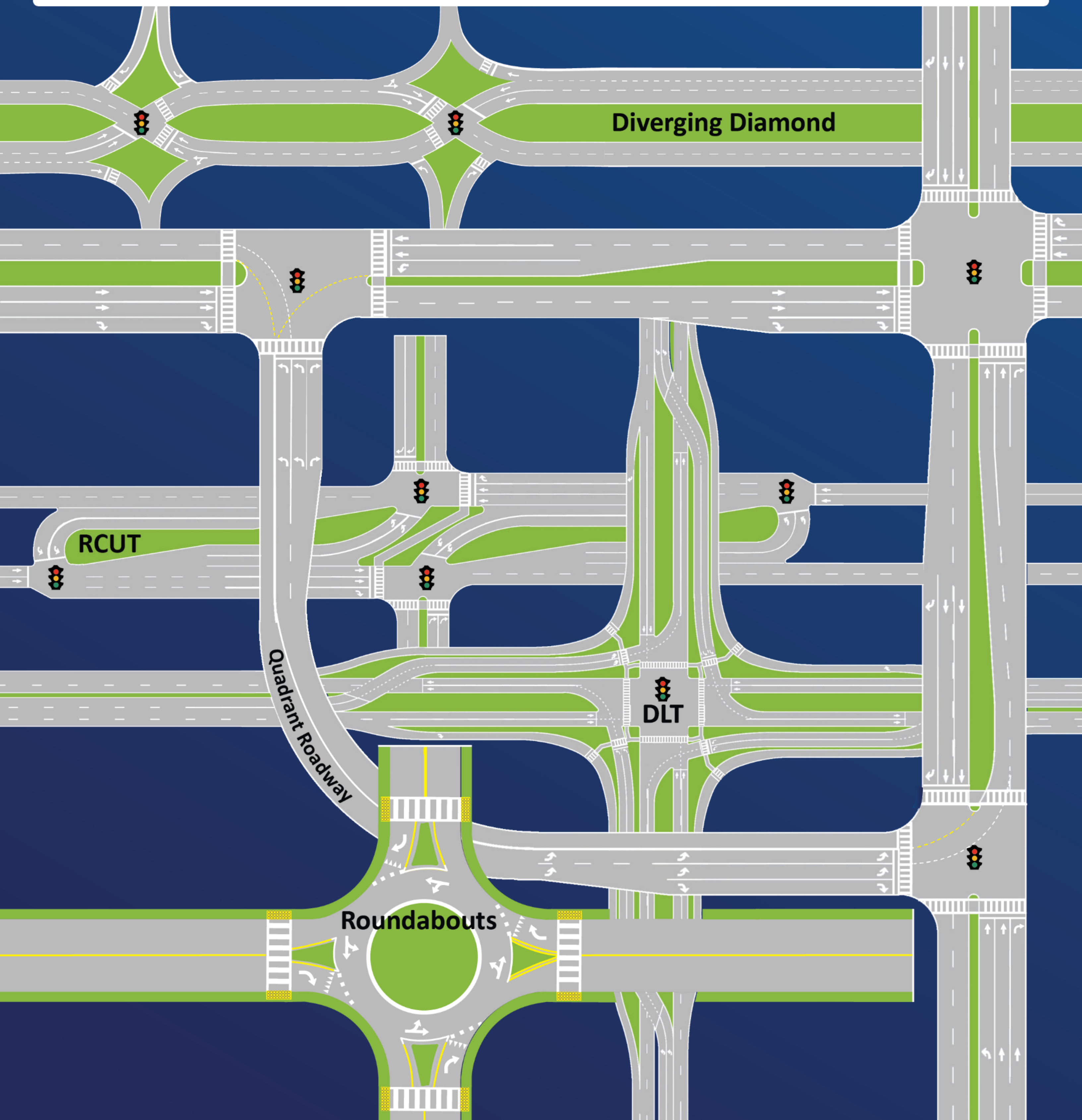
Manual on Intersection Control Evaluation

Effective January 1, 2025



MANUAL ON
INTERSECTION CONTROL EVALUATION

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LIST OF ACRONYMS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
CAP-X	Capacity Analysis for Planning of Junctions
CMF	Crash Modification Factor
DDE	District Design Engineer
DDI	Diverging Diamond Interchange
DLT	Displaced Left Turn
DTOE	District Traffic Operations Engineer
FDM	FDOT Design Manual
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FI	Fatal-and-Injury
HSM	Highway Safety Manual
ICE	Intersection Control Evaluation
LOS	Level-of-Service
LPI	Leading Pedestrian Interval
LTS	Level of Traffic Stress
MUT	Median U-Turn
MUTCD	Manual on Uniform Traffic Control Devices
NASEM	National Academies of Sciences, Engineering, and Medicine
NCHRP	National Cooperative Highway Research Program
PD&E	Project Development and Environment
PE	Professional Engineer
PER	Preliminary Engineering Report
PTAR	Project Traffic Analysis Report
QR	Quadrant Roadway
RCUT	Restricted Crossing U-Turn
SHS	State Highway System
SPICE	Safety Performance for Intersection Control Evaluations
SSI	Safe System for Intersections
v/c	Volume-to-Capacity

CHAPTER 1
ADOPTION PROCEDURE

1.1 Purpose

The Manual on Intersection Control Evaluation (ICE), hereafter referred to as the ICE Manual, sets forth procedures, standards, and guidelines for evaluating intersection control strategies on the State Highway System (SHS).

1.2 Authority

Sections 20.23(3)(a) and 334.048(3), Florida Statutes.

1.3 References

- Chapter 316, Florida Statutes
- Rule 14-15.010: Manual on Uniform Traffic Control Devices (MUTCD), Florida Administrative Code
- Rule 14-96: State Highway System Connection Permits, Florida Administrative Code

1.4 Scope

The ICE Manual affects the following Florida Department of Transportation (FDOT) Offices at the state and district level: Traffic Engineering and Operations, Safety, Roadway Design, Environmental Management, Access Management, Program Management, and Permitting.

1.5 Distribution

The ICE Manual is available electronically on the State Traffic Engineering and Operations website at: *https://www.fdot.gov/traffic/trafficservices/intersection-control-evaluation*.

1.6 Revisions and Updates

Users are encouraged to submit comments and suggestions for changes to the ICE Manual and the associated software tools by emailing the State Traffic Services Section at *FDOT-StateTrafficServicesSection@dot.state.fl.us* or using the ICE Comments Form on FDOT's ICE webpage at: *https://www.fdot.gov/traffic/trafficservices/intersection-control-evaluation*.

When comments and suggestions are received, they will be reviewed by appropriate staff to assess the significance and impact of any proposed changes. Items requiring further discussion will be coordinated with the statewide ICE Collaboration Team, District Traffic Operations Engineers (DTOEs), District Design Engineers (DDEs), and other offices in the Central Office affected by the proposed change. Substantive revisions that result in policy change may be coordinated with the Executive Committee for adoption. Unless warranting immediate change, approved revisions and updates to the ICE Manual will be reflected in the publication to be released during the regular publishing cycle. Items warranting immediate change will be made any time during a year with the approval of the Director of the State Traffic Engineering and Operations Office/State Traffic Engineering and Operations Engineer.

Notification of the adopted revisions and updates to the ICE Manual will be made in the form of a bulletin and distributed to registered users of the manual through the FDOT's Contact Management Database.

The State Traffic Engineering and Operations Office Bulletins are posted online at: *https://www.fdot.gov/traffic/trafficops-bulletins.shtm*.

Users interested in receiving automatic notifications of revisions to the ICE Manual by e-mail may register to the FDOT Contact Management Database at: *https://fdotewp1.dot.state.fl.us/ContactManagement*.

Users are encouraged to regularly check and download the latest version of the associated software tools by visiting the State Traffic Engineering and Operations website at: *https://www.fdot.gov/traffic/trafficservices/intersection-control-evaluation*. An updated version of any of the tools may be released anytime during a year if software bugs and errors are identified and fixed. A bulletin may not be released in this case.

1.7 Training

Training was previously provided by the State Traffic Engineering and Operations Office. The training materials are available on FDOT's ICE webpage at: *https://www.fdot.gov/traffic/trafficservices/ice-training-materials.*

Computer-based training modules are under development and will be available through the Department's Learning Management System, also known as the Learning Curve.

1.8 Forms Access

The FDOT ICE Form (Form No. 750-010-30) is available on the FDOT Procedural Document Library at: *https://pdl.fdot.gov*. The Form is also available on FDOT's ICE webpage at: *https://www.fdot.gov/traffic/trafficservices/intersection-control-evaluation*.

CHAPTER 2
INTERSECTION CONTROL EVALUATION

2.1 Background and Purpose

Intersections play an essential role in the roadway network by facilitating the movement and flow of road users among different routes and facilities. However, as different movements and paths cross, join, or separate at intersections, they create potential conflict points that can lead to crashes. Specific intersection characteristics such as the geometry and intersection control can also contribute to the likelihood and severity of crashes. Statistics show that roughly 35% of all traffic fatalities in Florida are associated with intersection-related crashes. As such, enhancing intersection safety is one of the 12 emphasis areas identified in the Florida's *Strategic Highway Safety Plan*.

While certain intersections represent a high potential for crashes, there are several intersection designs and control strategies that can improve safety, mobility, and connectivity. Innovative intersection and interchange designs are a proactive approach to improve intersection safety. Designs that reduce the number of intersection conflict points, control conflict angles, and manage speeds are most effective at improving safety. For instance, those designs that reduce high-speed conflict types between opposing movements are most effective at preventing severe injuries in the event of a crash. Examples of such innovative intersection and interchange designs include roundabouts, U-turn-based designs (e.g., median U-turn, restricted crossing U-turn), and crossover-based designs (e.g., diverging diamond interchange). Limiting the number of conflict points at an intersection may not only reduce the frequency and severity of crashes but also improve the overall operation and mobility of the roadway system.

Finding the optimal intersection strategy—whether conventional or innovative—at a particular location depends on several factors, including traffic flows by approach and movement as well as the needs of the community and all road users. This requires a procedure that allows for comprehensive evaluation of potential intersection control strategies to help make informed decisions.

FDOT's ICE procedure supports objective assessments and comparisons of intersection control types or control strategies. The ICE procedure is flexible and may vary based on project type and complexity. ICE users should exercise judgment in applying the ICE procedure in a way that meets project needs and follows the process described in this **Manual**.

The goal of ICE is to better inform FDOT's decision-makers in identifying and selecting an intersection control strategy that meets the project's purpose and need, fits the intersection location's context classification, provides efficient and safe travel for all road users, and reflects the best value. Applying the ICE process has the following benefits:

- It is a data-driven performance-based procedure to quantitatively assess the operational and safety performance of intersection control strategies.
- It enhances the practice of integrating safety into the decision-making process.
- It encourages thoughtful consideration of innovative intersection and interchange designs.
- It provides means to identify cost-effective solutions.
- It allows for flexibility and scalability tailored to project type and complexity.
- It ensures consistent documentation of decisions and supporting analyses.

2.2 Applicability

An ICE is required for intersections on the SHS when any of the following applies:

(a) New intersection signalization is proposed (i.e., any existing or new intersection is projected to meet signal warrants).

(b) Major reconstruction of an existing signalized intersection is proposed (e.g., adding a left-turn lane to an approach, adding an intersection leg, and converting to a roundabout).

(c) A change from a directional or bi-directional median opening to a full median opening is proposed.

(d) The District Design Engineer (DDE) and the District Traffic Operations Engineer (DTOE) consider an ICE a good fit for the project.

(e) A single connection to the SHS generates or is expected to generate 4,001 average daily traffic or more under E, F, and G standard connection categories (defined by average vehicle trips per day thresholds in Rule 14-

96.004, F.A.C.) or a connection permit is proposed with the removal, installation, or modification of traffic signal or any of the above in (b) through (d).

An ICE is not required for the following applications:

(a) Signalization of a midblock pedestrian crosswalk.

(b) Work involved does not include any substantive proposed changes to an intersection (e.g., a project limited to only “mill and resurface” pavement with no change to intersection geometry or control; converting a two-way stop-controlled intersection to a four-way stop-controlled intersection; changing a full median opening to a directional median opening).

(c) Minor intersection operational improvements (e.g., adding right-turn lanes or changing signal phasing/timing or signal replacement projects where the primary purpose is to upgrade deficient equipment and installations).

An ICE is recommended for ramp terminal intersections at service interchanges. For example, the ICE procedure can be used to comparatively evaluate the ramp terminal intersections of different diamond interchange types such as signalized standard diamond, diverging diamond, and single point diamond. Also, if a diamond configuration is selected, the ICE procedure can be used to consider and recommend a control strategy at the ramp terminal intersections, with options including stop control, signalized, or yield control (e.g., roundabouts). It should be noted that ICE does not replace FDOT’s Interchange Access Request process and procedure, which is required for all modifications at interchanges with limited access facilities. Please refer to the *FDOT Interchange Access Request User’s Guide* on this process.

FDOT encourages local agencies and counties to perform ICE for projects they lead on locally maintained roadways, but ultimately it is the choice of the local jurisdiction.

2.3 Intersection Control Strategies

The ICE procedure supports the comparative evaluation of various intersection control strategies for both at-grade intersections and crossroad ramp terminal intersections. The ICE procedure is applicable for assessing and comparing the following at-grade intersection control strategies:

- Minor Road Stop Control
- All-Way Stop Control

- Signalized Control
- Roundabout
- Median U-Turn (MUT)
- Restricted Crossing U-turn (RCUT)
- Jughandle
- Displaced Left-Turn (DLT)
- Continuous Green T (CGT)
- Quadrant Roadway (QR)
- Thru-Cut
- Bowtie

The ICE procedure is also applicable for assessing and comparing the ramp terminal intersections associated with the following interchange configurations:

- Diamond
- Half Diamond
- Tight Diamond
- Diverging Diamond
- Single-Point Diamond
- Two-Quadrant Partial Cloverleaf A
- Four-Quadrant Partial Cloverleaf A
- Two-Quadrant Partial Cloverleaf B
- Four-Quadrant Partial Cloverleaf B
- Roundabout

Several variations of the above intersection control strategies are available for evaluation using the ICE procedure. For example, the evaluation for one intersection type may vary by control type (signal, stop, or yield control), area type (urban and suburban, rural), roadway geometry (e.g., number of approach lanes, number of circulating lanes, intersection of all one-way approach legs, intersection of one-way and two-way approach legs), and roadway speed limit. Note that the ICE procedure is applicable for ramp terminal intersections at service interchanges only. It does not include safety or operations analysis of the system interchanges and ramps.

See **Appendix A** for a brief description of each intersection control strategy.

2.4 Conducting an ICE

An ICE shall be conducted under the supervision of a licensed Professional Engineer (PE) in the State of Florida. Conducting an ICE requires three important elements to be initially addressed, which are discussed below.

(1) **Project Purpose and Need.** Projects may be initiated for a variety of reasons. Traffic operations, safety, multimodal access, land access, and placemaking are examples of potential project needs. The project's purpose and need and the project location's context classification are the primary determinants to come up with a reasonable list of potential control strategies for preliminary screening.

(2) **Design Year.** Depending on the project purpose and type, an ICE may need to be conducted for the design year. The design year is 10 years for operation improvement projects such as signalization; resurfacing, restoration, and rehabilitation; and safety or operational improvements. The design year is 20 years for projects that add capacity with new construction or reconstruction. See *Florida Design Manual (FDM) Section 201.3* for further information. For interchange access requests, additional analysis years may be requested. The DTOE or the DDE may require the analysis to be done for an extended design year. The development of design year traffic volumes should follow the *FDOT Project Traffic Forecasting Handbook* and the guidance given for Project Traffic Demand Forecasting in the *FDOT Traffic Analysis Handbook*.

(3) **Study Area.** ICE is focused on an isolated intersection. An ICE can be conducted for a group of intersections in a corridor given the intersections are independent of and uncoordinated with each other. However, evaluations may need to be expanded beyond the study intersections using some other tools for any of the following situations:

- Queue spillback is anticipated to impact the operations of adjacent intersections or freeway mainline for ramp terminal intersections.
- Modifications are to be made to an intersection within a coordinated signal system.
- Modifications are to be made to intersections that do not operate independently of each other.

2.4.1 ICE Stages

Following the determination of project purpose and need, the ICE procedure entails activities up to three stages. The stages are:

(1) **Stage 1 - Screening/Preliminary Analysis.** Stage 1 is conducted during a project's initial stage. The purpose of Stage 1 is to screen potential control strategies and identify a single preferred control strategy or, if not possible, only a few viable control strategies narrowed down from the initial consideration based on preliminary analysis of traffic operations, safety, and other related factors.

(2) **Stage 2 - Detailed Analysis.** Stage 2 is required only if a single control strategy cannot be determined in Stage 1. Stage 2 involves more detailed safety and operational analyses. Economic analysis of the alternative strategies, where applicable based on project funding source, is also part of Stage 2 evaluation.

(3) **Stage 3 - Supplemental Analysis.** Stage 3 is required only if a single control strategy cannot be determined in Stage 2.

However, determining the most viable intersection control strategy may not require all three stages. In most cases, the evaluation should not go beyond Stage 2. The activities involved in ICE Stages are discussed in detail in **Section 2.5.**

2.4.2 ICE Form

At the completion of analysis in each stage, the FDOT ICE Form (Form No. 750-010-30) as appropriate to the corresponding stage (e.g., Stage 1 ICE Form for Stage 1 analysis, Stage 2 ICE Form for Stage 2 analysis, and Stage 3 ICE Form for Stage 3 analysis) is required to be submitted to the DTOE and the DDE with supporting documentation for all projects that require an ICE as outlined in **Section 2.2**. Supporting documentation shall be signed and sealed by the PE overseeing the evaluation. The breadth of supporting documentation appended to the form should be proportionate to the level of analysis required to identify the selected control strategy. Details of the FDOT ICE Forms can be found in **Appendix B.**
The party responsible for completing and submitting the ICE Form(s) and supporting analyses varies by project type, as follows:

- For FDOT projects, the FDOT staff or their consultants shall complete the ICE Form(s).

- For driveway connection permits on the SHS, the applicant or the engineer appointed by the party shall complete the ICE Form(s).

The ICE Form for each stage shall be approved by the DTOE and the DDE. FDOT retains final approval authority of the ICE Form for projects and connection permits on the SHS.

The DTOE's and the DDE's approval of a single control strategy in the ICE Form indicates that a preferred control strategy has been selected to be advanced to final design. During final design when more detailed information is available, the preferred alternative may no longer be the best improvement option for many reasons. One such example is the discovery of a contamination site on a parcel needed for right-of-way acquisition, leading to a decision to not acquire the parcel. Another example is a new nearby development approved by local government may impact the intersection's traffic volumes and the preferred control strategy's operations and safety. In cases such as these, the DTOE and/or the DDE may direct the analysis to be re-evaluated.

2.4.3 Analytical Tools for ICE

Conducting an ICE requires using multiple tools depending on the intended purpose and stage for which ICE is being conducted. The following tools can be used to perform Stage 1 and Stage 2 analyses:

- FDOT Capacity Analysis for Planning of Junctions (CAP-X) Tool
- FDOT Safety Performance for Intersection Control Evaluation (SPICE) Tool
- Traffic Simulation Software
- FDOT Economic Analysis Tool for ICE

Note that no specific tools are exclusively attributed for Stage 3 evaluation. Any of the tools used in Stage 2 and/or additional tools as deemed necessary by the PE can be used for Stage 3 evaluation. A brief description of the analytical tools is provided below.

2.4.3.1 FDOT CAP-X Tool

The CAP-X Tool was originally developed by Federal Highway Administration (FHWA), intended to be used as a planning-level analysis tool during the Stage 1 ICE procedure to evaluate the operational performance of various at-grade and ramp terminal intersection control strategies based on the critical lane volume method. The FDOT CAP-X Tool is an expanded version of the original FHWA tool for use in Florida, with the inclusion of additional intersection and ramp control strategies and incorporation of a score-based methodology to evaluate pedestrian and bicycle accommodations at intersections. The FDOT CAP-X Tool is a macro-based Microsoft Excel workbook. It consists of a series of worksheets, including several worksheets with basic information about the tool, multiple input worksheets, result worksheets, and individual worksheets for each control strategy (by major road direction) showing the computation of critical lane volume and volume-to-capacity (v/c) ratio. The required user inputs however are minimal, and include number of intersection legs, major street direction, peak hour (AM and PM) turning volume counts, lane configuration, control strategy selection, and speed limit of roadways. Most variables used in determining pedestrian and bicycle accommodation score have pre-defined values in the worksheets based on assumptions for typical conditions. Users are encouraged to validate these pre-defined values for the strategies being analyzed. See **Appendix C** for the details of the pedestrian and bicycle evaluation methodology used in the FDOT CAP-X Tool. The *Capacity Analysis for Planning of Junctions (CAP-X) Tool User Manual* published by FHWA is another useful resource on the CAP-X tool (Jenior et al., 2018).

2.4.3.2 FDOT SPICE Tool

The FDOT SPICE Tool is an expanded version of the original FHWA tool for safety analysis of intersection control strategies. Like the FDOT CAP-X Tool, the FDOT SPICE Tool is a macro-based Microsoft Excel workbook. The FDOT SPICE Tool includes two complementary approaches for safety analysis:

(1) **Crash Prediction Method.** Crash predictions in the FDOT SPICE Tool are primarily based on the predictive method in the *Highway Safety Manual (HSM) Part C*, published by American Association of State Highway and Transportation Officials (AASHTO). The predictive method provides a mechanism to predict crash frequency by severity (e.g., total crash frequency, fatal and injury (FI) crash frequency) using a base Safety Performance Function (SPF), a set of Adjustment Factors (AFs) (also referred to as Crash Modification Factors (CMFs)), and a calibration factor. A base SPF is a regression equation associating crash frequency with traffic exposure (e.g., Annual Average Daily Traffic (AADT)) of major and minor road approaches at an intersection under specific (base) roadway geometry and control features. The AFs are used to account for non-base conditions at the study intersection (i.e., when roadway geometry and

control features at the study intersection vary from the base conditions). The calibration factor accounts for differences between the jurisdiction and time period for which the base SPFs are developed and the jurisdiction and time period to which the SPFs are applied. (AASHTO, 2010). Both the AFs and the calibration factor are multiplied by the base SPF prediction to estimate crashes specific to local conditions. When the roadway conditions match the base condition, the AF or CMF value is equal to 1.0. When a calibration factor is not determined, it can be assumed to be equal to 1.0.

Note that SPFs may not be available for an intersection control strategy. In these cases, the FDOT SPICE Tool includes CMFs or Crash Modification Functions, if available, for predicting crashes at the control strategy relative to crash predictions for a base control strategy. See **Appendix D** for sources of the crash prediction method used in the FDOT SPICE Tool to evaluate each intersection control strategy.

(2) **Safe System for Intersections (SSI) Method.** The SSI method provides a technical basis to apply Safe System-based principles through the following concepts:

- Conflict point identification and classification - crossing, diverging, merging, and non-motorized.
- Exposure for different conflict point types.
- Conflict point severity – an estimate of the probability of at least one fatality or serious injury (P(FSI)) between road users making the conflict point movements, where the fatality or serious injury in this method is defined as an injury with a score ≥ 3.0 in the Maximum Abbreviated Injury Scale (MAIS) (see Association for the Advancement of Automotive Medicine (2015) for further details on the MAIS score).
- Intersection movement complexity for movements passing through different conflict point types.

Application of the SSI method leads to the determination of SSI scores that can be used as additional safety metrics to screen alternatives for an intersection control strategy. The SSI score for an intersection control strategy ranges from zero to 100, with higher scores indicating higher levels of safe system performance (i.e., lower probability of fatalities and serious injuries). Note that the calculations in the SSI method are based on several assumptions for each at-grade and ramp terminal intersection type. The assumptions are provided in **Appendix D**. Details of the SSI method can be found in FHWA Report, titled *A Safe System-Based Framework and Analytical Methodology for Assessing Intersections* (Porter et al., 2021).

The SSI method offers an advantage over the crash prediction method in cases where it is not possible to conduct crash prediction-based analyses on one or more alternatives due to lack of SPFs or CMFs. For example, no SPFs and CMFs are available for Thru-Cut (signalized and unsignalized) and Bowtie intersections; however, the SSI method within the FDOT SPICE Tool can be used to evaluate the safety performance of these intersection control strategies.

User inputs for the FDOT SPICE Tool vary between Stage 1 and Stage 2 of the ICE procedure. The inputs that are common to both ICE stages are the number of intersection legs, rural or urban facility type, AADT of intersection approach legs, posted speed limit, and road type of approach legs (i.e., all two-way roads, all one-way roads, intersection of one-way and two-way roads).

At the planning level or the early stage of a project, it may not be possible to know the detailed geometry and control features of each control strategy considered for evaluation. As such, during Stage 1, the crash prediction method in the FDOT SPICE Tool can be used by assuming that base conditions prevail at the intersection (i.e., AFs equal to 1.0). The only exception is lighting where it is default to 'lighting present' contrary to the base condition that lighting is not present. At the same time, the SSI method is primarily intended for Stage 1 evaluation only, which does not require detailed inputs on design, operations, or control features.

During Stage 2 evaluation, additional inputs are required in the FDOT SPICE Tool to obtain a reliable estimate of crash predictions for local conditions. The default values assumed for AFs or CMFs in Stage 1 shall now be replaced actual values based on the conceptual design developed in Stage 2. While the SSI method is primarily for Stage 1, it is appropriate to update the analysis in Stage 2 if there is a change in lane configuration, roadway speed limit, median presence, or pedestrian volume.

Given at least two years of crash data are entered into the *Historical* worksheet, crash predictions for the existing intersection control strategy reflects the expected crash frequency, estimated using the empirical Bayes method. Details of the empirical Bayes method can be found in the *HSM*.

2.4.3.3 FDOT Economic Analysis Tool for ICE

The FDOT Economic Analysis Tool for ICE, formerly known as FDOT ICE Tool, is a modified version of the Life-Cycle Cost Estimating Tool that was developed as part of the *National Cooperative Highway Research Program* (*NCHRP) Project 03-110: Estimating the Life-Cycle Cost of Intersection Designs*. This macro-based Microsoft Excel spreadsheet tool is intended for use during Stage 2 evaluation to compare the economic viability of various intersection control strategies. The tool estimates annualized cost over the project life cycle for the following cost elements: vehicular delay, operations and maintenance, design and construction, and right-of-way. The benefit is measured by associating the predicted or expected crash frequency over the project life cycle to an equivalent crash cost by severity. Based on the estimated costs and benefits for each control strategy, the tool provides benefit-cost ratios and net present values for comparative evaluation of control strategies. The economic analysis is not required for projects that are not federally funded.

2.4.3.4 Traffic Simulation Software

FDOT has published a series of **Synchro** templates for traffic simulation and analysis of vehicular delays for several intersection control strategies, which are available at: *https://www.fdot.gov/traffic/trafficservices/intersection-control-evaluation*. Analysts are encouraged to use **Sidra Intersection** software to get an estimate of delays at roundabouts.

2.4.4 Considerations for Control Strategy Evaluation

The selection of a preferred control strategy at an intersection should be based on a comprehensive evaluation of various factors. While several performance measures (e.g., v/c ratio, FI crash frequency predictions, SSI score, etc.) are used to rank control strategies, the ranking should not be the only criterion to decide on the preferred control strategy. This is partly because the ranking does not account for the inherent analytical constraints present in the performance measures and the lack of model parameters applicable to local or prevailing conditions. Also, the ranking of control strategies based on operational performance may significantly differ from the ranking based on safety performance. The following factors should be considered while evaluating control strategies:

- **Project Scope:** While several viable control strategies may show the anticipated safety and operational benefits, the project type or scope should guide the selection of a preferred control strategy. In general, intersections that are part of larger projects may impact operations of adjacent intersections and connected roadways and may require further vetting than smaller projects.

- **AADT Outside the Applicable Range:** If the study intersection's major and minor approach AADT are outside the specified AADT ranges for which the SPFs and CMFs are applicable, a reliable estimate of crash predictions may not be provided. The greater the difference in AADT exceeding the maximum value applicable for the model (i.e., SPFs or CMFs), the less reliable the crash predictions could be.
- **CMF-based Prediction:** If a single-value CMF (i.e., in absence of SPFs) is used to evaluate the control strategy without account for the effects of various geometric, operational, and traffic features at the intersection when compared to the base control strategy, it may not provide reliable estimates of crash predictions given the likelihood of crashes varies by traffic and other features. A detailed understanding of the conditions applicable to CMFs may help determine the reliability of safety performance estimates.
- **Model Applicability to Local Conditions:** If field conditions or design elements of a control strategy substantially vary from default assumptions in the SSI method or from conditions that have not been accounted for in the SPF-based predictions, it may have a significant impact on the anticipated safety performance. The applicability of the method to the actual conditions, the nature of any variations, and the potential effect of variations should be determined based on existing knowledge and/or engineering judgment.
- **Operational Analysis:** In addition to v/c ratio, applying advanced operational analysis methodologies along with microscopic traffic simulation to model traffic flow parameters (e.g., vehicular delay) may help determine the optimal performance of each control strategy.
- **Multimodal Accommodation:** The selected control strategy should serve the needs of all transportation system users. The following design elements for non-motorized and transit users should be considered while evaluating the viability of each control strategy for all modes of traffic:
  - Volume of non-motorized users
  - Location of pedestrian crossings
  - Pedestrian crossing time and out-of-direction travel
  - Presence of pedestrian refuge area

- Exclusive pedestrian signal phase
- Intersection width
- Type of bicycle facility
- Location of transit stops
- Target speed
- Number of access points within the intersection influence area
- Available turning radii to serve design vehicle
- Proportion of large vehicles
- Special treatment required to serve design vehicle or large vehicles

- **Agency Coordination and Public Input:** Evaluations should assess driver expectations, agency coordination, and public input for each viable control strategy. When selecting a preferred control strategy, evaluators should typically consult the local jurisdictions, other stakeholders, and potentially the public. The project manager, in consultation with local stakeholders and FDOT functional units, should determine the degree of public involvement necessary/required in the discussion of control strategy options. The evaluators should make stakeholders aware of the technical merits and potential issues of each control strategy.
- **Economic Analysis:** If additional right-of-way is required for some intersection control strategies being evaluated, a comparative economic analysis with estimations of the benefit-cost ratio and the net present value may provide a better understanding of the suitability of the control strategies. Also, in cases when multiple control strategies have the potential to improve safety and operational performance and not requiring additional right-of-way, assessing the economic viability may be a key factor in the selection of a preferred control strategy.
- **Adjacent Intersections and Coordinated Signal Systems:** The spacing of intersections along a highway corridor should be consistent with the spacing of primary full-movement intersections (see the *FDOT Access Management Policy*). A comprehensive traffic analysis should be conducted to determine if it is appropriate to locate a roundabout within a coordinated signal network. The DTOE may allow intersection spacing exceptions for roundabouts based on justifiable merits on a case-by-case basis.
- **System Consistency:** On Strategic Intermodal System (SIS) facilities or other highways where a corridor study was previously prepared, any ICE

should address the impact on the SIS performance or compare control strategies to those recommended in the corridor study.

2.5 ICE Stage Activities

ICE activities could potentially be streamlined on some projects while other projects may require more extensive analyses. This could result in early, sketch-level evaluations to support quick planning-level decisions or detailed and robust evaluations to address complex projects. Analysts should use their judgment to apply the ICE procedure in the way that meets project needs, accomplishes ICE procedure goals, and follows the process described in this **Manual**.

2.5.1 Stage 1: Screening/Preliminary Analysis

Stage 1 is conducted during a project's preliminary stage where a project can be initiated for a variety of reasons. Analysis required for ICE as part of PD&E study varies based on the level of engineering analysis needed for the PD&E phase. At a minimum, the Stage 1 ICE should be performed as part of the PD&E's Alternative Analysis process. The analysis results should be documented with the Project Traffic Analysis Report (PTAR) and summarized in the Preliminary Engineering Report (PER).

For driveway connection permit applications, the engineers representing the applicant and the FDOT staff should determine at the pre-application meeting or at a district's access management review committee meeting which viable control strategies the applicant should assess. The completed Stage 1 ICE Form should be provided by the applicant-appointed engineers at the pre-application meeting to facilitate this discussion.

Figure 2-1 illustrates the flowchart of stepwise activities involved in Stage 1. Each step in Stage 1 is discussed below.

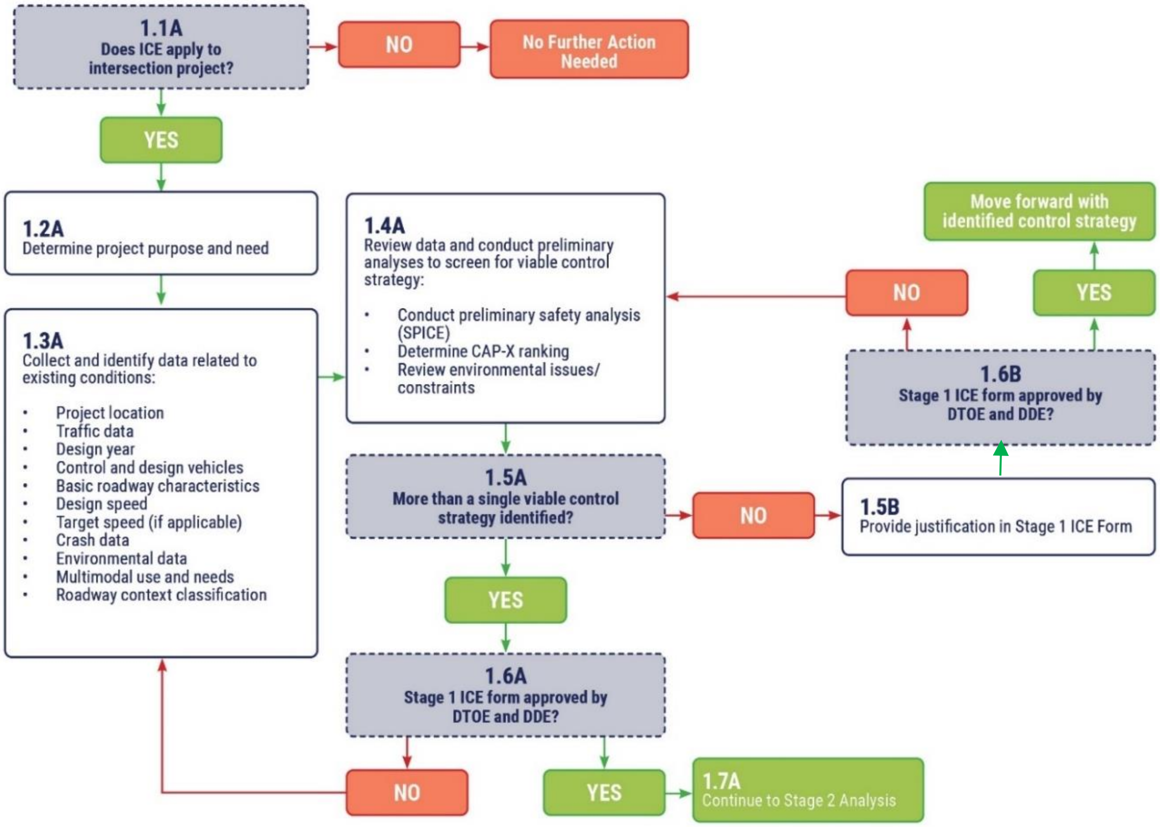

Figure 2- 1: Flowchart of ICE Stage 1 Steps

Step 1.1A: Does the intersection require an ICE? It refers to determining whether an ICE is required for the study intersection based on the criteria specified in **Section 2.2**.

Step 1.2A: Determine project purpose and need. Determine the purpose and need for the project.

Step 1.3A: Collect data on existing conditions. Collect certain minimum information about the existing conditions. This includes the project location, traffic data (including peak hour data), basic roadway characteristics, control and design vehicles, design and target speeds, crash data, environmental data, multimodal use(s), and roadway context classifications. Refer to the analytical tools for conducting an ICE, FDOT ICE Forms, *FDM, FDOT Project Traffic Forecasting Handbook*, and *FDOT Traffic Analysis Handbook* for specific data requirements. Make a preliminary determination whether there are any environmental or right-of-way factors that may preclude a control strategy from selection. Identify whether the project is federally or non-federally funded.

Step 1.4A: Review data and conduct preliminary analyses to screen for viable control strategy. Conduct preliminary analyses, including operational, pedestrian accommodation, and bicycle accommodation, using the FDOT CAP-X Tool. Also, conduct a preliminary safety analysis based on the crash prediction method and the SSI method using the FDOT SPICE Tool. Review environmental issues or constraints. Refer to **Appendix A** to determine the viability of a control type. Apply engineering judgement in evaluating these aspects. The volume forecast should be prepared in accordance with the *FDOT Project Traffic Forecasting Handbook* and the *FDOT Traffic Analysis Handbook*.

Step 1.5A: More than a single viable control strategy identified? The PE overseeing the evaluation has discretion to determine whether multiple control strategies are still viable based on the screening or preliminary analysis results. It is suggested to coordinate efforts and results with District's Traffic Operations Office and Design Office staff throughout the evaluation process to ensure acceptance of the results and recommendation.

Step 1.5B: Provide justification in Stage 1 ICE Form. If a preferred intersection control strategy is identified through preliminary analyses, include the justification in the completed Stage 1 ICE Form. Submit the Stage 1 ICE Form to the DTOE and the DDE for their concurrence and approval. Attach supporting documentation, including CAP-X and SPICE analysis spreadsheet output sheets and analysis data. Factors used for justification include the following:

- Existing safety and congestion issues
- Future anticipated traffic volumes
- Plans for the roadway based on an adopted corridor or PD&E study
- Pedestrian and bicycle usage and needs
- The spacing of nearby intersections or driveways and how they conform to adopted access management guidelines
- Area type (urban, suburban, or rural)
- FHWA vehicle classification
- Design vehicle accommodation
- Sight distance
- Available right-of-way
- Adjacent environment and land uses (existing and proposed)

- Environmental constraints
- Community goals and objectives
- Support of the local users, local agencies, and local government

Step 1.6A: Stage 1 ICE Form approved by DTOE and DDE? This step follows Step 1.5A (i.e., when more than one viable control strategy is identified). If the Stage 1 ICE Form that recommends multiple control strategies for further analysis is approved, proceed to follow the steps in Stage 2 (see **Section 2.5.2**). If the Stage 1 ICE Form is not approved by the DTOE and/or DDE, return to Step 1.3A, address their comments, and reevaluate the factors and analysis details to identify either a single control strategy or more appropriate (and preferably fewer) control strategies.

