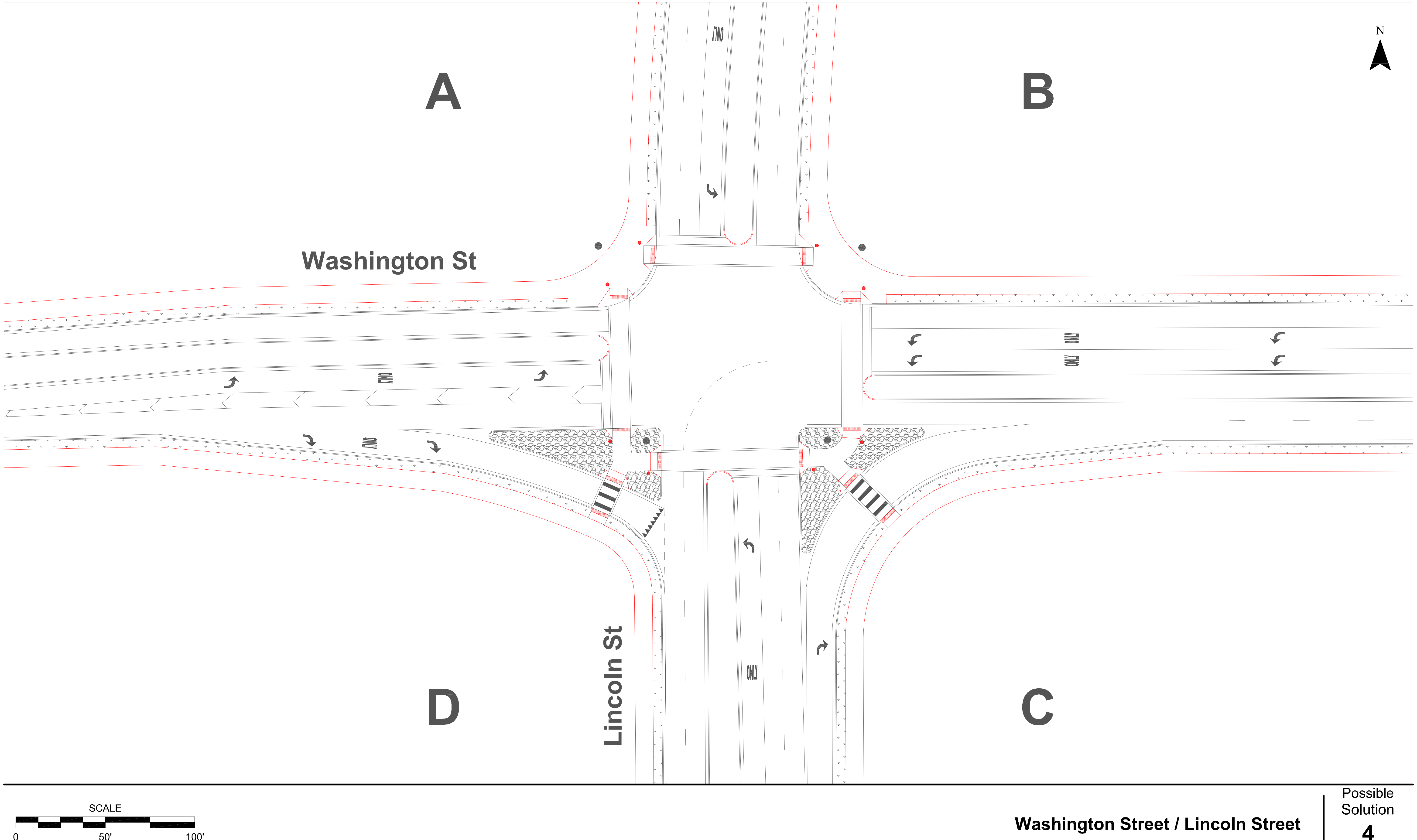

Washington Street / Lincoln Street

Possible Solution 4