Step 1.6B: Stage 1 ICE Form approved by DTOE and DDE? This Step follows Step 1.5B. If the recommendation of the single strategy in the Stage 1 ICE Form is approved by the DTOE and the DDE, proceed to preliminary design for the selected control strategy. If the Stage 1 ICE Form is not approved and the DTOE or the DDE may require additional analysis to determine appropriate viable control strategies, return to Step 1.4A to reconsider the factors involved in Stage 1 analysis and follow the same steps therefrom.

Step 1.7A: Continue to Stage 2 Analysis. If a preferred control strategy is not identified in Stage 1, conduct a more detailed analysis of the remaining control strategies in Stage 2: Control Strategy Assessment.

2.5.2 Stage 2: Detailed Analysis

Stage 2 initiates with the concept development for all potential control strategies selected at the end of Stage 1 evaluation. These conceptual designs are essential for communicating control strategy concepts to the public and evaluating factors such as safety, cost, right-of-way impacts, and environmental impact on a site-specific basis. Stage 2 is typically completed immediately following the project's initial study portion or as part of the project's alternatives and comparative evaluation.

If a PD&E study's level of detail includes a final design component or the project is programmed as a Design-Build project, the Stage 2 ICE should be incorporated into the PD&E's Alternative Analysis process unless a single preferred intersection strategy is selected in Stage 1. The Stage 2 traffic operational analysis of the alternative control strategies should be based on the project's design year traffic volumes and conducted using microsimulation software tools. The analysis process and results should be detailed into the PTAR and summarized in the PER. The design year safety analysis results from the FDOT SPICE Tool should also be summarized in the PER. In cases where the alternative intersection type does not have an applicable crash prediction method, the SSI method can be used to compare the relative safety performance among intersection control strategies. For federally funded projects, the economic analysis results of alternative control strategies from the FDOT Economic Analysis Tool for ICE should also be summarized in the PER.

Figure 2-2 illustrates the flowchart of stepwise activities involved in Stage 2. Each step in Stage 2 is discussed below.

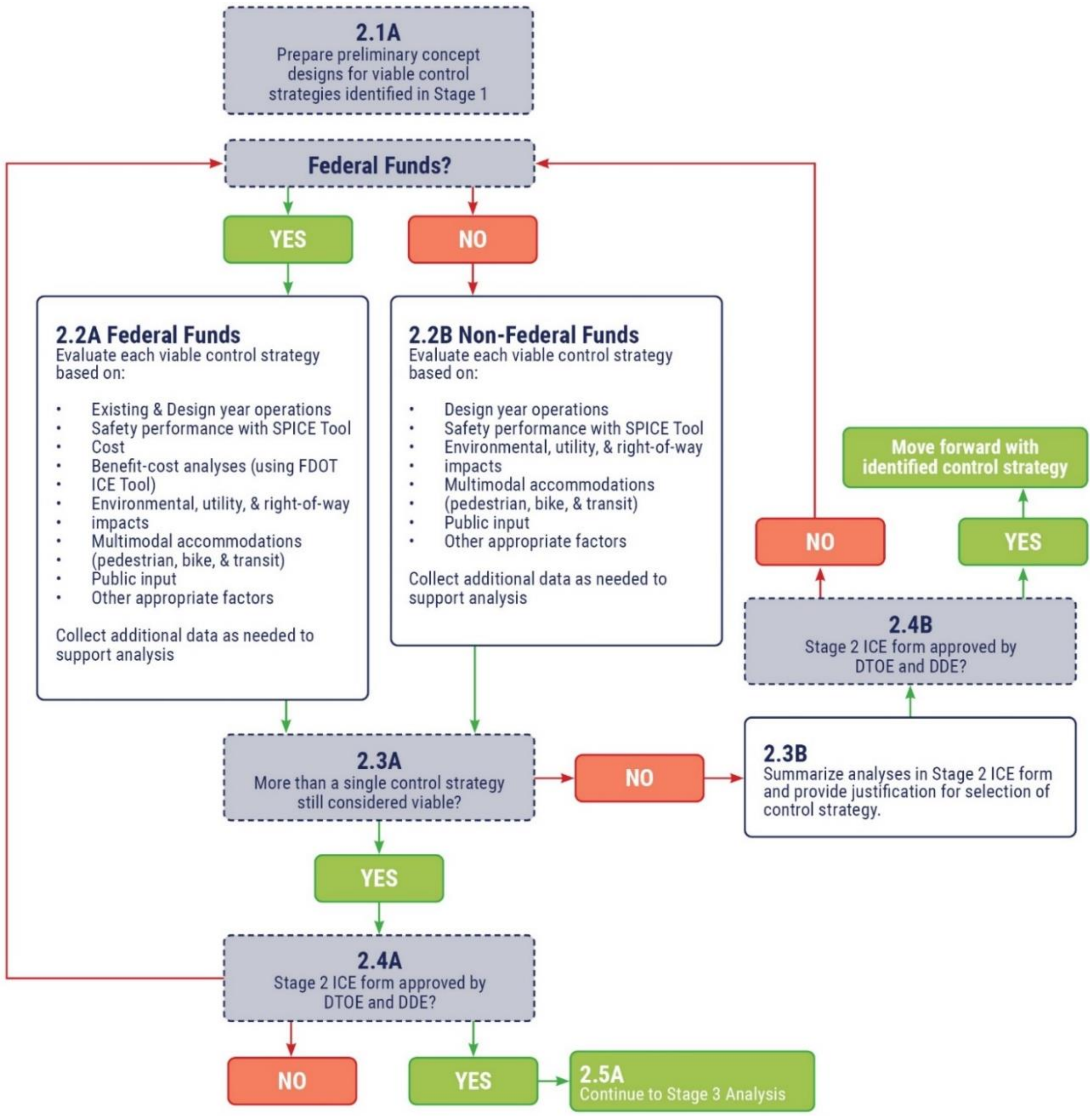

Figure 2- 2: Flowchart of ICE Stage 2 Steps

Step 2.1A. Prepare preliminary conceptual designs for viable control strategies identified in Stage 1. Prepare a conceptual plan or layout showing the proposed geometrics for each intersection control strategy. Document changes from the existing conditions in the plan. It is suggested that the operational analysis be conducted concurrently with the concept development. This conceptual design lays the foundation for much of the evaluation in Step 2.2A.

Step 2.2. Evaluate each viable control strategy for federally funded projects (Step 2.2A)/non-federally funded projects (Step 2.2B). Conduct a more detailed analysis of each control strategy based on the conceptual designs prepared in Step 2.1A. Areas of analysis include:

- Operations for opening and design year when the project is federally funded and for design year only when the project is non-federally funded.
- Safety Performance
- Construction, right-of-way, and design costs: applicable for federally funded projects only
- Benefit-cost analysis: applicable for federally funded projects only
- Environmental, utility, and right-of-way impacts
- Multimodal accommodations (including pedestrian, bike, and transit)
- Agency coordination and public input (if applicable)

Collect additional data if needed to conduct Stage 2 analysis. Refer to the *FDOT Traffic Analysis Handbook* for guidance on data collection and operational analysis tools.

Step 2.3A. More than a single control strategy still considered viable? The PE overseeing the ICE study has discretion to determine whether more than one control strategy is still viable based on evaluation of the conceptual designs. Coordinate efforts and results with District's Traffic Operations Office and Design Office staff throughout the evaluation to facilitate acceptance of the results and conclusions.

Step 2.3B: Summarize analyses in Stage 2 ICE Form and provide justification or selection of control strategy. If a preferred traffic control strategy is identified through the analysis of the conceptual designs, submit a completed Stage 2 ICE Form to the DTOE and the DDE. Include the proper justification for the selection or non-selection of each potential control strategy considered in Stage 2 to the Stage 2 ICE Form.

Step 2.4A: Stage 2 ICE Form approved by DTOE and DDE? This step follows Step 2.3A (i.e., when more than one viable control strategy is identified). If the Stage 2 ICE Form that recommends multiple control strategies for further analysis is approved, proceed to follow the steps in Stage 3 (see **Section 2.5.3**). If the Stage 2 ICE Form is not approved, return to Step 2.2A or 2.2B as appropriate, reevaluate the factors, and scrutinize the analysis details to identify either a single control strategy or more appropriate (and preferably fewer) control strategies.

Step 2.4B: Stage 2 ICE Form approved by DTOE and DDE? This step follows Step 2.3B (i.e., when a single control strategy is recommended). If the recommendation of the single strategy in the Stage 2 ICE Form is approved by the DTOE and the DDE, proceed to the preliminary design phase for the recommended control strategy. If the Stage 2 ICE Form is not approved, return to Step 2.2A or 2.2B as appropriate, reevaluate the factors, and scrutinize the analysis details to come up with a preferred control strategy.

Step 2.5A. Continue to Stage 3 Analysis. Conduct a more detailed analysis of the remaining control strategies in Stage 3: Detailed Control Strategy Assessment.

2.5.3 Stage 3: Supplemental Analysis

Stage 3 requires a more in-depth analysis and/or public vetting of control strategy options if a consensus cannot be reached to a single preferred control strategy at the end of Stage 2. This may involve the following:

- Advancement of design plans
- More detailed traffic analysis
- More detailed cost estimation and right-of-way need determination
- Additional assessment of environmental impacts
- Additional engagement with the public or local officials
- Additional engagement with road users (e.g., freight industry, school bus operators, adjacent property owners)
- Any other activities necessary to identify the preferred control strategy

Detailed design plans are necessary only if they assist in evaluating the outstanding issues. For example, community engagement or multimodal needs may determine the preferred control strategy, instead of further technical analysis. When Stage 1 or

Stage 2 evaluation does not identify a selected control strategy, analysts may customize Stage 3 activities to address the outstanding issues. For a PD&E project, Stage 3 analysis is not required as the steps taken above are a normal part of the PD&E process and are documented in the PER and PTAR.

Figure 2-3 illustrates the flowchart of stepwise activities involved in Stage 3. Each step in Stage 3 is discussed below. Stage 3 shall always result in one outcome: a single control strategy.

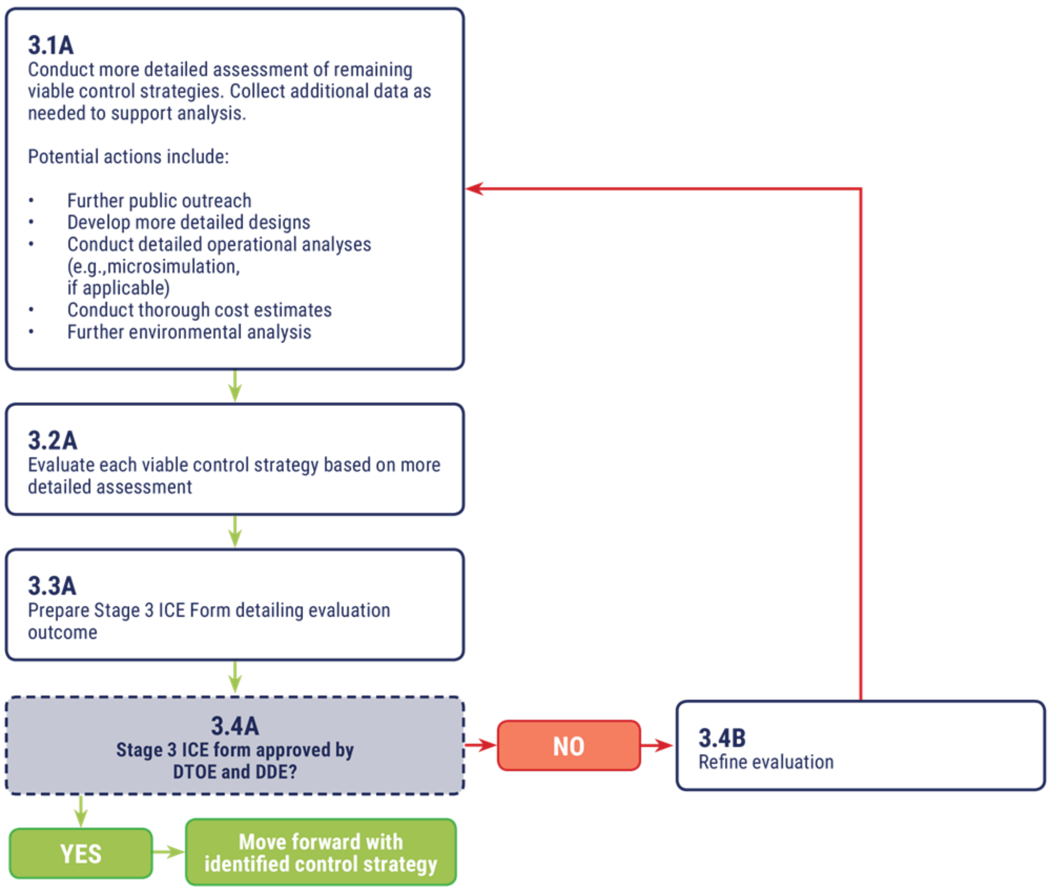

Figure 2- 3: Flowchart of ICE Stage 3 Steps

Step 3.1A: Conduct more detailed assessment of remaining control strategies. Conduct detailed analyses regarding issues and/or findings that have led a control strategy to not to be selected in Stage 2 (i.e., areas warranting further investigation).

Step 3.2A: Evaluate each viable control strategy based on more detailed assessment. Coordinate efforts and results with FDOT throughout the evaluation to facilitate acceptance of the results and conclusions. However, discretion lies with the

PE overseeing the evaluation to determine which control strategy is the most viable alternative for the intersection.

Step 3.3A: Prepare Stage 3 ICE Form detailing evaluation outcome. Prepare a Stage 3 ICE Form detailing or justifying the selected control strategy. Attach supporting documentation to the Form.

Step 3.4A. Stage 3 ICE Form approved by DTOE and DDE? If the Stage 3 ICE Form obtains approval from the DTOE and the DDE, proceed to preliminary design for the recommended control strategy.

Step 3.4B: Refine evaluation. If the submission of the Stage 3 ICE Form is not approved, the party responsible for submitting the ICE Form must revise their analysis or modify their evaluation based on the comments received from the DTOE and/or the DDE (i.e., repeat Step 3.1A with revisions). This may include modifications to control strategy designs, operational analyses, or additional evaluations. Resubmit the Stage 3 ICE Form after accounting for comments from the DTOE and/or the DDE. Coordinate efforts and results with FDOT throughout the evaluation to avoid unnecessary iterations.

2.6 References

Association for the Advancement of Automotive Medicine (2018). *Abbreviated Injury Scale: 2015 Revision (6th Edition).* Chicago.

American Association of State Highway and Transportation Officials (AASHTO) (2010). *Highway Safety Manual, 1st Edition*. Washington, DC.

Jenior, P., Haas, P.J., Butsick, A., and Ray, B.L. (2018). *Capacity Analysis for Planning of Junctions (CAP-X) Tool User Manual*. Publication No. FHWA-SA-18-067. Federal Highway Administration (FHWA), Washington, DC.

Porter, R.J., Dunn, M., Soika, J., Huang, I., Coley, D., Gross, A., Kumfer, W., and Heiny, S. (2021). *A Safe System-Based Framework and Analytical Methodology for Assessing Intersections*. Publication No. FHWA-SA-21-008. FHWA Office of Safety, Washington, DC.

APPENDIX A
INTERSECTION CONTROL STRATEGY DESCRIPTIONS

CONTENTS

LIST OF FIGURES

A.1 Intersection Control Practices and Supporting Resources

Appendix A describes two groups of intersection control strategies, applicable to at-grade intersections and ramp terminals, respectively. The description of each intersection control strategy highlights differentiating features of that strategy that can be considered during ICE. General considerations, especially those that apply to conventional at-grade and ramp terminal intersections, are summarized in **Sections 0 and 0**. Additional resources that inform the intersection strategy considerations and mode accommodations are exhibited in **Section 0**.

A.1.1 General Considerations – At-Grade Intersections

The following considerations apply to at-grade intersections, especially conventional signalized and unsignalized intersections. Additional considerations for alternative intersections are provided in their respective descriptions.

Traffic Control

At-grade intersections may be signalized, stop-controlled, yield-controlled, or uncontrolled. **Appendix A** describes a series of intersections with signal control, stop control, or yield control (in the form of a roundabout). Uncontrolled intersections are not covered by this ICE guidance.

Conventional intersections, as well as some alternative intersection control strategies, may incorporate signal control or stop control based on traffic volumes and other factors. Traffic signal warrants are defined in the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) Chapter 4C. Additional traffic signal information, including that pertaining to bicycle and pedestrian signals, is also discussed in MUTCD Part 4.

Bicycle Facilities

Bicycle facilities may comprise of on-street facilities, such as bike lanes, and off-street facilities, such as shared-use paths. At conventional intersections, bicyclists may use general travel lanes or a dedicated facility to navigate. Bicycle accommodations for specific alternative intersections are cited in their descriptions.

Pedestrian Crossings

Pedestrian crossings at intersections should be marked with crosswalks. At signalized intersections, a pedestrian signal should also be provided. At signalized intersections with a high proportion of right-turn movements, implementation of a leading pedestrian interval (LPI) may be considered. LPIs start the pedestrian WALK phase a few seconds before vehicles are given a green signal indication.

Curb Radius

Curb radius refers to the radius of the curb between two intersection approaches. A sufficient curb radius is required to facilitate turning movements for the design vehicle; however, larger curb radii may increase pedestrian crossing distances.

A.1.2 General Considerations – Ramp Terminal Intersections

In addition to the general considerations applicable to at-grade intersections, the following items also apply to ramp terminals.

Pedestrian Crossings at Ramp Terminals

Pedestrian crossings at loop ramps should have markings and traffic control devices to comply with MUTCD Chapter 3C. The installation of shared-use paths should be considered at loop ramps and other ramp terminals with free-flowing movements.

Trucks and Other Large Vehicles

Trucks and other large vehicles may represent a higher proportion of traffic at ramp terminal intersections. Consideration should be given to accommodate large vehicles in a way that minimizes conflicts with bicyclists, pedestrians, and other mode users.

A.1.3 Additional Resources

FDOT Pedestrian and Bicycle Safety Videos illustrate pedestrian and bicycle safety treatments applicable to the following intersection control strategies:

- Median U-Turn (MUT) Intersections
- Signalized Restricted Crossing U-Turn (RCUT) Intersections
- Displaced Left-Turn Intersections

The videos are available on FDOT's ICE webpage under the *Pedestrian and Bicycle Treatments at Alternative Intersections* tab at: *https://www.fdot.gov/traffic/trafficservices/intersection-control-evaluation*.

NCHRP Report 948: Guide for Pedestrian and Bicycle Safety at Alternative Intersections and Interchanges provides additional guidance for implementing pedestrian and bicycle safety treatments for the following intersection control strategies:

- Median U-Turn (MUT)
- Restricted Crossing U-Turn (RCUT)
- Displaced Left-Turn
- Diverging Diamond Interchanges

FHWA's Synthesis of Alternative Intersection Forms presents a series of aids that cover 20 forms of alternative intersection designs, with additional discussion pertaining to the incorporation of connected and autonomous vehicles. Key features discussed in each aid include design features, operational considerations, safety performance, vehicle traffic demand patterns, multimodal considerations, freight consideration, and historical context.

A.2 At-Grade Intersection Control Strategies

A.2.1 Minor Road Stop Control

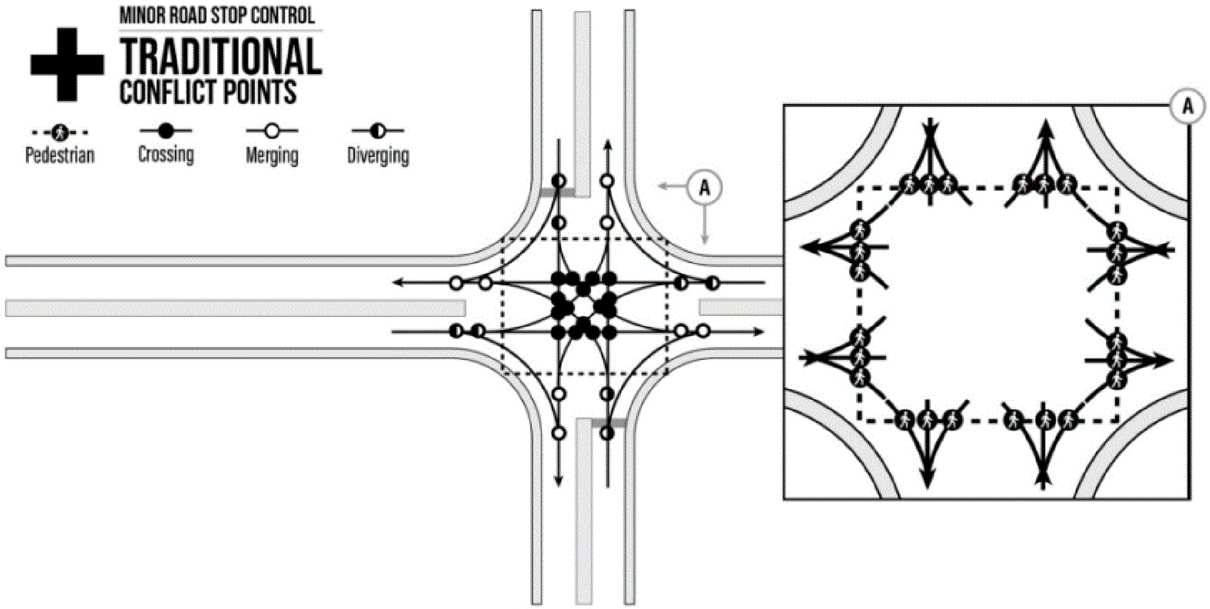

Figure A-1: Diagram of Movement-Based Conflict Points for Minor Road Stop Control Intersections

Source: FHWA

Description

Minor Road Stop Control is a conventional intersection control strategy in which minor street approaches are stop-controlled and major street movements do not encounter any traffic control devices. Through and right-turn movements on the major street approaches are free-flow movements, while left-turn movements are permissive. All minor street movements must stop before proceeding through the intersection.

Considerations

Minor Road Stop Control is the most common intersection control strategy and is easily understood by road users. It is simple and low-cost to implement, but it is not effective in serving higher traffic volumes.

Mode Accommodations

Pedestrians crossing any approaches have the right-of-way; however, the lack of traffic control on the major road does not provide any protected pedestrian movement across the major street. Consider enhanced pedestrian crossing accommodations (signs, markings, refuge, beacons) to improve driver yielding rates and pedestrian safety, particularly for multilane, higher speed, and higher volume roads.

Bicyclists and large trucks exhibiting slower acceleration rates may experience increased difficulty in making through and left-turn movements from the minor street. *Section 9.5.3.2* of the AASHTO *Policy on Geometric Design of Highways and Streets* provides additional guidance and inputs to determine the appropriate intersection sight distance at Minor Road Stop Control intersections for large vehicles.

A.2.2 All-Way Stop Control

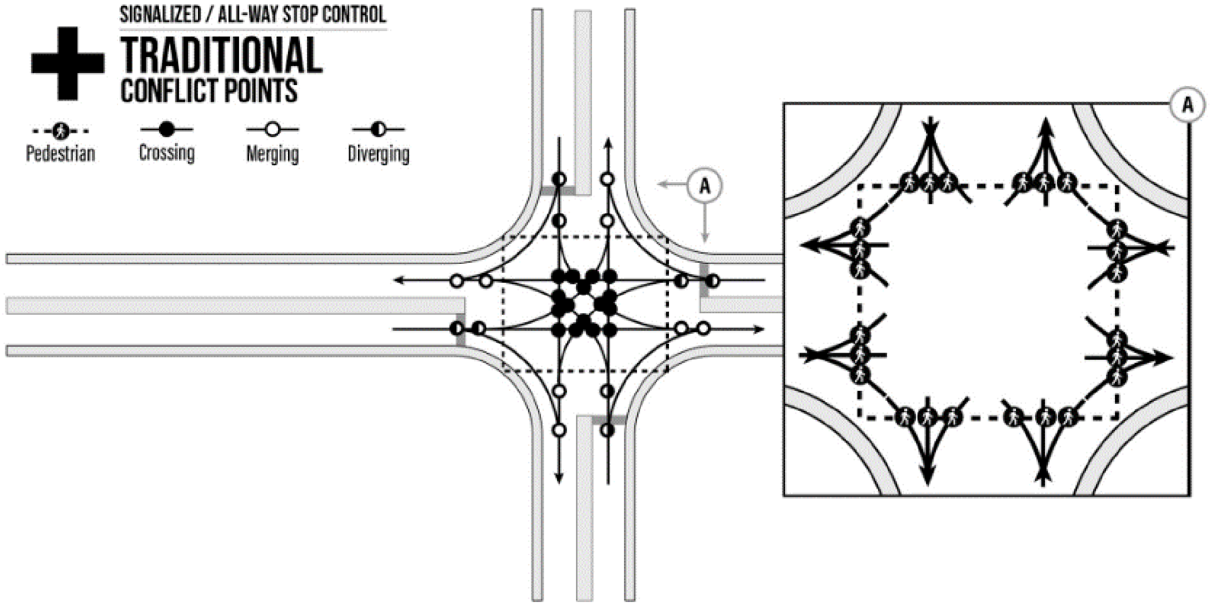

Figure A-2: Diagram of Traditional Movement-Based Conflict Points for All-Way Stop Control Intersections

Source: FHWA

Description

All-Way Stop Control is a conventional intersection control strategy in which every intersection approach is stop-controlled with a supplemental ALL WAY plaque. Right-of-way is determined by the order in which users reach the intersection. If two vehicles arrive at the intersection at nearly the same time, then the vehicle on the right has the right-of-way.

Considerations

All-Way Stop Control can be a simple, effective, and low-cost solution. Intersections with Minor Road Stop Control may benefit from conversion to All-Way Stop Control when limited sight distance or other safety concerns are present. However, All-Way Stop Control intersections have the lowest capacity of any intersection control strategy.

Mode Accommodations

As a conventional intersection control strategy, All-Way Stop Control intersections entail traditional considerations for non-motorists, large vehicles, and other mode users, which are presented in **Section A.1.1**.

A.2.3 Signalized Control

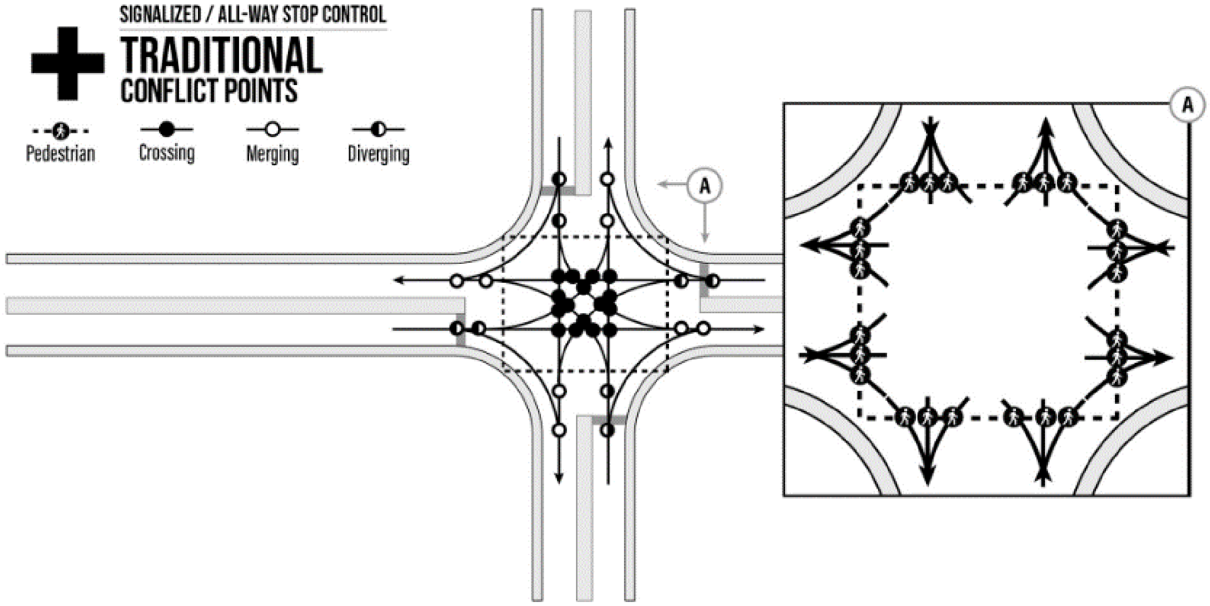

Figure A-3: Diagram of Traditional Movement-Based Conflict Points for Signalized Intersections

Source: FHWA

Description

The traditional signalized intersection control strategy refers to signalization at conventional three or four-legged intersections, where each approach is controlled through protected, permissive, or prohibited lights on the traffic signal. Traditional signalization allows direct movements (left, thru, and right) on all approaches. Additional traffic control devices may be used by FDOT or local agencies to restrict certain movements.

Considerations

As the most common form of control for higher volume intersections, signalization is fully established and generally understood by users. However, the traditional signalization strategy may increase delay at higher volumes compared to innovative intersections.

Mode Accommodations

When implemented in a conventional configuration, signalized intersections entail traditional considerations for non-motorists, large vehicles, and other mode users, which are presented in **Section A.1.1**.

A.2.4 Roundabout

Subtypes: Single-lane, Multi-lane

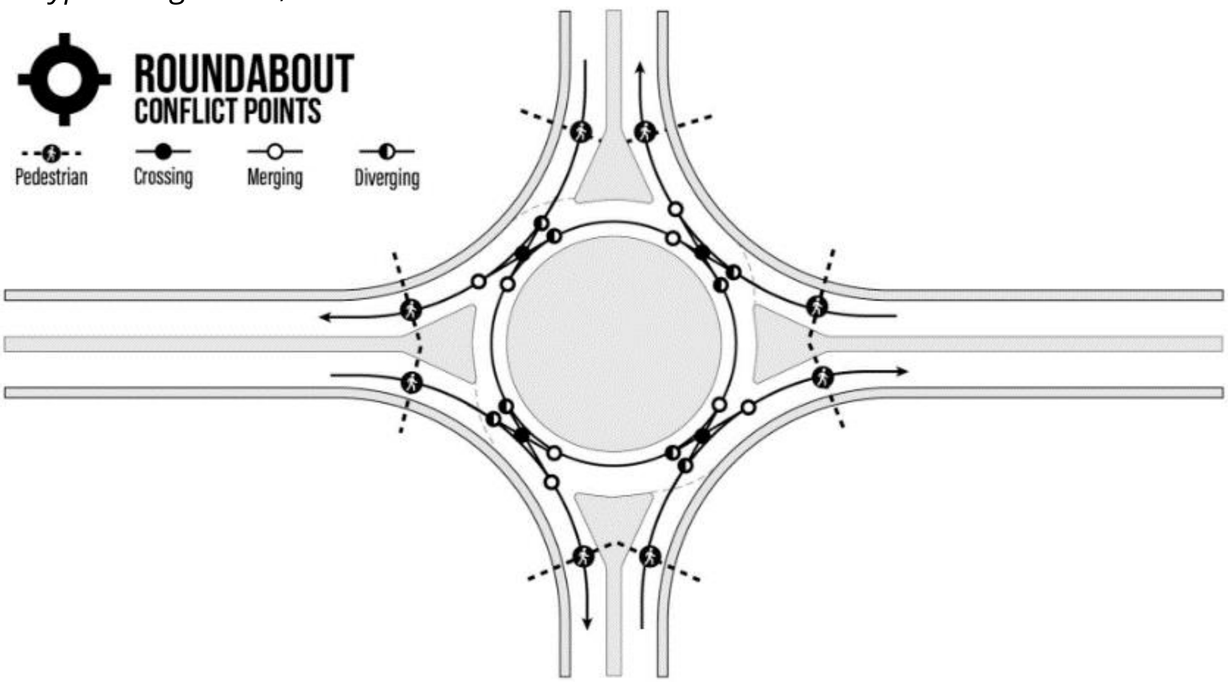

Figure A-4: Diagram of Movement-Based Conflict Points for Single-Lane Roundabouts
Source: FHWA

Description

Roundabouts feature yield control for all entering vehicles, channelized approaches, and horizontal curvature to induce desirable vehicle speeds. Three roundabout geometries are commonly considered:

- Single-lane (or "1x1") roundabout, at which all approaches yield to a single circulating lane.
- "2x1" roundabout, at which 2 lanes in each direction are present on the major road, yielding to one circulating lane, and 1 lane in each direction is present on the minor road, yielding to two circulating lanes.
- "2x2" roundabout, at which two lanes in each direction are present on all approaches, yielding to two circulating lanes.

Both "2x1" and "2x2" roundabouts are commonly referred to as multi-lane roundabouts. Roundabouts with three or more circulating lanes should generally be avoided.

Considerations

Roundabouts feature fewer conflict points than conventional intersections, lower design speeds within the circulating roadway, and shallower collision angles, typically resulting in less fatal and injury crashes compared to signalized intersections. By slowing vehicles through roadway geometry instead of signalization, roundabouts operate at a steady pace that, in many cases, reduces delay, noise, and idling emissions compared to signalized control.

NCHRP Report 1043: *Guide for Roundabouts* provides guidance for all aspects of roundabout planning and implementation, including operational analysis and example of ICE process for consideration. Depending on the intersection AADT and the percentage of left-turn movements, single-lane roundabouts generally perform well up to 17,000 vehicles per day (vpd) and may accommodate up to 25,000 to 28,000 vpd based on additional analysis. Multi-lane roundabouts generally perform well up to 25,000 to 30,000 vpd, with the potential to accommodate up to 37,500 to 44,000 vpd based on additional analysis.

Roundabouts may result in an initial increase in the total number of crashes, particularly in areas where roundabouts are uncommon and drivers are unfamiliar with the operation. The increase in total crashes is typically short-term and may not be a concern in areas where roundabouts are common. In addition, roundabouts typically require more right-of-way than conventional intersections, entailing a higher installation cost.

Mode Accommodations

Pedestrian crossings are located across each leg of the roundabout, typically separated from the circulatory roadway by at least one vehicle length. Channelization islands should be wide enough at these locations to provide a pedestrian refuge and facilitate two-stage crossing.

Bicyclists may ride in the roadway with vehicles or transition to multi-use paths via bicycle ramps (if present). Bike lanes should not be used at roundabouts.

The width of the circulating roadway should be wider than a typical travel lane to accommodate turning movements, particularly for larger vehicles. Larger design vehicles may be accommodated by concrete truck aprons located within the center island or outside the circulating lane between approaches.

A.2.5 Median U-Turn (MUT)

Subtypes: Full, Partial

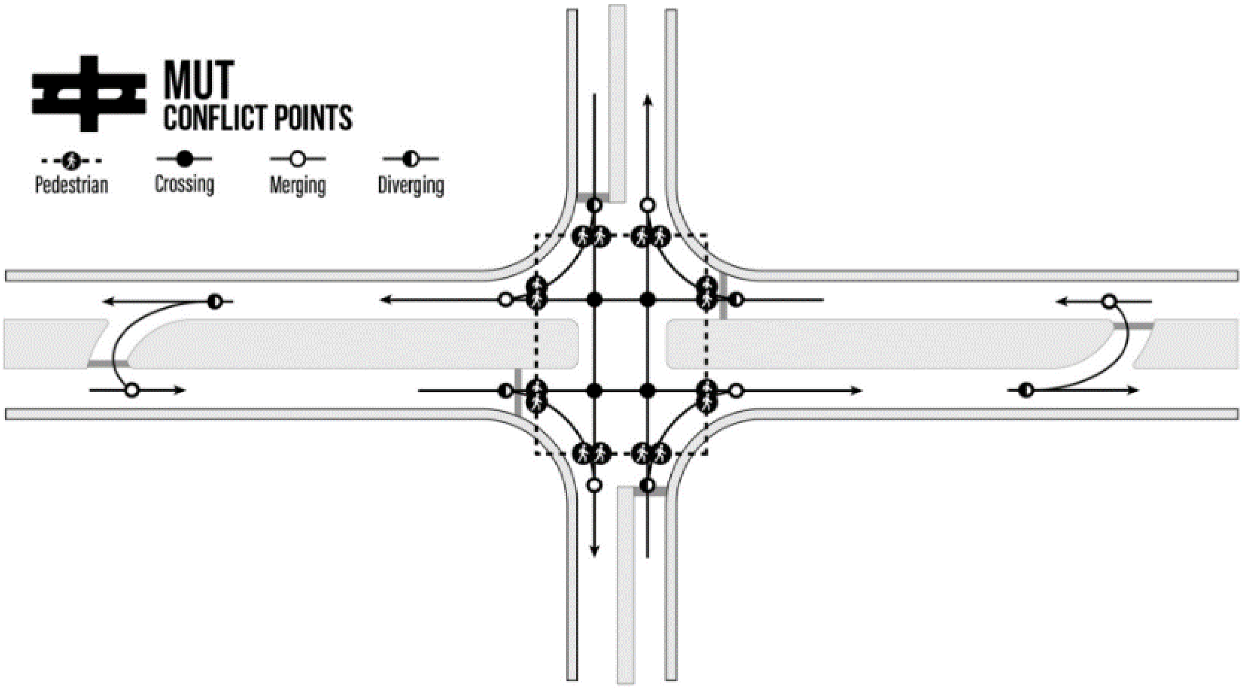

Figure A-5: Diagram of Movement-Based Conflict Points for MUT Intersections
Source: FHWA

Description

The Median U-Turn (MUT) intersection control strategy eliminates direct left turns at signalized intersections and replaces them with U-turns on the major street. These U-turn movements can be either signalized or unsignalized.

Full MUTs eliminate direct left turns from the major and minor approaches, while partial MUTs eliminate direct left turns from only the major approaches, allowing left turns from the minor street to pass through the median. The MUT intersection control strategy can be effectively implemented along a corridor or at a single intersection location.

Considerations

MUTs require out-of-direction travel for left-turn movements and either a wider median or additional right-of-way to facilitate U-turn movements, especially for larger vehicles. When wider medians are used, longer clearance intervals are required for the cross-street signal phase. In either case, MUTs offer fewer signal phases and conflict points than a conventional signal, and they are better suited to handle higher cross-street through volumes than RCUTs.

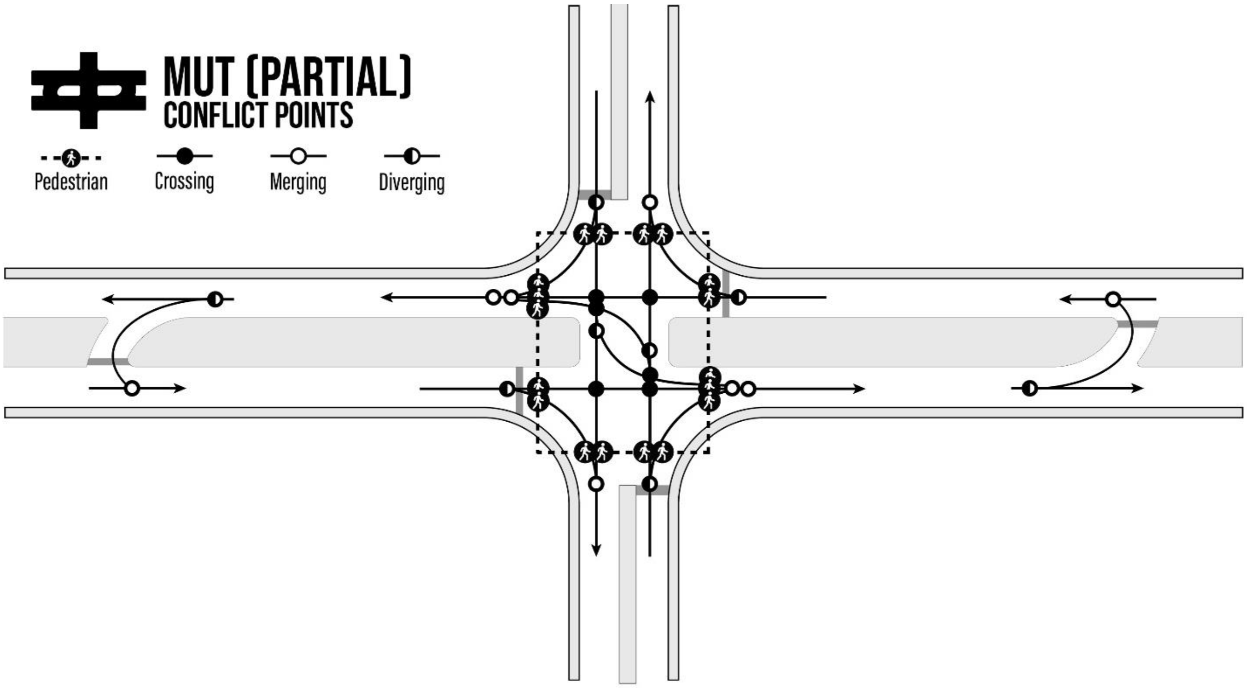

Figure A-6: Diagram of Movement-Based Conflict Points for Partial MUT Intersections

Mode Accommodations

Pedestrian crossings at MUTs may be one-stage or two-stage depending on median width and other factors. When wider medians are used, MUTs often feature two-stage crossings, which may shorten signal intervals but increase pedestrian delay. Generally, one-stage crossings are more desirable for pedestrians but result in longer signal cycles.

Increased right-turn volumes from the minor street may lead to more vehicle-pedestrian conflicts, which can be mitigated through leading pedestrian intervals or prohibiting right-turn-on-red. In addition, midblock crossings may be provided at the median U-turn crossover with minimal delay to outbound traffic.

Bicyclists making left-turn movements from the major or minor street may do so by following the same procedure as motor vehicles or by using pedestrian crossings. Installation of a two-stage bicycle turn box may also be considered to facilitate direct left turns for bicycles.

A.2.6 Restricted Crossing U-Turn (RCUT)

Subtypes: Signalized, Unsignalized

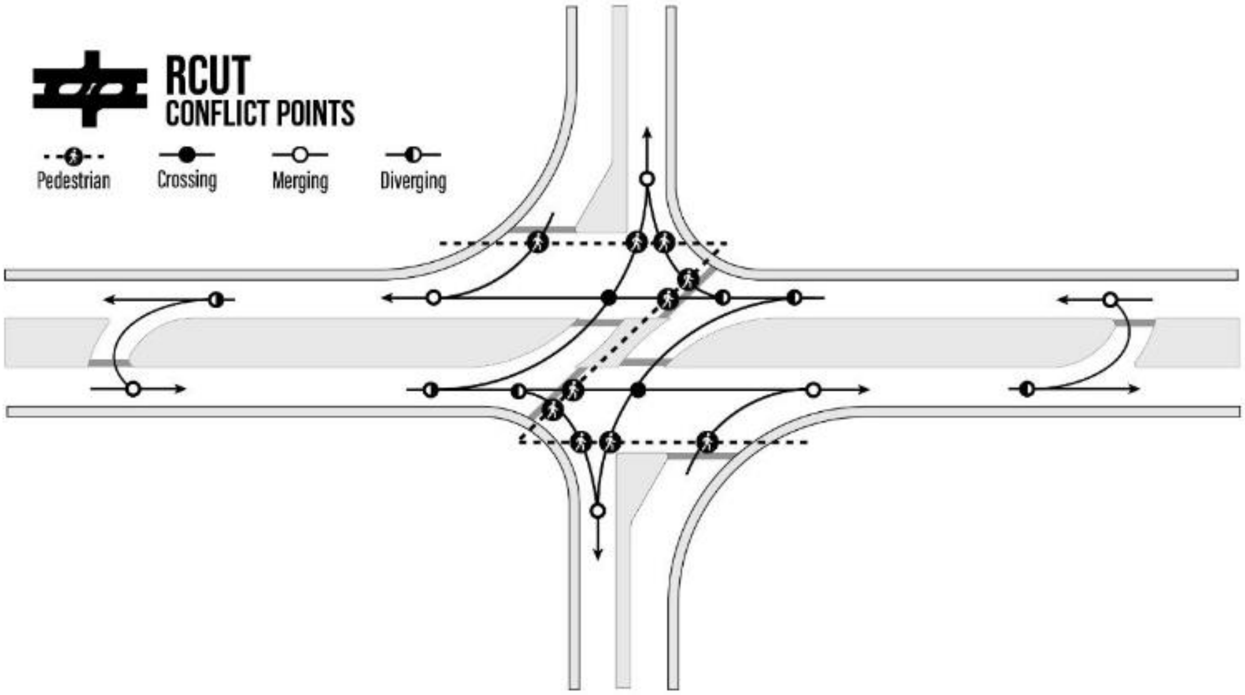

Figure A-7: Diagram of Movement-Based Conflict Points for RCUT Intersections
Source: FHWA

Description

The Restricted Crossing U-Turn (RCUT) intersection control strategy restricts left-turn and through movements from the minor street approaches. To complete left-turn and through movements, minor street traffic turns right onto the major street and making a U-turn at the median opening, typically 400 to 800 feet after the minor street intersection for signalized RCUTs and 600 to 1,000 feet after the intersection for unsignalized RCUTs. Like MUTs, RCUTs feature a wider median or U-turn bulb-outs on the major street to accommodate U-turn movements.

Unsignalized RCUTs, also known as J-Turn intersections, are typically present in rural areas and facilitate minor street demands of 5,000 vpd or less. Signalized RCUTs are more prevalent in urban areas and may facilitate a minor street demand of up to 25,000 vpd, based on the proportion of left and opposing through movements. While both MUTs and RCUTs can be controlled by two signal phases at the central intersection, the restriction on minor street through movements gives RCUTs a unique operational advantage, allowing each direction on the major street to be controlled as if they were separate one-way streets, improving signal coordination when multiple RCUTs are installed sequentially. The term “superstreet” refers to such corridors.

Considerations

RCUTs require out-of-direction travel for left-turn movements and either a wider median or additional right-of-way to facilitate U-turn movements. RCUTs offer fewer signal phases and conflict points than conventional intersections; however, they are not as suitable as MUTs for facilitating higher volumes of minor street through movements. Instead, RCUTs offer the unique operational advantage of restricting traffic crossing the major street, allowing both directions to be treated as a “one-way couplet” if signalized.

Mode Accommodations

Pedestrian crossings on the major road are usually accommodated on one diagonal “Z” path from one corner to the opposite corner of the intersection with signalization. Direct paths across all four legs are also possible. Like MUTs, mid-block crossings may be provided at the median U-turn locations.

Increased right-turn volumes from the minor street may result in more conflicts between vehicles and pedestrians, which can be mitigated through leading pedestrian intervals or prohibiting right-turn-on-red.

Bicyclists performing through or left-turn movements from the minor street can use pedestrian crossings to avoid U-turn movements. At rural, unsignalized RCUTs where dedicated pedestrian facilities may not be provided, cut throughs in the median island can facilitate direct crossings on the minor street for bicyclists.

A.2.7 Jughandle

Subtypes: Forward Ramps, Reverse Ramps

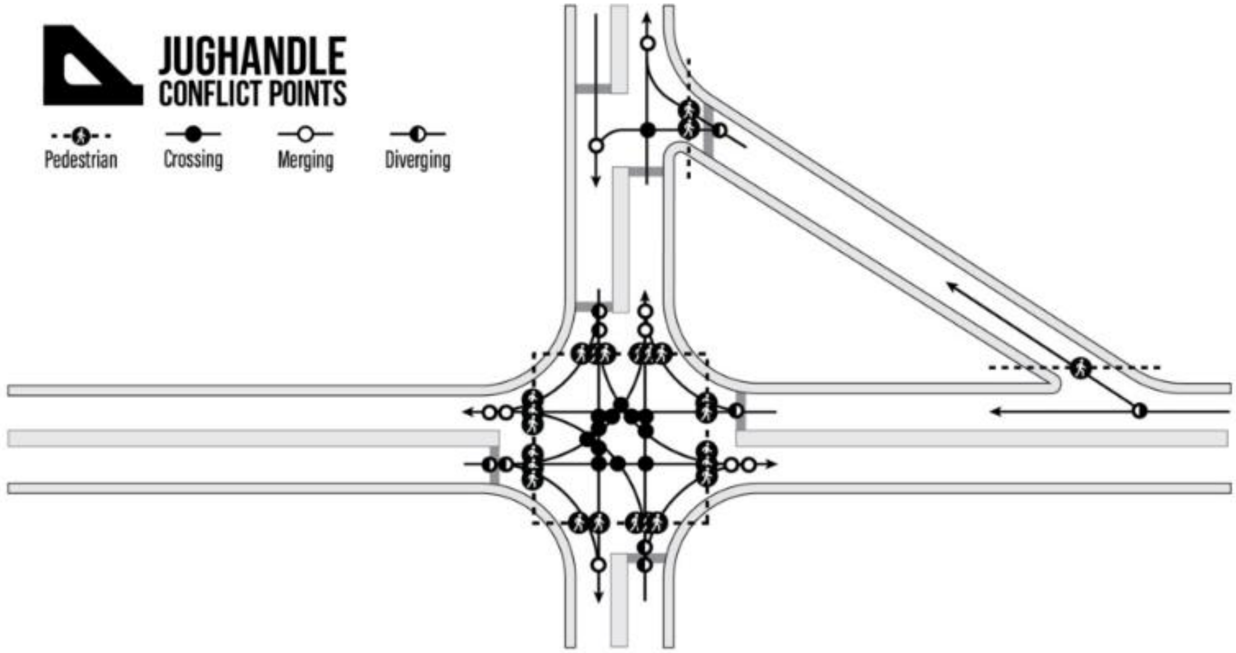

Figure A-8: Diagram of Movement-Based Conflict Points for Jughandle Intersections (Forward Ramp Configuration)
Source: FHWA

Description

The Jughandle intersection control strategy uses one or more at-grade ramp connectors (or “jughandles”) between intersecting roads to facilitate indirect left-turns or U-turns. While the main intersection is signalized, left turns from the at-grade ramp connector are stop-controlled, and right turns may be either stop-controlled or yield-controlled.

The at-grade ramp connector(s) can be located upstream or downstream of the minor street. A forward ramp configuration is more common and uses a diagonal ramp upstream of the minor street, while a reverse ramp configuration uses a loop connector downstream of the minor street.

Considerations

Jughandle intersections offer fewer phases and conflict points than a conventional signal. However, they also require out-of-direction travel for certain left-turn movements and additional right-of-way requirements, beyond those that would be required for widening. The Jughandle intersection control strategy is suitable for intersections with relatively low left-turn volumes and may reduce the rate of right-angle crashes.

Mode Accommodations

With the addition of the diagonal ramp or loop connector, pedestrians and bicyclists may need to cross an additional street compared to a conventional signalized intersection. However, the conflicting volumes and movement types do not differ greatly from conventional intersections.

A.2.8 Displaced Left-Turn (DLT)

Subtypes: Full, Partial

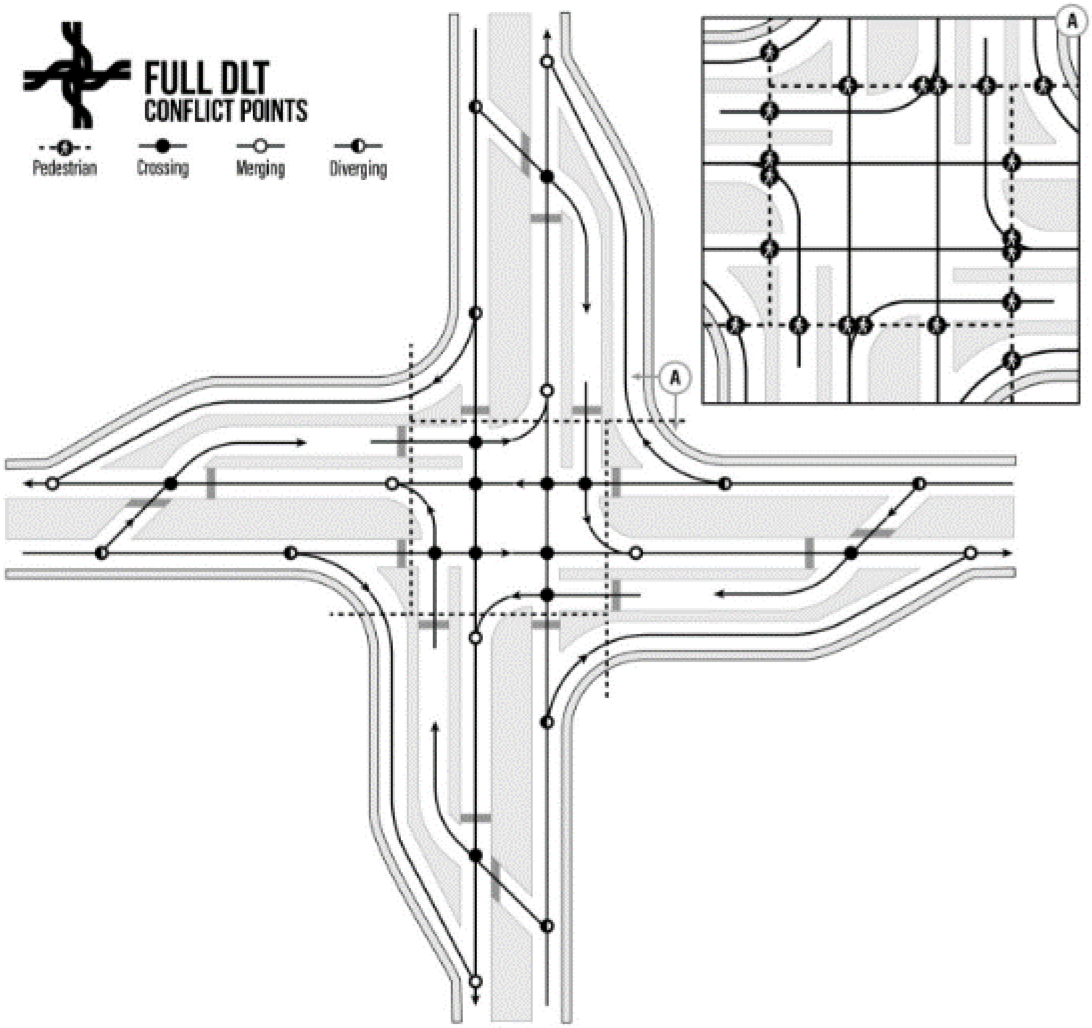

Figure A-9: Diagram of Movement-Based Conflict Points for Full DLT Intersections

Source: FHWA

Description

The Displaced Left Turn (DLT) intersection control strategy relocates one or more left-turn movements to the other side of the opposing traffic flow. On each affected approach, left-turning traffic crosses over to the left-hand side of the road at a secondary signalized intersection located several hundred feet upstream of the central junction. Left-turn movements then proceed through the intersection simultaneously with the through movements without conflicting one another, eliminating the left-turn phase on the approach and reducing the number of intersection conflict points.

DLTs may be either full or partial in nature. At full DLTs, left turns are displaced on all intersection approaches, while at partial DLTs, left turns are only displaced on major street, as shown in Figure A-9.

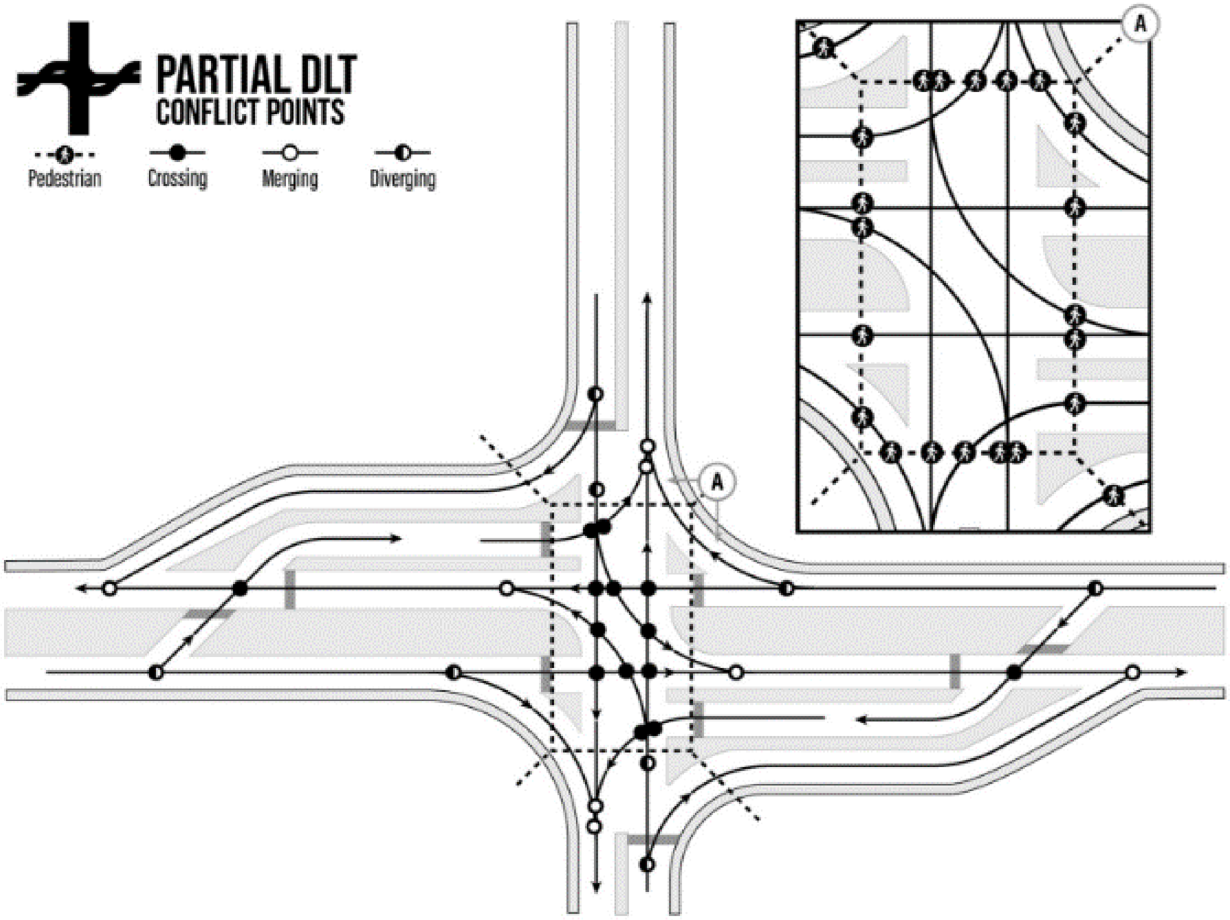

Figure A-10: Diagram of Movement-Based Conflict Points for Partial DLT Intersections

Source: FHWA

Considerations

By eliminating the left-turn signal phase on displaced approaches, DLTs are especially equipped to handle higher volumes of left-turn and through movements and feature fewer signal phases than a conventional signal. Fewer signal phases may yield improved coordination with adjacent signals.

While DLTs may significantly improve operations at a single location or along a corridor, they require substantial right-of-way. The displacement of traffic to the left-hand side of the road may result in traffic approaching from an unexpected direction. In addition, the crossing over of traffic several hundred feet in advance of the intersection may result in significant access restrictions within the intersection footprint. However, this displacement does reduce the number of crossing conflict points at the main intersection and may reduce the frequency of crashes associated with left-turning vehicles.

Mode Accommodations

U-turns at the main intersection are not possible on displaced approaches at a DLT intersection given the shifting of the left turn lanes to the other side of the opposing through lanes. Instead, it is possible to accommodate U-turn movements using a downstream median opening if necessary. (At a partial DLT intersection, U-turns may still be performed on the minor street approaches.)

Pedestrians may be required to cross more travel lanes than at a conventional intersection, and direction of traffic at pedestrian crossings may be counterintuitive. Many DLT intersections are set up for pedestrians to cross in multiple stages with median refuge islands, slightly mitigating this risk.

Crosswalks may be lined up between outbound travel lanes and inbound left turn lanes (as shown in Figures A-8 and A-9) or outside of the inbound left turn lanes (similar to a conventional intersection). Aligning crosswalks to land between outbound travel lanes and inbound left turn lanes for concurrent movement of pedestrians and left turning vehicles; however, this may be disorienting or uncomfortable to pedestrians who are unfamiliar with the intersection. On the other hand, aligning crosswalks outside of the inbound left turn lanes may require use of protected left turns to avoid vehicle-pedestrian conflicts.

Design techniques, such as two-stage left turn boxes, are available to facilitate direct left-turns for bicyclists, although these would only likely be used by the most confident bicyclists. Instead, shared-use paths and protected bicycle lanes should be strongly considered.

A.2.9 Continuous Green T (CGT)

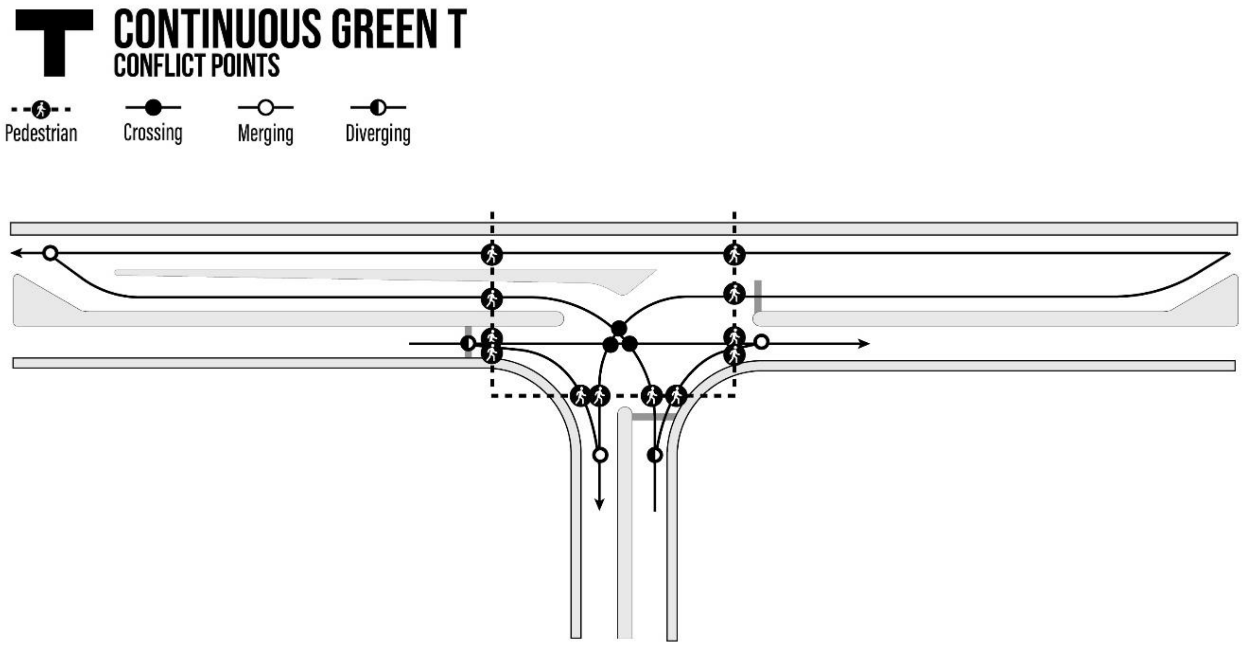

Figure A-11: Diagram of Movement-Based Conflict Points for Continuous Green T Intersections

Description

The Continuous Green-T (CGT) intersection control strategy is used at signalized 3-leg intersections, featuring a raised channelization that separates the “top” through movement from the other movements of the intersection, enabling the top through movement to operate uncontrolled with no conflicting movement.

Considerations

At CGT intersections, one direction of traffic never has to stop. However, this free-flowing traffic decreases the feasibility of pedestrian travel across the major street.

Mode Accommodations

Permissive pedestrian crossings are provided across the minor street at the signal. Due to the continuous flowing nature of through movements on one of the major approaches, pedestrian movements across the mainline must be provided using an actuated pedestrian signal phase that stops traffic on both major road approaches, including the continuous through movement. This can disrupt driver expectation. Alternatively, pedestrian movements across the mainline can be accommodated at an adjacent intersection or via a mid-block crosswalk, as appropriate.

A.2.10 Quadrant Roadway (QR)

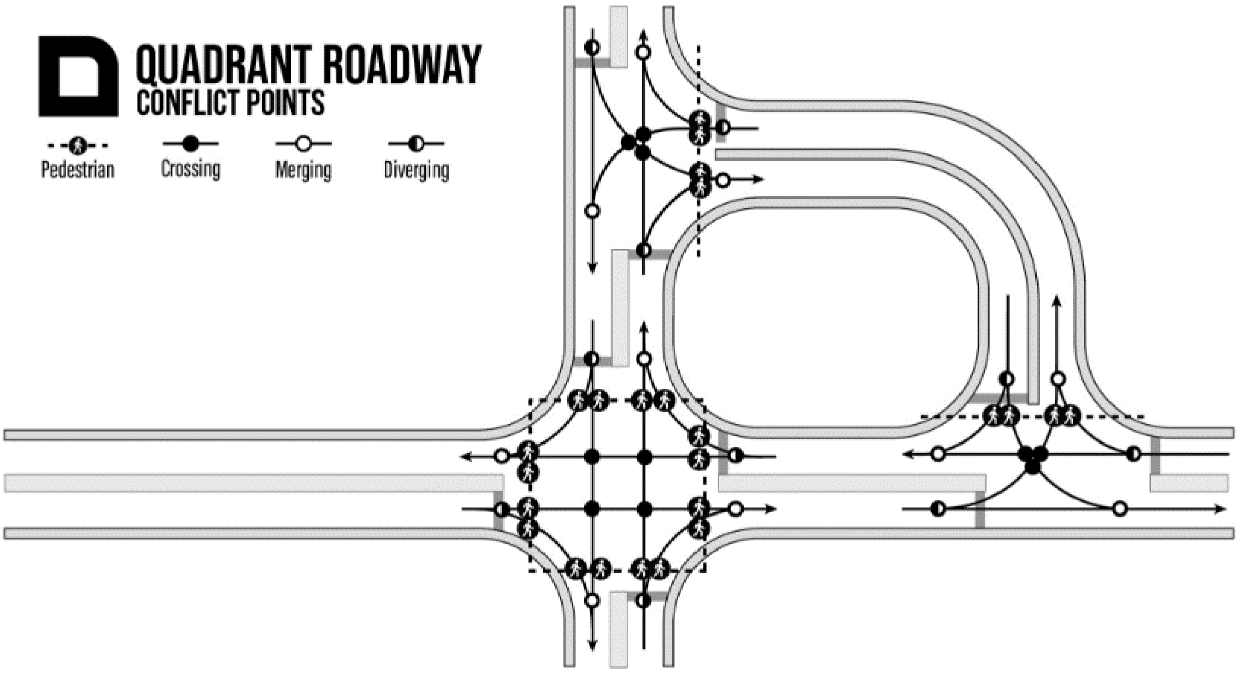

Figure A-12: Diagram of Movement-Based Conflict Points for Quadrant Roadway Intersections-
Source: FHWA

Description

A Quadrant Roadway (QR) intersection is intended to eliminate all direct left-turn movements from the main intersection by re-routing them to turns to and from a connector roadway located in one quadrant.

Considerations

The QR design has the advantage of reducing the necessary signal phases at the main intersection. The consequence is that some movements require out-of-direction travel and may necessitate additional signing and road user education. Furthermore, the connector roadway increases the required right-of-way for the intersection and may introduce challenges with access management.

Mode Accommodations

Depending on the location of sidewalks, some pedestrians are required to cross an extra street to make their desired movement compared to a conventional intersection. These additional conflicts can be mitigated using LPI, exclusive pedestrian phasing, or other treatments. The two-phase signal operation reduces pedestrian delay at the main intersection. Treatments such as two-stage turn boxes can be used at the main intersection to facilitate bicyclist left turns.

A.2.11 Thru-Cut

Subtypes: Signalized, Unsignalized

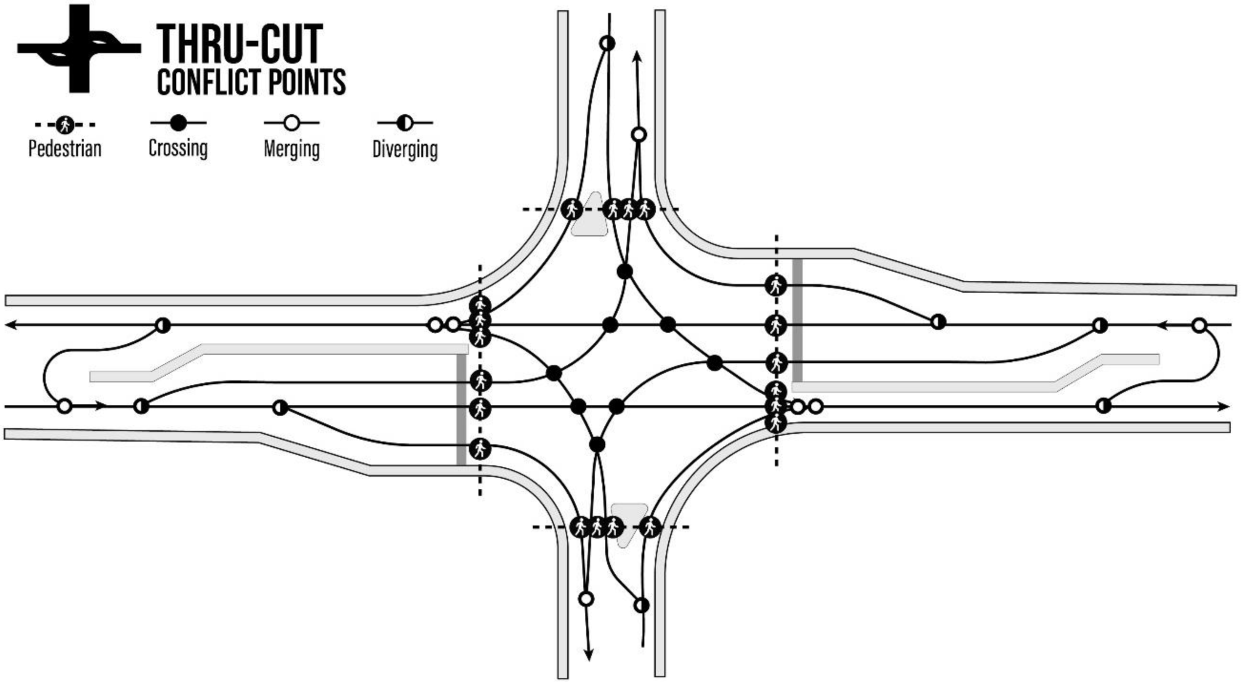

Figure A-13: Diagram of Movement-Based Conflict Points for Thru-Cut Intersections

Description

The Thru-Cut intersection design restricts through movements from the minor street approaches. In this way the Thru-Cut is similar to the RCUT, with the key difference being that it allows direct left turns from the minor approaches. Signalized Thru-Cut intersections effectively provide protected left turns for the minor approaches. Thru-Cuts can also operate with minor road stop control.

Considerations

Through movements from a minor road approach are replaced with a right turn, U-turn, right turn sequence. This results in some out-of-direction travel and requires either a wide median or additional right-of-way for downstream U-turn bulb-outs or loons.

Mode Accommodations

Pedestrian crossings can be similar to a conventional intersection, with crosswalks on all four legs. Increased right-turn volumes from the minor street may result in increased vehicle-pedestrian conflicts. At signalized Thru-Cuts, this can be mitigated by prohibiting right turn on red. Unsignalized Thru-Cuts are typically located in more rural contexts where pedestrian volumes are lower, but appropriate facilities should be provided if pedestrian demand exists. Bicyclists on the minor road approaches can use pedestrian crossings to avoid the use of the downstream U-turn. The wide median necessary for the U-turn openings can facilitate two-stage crossings for pedestrians and bicyclists.

A.2.12 Bowtie

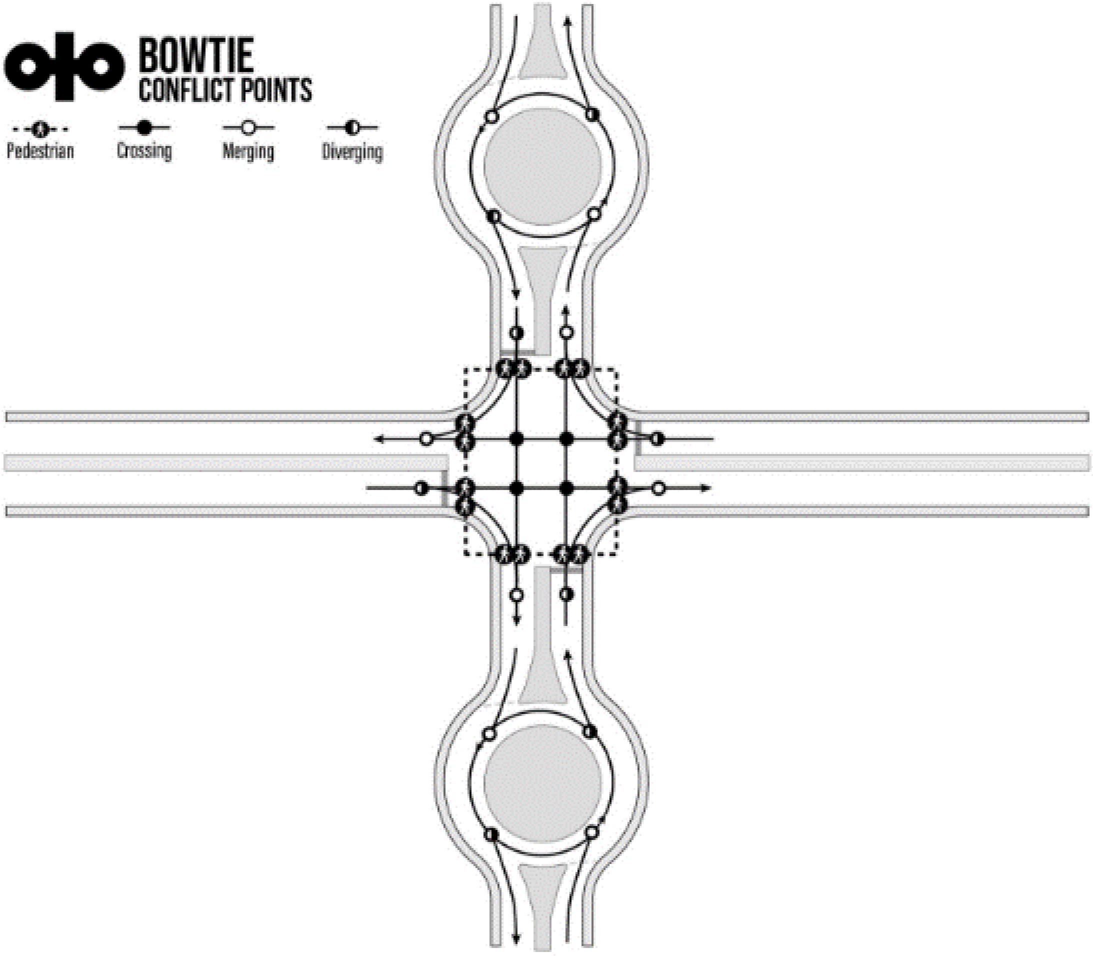

Figure A-14: Diagram of Movement-Based Conflict Points for Bowtie Intersections
Source: FHWA

Description

Bowtie intersections eliminate direct left turns from all approaches and replace them with U-turns executed via roundabouts on the minor street. The roundabouts can have two or more legs.

Considerations

Bowtie intersections are most effective in situations with higher through volumes and lower turning volumes on the major road. Removal of direct left turns at the main intersection allows for two-phase signal operations. However, the result is that left turn movements must make some out-of-direction travel. The bowtie intersection may be effective in situations where the major road right-of-way does not allow for the wide median required for designs such as the RCUT, MUT, or Thru-Cut, or where the right-of-way at the main intersection is not sufficient for a conventional roundabout. However, the roundabouts on the minor road approaches require additional right-of-way and may introduce challenges with access management. If the roundabouts have more than two legs this may introduce additional conflicts.

Mode Accommodations

Increased right-turn volume on all approaches may lead to increased vehicle-pedestrian conflicts. This can be mitigated by using LPI, prohibiting right turn on red, or implementing other treatments. Two-stage turn boxes can be implemented to allow bicyclist left turns at the main intersection. Pedestrians and bicyclists should be considered at the adjacent roundabouts as well as the main intersection. See section A.2.4 for further discussion of roundabout-specific pedestrian and bicyclist treatments.

A.3 Ramp Terminal Intersection Control Strategies

A.3.1 Diamond (Stop Control)

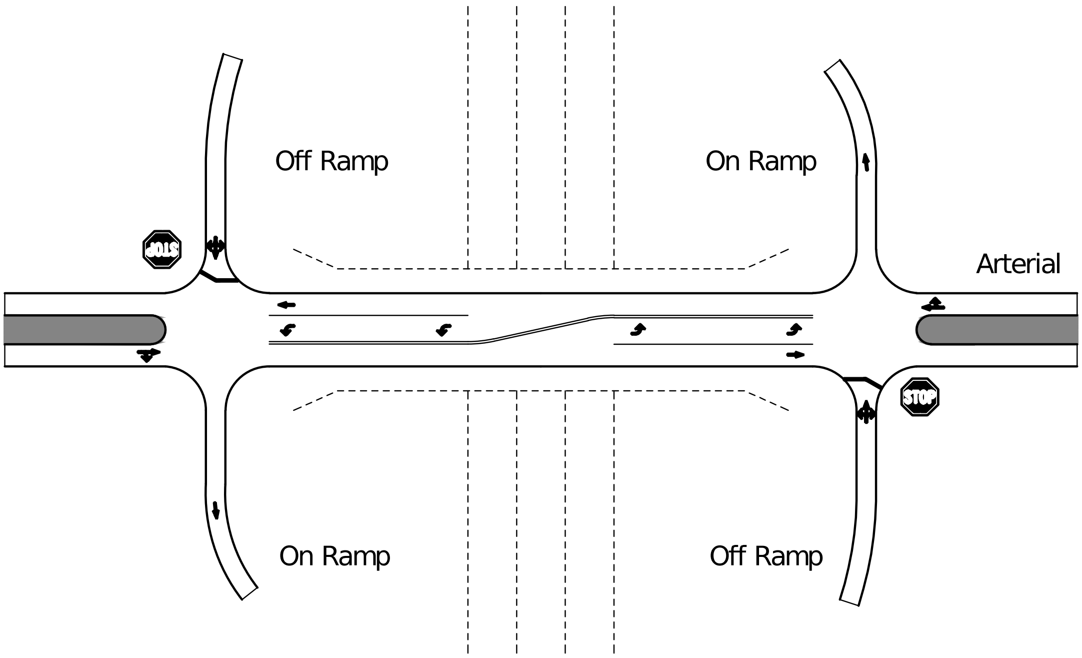

Figure A-15: Diagram of Stop Control at a Diamond Ramp Terminals

Description

The Diamond (Stop Control) ramp terminal configuration is a conventional control strategy in which the ramp terminal approaches are stop-controlled and the cross-street movements do not encounter any traffic control devices. Through- and right-turn movements on the cross-street approaches are free-flow movements, while left-turn movements are yield-controlled. This ramp terminal configuration operates as two Minor Road Stop Control intersections, typically spaced 650 to 1,000 feet apart. (See **Section 0** for more information on Minor Road Stop Control.)

Considerations

The Diamond (Stop Control) ramp terminal configuration is a common ramp terminal control strategy and is easily understood by road users. It is simple and low-cost to implement, but it is not effective in serving higher traffic volumes.

Mode Accommodations

Pedestrians crossing any approach have the right-of-way; however, the lack of traffic control on the cross street and entry to the on-ramps does not provide any protected pedestrian movement. Pedestrians crossing the ramp terminals have some support through the stop-control on the ramp terminal.

Consider enhanced pedestrian crossing accommodations (signs, markings, refuge, beacons) to improve driver yielding rates and pedestrian safety, particularly for multilane, higher speed, and higher volume roads.

Large trucks exhibiting slower acceleration rates may experience increased difficulty in making through and left-turn movements from the ramp terminals. *Section 9.5.3* of the AASHTO *Policy on Geometric Design of Highways and Streets* provides additional guidance and inputs to determine the appropriate intersection sight distances for large vehicles.

A.3.2 Diamond (Signal Control)

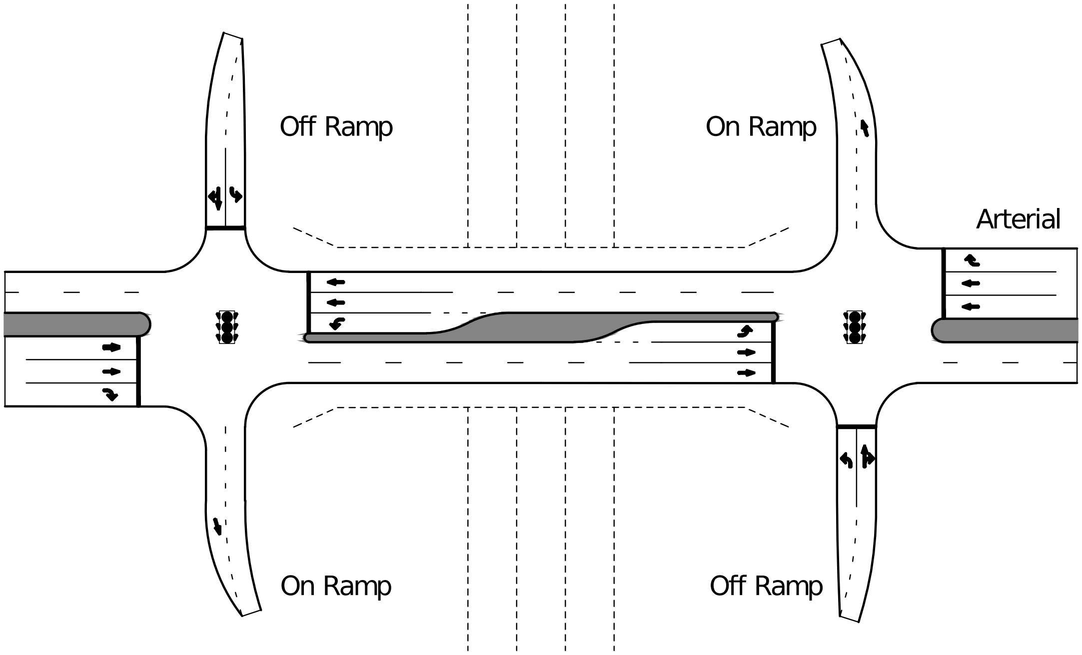

Figure A-16: Diagram of Signal Control at Diamond Ramp Terminals

Description

The Signalized Diamond ramp terminal control strategy is a conventional configuration in which each approach is controlled by a traffic signal. Ramp terminals at signalized diamond interchanges are typically 650 to 1,000 feet apart, allowing the ramp terminal intersections to operate independently as two signalized intersections.

Considerations

As the most common form of control for ramp terminals at higher volume service interchanges, the Signalized Diamond is fully established and generally understood by users. However, this conventional control strategy may increase delay at higher volumes compared to alternative ramp terminal control.

Mode Accommodations

Pedestrian crossings across the cross street are typically provided on the outside of the ramp terminals. Crossings on the inside of ramp terminals will need additional signal consideration. Due to their conventional layout and a lack of free-flowing movements, Signalized Diamond ramp terminals give bicyclists the option to use general travel lanes, on-street bicycle facilities, or off-street bicycle facilities to effectively navigate the interchange.

A.3.3 Signalized Tight Diamond

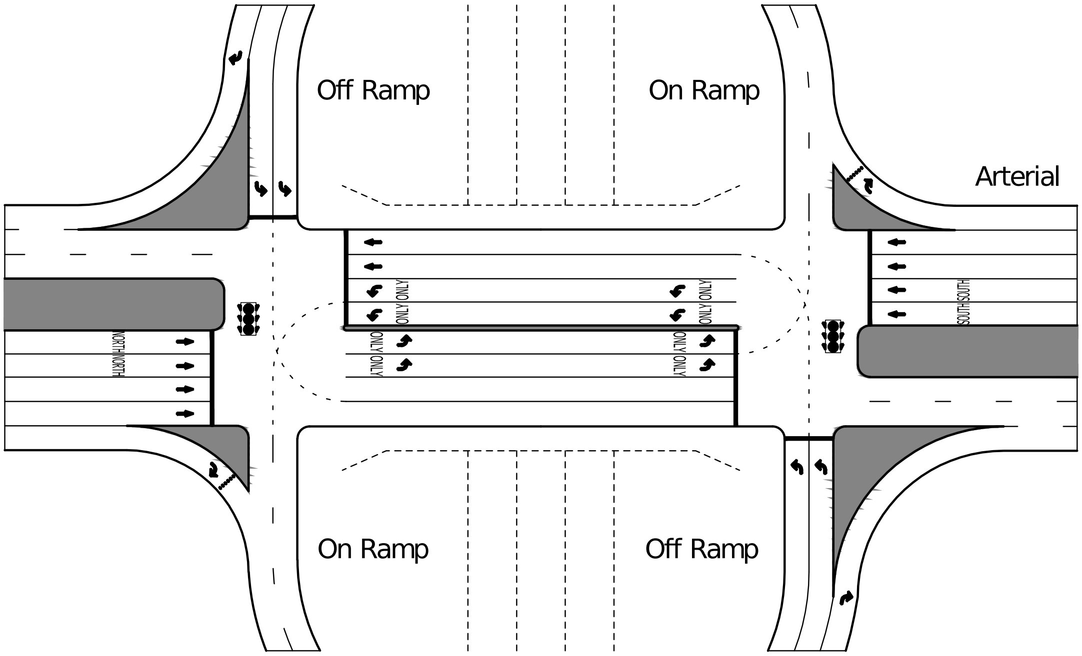

Figure A-17: Diagram of Signal Control at Tight Diamond Ramp Terminals

Description

The Signalized Tight Diamond ramp terminal control strategy is a compressed diamond design featuring two closely spaced intersections, approximately 200-400 feet apart. Left turn lanes are developed in advance of the upstream intersection.

Considerations

Signalized Tight Diamond interchanges require less right-of-way than traditional diamond interchanges, making them a valuable option for highly developed urban contexts or locations with significant topographic constraints.

Signalized Tight Diamond interchanges manage long left turn queues from the cross-street by developing left turn lanes ahead of the upstream intersection, resulting in wider bridge structure widths. Due to the close spacing between ramp terminal on the cross street, the signal phasing for both intersections should be coordinated.

Mode Accommodations

Mode accommodations at Signalized Tight Diamond ramp terminals are similar to those for Signalized Diamond ramp terminals. (See **Section** Error! Reference source not found. for Signalized Diamond ramp terminals.)

A.3.4 Single-Point Diamond

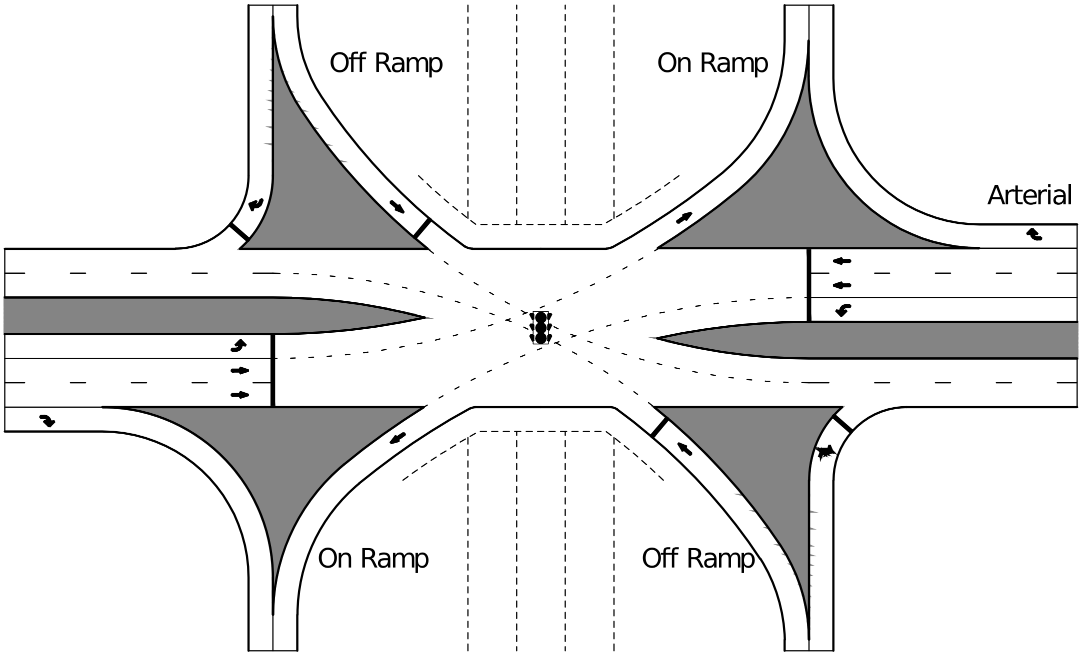

Figure A-18: Diagram of Intersection Control at Single-Point Diamond Ramp Terminals

Description

The Single-Point Diamond ramp terminal control strategy directs all left-turn movements from the ramp terminals and the cross street to a single intersection controlled by one traffic signal. Opposing left turn movements operate to the left of each other, allowing them to run concurrently without conflicting; however, this requires a protected signal phase, separate from that for cross-street through movements.

Right-turn movements from the cross-street are free-flow movements, while those from the ramp terminals are generally yield-controlled or served through permissive signal indications.

Considerations

Compared to conventional diamond interchanges, Single-Point Diamond interchanges typically exhibit reduced right-of-way requirements and greater capacity than diamond interchanges, as all movements can be served using a single controller. However, the geometry of this ramp configuration requires a wider structure, typically resulting in higher construction costs.

Mode Accommodations

Due to orientation of left-turn movements and presence of free-flowing right-turn movements at separate locations, intersections at Single-Point Diamond ramp terminals are particularly difficult for pedestrians and bicyclists to navigate. To avoid conflicts with vehicular traffic, consideration should be given to shared-use paths throughout the interchange area.

Pedestrians and bicyclists may cross the ramp terminal approaches with non-conflicting signal phases; however, the broader intersection footprint results in longer crossing distances. The use of pedestrian signals across the ramp terminal approaches may result in longer signal cycles and increased delay. Exclusive pedestrian phases are necessary if pedestrian crossings across the cross street are provided at the intersection.

A.3.5 Diverging Diamond

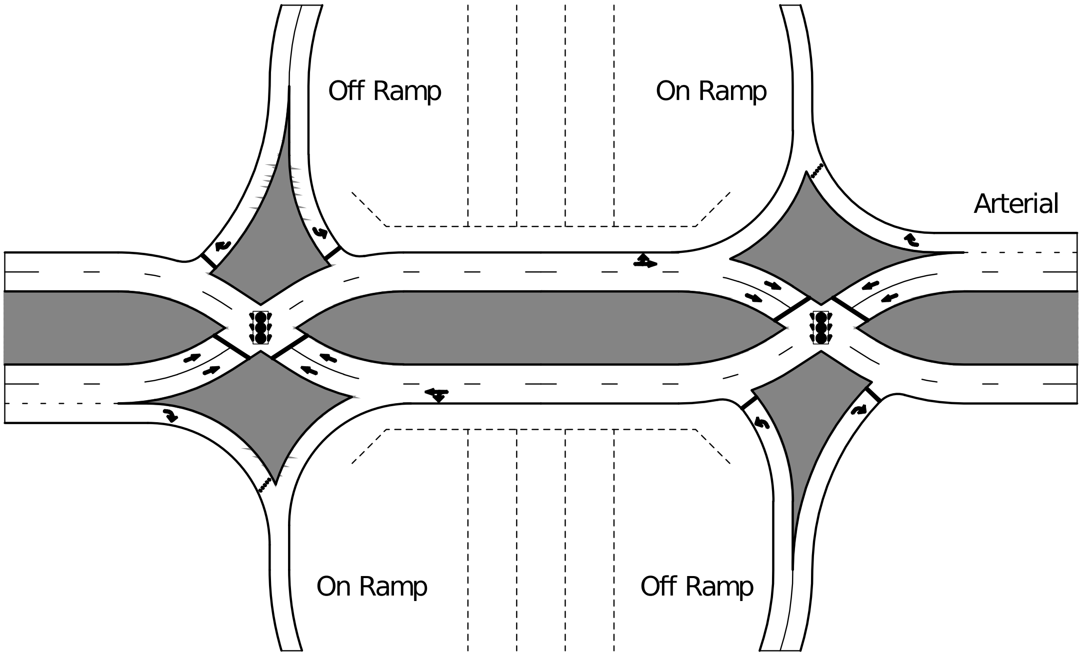

Figure A-19: Diagram of Intersection Control at Diverging Diamond Ramp Terminals

Description

Intersection control at Diverging Diamond (or Double Crossover) Interchanges (DDI) features a diamond design in which the cross-street through and left turning vehicles are routed onto the left side of the cross-street at the upstream signalized crossover. Right turn movements can be either free flowing or signalized. At the downstream crossover, cross-street vehicles return to the right side of the street.

Considerations

DDI's are becoming increasingly familiar to road users, but redirection onto the left side of the cross street still defies driver expectation. Additional right-of-way may be needed immediately upstream of each crossover to allow for proper alignment. However, DDI's can increase throughput without increasing bridge width, allowing existing bridges to be retained. Operationally, the Diverging Diamond intersection control strategy especially benefits interchanges with a high proportion of left turns, as left turns on and off the limited access facility turn without conflicting with through vehicles on the cross-street.

Mode Accommodations

The crossover geometry of DDI ramp terminals presents additional constraints for non-motorists to navigate. To reduce conflicts, a shared-use path may be provided in the cross-street median; however, this may be uncomfortable to pedestrians and bicyclists. As an alternative, a shared-use path may be provided on either side of the cross-street, providing more space for pedestrians and bicyclists but conflicting with the ramp turning movements, which may be signalized or free-flowing. In the case of signalized ramp terminals, pedestrians cross the ramp terminals with non-conflicting phases. Exclusive pedestrian phases are necessary if pedestrian crossings across the cross street are provided at the intersection. Bicyclists should exercise increased care when navigating a DDI and should utilize shared-use paths when provided.

A.3.6 Half-Diamond

Subtypes: Signalized, Stop Control

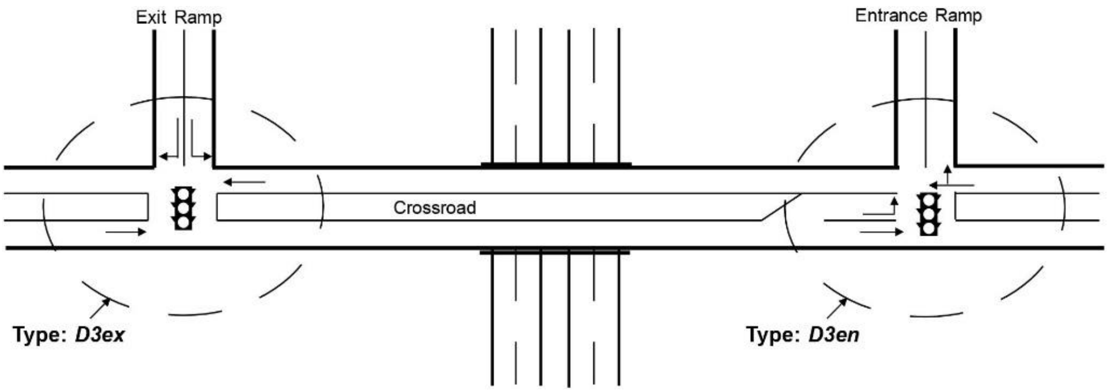

Figure A-20: Diagram of Intersection Control at Half Diamond Ramp Terminals

Description

The Half Diamond ramp terminal control strategy is present at interchanges that provide partial access between the cross street and limited access facility by having an entrance ramp and exit ramp in two interchange quadrants. Typically, a left-turn lane is provided from the cross-street to the entrance ramp. The ramp terminal intersections may be signalized, stop-controlled, or controlled by a roundabout. (Please refer to **Section 0** for more information about ramp terminal intersections controlled by roundabouts.)

Considerations

Intersections at Half Diamond ramp terminals are generally lower volume due to limited freeway access. However, these intersections may be confusing to some drivers as full freeway access is not provided.

Mode Accommodations

Half Diamond ramp terminals are controlled through conventional means, entailing traditional considerations for bicycles, pedestrians, and large vehicles.

A.3.7 Four-Quadrant Partial Cloverleaf A

Subtypes: Signalized, Stop Control

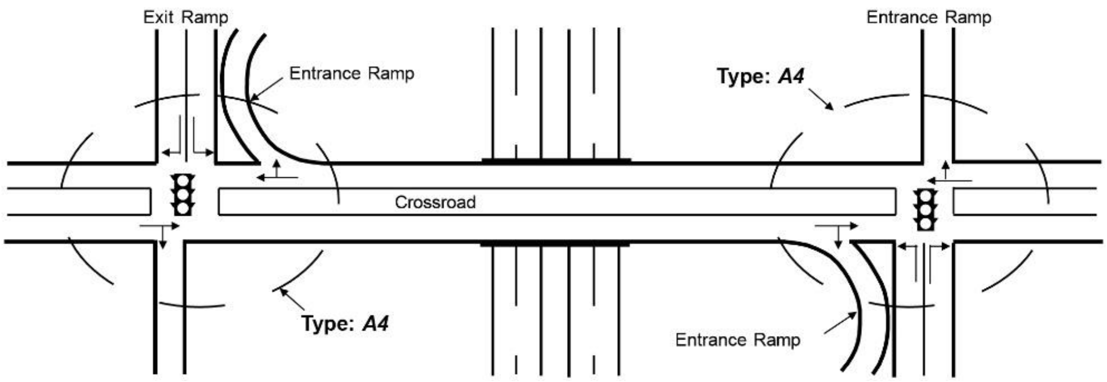

Figure A-21: Diagram of Intersection Control at Four-Quadrant Partial Cloverleaf Ramp Terminals - Type A

Description

The Partial Cloverleaf A interchange has two entrance loop ramps. The four-quadrant variant of this interchange incorporates two additional exit ramps to provide free-flow movements from the cross street to the limited access facility in both directions, eliminating left-turn movements from the cross street at the ramp terminal intersections.

The two intersections at which the ramp terminals are present may be signalized or stop-controlled. If signalized, the ramp terminal intersections each have two-phase signal operation, with one left-turn movement from the exit ramp.

Considerations

By providing a combination of entrance loops and diagonal ramps in both directions, left-turn movements at the ramp terminal intersections are eliminated, enabling two-phase signal operation and reducing delay. However, Four-Quadrant Partial Cloverleaf interchanges require more right-of-way than Two-Quadrant Partial Cloverleaf interchanges.

Mode Accommodations

When the ramp terminals are stop-controlled, large trucks exhibiting slower acceleration rates may experience increased difficulty in making through and left-turn movements from the ramp terminals. *Section 9.5.3* of the AASHTO *Policy on Geometric Design of Highways and Streets* provides additional guidance and inputs to determine the appropriate intersection sight distances for large vehicles.

Similar to ramp terminals at diamond interchanges, cross-street pedestrian crossings at partial cloverleafs should be located outside of the ramp terminal intersections. Due to the presence of loop ramps, consideration should be given to shared-use paths throughout the interchange area. Please refer to **Section 0** for additional pedestrian accommodations at loop ramps and diagonal ramp terminals.

A.3.8 Two-Quadrant Partial Cloverleaf A

Subtypes: Signalized, Stop Control

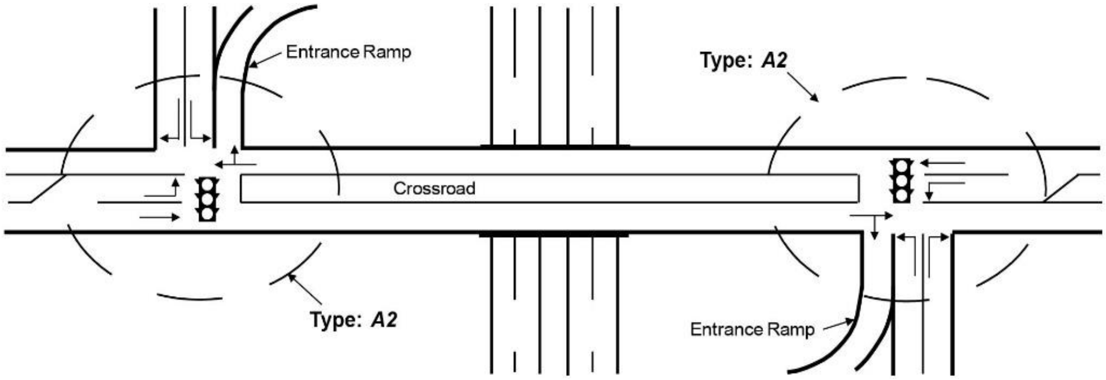

Figure A-22: Diagram of Intersection Control at Two-Quadrant Partial Cloverleaf Ramp Terminals - Type A

Description

The Partial Cloverleaf A interchange has two entrance loop ramps. The two-quadrant variant of this interchange provides access to each entrance ramp from both cross-street directions, requiring left-turn movements to be completed at the ramp terminal intersections. The two intersections at which the ramp terminals are present may be signalized or stop-controlled. In both cases, the right-turn movement from the cross-street to the entrance ramp is typically free-flowing.

Considerations

Two-Quadrant Partial Cloverleaf interchanges provide full access while only impacting property in two interchange quadrants. However, this layout opens the potential for wrong-way movements at the ramp terminal intersections.

Mode Accommodations

When the ramp terminals are stop-controlled, large trucks exhibiting slower acceleration rates may experience increased difficulty in making through and left-turn movements from the ramp terminals. *Section 9.5.3* of the AASHTO *Policy on Geometric Design of Highways and Streets* provides additional guidance and inputs to determine the appropriate intersection sight distances for large vehicles.

Similar to ramp terminals at diamond interchanges, cross-street pedestrian crossings at partial cloverleafs should be located outside of the ramp terminal intersections. Due to the presence of loop ramps, consideration should be given to shared-use paths throughout the interchange area. Please refer to **Section 0** for additional pedestrian accommodations at loop ramps and diagonal ramp terminals.

A.3.9 Four-Quadrant Partial Cloverleaf B

Subtypes: Signalized, Stop Control

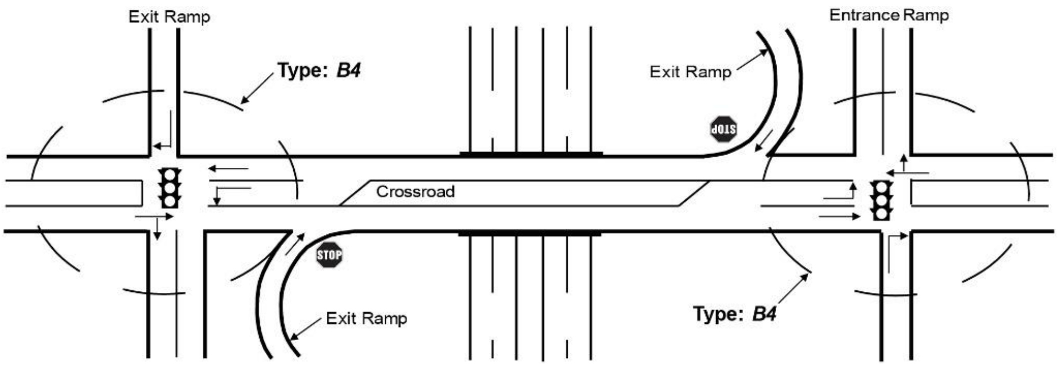

Figure A-23: Diagram of Intersection Control at Four-Quadrant Partial Cloverleaf Ramp Terminals - Type B

Description

The Partial Cloverleaf B interchange has two exit loop ramps that discharge into the cross street. The four-quadrant variant of this interchange incorporates two additional exit ramps to provide free-flow movements from the limited access facility to the cross street in both directions.

The two intersections at which the ramp terminals are present may be signalized or stop-controlled. If signalized, the ramp terminal intersections each have two-phase signal operation, protecting left-turn movements to the entrance ramp and cross-street through movements, respectively. Right-turn movements to the entrance ramps are typically free-flowing.

Considerations

By providing a combination of exit loops and diagonal ramps in both directions, left-turn movements from the exit ramps are eliminated, enabling two-phase signal operation and reducing delay. However, Four-Quadrant Partial Cloverleaf interchanges require more right-of-way than Two-Quadrant Partial Cloverleaf interchanges. Compared to Type A Partial Cloverleafs with entrance loops, Type B Partial Cloverleafs with exit loops must provide enough distance for exit loop traffic to merge with cross-street traffic before the upcoming ramp terminal intersection.

Mode Accommodations

When the ramp terminals are stop-controlled, large trucks exhibiting slower acceleration rates may experience increased difficulty in making through and left-turn movements from the ramp terminals. *Section 9.5.3* of the AASHTO *Policy on Geometric Design of Highways and Streets* provides additional guidance and inputs to determine the appropriate intersection sight distances for large vehicles.

Similar to ramp terminals at diamond interchanges, cross-street pedestrian crossings at partial cloverleafs should be located outside of the ramp terminal intersections. Due to the presence of loop ramps, consideration should be given to shared-use paths throughout the interchange area. Please refer to **Section 0** for additional pedestrian accommodations at loop ramps and diagonal ramp terminals.

A.3.10 Two-Quadrant Partial Cloverleaf B

Subtypes: Signalized, Stop Control

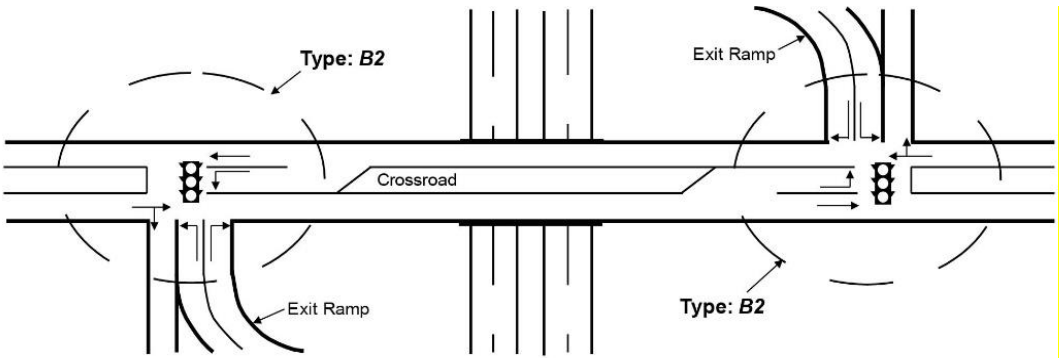

Figure A-24: Diagram of Intersection Control at Two-Quadrant Partial Cloverleaf Ramp Terminals - Type B

Description

The Partial Cloverleaf B interchange has two exit loop ramps that provide free-flow right-turn movements to the cross street. However, the two-quadrant variant of this interchange requires left-turn movements from the exit loop ramp to be signalized or stop-controlled. In both cases, the right-turn movement from the cross-street to the entrance ramp is typically free-flowing.

Considerations

Two-Quadrant Partial Cloverleaf interchanges provide full access while only impacting property in two interchange quadrants. However, this layout opens the potential for wrong-way movements at the ramp terminal intersections.

Mode Accommodations

When the ramp terminals are stop-controlled, large trucks exhibiting slower acceleration rates may experience increased difficulty in making through and left-turn movements from the ramp terminals. *Section 9.5.3* of the AASHTO *Policy on Geometric Design of Highways and Streets* provides additional guidance and inputs to determine the appropriate intersection sight distances for large vehicles.

Similar to ramp terminals at diamond interchanges, cross-street pedestrian crossings at partial cloverleafs should be located outside of the ramp terminal intersections. Due to the presence of loop ramps, consideration should be given to shared-use paths throughout the interchange area. Please refer to **Section 0** for additional pedestrian accommodations at loop ramps and diagonal ramp terminals.

A.3.11 Roundabout

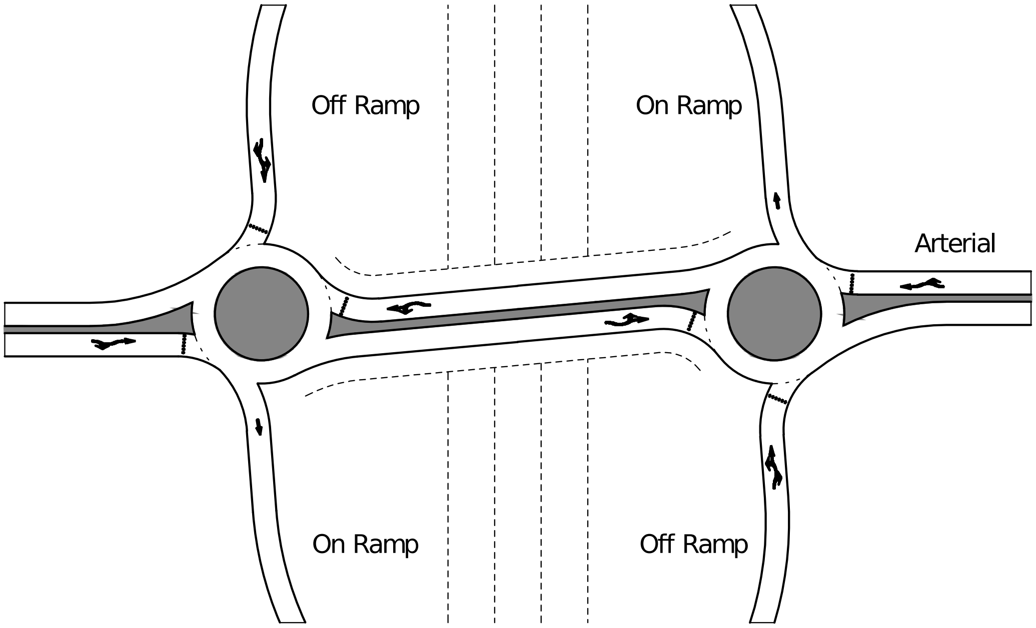

Figure A-25: Diagram of Intersection Control at Roundabout Ramp Terminals

Description

Roundabouts are a subset of traffic circles that feature yield control of all entering vehicles, channelized approaches, and horizontal curvature to induce desirable vehicle speeds. They can be used to control ramp terminals at a variety of interchange configurations, including diamond interchanges, partial diamond interchanges, and certain forms of partial cloverleaf interchanges. (Refer to **Section 0** for more information about roundabouts, including at-grade intersection considerations.)

Considerations

Roundabouts feature less conflict points than conventional intersections, lower design speeds within the circulating roadway, and shallower collision angles, typically resulting in less fatal and injury crashes compared to signalized intersections. By slowing vehicles through roadway geometry instead of signalization, roundabouts operate at a steady pace that, in many cases, reduces delay, noise, and idling emissions compared to signalized control.

Roundabouts may result in an initial increase in the total number of crashes, particularly in areas where roundabouts are uncommon and drivers are unfamiliar with the operation. The increase in total crashes is typically short-term and may not be a concern in areas where roundabouts are common. In addition, roundabouts typically require more right-of-way than conventional intersections, entailing a higher installation cost.

Mode Accommodations

Compared to other alternative ramp terminal control types, roundabouts are particularly friendly to pedestrians and bicyclists due to their geometry and the accompanying decrease in prevailing cross-street speeds.

Pedestrian crossings are located across each leg of the roundabout, typically separated from the circulatory roadway by at least one vehicle length. Channelization islands should be wide enough at these locations to provide a pedestrian refuge and facilitate two-stage crossing.

Bicyclists may ride in the roadway with vehicles or transition to multi-use paths via bicycle ramps (if present). Bike lanes should not be used at roundabouts.

The width of the circulating roadway should be wider than a typical travel lane to accommodate turning movements, particularly for larger vehicles that may be a greater proportion of traffic at ramp terminal locations. Larger design vehicles may be accommodated by concrete truck aprons located within the center island or outside the circulating lane between approaches.

APPENDIX B
FDOT ICE FORMS

CONTENTS

LIST OF FIGURES

B.1 General Information

The ICE Forms for Stages 1, 2, and 3 are set up in Microsoft Excel spreadsheet format to record project, analysis results, and other pertinent information, provide recommendation on control strategy selection, and submit to FDOT for DTOE's and DDE's approval. The spreadsheet has four worksheets: (i) Input, (ii) Stage 1, (iii) Stage 3, and (iv) Stage 4. The yellow-shaded cells contain drop-down menus to select an option from the list.

Figure B-1 shows the initial setup of the *Input* worksheet. Users can document the project information here, and once done, the information will be reflected in the other worksheets. The initial input items are described below:

Florida Department of Transportation
Intersection Control Evaluation (ICE) Form
Initial Inputs

Intersection Control Evaluation Form 750-010-30

This spreadsheet was developed by FDOT to support the ICE Policy. This spreadsheet tool shall be used to document the findings of the ICE procedure. **A selection must be made in the "Intersection Type" cell below for the appropriate Stage 1 form to fully populate.**

Project Name			FDOT Project #		
Submitted By		Agency/Company		Date	
Email		FDOT District		County	
Project Locality (*City/Town/Village*)					
Intersection Type		FDOT Context Classification			
Project Type		Other			

Figure B-1: ICE Form – Input Worksheet

- **Project Name**: Enter the project name associated with the project.
- **FDOT Project #:** Enter the FDOT project number assigned to the project. For a project conducting ICE as part of a driveway connection permit, enter "N/A".
- **FDOT District**: Select the appropriate FDOT District in which the project takes place.
- **County**: Select the appropriate county in which the project takes place.
- **Project Locality (City/Town/Village)**: Enter the specific city, town, or village in which the project takes place.
- **Intersection Type**: Select the appropriate intersection type from the two choices: (i) At-Grade Intersection or (ii) Ramp Terminal Intersection.
- **FDOT Context Classification**: Select the appropriate FDOT Context Classification for the project area from the Preliminary Context Classification feature class published in the FDOT Open Data Hub. If the information is not available, select the most appropriate FDOT Context

Classification that best describes the surrounding project area using the information presented in *FDM Section 200.4*.

- **Project Type**: Select the project type from the drop-down menu that best describes the proposed project. If the project does not fit any of the project types listed, select "Other (Please type)" and type a more applicable description following "Other" in the cell.

Upon selection of Intersection Type, the worksheet will be populated with a list of corresponding intersection control strategies (see **Figure B-2**). Select "Yes" to identify the control strategies that are evaluated in Stage 1. This selection is important to set up the remainder of the Stage 1 Form.

At Grade Control Strategies	To Be Considered?
Two-Way Stop-Control	
All-Way Stop-Control	
Signalized Control	
Roundabout (1-lane)	
Roundabout (2-lane)	
Median U-Turn	
Median U-Turn (Partial)	
Restricted Crossing U-turn (Signalized)	
Restricted Crossing U-turn (Unsignalized)	
Jughandle (Forward Ramps)	
Jughandle (Reverse Ramps)	
Displaced Left-Turn (Partial)	
Continuous Green Tee	
Quadrant Roadway	
Thru-Cut (Signalized)	
Thru-Cut (Unsignalized)	
Bowtie	
Other 1 (Type)	
Other 2 (Type)	
Other 3 (Type)	
Other 4 (Type)	
Other 5 (Type)	

Ramp Terminal Control Strategies	To Be Considered?
Diamond Signalized	
Diamond Signalized (Alt)	
Diverging Diamond	
Single-Point Diamond	
Diamond Stop Control	
Signalized Tight Diamond	
Roundabout (1-lane)	
Roundabout (2-lane)	
Half Diamond Signalized	
Half Diamond Stop Control	
Two Quadrant Partial Cloverleaf A Signalized	
Two Quadrant Partial Cloverleaf A Stop Control	
Four Quadrant Partial Cloverleaf A Signalized	
Four Quadrant Partial Cloverleaf A Stop Control	
Two Quadrant Partial Cloverleaf B Signalized	
Two Quadrant Partial Cloverleaf B Stop Control	
Four Quadrant Partial Cloverleaf B Signalized	
Four Quadrant Partial Cloverleaf B Stop Control	
Other 1 (Type)	
Other 2 (Type)	
Other 3 (Type)	
Other 4 (Type)	
Other 5 (Type)	

Figure B-2: ICE Form – List of Intersection Control Strategies to Select from in the Input Worksheet

B.2 Stage 1 ICE Form

The Stage 1 ICE Form comprises several sections, including project information, basic intersection information, crash history, control strategy evaluation, and resolution, for both at-grade Intersection control strategies and ramp terminal control strategies. Except the basic intersection information, the inputs in the Stage 1 ICE Form are identical for both at-grade Intersections and ramp terminal intersections. A description of each Stage 1 ICE Form section is provided in the following subsections.

B.2.1 Project Information

Figure B-2 shows the project information section of the Stage 1 ICE Form. All inputs other than the following three will be populated with information provided on the *Input* worksheet.

Florida Department of Transportation
Intersection Control Evaluation (ICE) Form
Stage 1: Screening

Intersection Control Evaluation Form 750-010-30

To fulfill the requirements of Stage 1 (Screening) of FDOT's ICE procedures, complete the following form and append all supporting documentation. Completed forms are to be submitted to the District Traffic Operations Engineer (DTOE) and District Design Engineer (DDE) for the project's approval.

Project Name			FDOT Project #		
Submitted By		Agency/Company		Date	
Email		FDOT District		County	
Project Locality (*City/Town/Village*)					
Intersection Type	At-Grade Intersection	FDOT Context Classification			
		Project Type			
Project Purpose (*What is the catalyst for this project and why is it being undertaken?*)					
Project Setting Description (*Describe the area surrounding the intersection*)					
Multimodal Context (*Describe the pedestrian, bicycle, and transit activity in the area and the potential for activity based on surrounding land uses and development patterns*)					

Figure B-3: Stage 1 ICE Form – Project Information

- **Project Purpose**: Describe the catalyst for the project and why it is being undertaken (e.g., a private developer seeking a new access point for their proposed development).
- **Project Setting Description**: Describe the area surrounding the intersection, including information pertaining to adjacent land uses, presence of potential constraints (e.g., environmental and right-of-way constraints), and any other

pertinent information regarding the study area that may affect the application of some control strategies.

- **Multimodal Context**: Describe pedestrian, bicycle, and transit activity in the area and the potential for activity based on surrounding land uses and development pattern.

B.2.2 Basic Intersection Information – At-Grade Intersection

Figures B-4 and B-5 show the Stage 1 ICE Form for at-grade intersections with inputs on basic information about major and minor street approaches, respectively. Note that the terminologies, including roadway(s), road(s), and street(s), are used interchangeably.

<u>**Major Street Information**</u>: Major street is defined as the street normally carrying the higher volume of vehicular traffic (i.e., AADT). The input items for major street are described below:

Major Street Information					
Roadway ID		Route Name(s)		Milepoint	
Existing Control Type		Existing AADT		Design Year AADT	
Design Vehicle		Control Vehicle			
Primary Functional Classification				Design Speed (mph)	
Secondary Functional Classification (if app.)				Target Speed (mph) [if app.]	

Approach	Item		Number of Lanes		Study Period #1 Traffic Volumes		Study Period #2 Traffic Volumes	
Approach #1	Direction							
	Sidewalks along:		Left-Turn					
	Crosswalk on Approach?		Left-Through					
	On-Street Bike Facilities?		Through		Left		Left	
	Multi-Use Path?		Left-Through-Right		Through		Through	
	Scheduled Bus Service?		Through-Right		Right		Right	
	Bus Stop on Approach?		Right-Turn		Daily Truck %			
Approach #2	Direction							
	Sidewalks along:		Left-Turn					
	Crosswalk on Approach?		Left-Through					
	On-Street Bike Facilities?		Through		Left		Left	
	Multi-Use Path?		Left-Through-Right		Through		Through	
	Scheduled Bus Service?		Through-Right		Right		Right	
	Bus Stop on Approach?		Right-Turn		Daily Truck %			

Figure B-4: Stage 1 ICE Form - Basic Information on Major Street for At-Grade Intersection

- **Roadway ID**: Enter the FDOT Roadway ID for the major street.
- **Route Name(s)**: Enter the route number and/or route name of the major street (e.g., SR 45/US 41/Tamiami Trail).

- **Milepoint**: Enter the milepoint of the major street at the intersection (e.g., 2.54). This information can be found from FDOT's Straight-Line Diagrams Online GIS Web Application: *https://slogis.fdot.gov/.*
- **Existing Control Type**: Select the existing control strategy employed at the intersection. If no intersection currently exists (i.e., the project is proposing a new intersection), select "None/New Intersection".
- **Existing AADT**: Enter the most recent AADT along the major street. If AADT varies between major street approaches, enter the higher values of AADT. The latest AADT values can be found on FDOT's Florida Traffic Online viewer: *https://tdaappsprod.dot.state.fl.us/fto/*.
- **Design Year AADT**: Enter AADT estimated for design year.
- **Design Vehicle**: Select the most appropriate design vehicle for the major street. The design vehicle is defined as the largest vehicle that is accommodated without encroachment on curbs (when present) or into adjacent travel lanes. For more information on design vehicles, see *FDM Section 201.6.*
- **Control Vehicle**: Select the most appropriate control vehicle for the major street. The control vehicle is defined as an infrequent vehicle that is accommodated by encroachment into opposing lanes if no median is present and minor encroachment onto curbs and areas within the curb return (if no critical infrastructure present). For more information on control vehicles, see *FDM Section 201.6.1*.
- **Primary Functional Classification**: Select the functional classification of the major street approach legs. If the classification of the major street changes at the intersection, select the higher order functional classification.
- **Design Speed**: Enter the design speed for the major street. Design speed is defined as the principal design control that regulates the selection of many project standards and design criteria. For more information on design speed, see *FDM Section 201.5*.
- **Secondary Functional Classification (if applicable)**: Given the functional classification of the major street changes at the intersection, select the lower-order functional classification in this cell.
- **Target Speed**: Enter the target speed for the major street. Target speed is defined as the speed at which vehicles should operate in a specific land use context and consistent with the multimodal activity generated by adjacent land uses. For more information on target speed, see *FDM Section 202.2.1*.
- **Direction**: Select direction of travel of the corresponding major street approach.

- **Sidewalks along**: Select whether sidewalks are present along one side, both sides, or neither side of the corresponding major street approach.
- **Crosswalk on Approach**: Select “Yes” if a crosswalk is present for pedestrians to cross the corresponding major street approach; otherwise, select “No”.
- **On-Street Bike Facilities**: Select “Yes” if on-street bike facilities (e.g., protected bike lanes) are present along the corresponding major street approach; otherwise, select “No”.
- **Multi-Use Path**: Select “Yes” if a multi-use path is present along one or more sides of the corresponding major street approach; otherwise, select “No”.
- **Scheduled Bus Service**: Select “Yes” if scheduled bus services operate along the corresponding major street approach; otherwise, select “No”. Note that a bus stop does not need to be located at or close to the intersection to check this box.
- **Bus Stop on Approach**: Select “Yes” if a bus stop serving a scheduled bus line is located along the corresponding major street approach within 1,000 feet of the center of the intersection; otherwise, select “No”.
- **Number of Lanes**: Enter the number of lanes along the corresponding major street approach for the movements provided in the cells below this item.
- **Study Period Traffic Volumes**: Use the drop-down menu to select a time period for traffic volumes provided in the cells below this item. Enter hourly volumes for each movement in appropriate cells. Also, enter daily truck percentage along the corresponding major street approach.

Minor Street Information: Minor street is defined as the street carrying the lower volume of vehicular traffic. If a third approach is present (e.g., a five-leg intersection), the information for all minor street legs should be input under this same section. The input items for minor street are described below:

- **Roadway ID**: Enter the FDOT Roadway ID for the minor street. If the minor street is a local road, the roadway ID may not be available. Keep the cell blank in that case.
- **Route Name(s)**: Enter the route number and/or route name of the minor street (e.g., SR 212/US 90/Beach Blvd.).
- **Milepoint**: Enter the milepoint of the minor street at the intersection (e.g., 14.82). If the minor street is a local road, the milepoint of the road may not be available. Keep the cell blank in that case.

Minor Street Information					
Roadway ID		Route Name(s)		Milepoint (if app.)	
Existing Control Type		Existing AADT		Design Year AADT	
Design Vehicle		Control Vehicle			
Primary Functional Classification				Design Speed (mph)	
Secondary Functional Classification (if app.)				Target Speed (mph) [if app.]	

Approach #1	Direction		Number of Lanes		Study Period #1 Traffic Volumes		Study Period #2 Traffic Volumes	
	Sidewalks along:		Left-Turn					
	Crosswalk on Approach?		Left-Through					
	On-Street Bike Facilities?		Through		Left		Left	
	Multi-Use Path?		Left-Through-Right		Through		Through	
	Scheduled Bus Service?		Through-Right		Right		Right	
	Bus Stop on Approach?		Right-Turn		Daily Truck %			
Approach #2	Direction		Number of Lanes		Study Period #1 Traffic Volumes		Study Period #2 Traffic Volumes	
	Sidewalks along:		Left-Turn					
	Crosswalk on Approach?		Left-Through					
	On-Street Bike Facilities?		Through		Left		Left	
	Multi-Use Path?		Left-Through-Right		Through		Through	
	Scheduled Bus Service?		Through-Right		Right		Right	
	Bus Stop on Approach?		Right-Turn		Daily Truck %			
Approach #3	Direction		Number of Lanes		Study Period #1 Traffic Volumes		Study Period #2 Traffic Volumes	
	Sidewalks along:		Left-Turn					
	Crosswalk on Approach?		Left-Through					
	On-Street Bike Facilities?		Through		Left		Left	
	Multi-Use Path?		Left-Through-Right		Through		Through	
	Scheduled Bus Service?		Through-Right		Right		Right	
	Bus Stop on Approach?		Right-Turn		Daily Truck %			

Figure B-5: Stage 1 ICE Form - Basic Information on Minor Street for At-Grade Intersection

- **Existing Control Type**: Select the existing control strategy employed at the intersection. If no intersection currently exists (i.e., the project is proposing a new intersection), select “None/New Intersection”.
- **Existing AADT**: Enter the most recent AADT along the minor street. If AADT varies between minor street approaches, enter the highest values of AADT.
- **Design Year AADT**: Enter AADT estimated for design year.
- **Design Vehicle**: Select the most appropriate design vehicle for the minor street. The design vehicle is defined as the largest vehicle that is accommodated without encroachment on curbs (when present) or into adjacent travel lanes. For more information on design vehicles, see *FDM Section 201.6*.
- **Control Vehicle**: Select the most appropriate control vehicle for the minor street. The control vehicle is defined as an infrequent vehicle that is accommodated by encroachment into opposing lanes if no median is

present and minor encroachment onto curbs and areas within the curb return (if no critical infrastructure present). For more information on control vehicles, see *FDM Section 201.6.1*.

- **Primary Functional Classification**: Select the functional classification of the minor street approach legs. If the classification of the minor street changes at the intersection, select the higher order functional classification.
- **Design Speed**: Enter the design speed for the minor street. Design speed is defined as the principal design control that regulates the selection of many project standards and design criteria. For more information on design speed, see *FDM Section 201.5*.
- **Secondary Functional Classification**: If the functional classification of the minor street changes at the intersection, select the lower-order functional classification in this cell.
- **Target Speed**: Enter the target speed for the minor street. Target speed is defined as the speed at which vehicles should operate in a specific land use context and consistent with the multimodal activity generated by adjacent land uses. For more information on target speed, see *FDM Section 202.2.1*.
- **Direction**: Select direction of travel of the corresponding minor street approach.
- **Sidewalks along**: Select whether sidewalks are present along one side, both sides, or neither side of the corresponding minor street approach.
- **Crosswalk on Approach**: Select “Yes” if a crosswalk is present for pedestrians to cross the corresponding minor street approach; otherwise, select “No”.
- **On-Street Bike Facilities**: Select “Yes” if on-street bike facilities (e.g., protected bike lanes) are present along the corresponding minor street approach; otherwise, select “No”.
- **Multi-Use Path**: Select “Yes” if a multi-use path is present along one or more sides of the corresponding minor street approach; otherwise, select “No”.
- **Scheduled Bus Service**: Select “Yes” if scheduled bus services operate along the corresponding minor street approach; otherwise, select “No”. Note that a bus stop does not need to be located along the approach at or near the intersection to check this box.
- **Bus Stop on Approach**: Select “Yes” if a bus stop serving a scheduled bus line is located along the corresponding minor street approach within 1,000 feet of the center of the intersection; otherwise, select “No”.

- **Number of Lanes**: Enter the number of lanes along the corresponding minor street approach for the movements provided in the cells below this item.
- **Study Period Traffic Volumes**: Use the drop-down menu to select a time period for traffic volumes provided in cells below this item. Enter hourly volumes for each movement in appropriate cells. Also, enter daily truck percentage along the corresponding minor street approach.

B.2.3 Basic Intersection Information – Ramp Terminal Intersection

Figures B-6 shows the Stage 1 ICE Form for ramp terminal intersections with inputs on basic information about cross-street (crossroad) and exit ramps. Note that the terminologies, including roadway(s), road(s), and street(s), are used interchangeably. This is very similar to the entry information for the at-grade intersection. This Section will only discuss the differences from Section B.2.3.

Cross Street Information: Cross street is defined as the surface street crossing through the interchange area. The Ramp Terminal Intersection is formed by the intersection of the limited access facility ramps and the cross street. The entries are the same as previously described in Major Street for At-Grade Intersection.

Exit Ramp Information: Exit ramp is defined as the roadway exiting from the limited access facility to the cross street. The input items for minor street are described below:

- **Roadway ID**: Enter the FDOT Roadway ID of the exit ramp.
- **Route Name**: Enter the common name of the ramps related to limited access roadway (e.g., “I-95 NB Ramp”).
- **Milepoint**: Enter the milepoint of the exit ramp at the ramp terminal intersection (e.g., 1.2).
- **AADT**: Enter the most recent AADT along the ramp.
- **Primary Functional Classification**: Select the functional classification of the ramp from the drop-down menu.
- **Secondary Functional Classification:** This value will not apply in most cases.
- **Direction**: Select the direction of vehicular travel along the exit ramp.
- **Crosswalk on Approach**: Select “Yes” if a crosswalk is present for pedestrians to cross the ramp terminal; otherwise, select “No”.
- **Number of Lanes**: Enter the number of lanes along the corresponding ramp for the movements provided in the cells below this item.

Cross-Street Information								
Roadway ID		Route Name(s)					Milepoint	
Existing Ramp Control Type			Existing AADT				Design Year AADT	
Design Vehicle			Control Vehicle					
Primary Functional Classification							Design Speed (mph)	
Secondary Functional Classification (if app.)							Target Speed (mph) [if app.]	
Approach #1	Direction		Number of Lanes		Study Period #1 Traffic Volumes		Study Period #2 Traffic Volumes	
	Sidewalks along:		Left-Turn					
	Crosswalk on Approach?		Left-Through					
	On-Street Bike Facilities?		Through		Left		Left	
	Multi-Use Path?		Left-Through-Right		Through		Through	
	Scheduled Bus Service?		Through-Right		Right		Right	
	Bus Stop on Approach?		Right-Turn		Daily Truck %			
Approach #2	Direction		Number of Lanes		Study Period #1 Traffic Volumes		Study Period #2 Traffic Volumes	
	Sidewalks along:		Left-Turn					
	Crosswalk on Approach?		Left-Through					
	On-Street Bike Facilities?		Through		Left		Left	
	Multi-Use Path?		Left-Through-Right		Through		Through	
	Scheduled Bus Service?		Through-Right		Right		Right	
	Bus Stop on Approach?		Right-Turn		Daily Truck %			
Approach #3	Direction		Number of Lanes		Study Period #1 Traffic Volumes		Study Period #2 Traffic Volumes	
	Sidewalks along:		Left-Turn					
	Crosswalk on Approach?		Left-Through					
	On-Street Bike Facilities?		Through		Left		Left	
	Multi-Use Path?		Left-Through-Right		Through		Through	
	Scheduled Bus Service?		Through-Right		Right		Right	
	Bus Stop on Approach?		Right-Turn		Daily Truck %			
Exit Ramp Information								
Roadway ID		Route Name(s)					Milepoint (if app.)	
Existing Ramp Control Type			Existing AADT				Design Year AADT	
Design Vehicle			Control Vehicle					
Primary Functional Classification							Design Speed (mph)	
Secondary Functional Classification (if app.)							Target Speed (mph) [if app.]	
Approach #1	Direction		Number of Lanes		Study Period #1 Traffic Volumes		Study Period #2 Traffic Volumes	
	Crosswalk on Approach?		Left-Turn					
			Left-Through					
			Through		Left		Left	
			Left-Through-Right		Through		Through	
			Through-Right		Right		Right	
			Right-Turn		Daily Truck %			
Approach #2	Direction		Number of Lanes		Study Period #1 Traffic Volumes		Study Period #2 Traffic Volumes	
	Crosswalk on Approach?		Left-Turn					
			Left-Through					
			Through		Left		Left	
			Left-Through-Right		Through		Through	
			Through-Right		Right		Right	
			Right-Turn		Daily Truck %			

Figure B-6: Basic Information for Ramp Terminal Intersection

- **Study Period Traffic Volumes**: Use the drop-down menu to select a time period for traffic volumes provided in cells below this item. Enter hourly volumes for each movement in appropriate cells. Also, enter daily truck percentage along the ramp.

B.2.4 Crash History

Figure B-7 shows the crash history section of the Stage 1 ICE Form. This section applies to existing intersection only. Extract the five most-recent years of crash data within the existing or proposed intersection influence area from the Signal Four (S4) Analytics. Summarize any trends or patterns observed in the crash history. Bes sure to make a note of fatal, injury, and total crashes. It is also especially important to note the numbers of angle and left-turn crashes at the existing intersection. For access to S4 Analytics, contact the FDOT Project Manager or the State Safety Office.

Crash History (Existing Intersections Only)
Append the most recent five-years of crash data for the intersection from the Signal Four (S4) Analytics. If the crash data evidences any issues relating to safety performance, discuss briefly here:

Figure B-7: Stage 1 ICE Form - Crash History (Existing Intersection Only)

B.2.5 Control Strategy Evaluation

Figure B-8 shows the control strategy evaluation section of the Stage 1 ICE Form. Use this section to report operational and safety performance results of each intersection control strategy evaluated in Stage 1 using the FDOT CAP-X Tool and the FDOT SPICE Tool, make a determination on whether a control strategy is to be advanced, and provide justification behind the determination. Finally, make a recommendation on the overall project determination at the end of Stage 1 evaluation. The input items for control strategy evaluation in Stage 1 are described below:

- **CAP-X Outputs**: Enter the AM and PM peak period v/c ratio, pedestrian accommodation score, and bike accommodation score from the CAP-X analysis. The lower v/c ratios indicate better vehicular operations. The higher ped and bike accommodation scores indicate better multimodal conditions.

Control Strategy Evaluation								
Provide a brief justification as to why each of the following control strategies should be advanced or not. Justification should consider potential environmental impacts.								
Control Strategy	CAP-X Outputs				SPICE Outputs		Strategy to be Advanced?	Justification
	V/C Ratio		Ped Accom. Score	Bike Accom. Score	Crash Prediction Rank	SSI Rank		
Recommendation								

Figure B-8: Stage 1 ICE Form - Control Strategy Evaluation

- **SPICE Outputs**: Enter the separate ranking of each control strategy based on crash prediction analysis and SSI analysis results from the FDOT SPICE Tool.
  - Crash Prediction Rank: Enter the relative ranking of each control strategy based on crash prediction analysis using the FDOT SPICE Tool. The control strategy having a ranking of “1” is predicted to have the lowest number of predicted or expected fatal-and-injury crashes.
  - SSI Rank: Enter the relative ranking of each control strategy based on the SSI analysis using the FDOT SPICE Tool. The control strategy having a ranking of “1” has the highest SSI score. The higher the SSI score for an alternative, the better it is in terms of safety.
- **Strategy to be Advanced**: Select “Yes” if a control strategy is selected to be the preferred alternative at the end of Stage 1 or a control strategy is to be advanced for further evaluation in Stage 2.
- **Justification**: Provide brief justification as to why a control strategy is selected to be advanced or not. Please refer to **Section 2.4.4** to determine factors that should be considered while selecting a preferred control strategy.
- **Recommendation**: Use the drop-down menu to select whether a single control strategy is recommended at the end of stage 1, or multiple viable control strategies are identified and the evaluation should continue to Stage 2 with the selected viable alternatives.

B.2.6 Resolution

Figure B-9 shows the Resolution section of the Stage 1 ICE Form, which is to be filled out by the FDOT DTOE and the FDOT DDE only. They may accept or reject the recommendation made in the control strategy evaluation section.

Resolution					
To be filled out by FDOT District Traffic Operations Engineer and District Design Engineer					
Identified Alternative Approved ☐		Identified Alternative Not Approved (Re-evaluate control strategies) ☐			
DTOE Name		Signature		Date	
DTOE Comments					
DDE Name		Signature		Date	
DDE Comments					

Figure B-9: Stage 1 ICE Form - Resolution

B.3 Stage 2 ICE Form

The Stage 2 ICE Form comprises the following sections: project information; operational analyses; safety performance; costs and benefit/cost ratios; multimodal accommodations; environmental, utility, and right-of-way impacts; public input/feedback; control strategy evaluation; and resolution. The inputs in each section are identical for both at-grade and ramp terminal intersections. A description of each Stage 2 ICE Form section is provided in the following subsections.

B.3.1 Project Information

Figure B-10 shows the project information section of the Stage 2 ICE Form. **The Project Funding Source (cells highlighted in yellow) shall be selected to set up the rest of the Stage 2 ICE Form.** Select from the drop-down whether the project is federally funded or non-federally funded. All the other fields in this section will be populated with information from the Stage 1 Form. No changes to this information are necessary, unless the person responsible for submitting the ICE Form has changed between stages.

Florida Department of Transportation
Intersection Control Evaluation (ICE) Form
Stage 2: Initial Control Strategy Assessment

Intersection Control Evaluation Form 750-010-30

To fulfill the requirements of Stage 2 (Intersection Control Strategy) of FDOT's ICE procedures, complete the following form and append all supporting documentation. **A selection must be made in the "Project Funding Source" cell below for the Stage 2 form to fully populate.** Completed forms are to be submitted to the District Traffic Operations Engineer (DTOE) and District Design Engineer (DDE) for the project's approval.

Project Name		FDOT Project #		Date	
Submitted By		Agency/Company		Email	
				Project Funding Source	
List all viable intersection control strategies identified in Stage 1 (Screening):					

Figure B-10: Stage 2 ICE Form - Project Information

B.3.2 Operational Analyses

Figure B-11 shows the operational analysis section of the Stage 2 ICE Form. The inputs for this section vary by the project's funding source, as shown in **Figure B-11(a)** for federally funded projects and **Figure B-11(b)** for non-federally funded projects. Expectedly, a federally funded project requires more input for operational analyses. The input items for operational analyses are described below:

- **Design Vehicle**: See **Section B.2.2** on the design vehicle input.
- **Control Vehicle**: See **Section B.2.2** on the control vehicle input.
- **Opening Year**: Enter the anticipated opening year for the improvement.
- **Design Year**: See **Section 2.4** to select the most appropriate design year.
- **Peak Hour**: Select the appropriate peak hour(s) from the drop-down menu for which operational analyses are conducted for opening year and design year, as applicable, for each control strategy. For a non-federally funded project, the opening year peak hour analysis is not required.
- **LOS**: Enter level-of-Service (LOS) score for the overall intersection or LOS score for the critical approach (if overall intersection LOS not applicable) corresponding to the peak hour for each control strategy. The value will be an output from the traffic simulation tool.

Operational Analyses									
Summarize the results of the peak hour analysis performed for each control strategy. Select analysis year based on guidance in the ICE procedures document. Refer to Exhibit 19-8 of the *Highway Capacity Manual, 6th Edition* (HCM6) to determine the appropriate LOS based on intersection delay (*hover over this cell for Exhibit 19-8*).									
Design Vehicle				Control Vehicle					
Opening Year									
Control Strategy	Peak Hour			Peak Hour			Peak Hour		
	LOS	Delay (sec.)	All Queues Accommodated?	LOS	Delay (sec.)	All Queues Accommodated?	LOS	Delay (sec.)	All Queues Accommodated?
Design Year									
Control Strategy	Peak Hour			Peak Hour			Peak Hour		
	LOS	Delay (sec.)	All Queues Accommodated?	LOS	Delay (sec.)	All Queues Accommodated?	LOS	Delay (sec.)	All Queues Accommodated?
Provide any additional discussion necessary regarding the results of the operational analysis:									

(a) Federally Funded Projects

Operational Analyses				
Summarize the results of the peak hour analysis performed for each control strategy. Select analysis year based on guidance in the ICE procedures document. Refer to Exhibit 19-8 of the *Highway Capacity Manual, 6th Edition* (HCM6) to determine the appropriate LOS based on intersection delay (*hover over this cell for Exhibit 19-8*).				
Design Vehicle		Control Vehicle		
Opening Year				
Control Strategy	Critical Peak Hour			
	LOS	Delay (sec.)	All Queues Accommodated?	
Provide any additional discussion necessary regarding the results of the operational analysis:				

(b) Non-Federally Funded Projects

Figure B-11: Stage 2 ICE Form - Operational Analyses

- **Delay**: Enter the delay estimated for the entire intersection or delay for the critical approach (if overall intersection delay not applicable) corresponding to the peak hour for each control strategy. The value can be obtained from the traffic flow modeling and simulation tools (e.g., Synchro, Sidra Intersection). The FDOT Economic Analysis Tool for ICE also provides a *delay* worksheet to do the calculation for an overall intersection delay for the minor road stop control, DLT, MUT, RCUT, Thru-Cut, and Bowtie intersections.
- **All Queues Accommodated**: Select "Yes" if the forecasted 95th percentile queues for all approaches are accommodated by the storage provided by each control strategy; otherwise, select "No". Be sure to account for queue spillback to adjacent intersections. If queues are not accommodated, it may be worthwhile to discuss queuing in the space provided at the end of the "Operational Analysis" section of the Form.
- **Provide any additional discussion necessary regarding the results of the operational analysis**: If any additional clarification is required regarding the opening and design year operational analyses, describe it here. For example, note down if additional operational metrics are evaluated that may help justify/refute the validity of a particular control strategy.

B.3.3 Safety Performance

Figure B-12 shows the safety performance section of the Stage 2 ICE Form. The input items for the safety performance section are described below:

Safety Performance							
Enter the most recent five (5) years of crash data from the S4 Analytics.				Most recent year of crash data available			
Crash Type							Total
Combined	Total						
	Fatal/Injury						
	PDO						
Single-Vehicle	Total						
	Fatal/Injury						
	PDO						
Multi-Vehicle	Total						
	Fatal/Injury						
	PDO						
Vehicle-Pedestrian	Fatal/Injury						
Vehicle-Bicycle	Fatal/Injury						
Total	All						

Apply the FDOT SPICE Tool to model anticipated safety performance of each control strategy. For intersection types not accommodated in the tool, manually apply crash modification factors detailed in the ICE procedures document or qualitatively describe anticipated safety impacts.

Control Strategy	Anticipated Impact on Safety Performance	Opening Year			Design Year		
		Predicted Total Crashes	Predicted Fatal+Injury Crashes	SSI Score	Predicted Total Crashes	Predicted Fatal+Injury Crashes	SSI Score

Figure B-12: Stage 2 ICE Form - Safety Performance

- **Most recent year of crash data available:** Enter the most recent year of crash data that are used to evaluate safety performance.
- **Crash Type:** Enter as appropriate the number of total, FI, and/or property damage only (PDO) crashes for single-vehicle, multi-vehicle, vehicle-pedestrian, and vehicle-bicycle crashes. Note that vehicle-pedestrian and vehicle-bicycle crashes only attribute to FI crashes. If the data is not available by crash type, enter the Combined total then.
- **Anticipated Impact on Safety Performance**: Based on review of crash data, analysis results from the FDOT SPICE Tool, and local factors, describe the anticipated impact of each control strategy on crash frequency.
- **Predicted Total Crashes**: Enter the predicted number of total crashes (opening and design year) from the FDOT SPICE Tool for each control strategy.
- **Predicted Fatal + Injury Crashes**: Enter the predicted number of fatal and injury crashes (opening and design year) from the FDOT SPICE tool for each control strategy.
- **Safe System for Intersection (SSI) Score**: Enter the overall intersection SSI score (opening and design year) from the FDOT SPICE Tool for each control strategy.

B.3.4 Costs and Benefit-Cost Ratios

Figure B-13 shows the costs and benefit/cost ratios section of the Stage 2 ICE Form. This section applies only to projects that are federally funded. The input items for this section are described below:

- **ROW Cost ($)**: Enter the estimated right-of-way costs required to implement each control strategy, as used in the FDOT Economic Analysis Tool for ICE.
- **Construction Costs ($)**: Enter the estimated design and construction costs required to implement each control strategy, as used the FDOT Economic Analysis Tool for ICE.
- **Delay B/C**: Enter the delay B/C estimated for each control strategy from the FDOT Economic Analysis Tool for ICE.
- **Safety B/C**: Enter the safety B/C estimated for each control strategy from the FDOT Economic Analysis Tool for ICE.
- **Overall B/C**: Enter the overall B/C estimated for each control strategy from the FDOT Economic Analysis Tool for ICE.

- **Net Present Value:** Enter the net present value of the overall benefits for each control strategy from the FDOT Economic Analysis Tool for ICE.

Costs and Benefit/Cost Ratios						
Remaining cognizant of the current level of detail of each control strategy's conceptual design, provide a cost estimate for each. You may want to include costs for preliminary engineering, required right-of-way acquisitions, construction, and a contingency. Apply the FDOT Economic Analysis Tool for ICE to determine the delay benefit-cost ratio (B/C), safety B/C, overall B/C, and net-present value for each control strategy.						
			FDOT Economic Analysis Tool for ICE Outputs			
Control Strategy	ROW Costs ($)	Construction Costs ($)	Delay B/C	Safety B/C	Overall B/C	Net Present Value

Figure B-13: Stage 2 ICE Form - Costs and Benefit/Cost Ratios

B.3.5 Multimodal Accommodations

Figure B-14 shows the multimodal accommodations section of the Stage 2 ICE Form. The input items for the multimodal accommodations section are described below:

- **Daily # of pedestrian crossing (all approaches)**: Enter the average number of pedestrians that cross the intersection on a daily basis.
- **Daily # of bicyclists crossing (all approaches)**: Enter the average number of bicyclists that cross the intersections on a daily basis.
- **Pedestrian Volume by Activity Level:** Based on the input on daily number of pedestrian crossing, the cell will be populated to identify whether the pedestrian activity falls into one of the five levels. The levels are low, medium-low, medium, medium-high, and high.
- **Summarize the ability of each viable control strategy to accommodate the existing and/or anticipated level** of pedestrians and bicyclists, transit services, and freight needs. The factors that can be considered here include but are not limited to road user needs, trip generations and attractions, long range transportation planning, and engineering assessment.

Multimodal Accommodations			
Note the existing/anticipated level of pedestrian/bicyclist activity at the study intersection during a typical day. After filling in the daily number of pedestrians crossing, the activity level field will auto-populate.			
Daily # of peds. crossing (all approaches):		Pedestrian Volume by Activity Level	
Daily # of bicyclists crossing (all approaches):			
Summarize the ability of each viable control strategy to accommodate the existing/anticipated level of:			
Control Strategy	Pedestrians and Bicyclists	Transit Services	Freight Needs

Figure B-14: Stage 2 ICE Form - Multimodal Accommodations

B.3.6 Environmental, Utility, and Right-of-Way Impacts

Figure B-15 shows the environmental, utility, and right-of-way impacts section of the Stage 2 ICE Form. Summarize any impacts of the proposed control strategy to the surrounding environment or adjacent properties. These need to focus on social, natural, or physical environment impacts which may preclude the advancement of a particular control strategy. It should also contain considerations for acquiring right-of-way due to costs or environmental impacts. This is also the location to document impacts to major utilities which may be impacted by implementing a control strategy.

Environmental, Utility, and Right-of-Way Impacts	
Summarize any issues related to environmental, utility, or right-of-way (including relocation) impacts specific to each control strategy. Be sure to consider the NEPA requirements for each control type.	

Figure B-15: Stage 2 ICE Form - Environmental, Utility, and Right-of-Way Impacts

B.3.7 Public Input/Feedback

Figure B-16 shows the public input/feedback section of the Stage 2 ICE Form. Summarize the feedback received from relevant agencies and the public during outreach efforts, even if that feedback does not present a preferred alternative.

Public Input/Feedback (if appropriate)
Summarize any agency or public input regarding the control strategies:

Figure B-16: Stage 2 ICE Form - Public Input/Feedback

B.3.8 Control Strategy Evaluation

Figure B-17 shows the control strategy evaluation section of the Stage 2 ICE Form. The input items for control strategy evaluation in Stage 2 are described below:

- **Strategy to be Advanced**: Select “Yes” if a control strategy is selected to be the preferred alternative at the end of Stage 2 or a control strategy is to be advanced for further evaluation in Stage 3.
- **Justification**: Provide brief justification as to why a control strategy is selected to be advanced or not. Please refer to **Section 2.4.4** to determine factors that should be considered while selecting a preferred control strategy.
- **Recommendation**: Use the drop-down menu to select whether a single control strategy is recommended at the end of Stage 2, or multiple viable

control strategies are identified and the evaluation should continue to Stage 3 with the selected viable alternatives.

Control Strategy Evaluation		
Provide a brief justification as to why each of the following is either viable or not viable. If a single control strategy is recommended, select it as the only strategy to be advanced.		
Control Strategy	Strategy to be Advanced?	Justification
Recommendation		

Figure B-17: Stage 2 ICE Form - Control Strategy Evaluation

B.3.9 Resolution

Figure B-18 shows the Resolution section of the Stage 2 ICE Form, which is to be filled out by the FDOT DTOE and the FDOT DDE only. They may accept or reject the recommendation made in the control strategy evaluation section.

Resolution					
To be filled out by FDOT District Traffic Operations Engineer and District Design Engineer					
Identified Alternative Approved ☐		Identified Alternative Not Approved (Re-evaluate control strategies) ☐			
DTOE Name		Signature		Date	
DTOE Comments					
DDE Name		Signature		Date	
DDE Comments					

Figure B-18: Stage 2 ICE Form - Resolution

B.4 Stage 3 ICE Form

The Stage 3 ICE Form comprises the following sections: project information, additional analysis, public input/feedback, control strategy evaluation, and resolution. The inputs in each section are identical for both at-grade and ramp terminal intersections. A description of each Stage 3 ICE Form section is provided in the following subsections.

B.4.1 Project Information

All fields in the "Project Information" section of the Form will be populated with information input during Stage 1 or Stage 2. No changes to this information are necessary unless the person responsible for submitting the Form has changed between stages.

Florida Department of Transportation Intersection Control Evaluation Form 750-010-30

Intersection Control Evaluation (ICE) Form

Stage 3: Detailed Control Strategy Assessment

To fulfill the requirements of Stage 3 (Detailed Control Strategy Assessment) of FDOT's ICE procedures, complete the following form and append all supporting documentation, which may include detailed design plans of each control strategy analyzed. Completed forms are to be submitted to the District Traffic Operations Engineer (DTOE) and District Design Engineer (DDE) for the project's approval.

Project Name		FDOT Project #		Date	
Submitted By		Agency/Company		Email	
List all viable intersection control strategies identified in Stage 2 (Initial Control Strategy Assessment):					

Figure B-19: Stage 3 ICE Form - Project Information

B.4.2 Additional Analysis

Figure B-20 shows the additional analysis section of the Stage 3 ICE Form. The input items for additional analysis are described below:

Additional Analysis	
What issues and/or findings to date have led to a control strategy NOT being selected in Stage 2?	
Category	Description of Issues/Findings
Describe specific evaluation activities undertaken in Stage 3 analysis to identify a preferred control strategy and discuss the findings:	
Category	Description of Issues/Findings

Figure B-20: Stage 3 ICE Form - Additional Analysis

- **Category**: Select the analysis area where additional analysis was conducted. This should be an analysis area needing further investigation to help differentiate the remaining control strategies.

- **Description of Issues/Findings**: Describe the issues/previous findings from Stage 1 and Stage 2 related to the analysis category. Be sure to discuss why this category is being investigated further (e.g., preliminary operational analyses did not identify a preferred control strategy; so, more rigorous evaluation methodologies are being employed).
- **Description of Additional (Stage 3) Analysis**: Describe the additional analyses undertaken in Stage 3 for each of the categories. Be sure to describe assumptions, methodologies and software used, results of the analyses, and any other pertinent information.

B.4.3 Public Input/Feedback

Figure B-20 shows the public input/feedback section of the Stage 3 ICE Form. If public input/feedback is not discussed under the Additional Analysis section, describe the additional outreach efforts made during Stage 3 analysis.

Public Input/Feedback
If not discussed as a part of the preceding section, summarize public input received or stakeholder considerations regarding the control strategies:

Figure B-21: Stage 3 ICE Form -Public Input/Feedback

B.4.4 Control Strategy Evaluation

Figure B-22 shows the control strategy evaluation section of the Stage 3 ICE Form. The input items for control strategy evaluation in Stage 2 are described below:

- **Strategy to be Advanced**: Select “Yes” if a control strategy is selected to be the preferred alternative at the end of Stage 3 Only a single control strategy should be advanced.
- **Justification**: Provide brief justification as to why a control strategy is selected to be advanced or not. Please refer to **Section 2.4.4** to determine factors that should be considered while selecting a preferred control strategy.

Control Strategy Evaluation		
Provide a brief justification as to why each of the following was either selected or not selected after conducting the additional analysis. ICE Stage 3 activities should result in a single control strategy being selected.		
Control Strategy	Control Strategy Selected?	Justification

Figure B-22: Stage 3 ICE Form - Control Strategy Evaluation

B.4.5 Resolution

Figure B-23 shows the Resolution section of the Stage 3 ICE Form, which is to be filled out by the FDOT DTOE and the FDOT DDE only.

Resolution					
To be filled out by FDOT District Traffic Operations Engineer and District Design Engineer					
Identified Alternative Approved ☐		Identified Alternative Not Approved (Re-evaluate control strategies) ☐			
DTOE Name		Signature		Date	
DTOE Comments					
DDE Name		Signature		Date	
DDE Comments					

Figure B-23: Stage 3 ICE Form - Resolution

APPENDIX C
EVALUATION OF PEDESTRIAN AND BICYCLE ACCOMMODATIONS

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C.1 Multimodal Pedestrian Accommodations Analysis

The FDOT CAP-X Tool provides the *Multimodal Ped* worksheet to evaluate pedestrian accommodations for each selected intersection control strategy. The worksheet includes several variables of which only one variable requires user input and others are populated with either default values or values carries over from inputs on other worksheets. Default values can be overridden by selecting options from the drop-down menus or by providing direct inputs, as applicable. The inputs for multimodal pedestrian accommodations analysis, the default crossing assignments and how to customize them, and the methodology to determine pedestrian accommodation score are described in the following subsections. Please see the assumptions in the worksheet to understand the applicability of the methodology.

C.1.1 Inputs for Pedestrian Accommodations Analysis

Roadway Speed Limits

This variable is a required input to obtain the pedestrian accommodation score for each intersection control strategy being evaluated in Stage 1. Enter the roadway speed limit for both major street and minor street when evaluating at-grade intersections and ramp speed limits when evaluating ramp terminal intersections. Roundabout entry and exit speed speeds for at-grade intersections are prepopulated with default values, varying by roundabout and ramp type. Values can be overridden if more appropriate information is available. Note that inputs must be positive integers and divisible by 5.

Out-of-Direction Travel

Out-of-direction travel considers whether pedestrians can cross an intersection in the most direct path possible. The input is gathered at the intersection level and prepopulated with default values for all control strategies. Values can be overridden using the drop-down menu by toggling between “Yes” or “No”. It should be flagged as “Yes” if one or more pedestrian paths between adjacent quadrants deviates significantly from a straight line. For example, as shown in **Figure C-1,** the out-of-direction travel for pedestrians at the partial DLT intersection is assumed to be “Yes” because a pedestrian crossing from the northwest quadrant to the northeast quadrant must first travel east, then south, then east again, and then back north to complete the crossing.

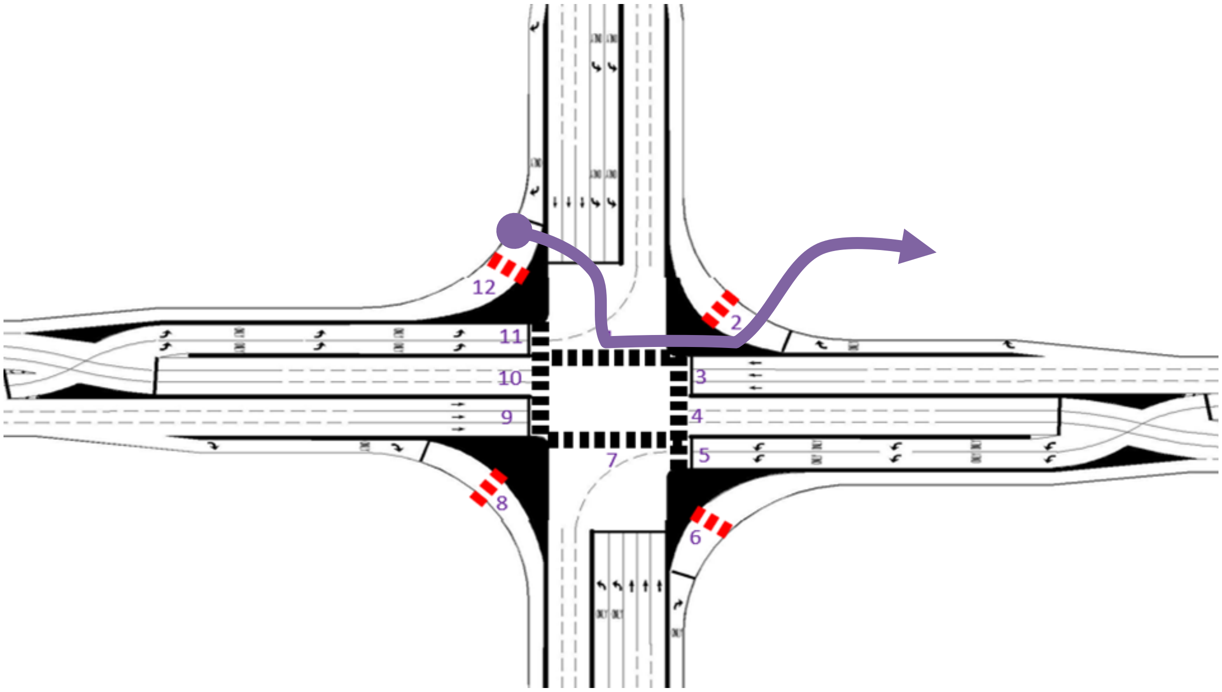


Figure C-1: Example of Pedestrians' Out-of-Direction Travel using Marked Crosswalks

Multistage Crossing

Multistage crossing is gathered at the intersection level and prepopulated with default values for all control strategies. The consideration of multistage crossings is by movement between adjacent quadrants, regardless of the presence of a direct path between two adjacent quadrants. For example, the RCUT design shown in **Figure C-2** does not have a direct path provided between the southeast and northeast quadrant, and it would require four stages for pedestrians to go from the southeast to the northeast quadrants using crosswalks 4, 5, 3, and 2. Default values can be overridden by selecting one of the following three categories:

- Yes, crossing(s) with 3+ stages – select if at least one movement between adjacent quadrants is completed in three or more stages.
- Yes, crossing(s) with 2 stages – select if at least one movement between adjacent quadrants is completed in two stages, but no movement is completed in three stages. A movement that features a median refuge but for which the signal timing allows the movement to be completed in one stage should be considered as two-stage crossing.
- No – select if all movements between adjacent quadrants are completed in one stage.

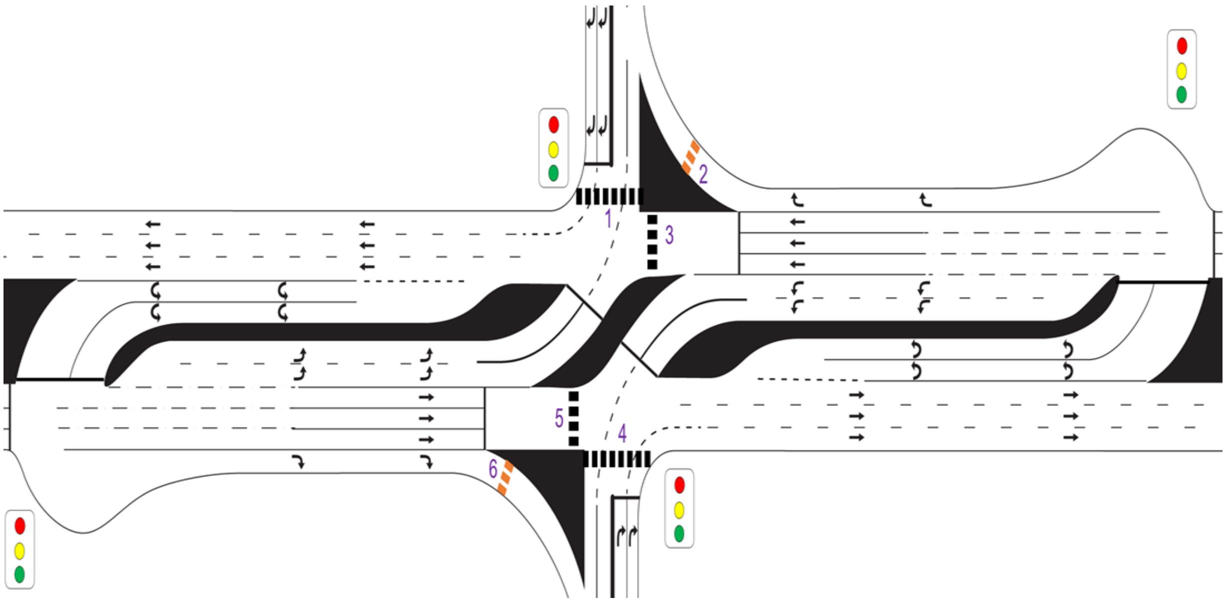


Figure C-2: Multistage Crossing at an RCUT Intersection

Number of Lanes

Number of lanes is gathered at the crossing level and populated based on user inputs on the *Alt Num Lanes Input* worksheet. Any overridden input must be a positive integer. This factor totals the number of approach and departure lanes intersecting the associated crossing.

Vehicle Volume

Vehicle volume is gathered at the crossing level and populated based on user inputs on the *Volume Input* worksheet. Any overridden input must be a positive integer. This factor totals the number of vehicles intersecting the crossing either as they approach or depart the intersection.

Conflicting Vehicle Type

Conflicting vehicle type is gathered at the crossing level and prepopulated with default values based on typical control at each intersection control strategy. Values can be overridden from the drop-down menu. This factor considers the most severe vehicle movement intersecting the pedestrian crossing. The categorical conflicting vehicle types from least to most severe are:

- Stop/Signal Controlled - select when all vehicle movements intersecting the crossing are either stop controlled or have protected signal control. This can also be selected when a yield-controlled movement, such as a channelized right turn, features a design element (e.g., a raised crosswalk) that reduces vehicle speeds to near 0 mph.

- Permissive Left – select when the most severe vehicle movement intersecting the crossing is a permissive left. However, if no pedestrians conflict with the permissive left because the pedestrians are moving under an exclusive pedestrian phase, “permissive left” may not be the most appropriate option; select “stop/signal controlled” instead.
- Yield Controlled – select when the most severe vehicle movement intersecting the crossing yields to oncoming traffic immediately after the pedestrian crossing, such as at a channelized turn lane. These vehicles are likely decelerating unlike free-flowing vehicles. “Yield controlled” should not be used for crossings where an otherwise free flowing vehicle must yield to a pedestrian in a crossing.
- Free Flowing – select when the most severe vehicle movement intersecting the crossing is free flowing, such as the uninterrupted leg of a two-way (minor-road) stop controlled intersection.

Markings

Marking type is gathered at the crossing level and prepopulated with default values. Values can be overridden using the drop-down menu by toggling between “Marked” and “Unmarked”. Note that regardless of marking presence, each intersection is assumed to have crossings on the major and minor streets for intersections or the crossroad and ramps for interchanges. At intersection control strategies where a crossing is not typically provided, the tool still assumes it is present and unmarked. This results in a decreased pedestrian score due to the lack of formal crossing availability.

C.1.2 Crossing Assignment – Defaults and Modifications

Each intersection has a default number of crossings, where a crossing is the path between any two curbs either at the edge of the roadway or along a median. Crossing between two adjacent roadways may have multiple crossing numbers varying by roadway or traffic control features, conflicting vehicle type, and marking type. Also, each crossing is color coded differently corresponding to the conflicting vehicle type and marking type (see **Figure C-3**).

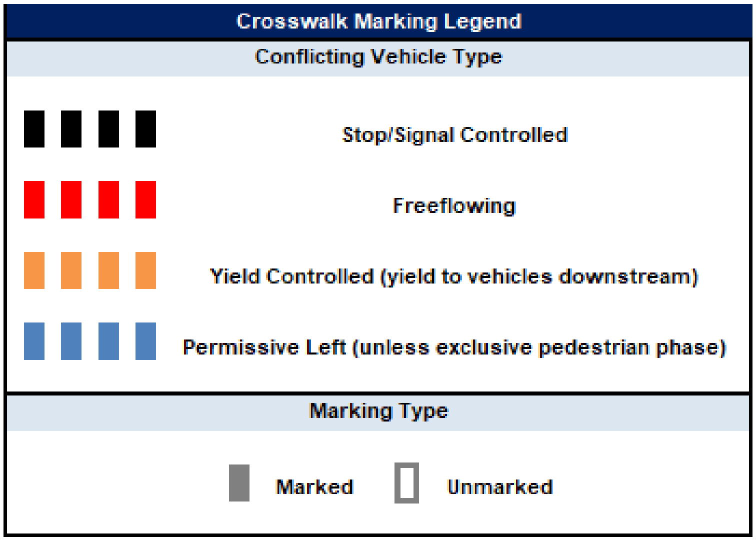


Figure C-3: Crosswalk Marking Legend

The location of each default crossing and crossing number assignment varying by conflicting vehicle type can be seen in the image that appears when hovering over the cells of the “Sheet” column accompanying the “Type of Intersection” column in the *Multimodal Ped* worksheet. These images are also available in **Section C.3**. Note the images are static and will not update with a change to inputs such as lane numbers.

Figure C-4 shows an example of the default crossing assignments, conflicting vehicle types, and marking types for the east-west Two-Way Stop Control design (i.e., uncontrolled major road along east-west). Note that directionality is important due to the importation of volumes that were entered earlier in the CAP-X workflow. This intersection design is assumed to have four crosswalks. The major street crosswalks, crossings 1 and 3, are assumed to conflict with free-flowing traffic (red) and are unmarked (hollow shading). The minor street crosswalks, crossings 2 and 4, are assumed to conflict with permissive left turns from the major street (blue) and are marked (solid shading).

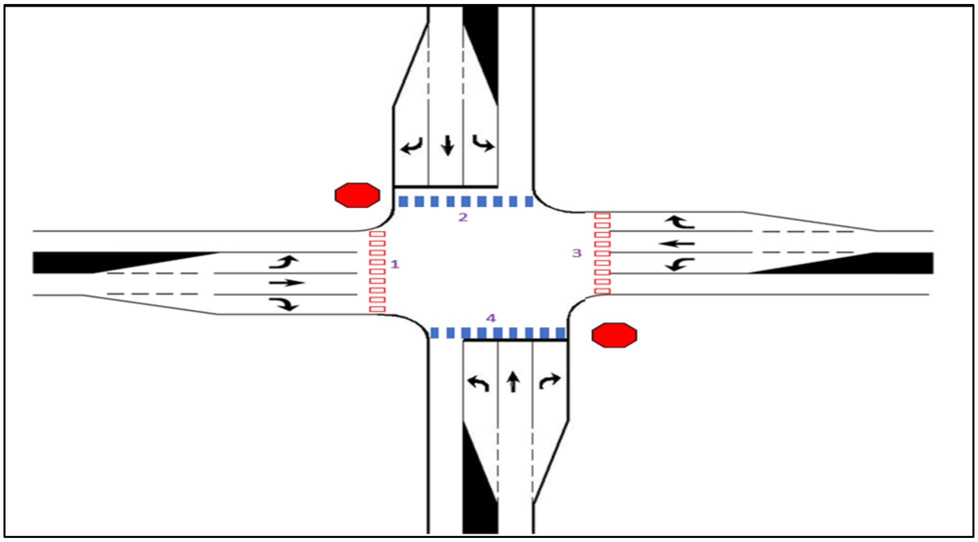
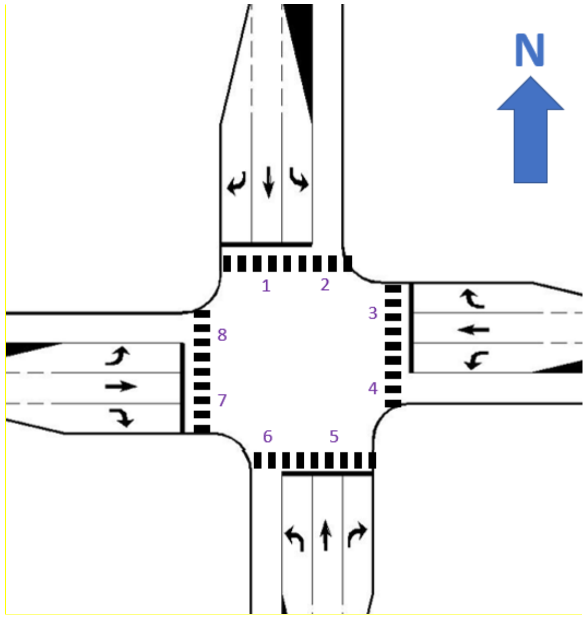


Figure C-4: Example of Crossing Assignments, Conflicting Vehicle Types, and Marking Types

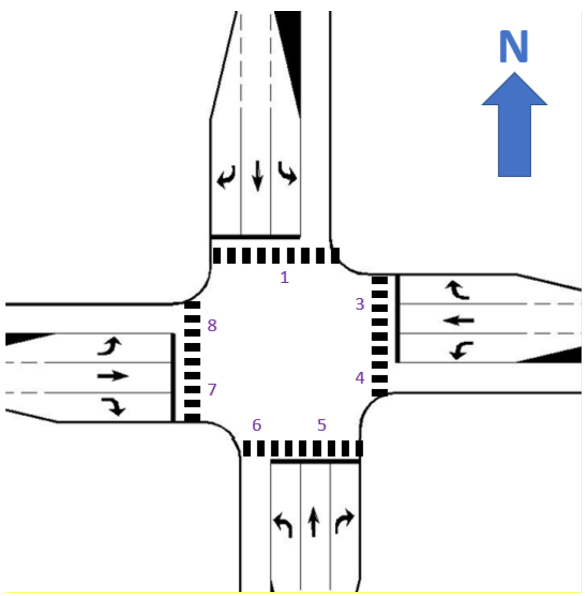
The default crosswalk locations and markings are intended to align with typical concept-level layouts of the intersection designs. However, it is possible that local design guidelines, prior project decisions, or emerging concepts for newer intersection designs result in different crossing quantities or locations. This is most likely to occur due to presence or absence of a median or channelized turn lanes and local practices regarding pedestrian facility designs for specific intersection types.
When eliminating or adding a crossing, the pedestrian volumes and the number of lanes in the remaining crossings are usually impacted, and so, the user will need to manually input (or manually rewrite cell formulas for) the values for the impacted crossings.

Following is an example of modifying the traffic signal evaluation to eliminate the median refuge island on the northern approach. **Figure C-5**Error! Reference source not found. shows the default crossing assignments and inputs (for crossings 1 and 2) where a median refuge island exists at each approach. (Note: because the images in the *Multimodal Ped* worksheet are static, median refuge islands are not shown but implied due to the presence of two crossing assignments). **Figure C-6** shows the crossing assignments and inputs where the median refuge island is eliminated on the northern approach. Note that crossing 2 will be no longer valid (empty cells) and the number of lanes and volume for the modified Crossing 1 will be the corresponding total of the default Crossings 1 and 2.



TYPE OF INTERSECTION	Sheet	Intersection Score	Out of Direction Travel	Multistage Crossing	Crossing #1					Crossing #2				
					# Lanes	Veh Speed	Volume	Conflicting Veh Type	Markings	# Lanes	Veh Speed	Volume	Conflicting Veh Type	Markings
Traffic Signal	FULL	4.78	No	Yes Crossing(s) with 2 stages	3	35	82	Stop/Signal Controlled	Unmarked	1	35	146	Stop/Signal Controlled	Marked

Figure C-5: Default Crossing Assignments and Inputs for Traffic Signal with Medians on All Four Approaches



TYPE OF INTERSECTION	Sheet	Intersection Score	Out of Direction Travel	Multistage Crossing	Crossing #1					Crossing #2				
					# Lanes	Veh Speed	Volume	Conflicting Veh Type	Markings	# Lanes	Veh Speed	Volume	Conflicting Veh Type	Markings
Traffic Signal	FULL	4.65	No	Yes Crossing(s) with 2 stages	4	35	228	Stop/Signal Controlled	Unmarked					

Figure C-6: Modified Crossing Assignments and Inputs for Traffic Signal with Median Absent on the Northbound Approach

Note that default values can always be reset using the “Reset Default Values” button located at the top of the worksheet.

C.1.3 Pedestrian Accommodation Scores

For pedestrian accommodation, each crossing receives a crossing score. The intersection score for pedestrian accommodation is a combination of each crossing score as well as scores for the intersection-based inputs of out-of-direction travel and multistage crossing. A higher score indicates a safer design with the highest possible score being 6 and the lowest possible score being 0.9.

The score for crossing *i* (C_i) is a combination of the factor scores for number of lanes (F_L), vehicle speed (F_S), vehicle volume and conflicting vehicle type (F_{VC}), and presence of markings (F_M), expressed as:

$$C_i = \frac{F_L + F_S + F_{VC} + F_M}{4}$$

The intersection score is a combination of all *n* crossing scores (C_i) and the factor scores for out-of-direction travel (F_T) and the multistage crossing (F_C), expressed as:

$$Intersection\ Ped\ Score = \left[\frac{\sum_{i=1}^{n}\sqrt{C_i}}{n}\right]^2 F_T F_C$$

The out-of-direction travel and multistage crossing factors are inputs to the intersection score rather than crossing score because one out-of-direction travel or multistage crossing experience occurs over multiple crossings. Averaging the square root of the crossing scores incentivizes improving poor performing crossings over making high performing crossings marginally better.

The individual factor scores for each crossing are described below:

Number of Lanes Score (F_L)

As shown in Table C-1, the score for the number of lanes ranges from 5 (best) to 1 (worst). It is based on the commonly accepted belief that the more lanes a pedestrian must cross, the more likely the pedestrian is exposed to crash contributing circumstances due to increased workload. This is confirmed by focus group data that pedestrians prefer crossing fewer lanes (National Academies of Sciences, Engineering, and Medicine (NASEM), 2021).

Table C-1: Number of Lanes Score

Number of Lanes	Score
1	5
2	4
3	3
4	2
5+	1

Vehicle Speed Score (F_S)

The score for the vehicle speed ranges from 5 (best) to 1 (worst) and is shown in **Table C-2**. It is based on the findings in the Tefft (2013) study.

Table C- 2: Vehicle Speed Score

Speed (mph)	Score
≤ 25	5
26-34	4
35-40	3
41-50	2
51+	1

Vehicular Volume and Conflicting Vehicle Control Type Score (F_{VC})

The score for the vehicle volume and conflicting vehicle control type ranges from 5 (best) to 1 (worst) and is shown in **Table C-3**. The volume thresholds are based on the relationship between AADT and pedestrian crashes as reported in the *Temporal Analysis of Predictors of Pedestrian Crashes* study (Guerra et al., 2020), which shows pedestrian-vehicle crashes tend to increase as AADT increases until 100,000 vehicles and then level off on average across all time periods. To generate hourly volumes, it is assumed that the typical hour K value is 9% and the volumes are identical across all four approaches. This yields an hourly volume of 1,500 vehicles, which is set as the threshold for a rating between 1 and 2. In assigning scores for the various conflicting vehicle control types, the separation of movements by time under protected stop/signal control results in the driver having fewer traffic streams to focus on and increasing the likelihood of identifying a pedestrian. So, all volumes for stop/signal controlled will receive a score of 5. Permissive and yield-controlled movements are similar in driver behavior such that the driver is looking for a gap in oncoming vehicles, and therefore, the scores are the same for those two conflicting vehicle types. Finally, free-flowing vehicles received the lowest scores because drivers typically are not anticipating yielding to other users, whether vehicle or pedestrian. At higher volumes, the gaps available to pedestrians are smaller in size; therefore, all volumes will receive a score of 1 when the free-flowing volume is above 450 veh/hr.

Table C- 3: Vehicular Volume and Conflicting Vehicle Control Type Score for Pedestrians

Volume (vph)	Conflicting Vehicle Control Type			
	Stop/Signal	Permissive Left	Yield	Free Flowing
≤ 225	5	5	5	3
226-450	5	4	4	2
451-1,350	5	3	3	1
1,351-2,250	5	2	2	1
>2,250	5	1	1	1

Presence of Markings Score (F_M)

The score for the presence of crosswalk markings is a binary of 5 (best) and 1 (worst) and is shown in **Table C-4**. Crosswalk markings at the intersection reduce the likelihood of right turning vehicles encroaching on the crossing. This also creates an additional disincentive for designs that fail to provide full access to pedestrians across major and minor streets (intersections) or ramps and crossroads (major intersections). Failure to mark a crosswalk does not result in a lack of pedestrian attempts to cross.

Table C- 4: Presence of Markings Score

Marking	Score
Present	5
Absent	1

Out-of-Direction Travel Score (F_T)

The score for out-of-direction travel is a binary of 1 (best) and 0.9 (worst) and is shown in **Table C-5**. It is based on the finding that pedestrians experiencing delay are more likely to exhibit risky behavior (Transportation Research Board, 2016).

Table C- 5: Out-of-Direction Travel Score for Pedestrians

Out-of-Direction Travel	Score
No	1.0
Yes	0.9

Multistage Crossing Score (F_C)

The score for the multistage crossing ranges from 1.2 (best) to 0.8 (worst) and is shown in **Table C-6**. It is based on the FHWA report, *Safety Effects of Marked vs Unmarked Crosswalks at Uncontrolled Locations,* which found the presence of raised medians reduced pedestrian crashes by 46% (Zegeer et al., 2002). This suggests a two-stage crossing improves pedestrian safety. However, surveys and focus groups of pedestrians found three or more stages to be confusing (NASEM, 2021).

Table C- 6: Multistage Crossing Score

Number of Stages	Score
1	1.0
2	1.2
3+	0.8

C.2 Multimodal Bicycle Accommodations Analysis

The FDOT CAP-X Tool also provides the *Multimodal Bike* worksheet to evaluate bicycle accommodations for each selected intersection control strategy. Like the *Multimodal Ped* worksheet, most of the variables in the *Multimodal Bike* worksheet are populated with either default values or values carries over from inputs on other worksheets. Default values can be overridden by selecting options from the drop-down menus or by providing direct inputs, as applicable. The inputs for multimodal bicycle accommodations analysis and the methodology to determine bicycle accommodation score are described in the following subsections. Please see the assumptions in the worksheet to understand the applicability of the methodology.

C.2.1 Inputs for Bicycle Accommodations Analysis

Facility Type

Facility type for both the major and minor roadways is a required input to evaluate bicycle accommodations. Values that can be chosen for this input using the drop-down menu include:

- Shared with Vehicles – select if bicycles and vehicles will use the same space on the roadway.
- On-Street Lane – select if a dedicated bicycle space is provided adjacent to the motor vehicle travel lane. This includes parking separated or bollard separated bicycle lanes. This facility type can still be selected if vehicle and bicycle paths cross at points near the intersection (e.g., for the opening of an exclusive right turn lane).
- Shared Use Path – select if an off-street facility is provided for bicycles. This includes facilities which are at the same elevation of the motor vehicle facilities but physically and continuously separated (e.g., by a continuous median or curb).

Roadway Speed Limits

Values of roadway speed limits are populated from the *Multimodal Ped* worksheet.

Leg AADT

AADT is gathered at the leg level and populated based on user inputs on the *Volume Input* worksheet. This factor considers the vehicular AADT adjacent to the bicyclist. Weekday *K* factors are calculated for each hour of the day by averaging the *K* factor for seven different roadway classifications found in the FDOT Economic Analysis Tool for ICE. The highest hourly *K* factor is then used to convert hourly volumes provided on the *Volume Input* worksheet into AADTs. Any overridden input must be a positive integer.

Number of Adjacent Thru Lanes

The Number of lanes is gathered at the leg level and populated based on user inputs on the *Alt Num Lanes Input* worksheet. This factor considers the number of through lanes a bicyclist would need to cross to move into the left turn lane. It totals the number of through lanes traveling in the same direction as the bicyclist on the same approach leg. If two stage left turn boxes or some other method of turning left will be provided, the input should be set to 1. For the minor legs of the signalized and unsignalized restricted crossing U-turn intersections, this factor considers the number of adjacent through lanes on the major leg after the bicyclist has made the right turn from the minor leg. Any overridden input must be a positive integer.

Conflicting Control Type

Conflicting vehicle type is gathered at the leg level and prepopulated with default values for all control strategies. This factor considers the dominant control type for vehicular traffic moving perpendicular to the direction of the bicyclist. Values can be overridden by selecting one of the following categories of conflicting control types using the drop-down menu:

- Stop/Signal Controlled - select when the conflicting vehicles operate under stop or signal control. This can still be selected if a right turning movement operates under yield control.
- Yield Controlled – select when the conflicting vehicles operate under yield control, such as at roundabouts.
- Free Flowing – select when the conflicting vehicles are free flowing, such as the uninterrupted leg of a minor-road stop control intersection.

Out-of-Direction Travel

Out-of-direction travel is gathered at the leg level and prepopulated with default values for all control strategies. This factor considers the desire of bicyclists to travel in the most direct path possible. It should be flagged as yes if any movement by a bicyclist on that leg results in vertical or horizontal out-of-direction travel. For example, the minor legs of the Restricted Crossing U-Turn intersection *Out-of-Direction Travel* is assumed to be "Yes" because a bicyclist desiring to go straight or turn left must turn right and travel to the downstream U-turn. It is assumed at Median U-Turns that bicyclists will perform a two-stage left turn even if no pavement marking for such is provided. Values can be overridden using the drop-down menu by toggling between "Yes" or "No".

Riding Between Opposing Travel Directions

Riding between travel lanes moving in two opposite directions is gathered at the leg level and prepopulated with default values for all control strategies. This factor considers instances where a bicyclist is traveling between opposing directions of motor vehicle traffic, such as at the displaced left turn. Values can be overridden using the drop-down menu by toggling between "Yes" or "No".

Riding Across Free Flow Ramp or Channelized Turn Lane

Riding across free flow ramp is gathered at the leg level and prepopulated with default values for all control strategies. This factor considers whether a bicyclist traveling along the leg must cross a free-flowing vehicle movement. This most often occurs when a bicyclist crosses the downstream end of a channelized turn lane or the up- or downstream end of a loop ramp. Values can be overridden using the drop-down menu by toggling between "Yes" or "No".

C.2.2 Bicycle Accommodation Scores

For bicycle accommodation, each crossing receives a leg score which is then combined with all other leg scores at the intersection. The intersection score for bicycle accommodation is a combination of each leg score. A higher score indicates a safer design with the highest possible score being 5 and the lowest possible score being 1.

The score for leg *i* (L_i) is a combination of the factor scores of facility type, leg AADT, and vehicle speed (F_{FAS}), number of adjacent thru lanes (F_A), conflicting control type (F_C), out-of-direction travel (F_T), riding between travel lanes (F_B), and riding across free flow ramps (F_R). The scores for these values are shown later in this document.

$$L_i = \frac{F_{FAS} + F_A + F_C + F_T + F_B + F_R}{6}$$

The intersection score is a combination of all *n* leg scores (L_i. Averaging the square root of the leg score incentivizes improving poor performing legs over making high performing legs marginally better.

$$Intersection\ Score = \left[\frac{\sum_{i=1}^{n} \sqrt{L_i}}{n}\right]^2$$

The individual factor scores for each leg are described below:

Facility Type, Leg AADT, and Roadway Operating Speeds Score (F_{FAS})

The score for the facility type, leg AADT, and roadway speeds ranges from 5 (best) to 1 (worst) and is shown in **Table C-7**. Grouping of facility type and vehicle speeds, as well as AADT thresholds of 3,000 and 7,000 veh/day were selected based on the FHWA Bikeway Selection Guide preferred bikeway types shown in **Figure C-7** (Schultheiss et al., 2019). Assigned scores for shared use paths were set to 5 due to the bicycle-vehicle interaction being limited to designated crossings.

Table C- 7: Roadway Operating Speed Score by Leg AADT for Various Bike Facilities

Bike Facility Type	Leg AADT (vpd)	Operating Speed (mph)			
		≤ 25	26-30	31-39	≥ 40
Shared Use Path	≤ 3,000	5	5	5	5
	3,001 - 7,000	5	5	5	5
	>7,000	5	5	5	5
On-Street Bike Lane	≤ 3,000	5	4	4	2
	3,001 - 7,000	4	4	4	2
	>7,000	3	2	2	1
Shared with Vehicle Lane	≤ 3,000	5	4	3	2
	3,001 - 7,000	3	3	2	1
	>7,000	2	1	1	1

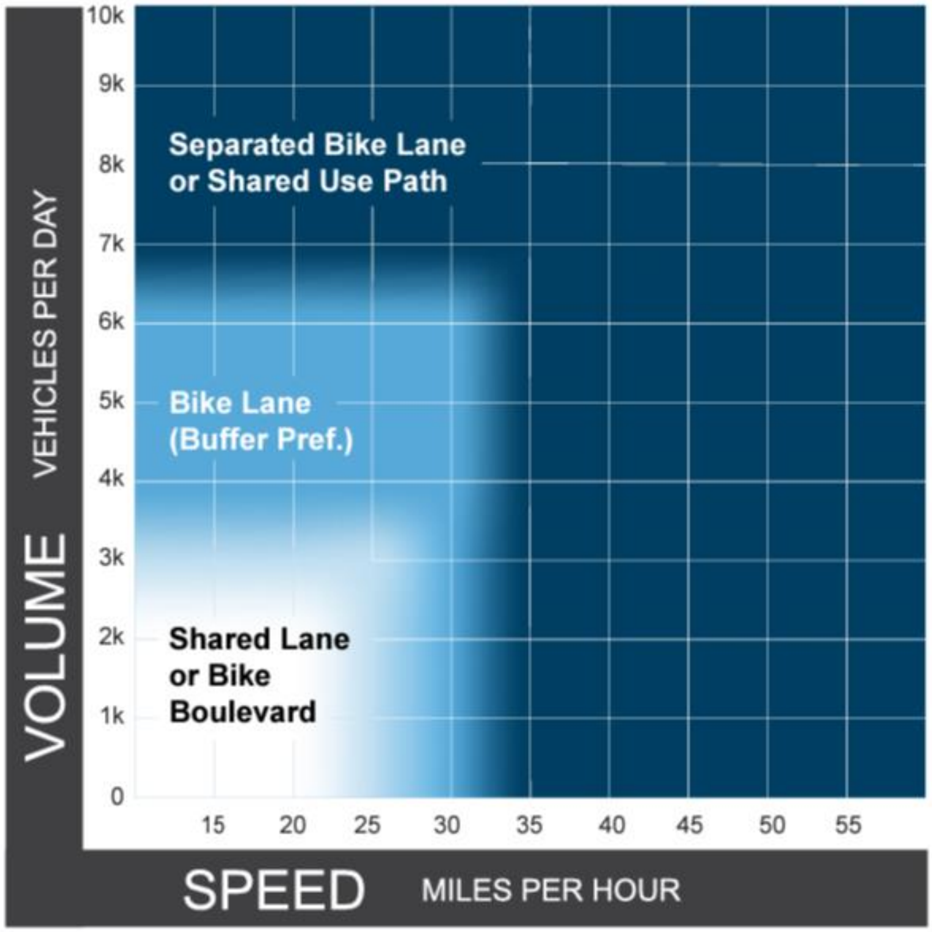


Figure C-7: Preferred Bikeway Type for Urban, Urban Core, Suburban, and Rural Town Contexts

Source: Schultheiss et al., 2019

Assigned scores for on-street lanes and shared lanes are guided by Level of Traffic Stress (LTS) scoring tables shown in **Figure C-8.** For on-street lane facilities, the mixed traffic criteria table is used (**Figure C-8a**). Where the LTS tables provided more granular scoring (e.g., sub-classification of AADTs), average values across all LTS are used. For example, in considering the score for on-street lanes with operating speeds between 26 and 30 mph and AADT less than or equal to 3,000 veh/day, all LTS scores which meet those criteria are averaged. For bike lane facilities, the "bike lanes and shoulders not adjacent to a parking lane" table is used (**Figure C-8b**). LTS for "1 thru lane per direction, or unlaned" is used to determine scores for AADTs less than or equal to 3,000 veh/day. LTS for "2 thru lanes per direction" is used to determine scores for AADTs between 3,000 and 7,000 veh/day. In both instances, LTS values are averaged across speed and bike lane width as necessary. LTS values for "3+ lanes per direction" is used to determine scores for AADTs greater than 7,000 veh/day (Furth, 2017).

Mixed traffic criteria

Number of lanes	Effective ADT*	Prevailing Speed ≤ 20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50+mph
Unlaned 2-way street (no centerline)	0-750	LTS 1	LTS 1	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	751-1500	LTS 1	LTS 1	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4
	1501-3000	LTS 2	LTS 2	LTS 2	LTS 3	LTS 4	LTS 4	LTS 4
	3000+	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
1 thru lane per direction (1-way, 1-lane street or 2-way street with centerline)	0-750	LTS 1	LTS 1	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	751-1500	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4
	1501-3000	LTS 2	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	3000+	LTS 3	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
2 thru lanes per direction	0-8000	LTS 3	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4
	8001+	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4
3+ thru lanes per direction	any ADT	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4	LTS 4	LTS 4

* Effective ADT = ADT for two-way roads; Effective ADT = 1.5*ADT for one-way roads

Bike lanes and shoulders not adjacent to a parking lane

Number of lanes	Bike lane width	Prevailing Speed ≤ 25 mph	30 mph	35 mph	40 mph	45 mph	50+ mph
1 thru lane per direction, or unlaned	6+ ft	LTS 1	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	4 or 5 ft	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4
2 thru lanes per direction	6+ ft	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 3
	4 or 5 ft	LTS 2	LTS 2	LTS 2	LTS 3	LTS 3	LTS 4
3+ lanes per direction	any width	LTS 3	LTS 3	LTS 3	LTS 4	LTS 4	LTS 4

Notes 1. If bike lane / shoulder is frequently blocked, use mixed traffic criteria.
2. Qualifying bike lane / shoulder should extend at least 4 ft from a curb and at least 3.5 ft from a pavement edge or discontinuous gutter pan seam
3.Bike lane width includes any marked buffer next to the bike lane.

Figure C-8: Level of Traffic Stress Criteria for Road Segments

Source: Furth, 2017

Number of Adjacent Thru Lanes Score (F_A)

The score for the number of adjacent thru lanes ranges from 5 (best) to 1 (worst) and is shown in **Table C-8**. It considers the number of lanes a bicyclist must cross to move from the right side of the road when making a left turn. Each movement across a lane is a potential interaction with at least one motor vehicle. Additional lanes result in increased interactions and therefore receive lower scores.

Table C- 8: Number of Adjacent Thru Lanes Score

Number of Lanes	Score
1	5
2	4
3	2
4+	1

Conflicting Control Type Score (F_C)

The score for the vehicle volume and conflicting vehicle type ranges from 5 (best) to 1 (worst) and is shown in **Table C-9**. In assigning scores for the various conflicting vehicle types, the separation of movements by time under stop/signal control results in additional protection for the bicyclist and therefore is given a score of 5. Yield controlled movements, found at roundabouts, receive a score of 4 because drivers have a slightly higher workload but are still actively looking for roadway users. Finally, free flowing vehicles receive the lowest score of 1 because drivers are not anticipating the need to yield to bicyclists and bicyclists must look for a gap in traffic.

Table C- 9: Conflicting Control Type Score for Bicyclists

Conflicting Control Type	Score
Stop/Signal	5
Yield	4
Free Flowing	1

Out-of-Direction Travel Score (F_T)

The score for out-of-direction travel is a binary of 5 (best) and 1 (worst) and is shown in **Table C-10**. It is based on the commonly accepted belief that bicyclists experiencing additional delay for out-of-direction travel are more likely to exhibit risky behavior.

Table C- 10: Out-of-Direction Travel Score for Bicyclists

Out-of-Direction Travel	Score
No	5
Yes	1

Riding Between Opposing Travel Directions Score (F_T)

The score for riding between travel lanes is a binary of 5 (best) and 1 (worst) and is shown in **Table C-11**. Bicyclists in focus groups confirmed riding between travel lanes increases discomfort due to being unable to maneuver away from an errant motor vehicle. Additionally, riding between travel lanes almost always results in bicycle and motor vehicle paths crossing at least once.

Table C- 11: Riding Between Travel Lanes Score

Riding Between Travel Lanes	Score
No	5
Yes	1

Riding Across Free Flow Ramp or Channelized Lane Score (F_R)

The score for riding across free flow ramps is a binary of 5 (best) and 1 (worst) and is shown in **Table C-12**. Vehicles making a free flow movement are typically not expected to yield to another user, so bicyclists crossing such a movement are at increased risk as compared to a bicyclist continuing to move parallel to motor vehicles.

Table C- 12: Riding Across Free Flow Ramp Score

Riding Across Free Flow Ramp	Score
No	5
Yes	1

C.3 Exhibits Showing Default Pedestrian Crossing Locations and Pavement Markings for Each Intersection Control Strategy

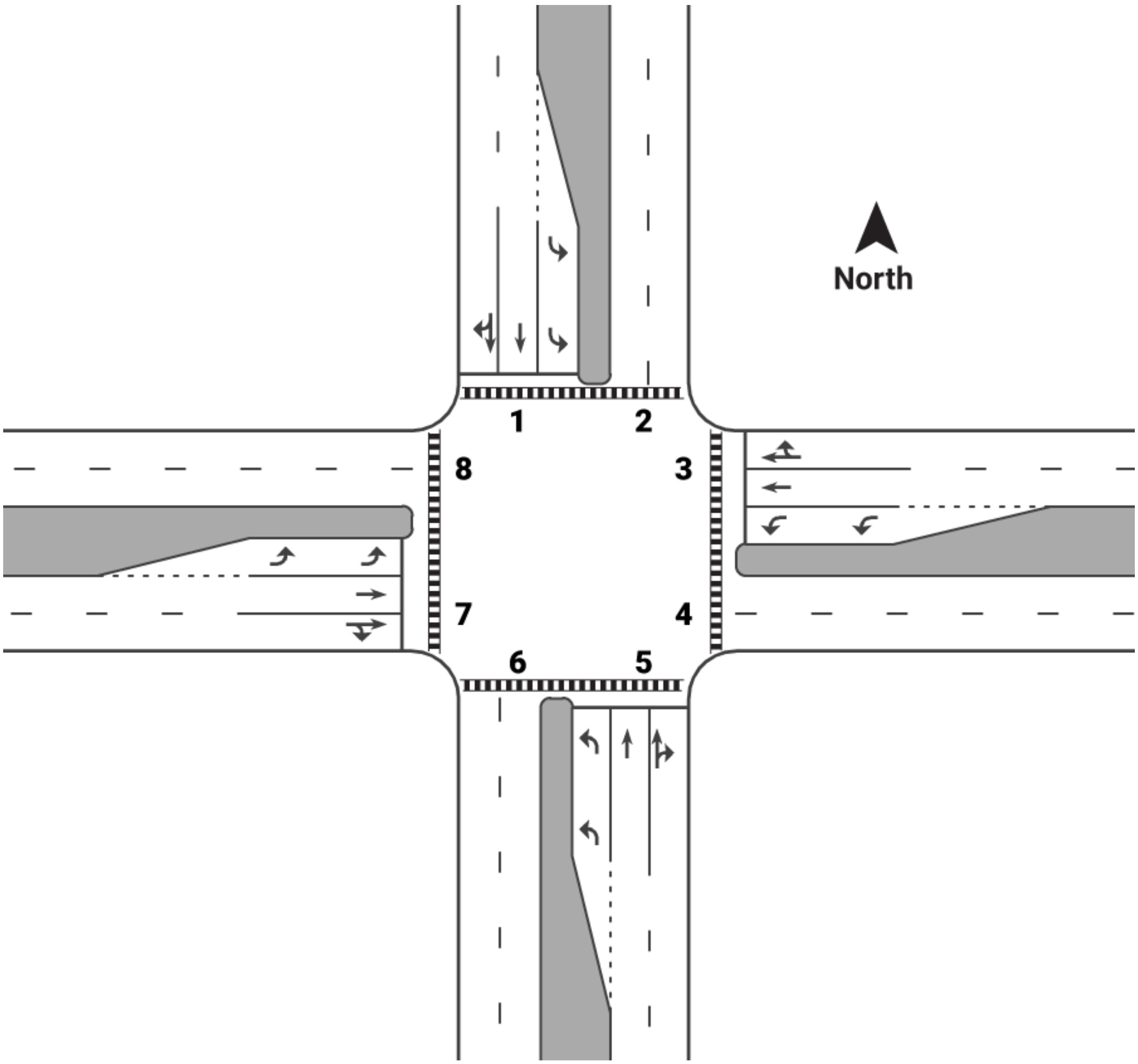


Figure C-9: Traffic Signal

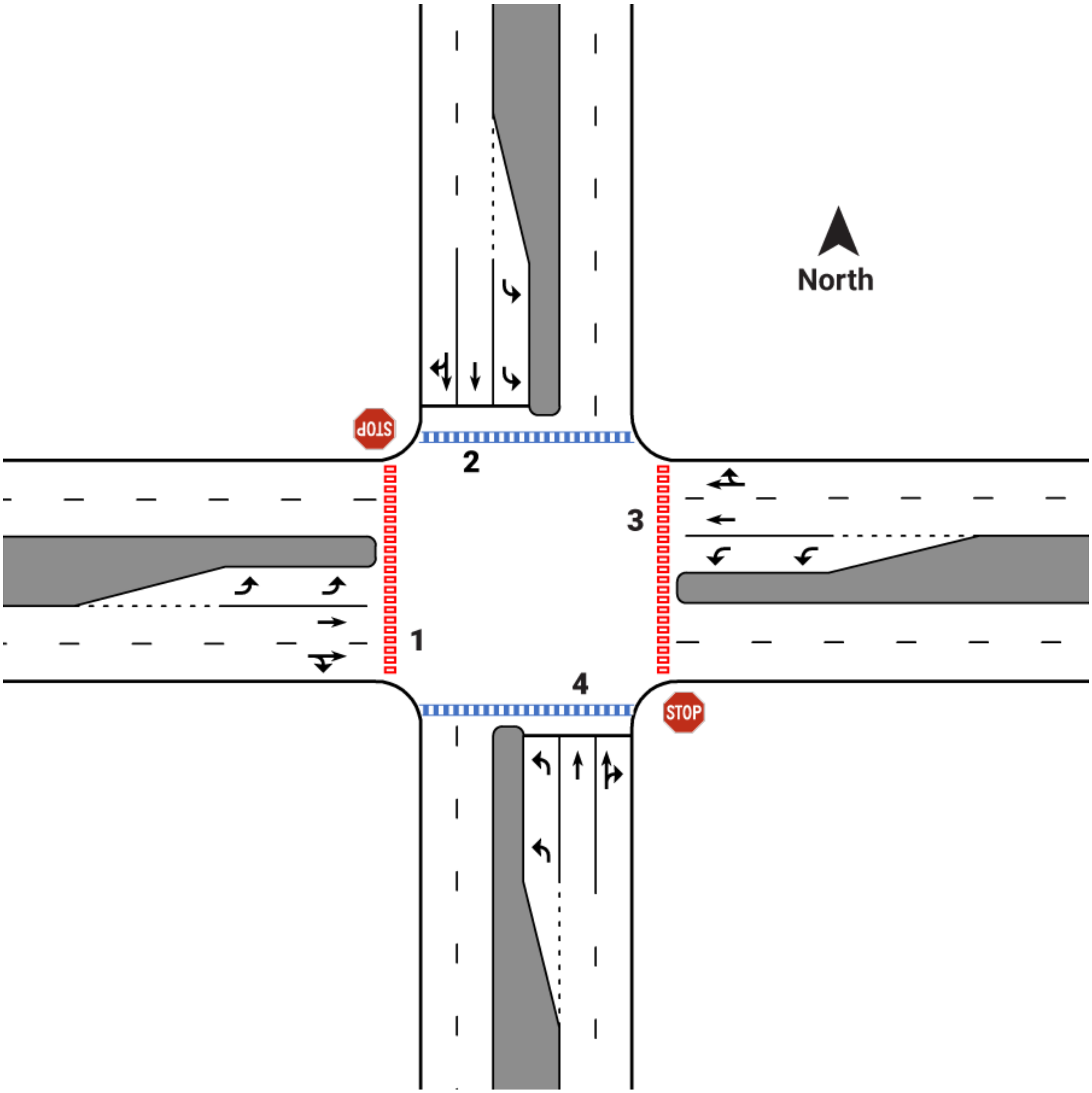


Figure C-10: Two-Way Stop Control (N-S)

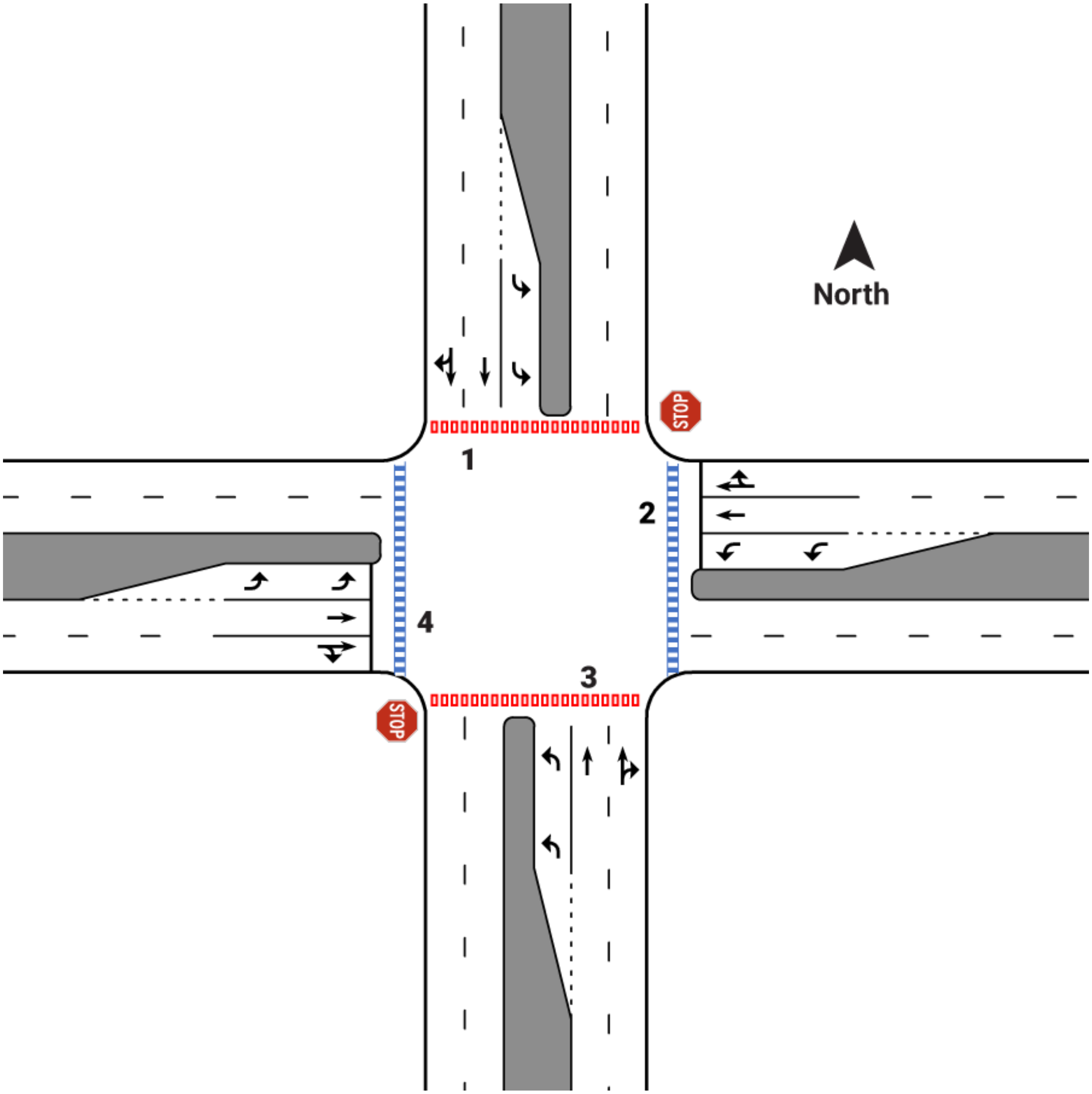


Figure C-11: Two-Way Stop Control (E-W).

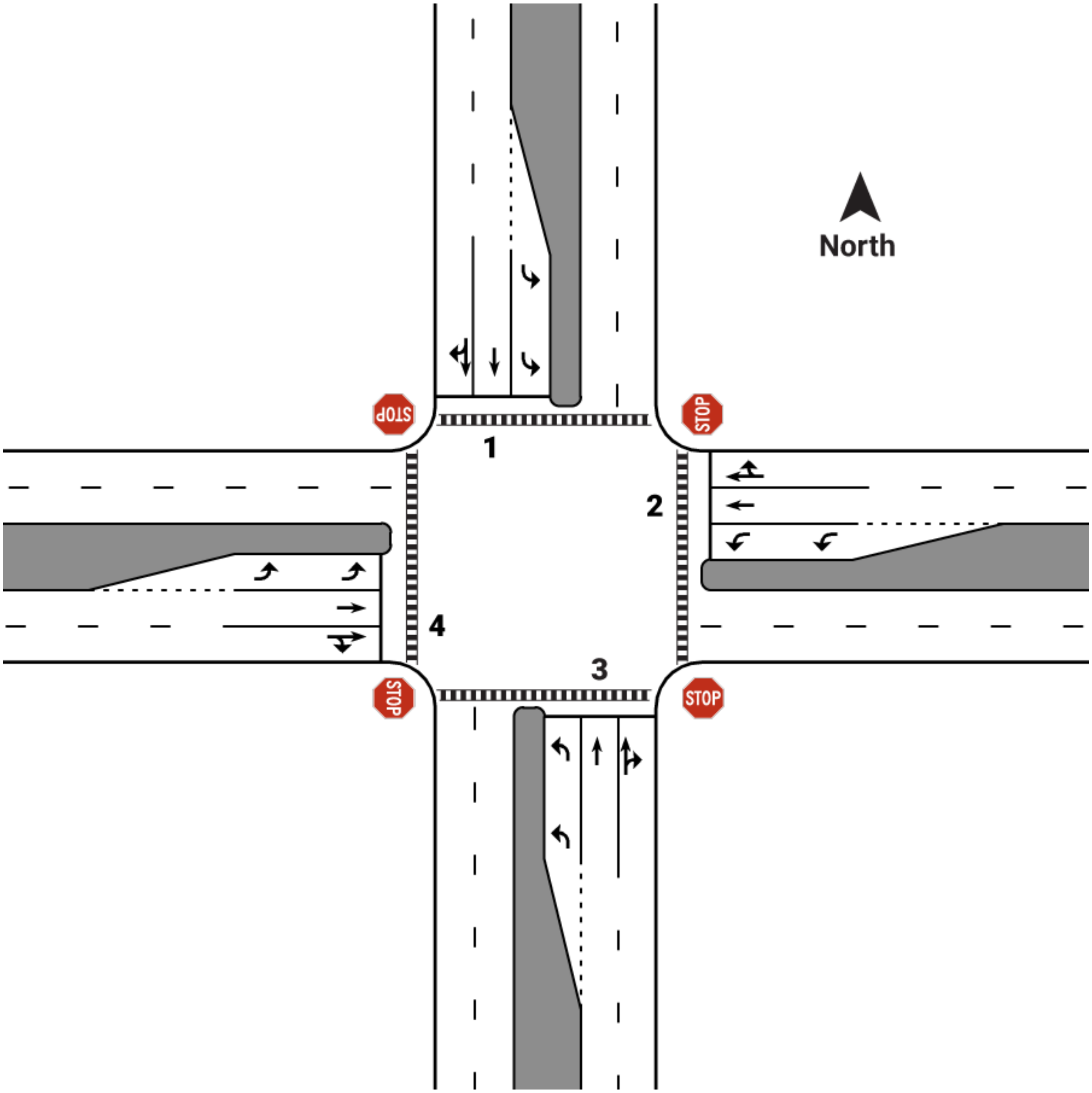


Figure C-12: All-Way Stop Control

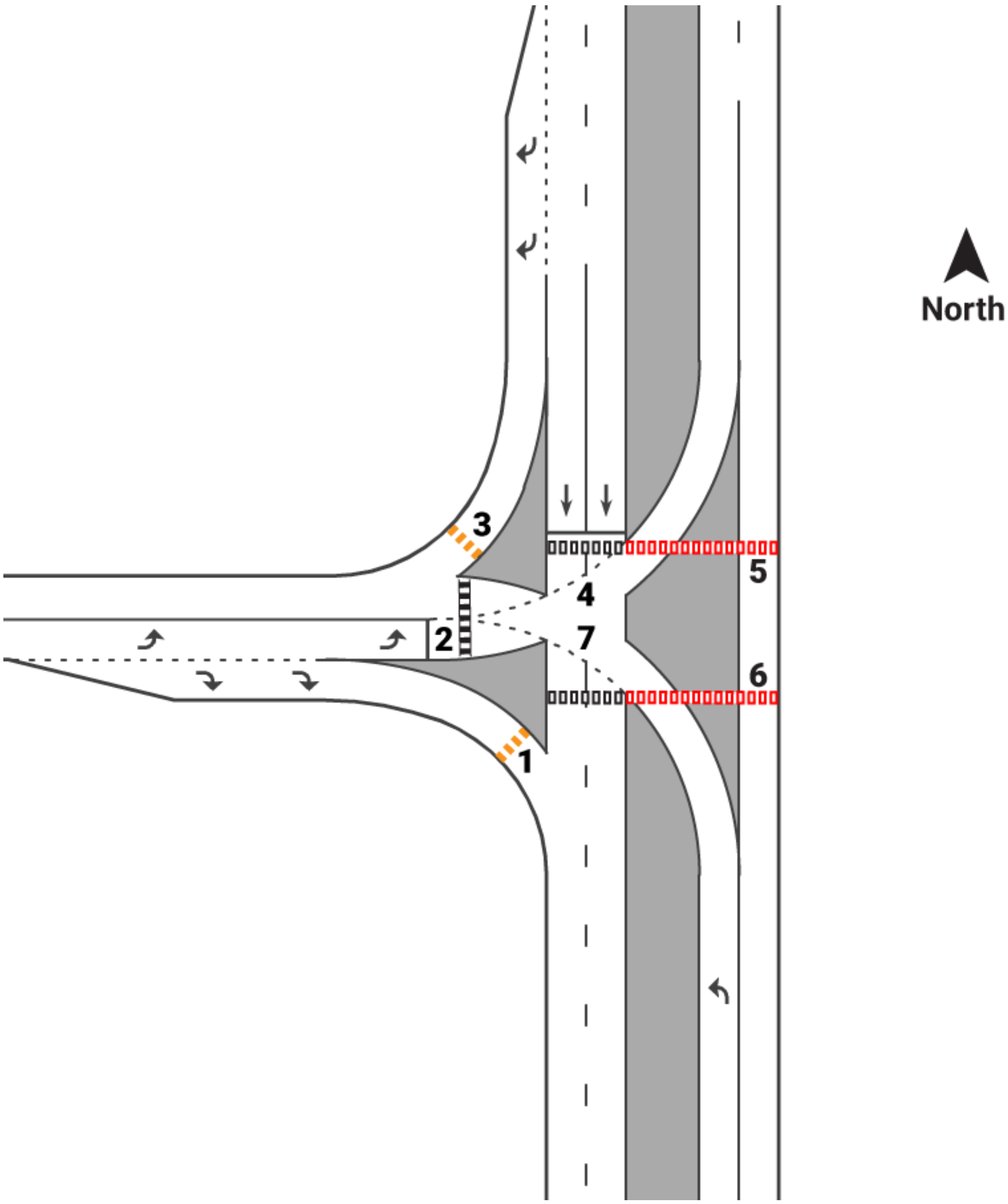


Figure C-13: Continuous Green T (W)

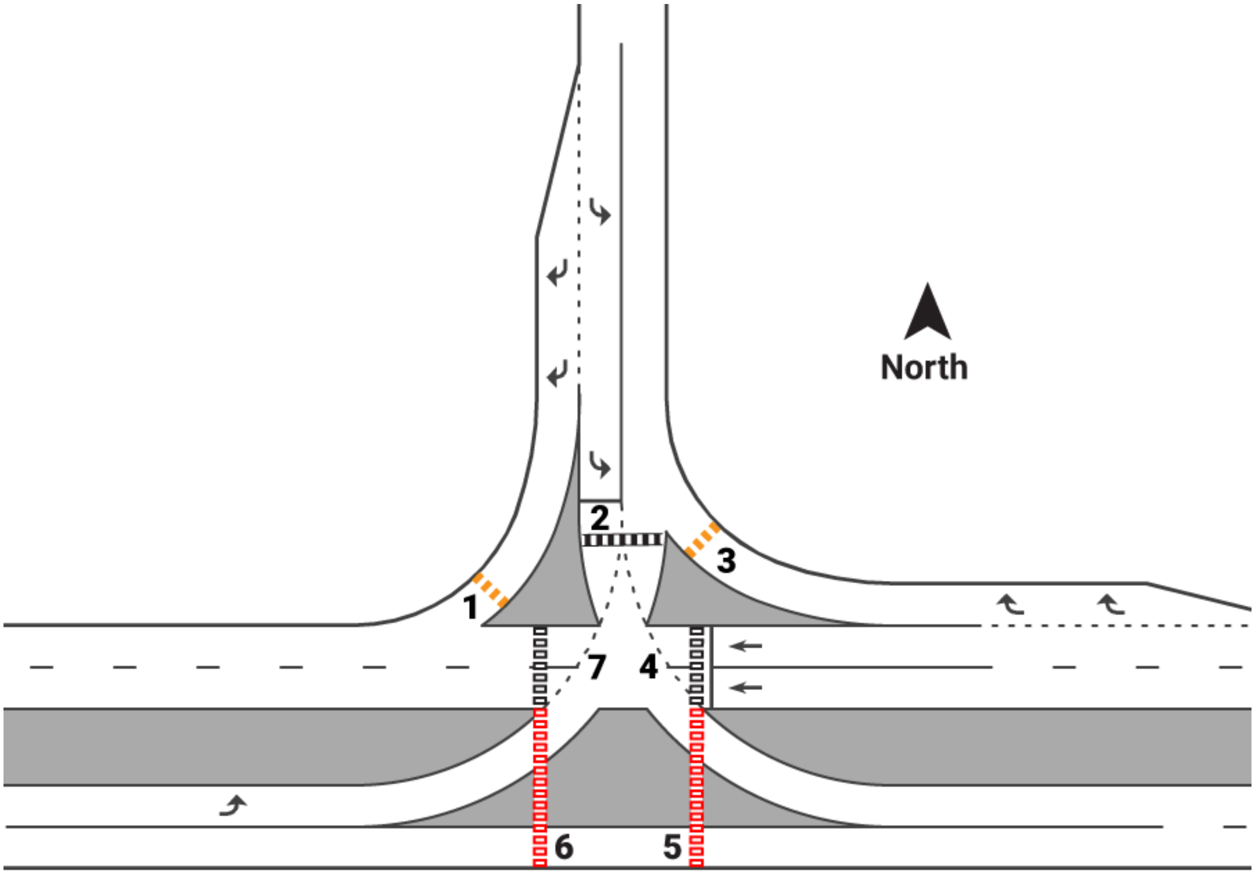


Figure C-14: Continuous Green T (N)

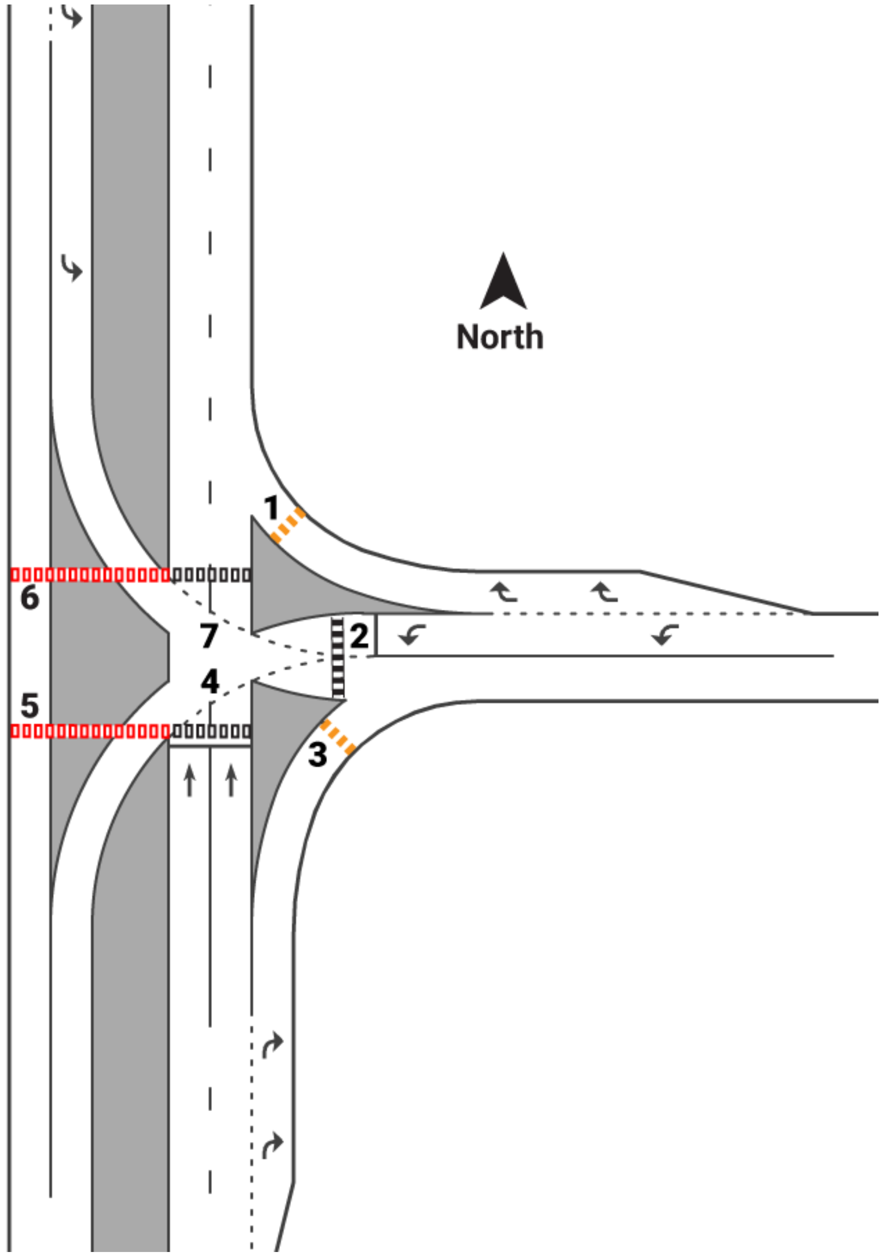


Figure C-15: Continuous Green T (E)

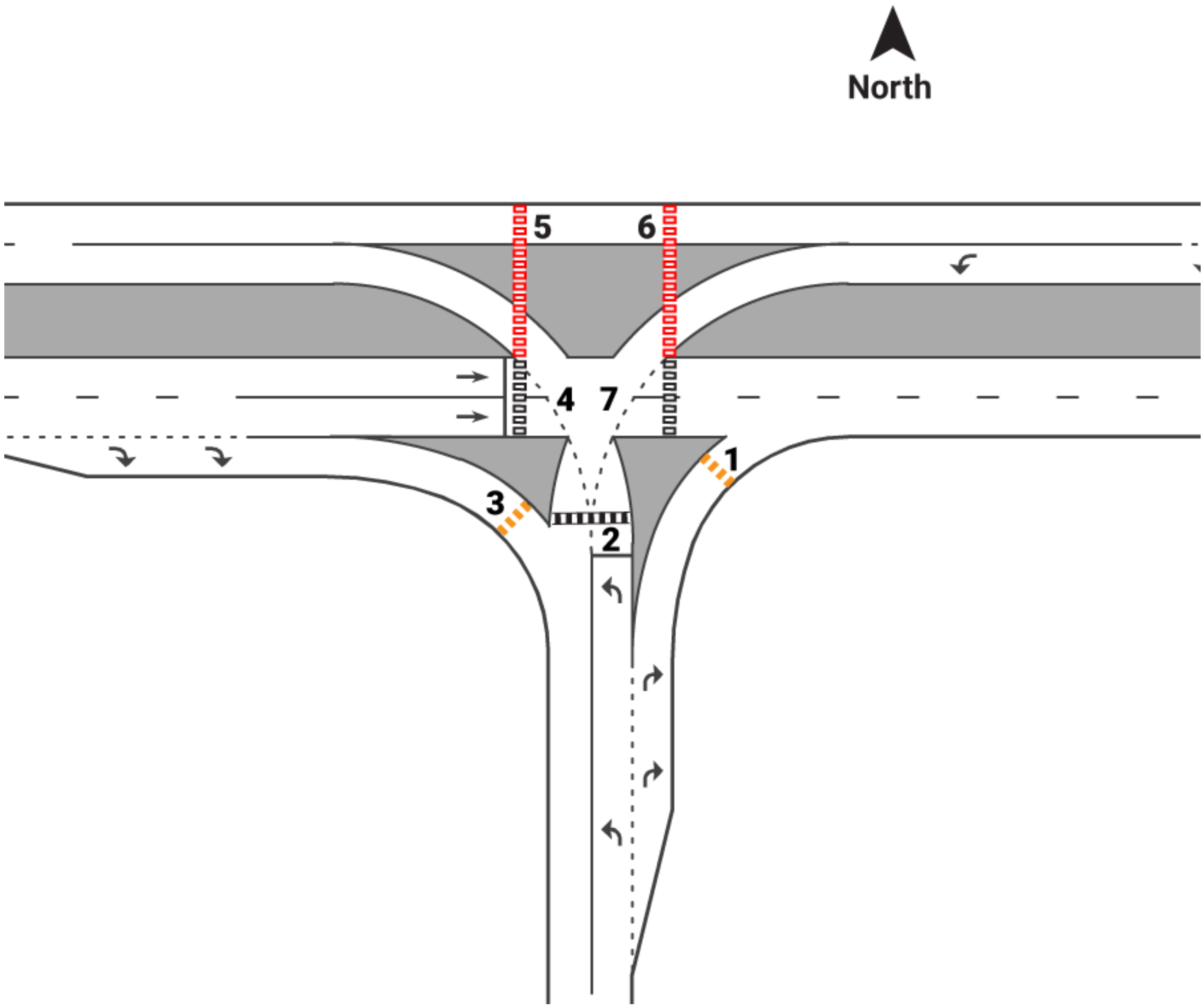


Figure C-16: Continuous Green T (S)

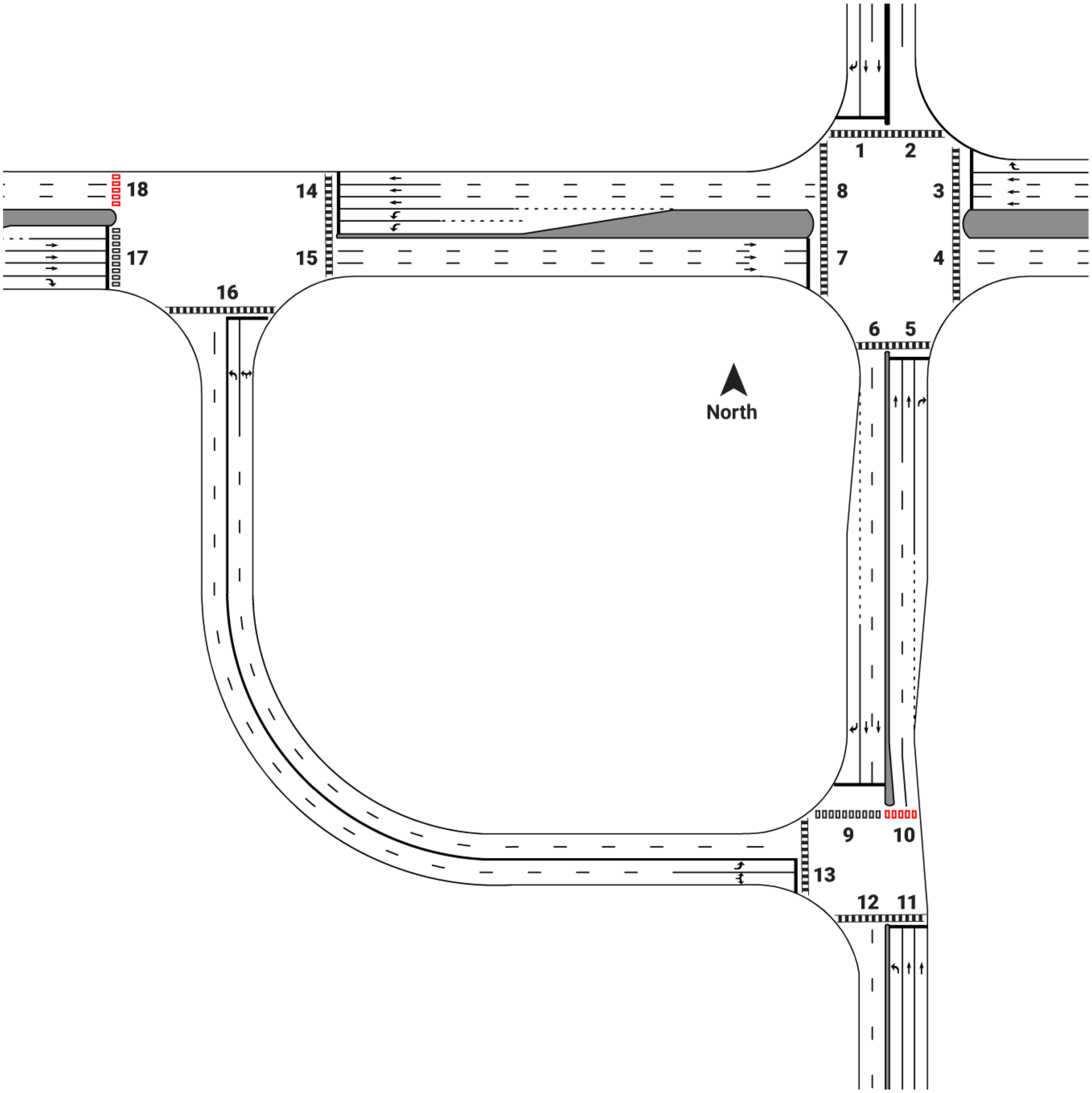


Figure C-17: Quadrant Roadway (S-W)

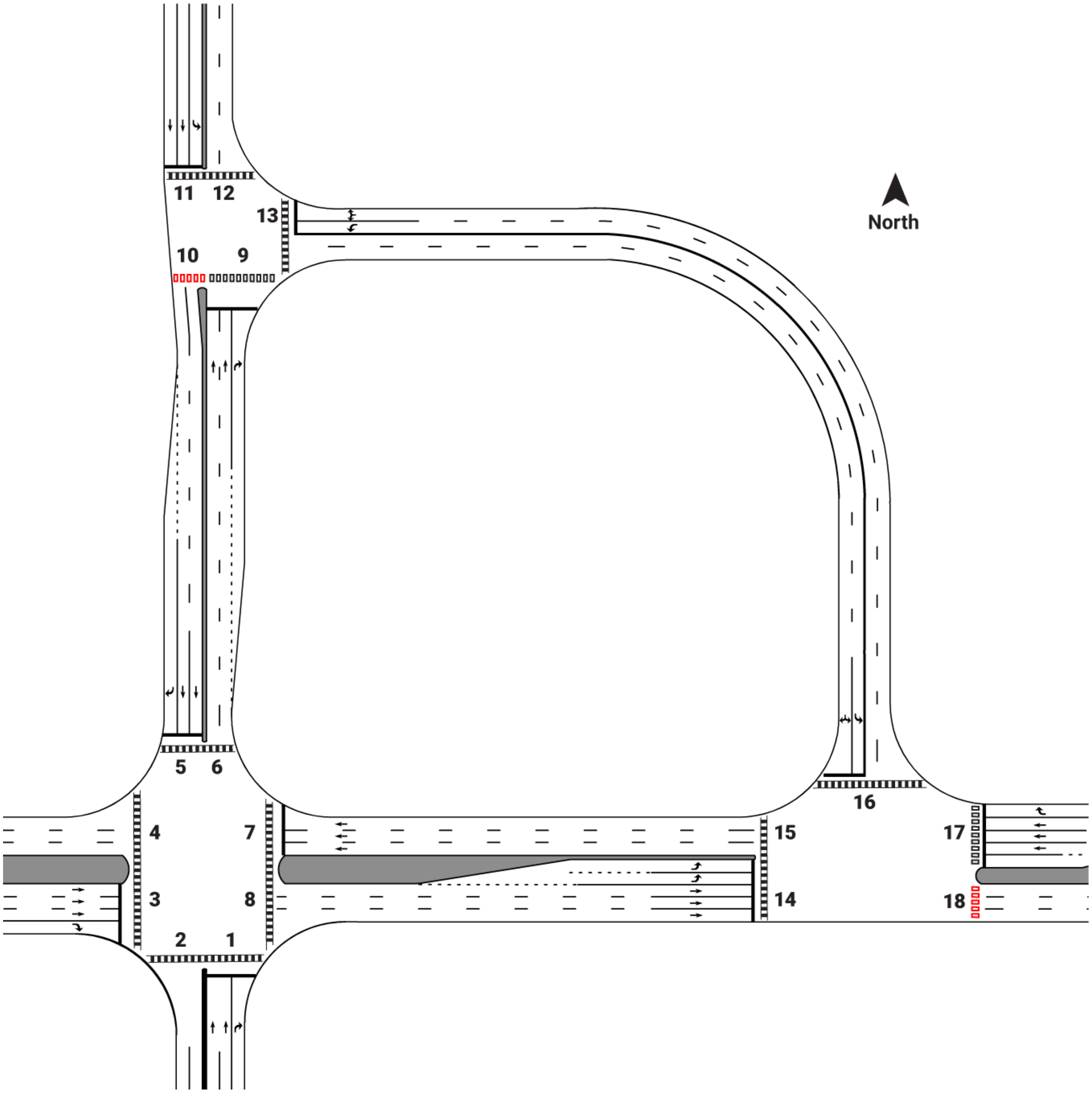


Figure C-18: Quadrant Roadway (N-E)

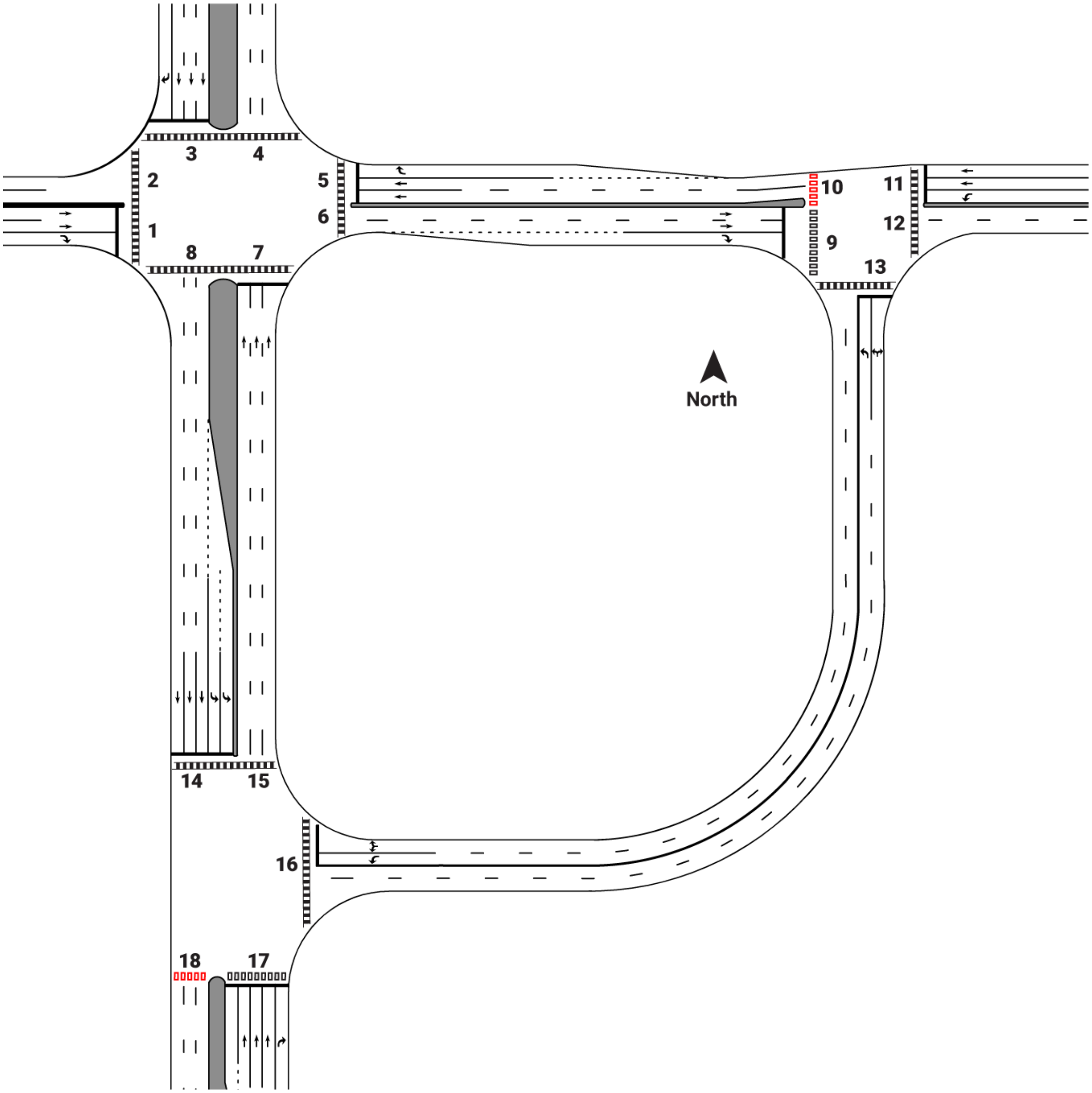


Figure C-19: Quadrant Roadway (S-E)

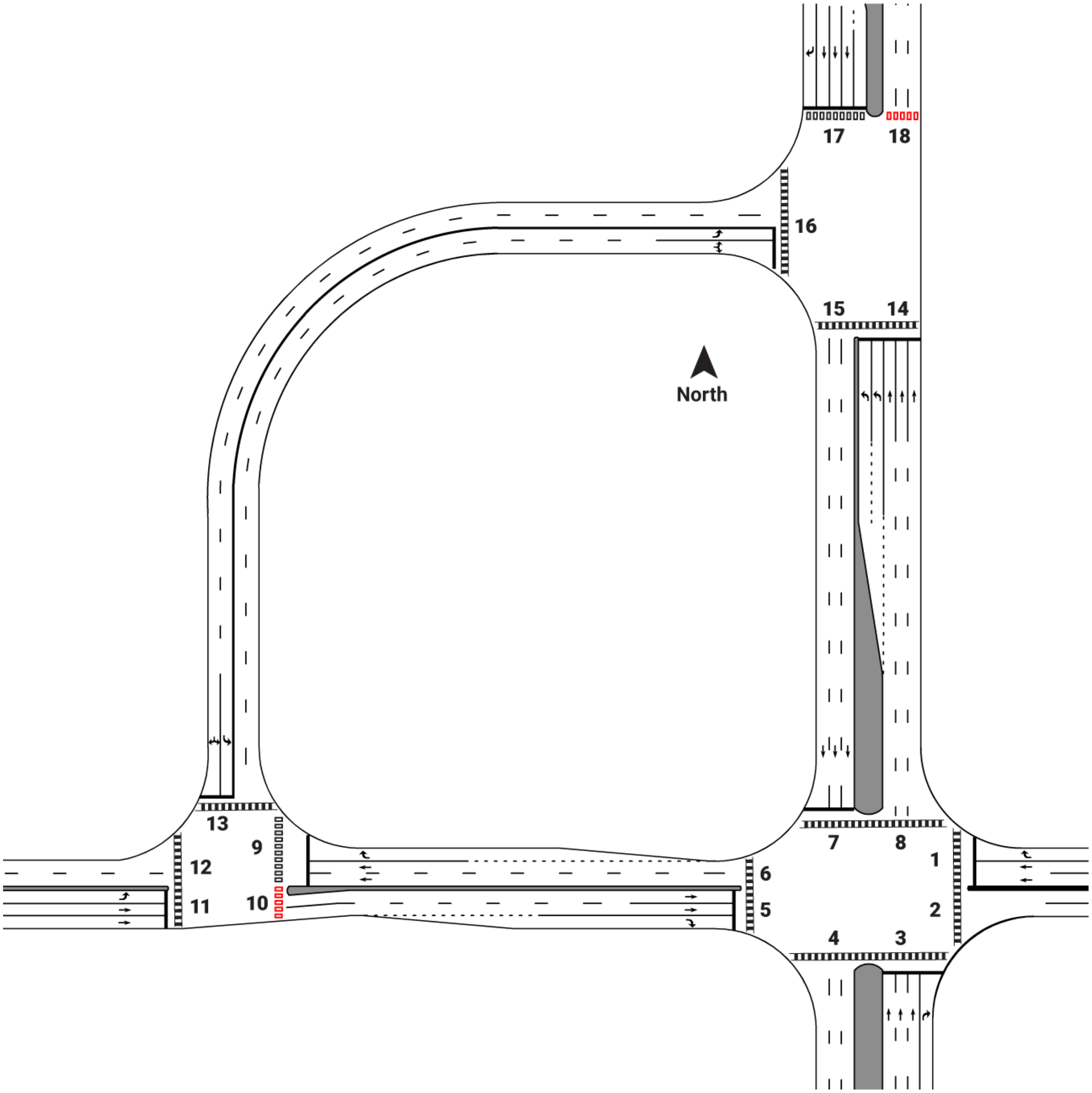


Figure C-20: Quadrant Roadway (N-W)

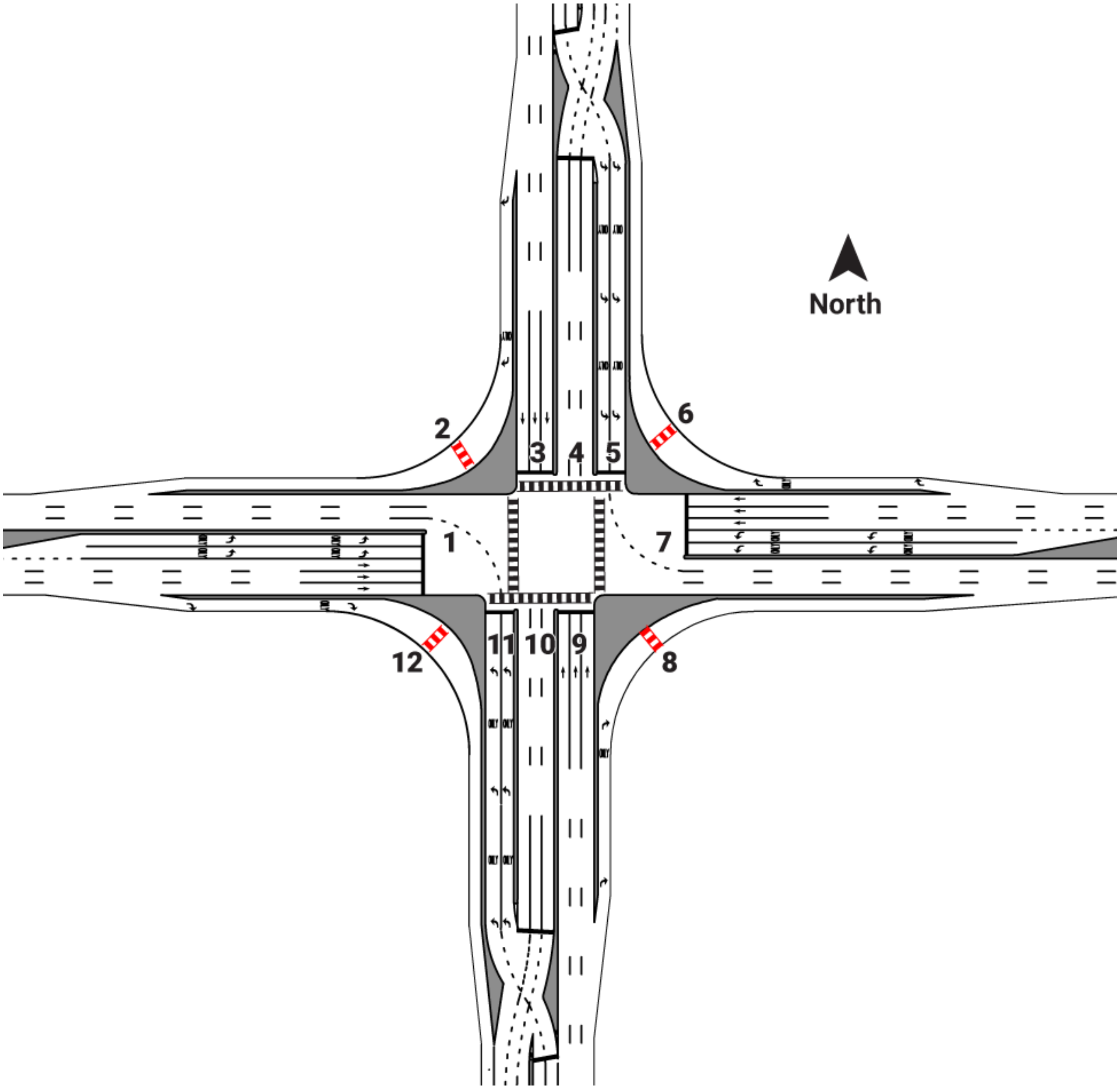


Figure C-21: Partial Displaced Left Turn (N-S)

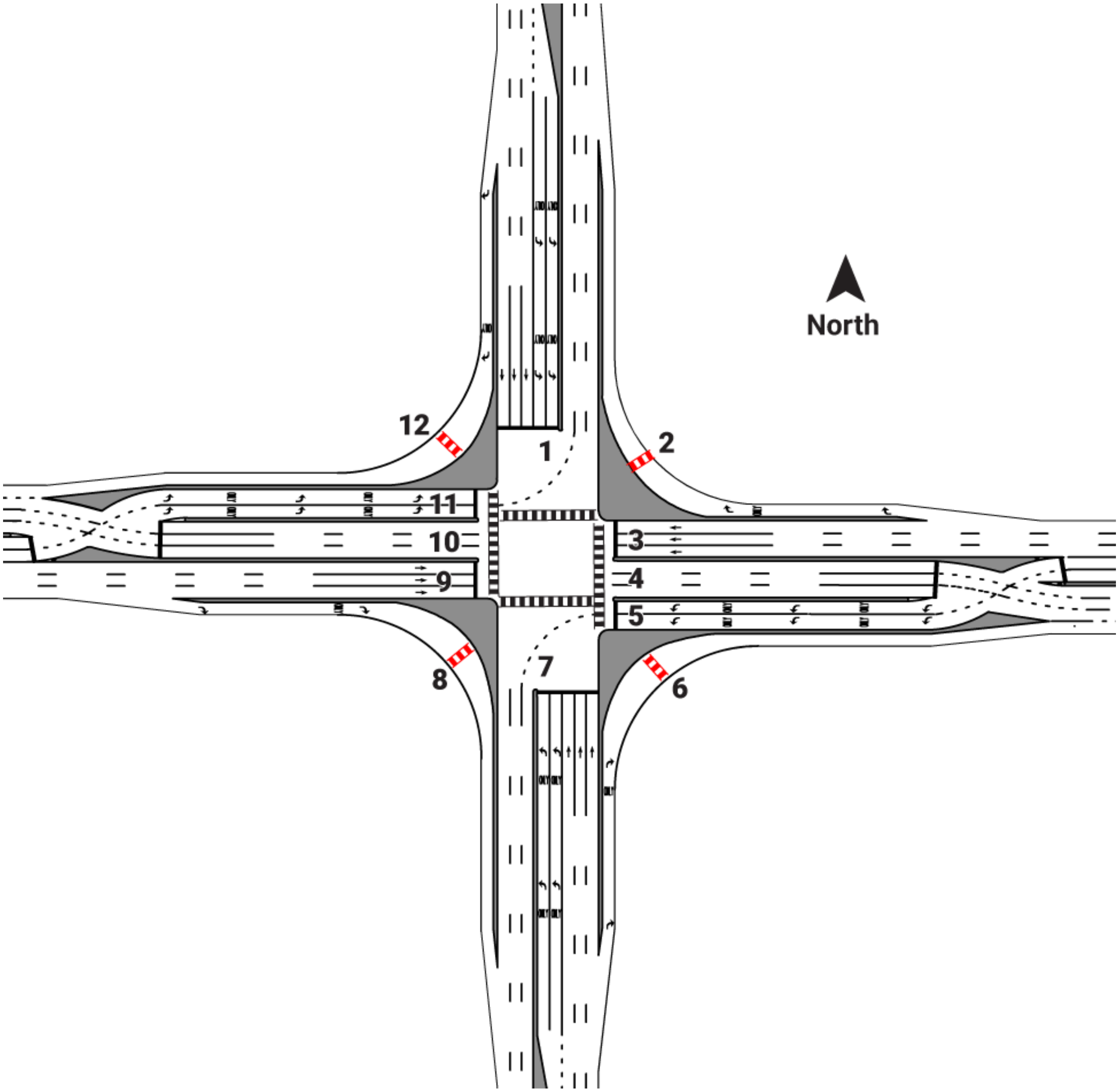


Figure C-22: Partial Displaced Left Turn (E-W)

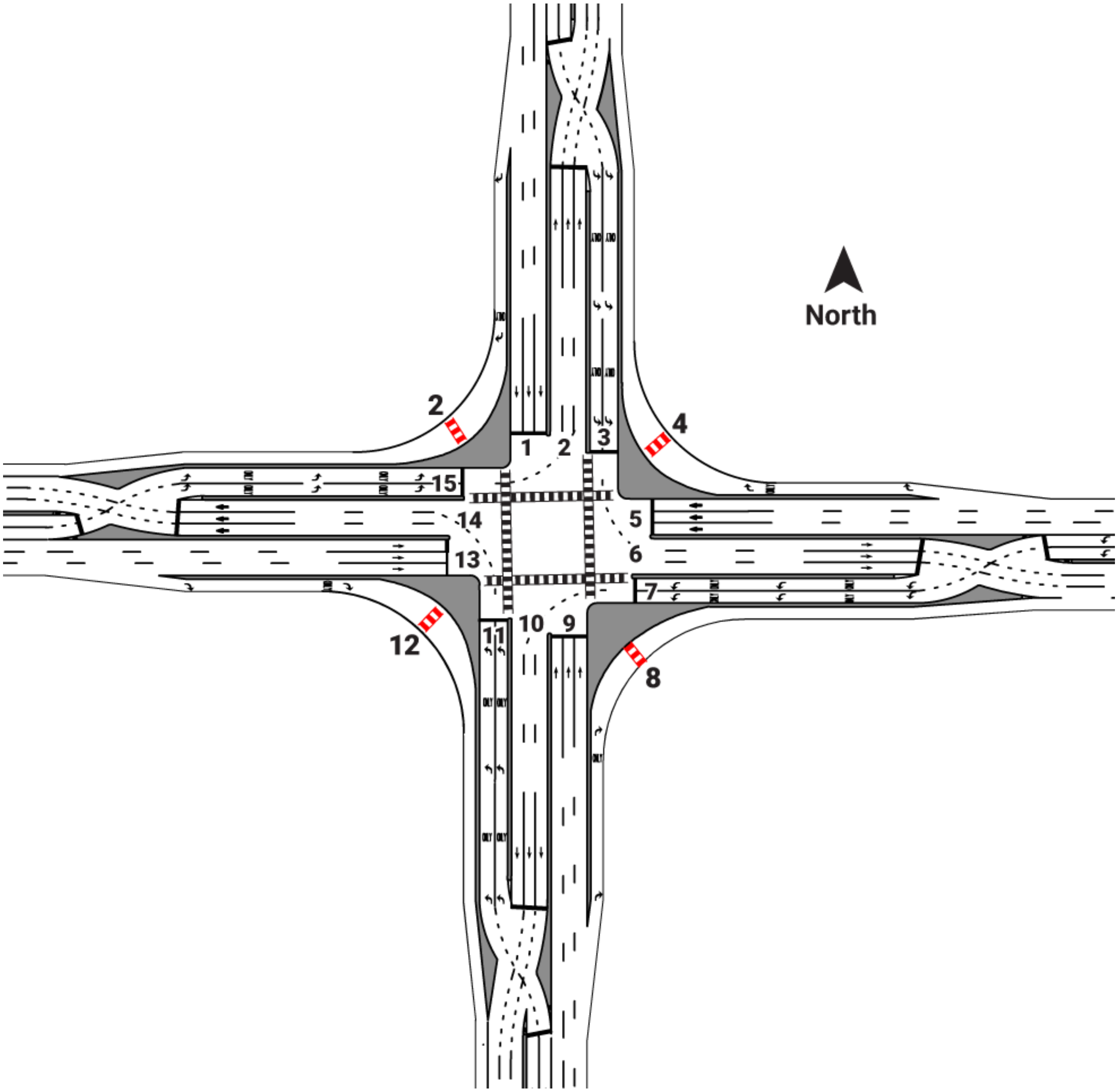


Figure C-23: Full Displaced Left Turn

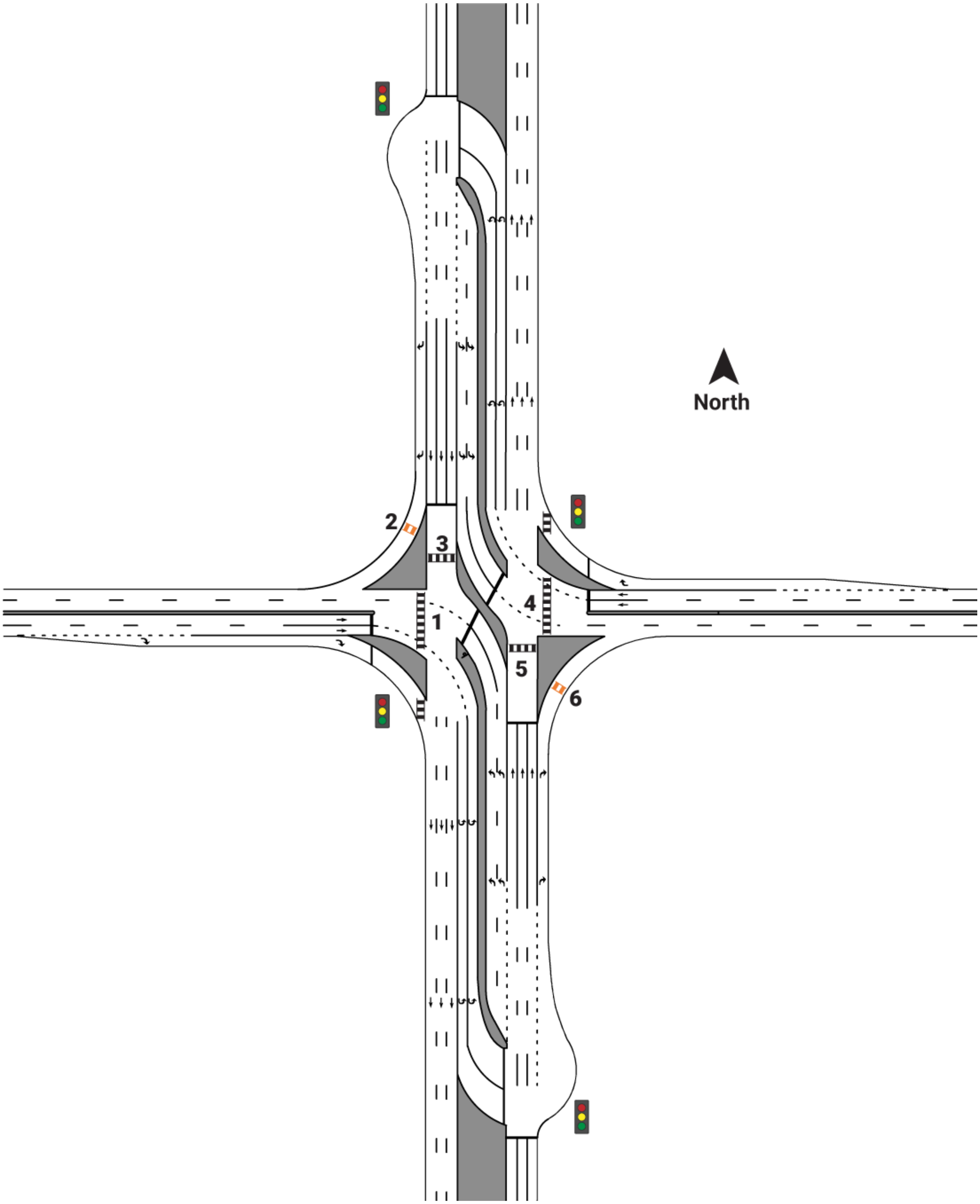


Figure C-24: Signalized Restricted Crossing U-Turn (N-S)

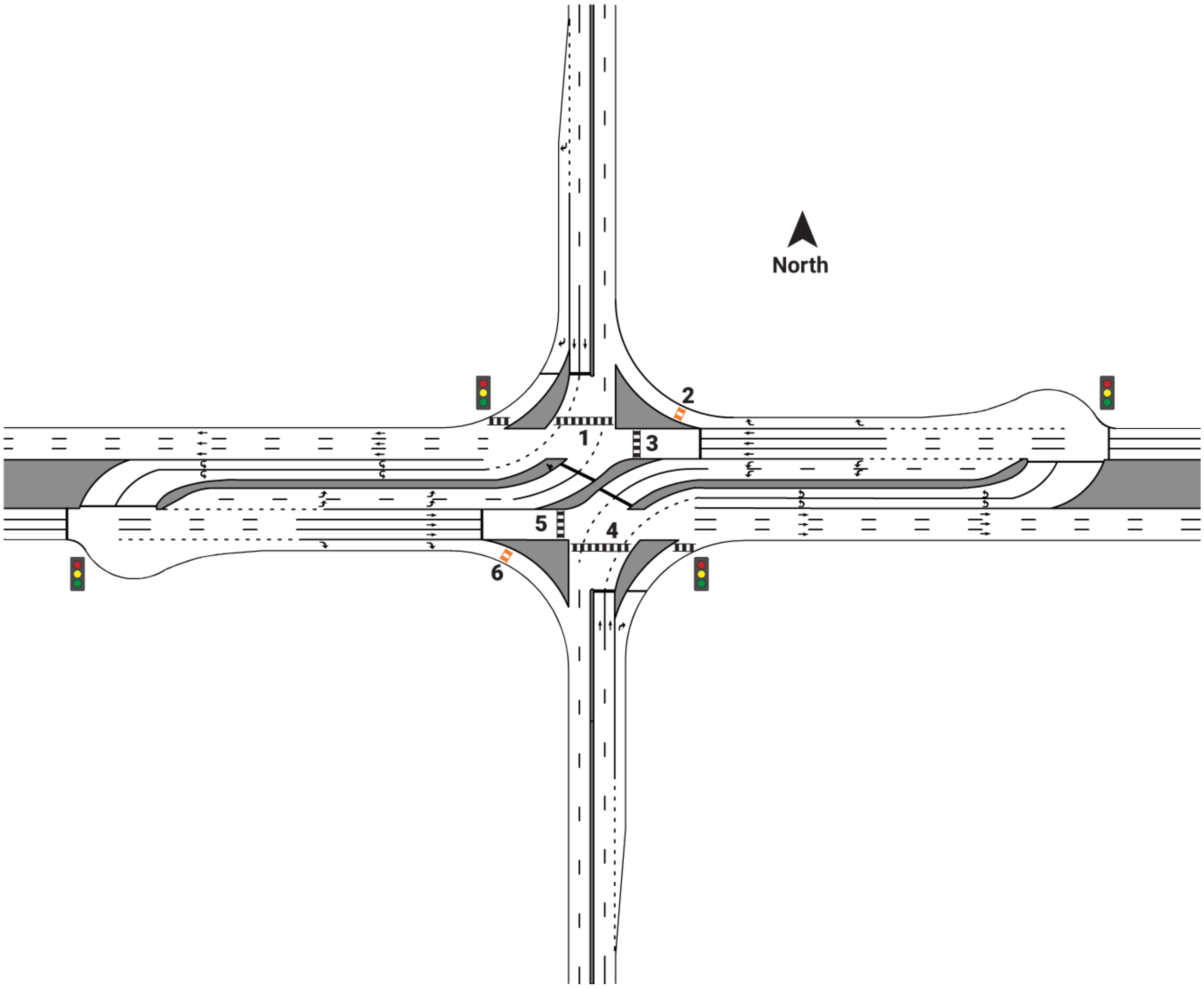


Figure C-25: Signalized Restricted Crossing U-Turn (E-W)

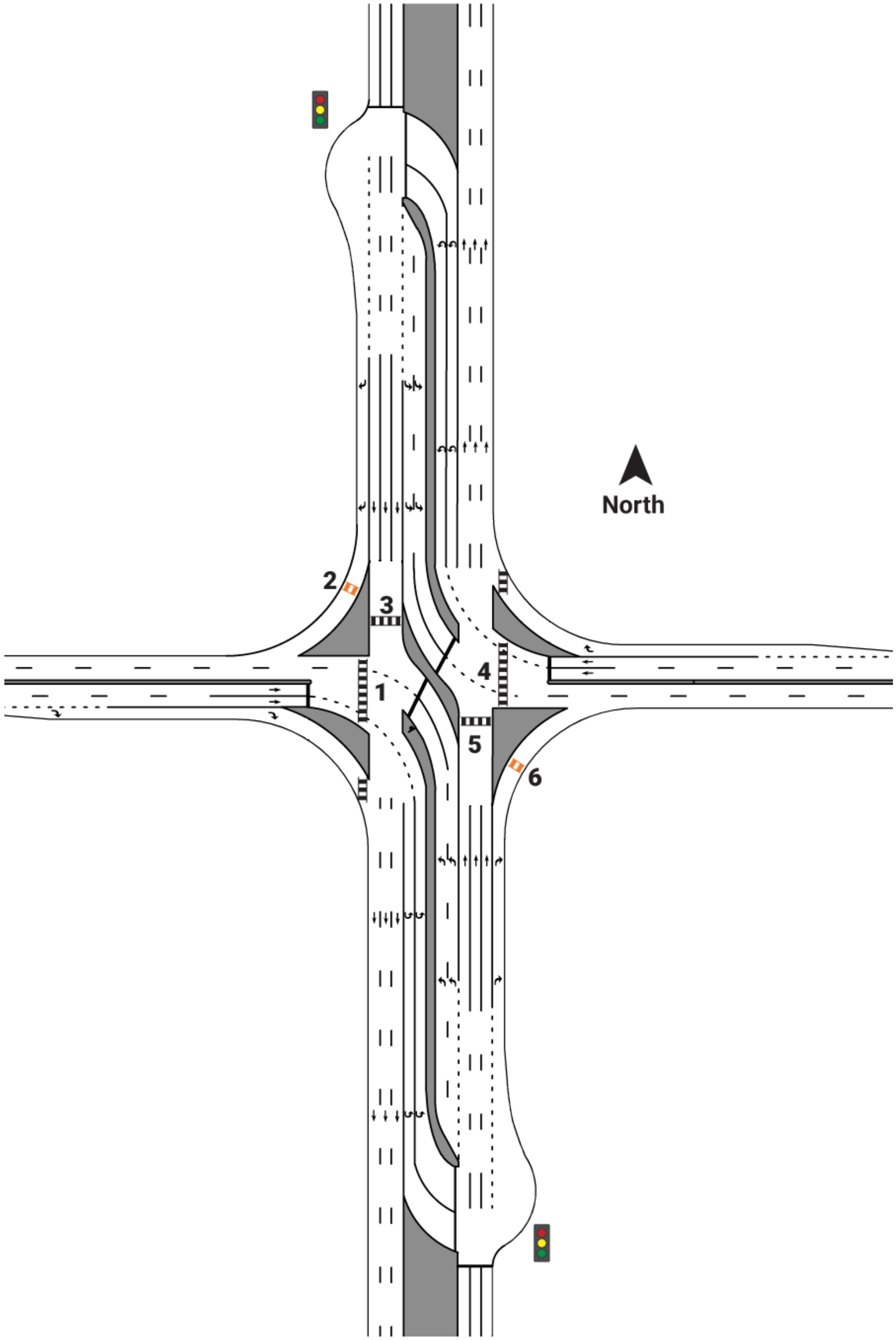


Figure C-26: Unsignalized Restricted Crossing U-Turn (N-S)

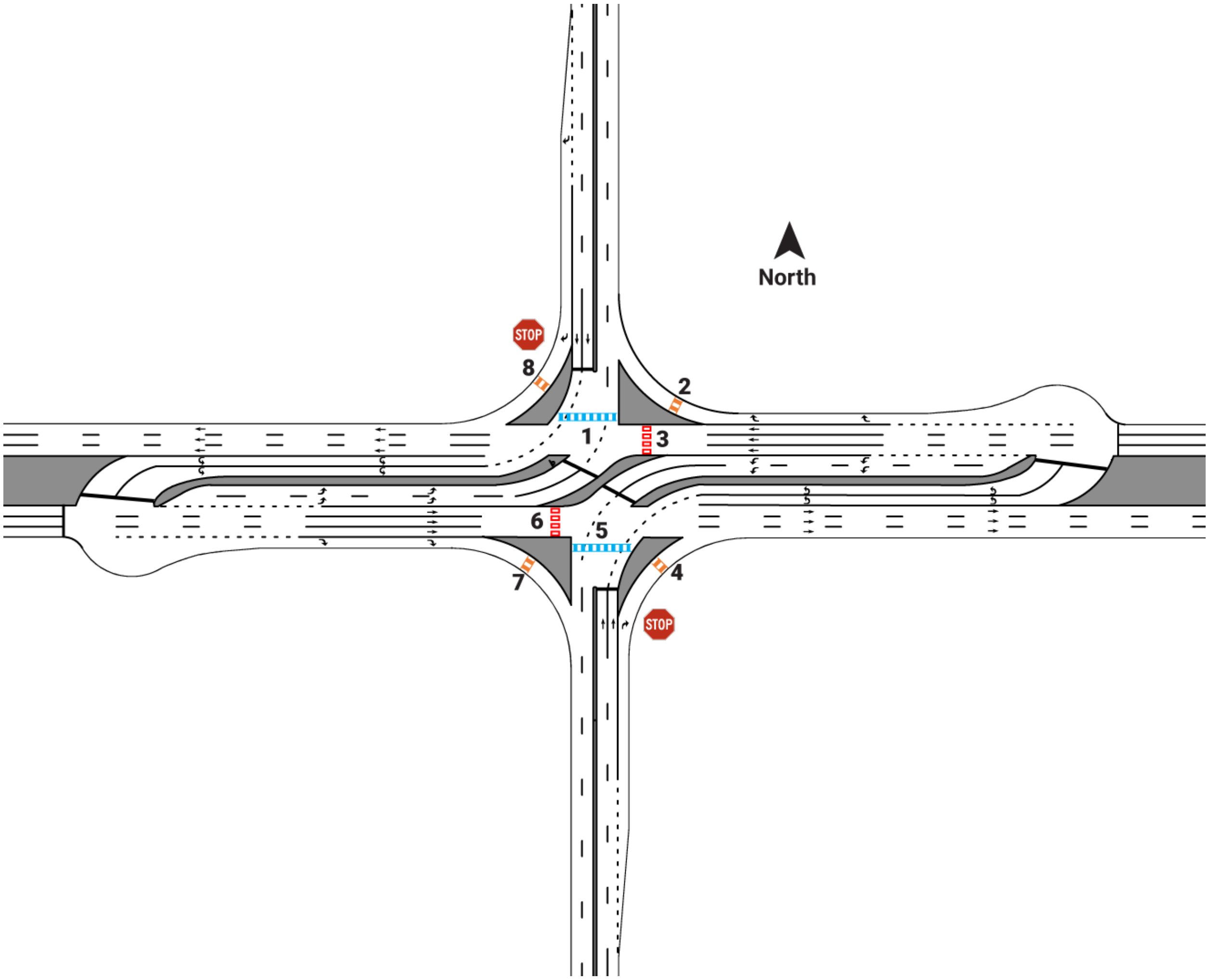


Figure C-27: Unsignalized Restricted Crossing U-Turn (E-W)

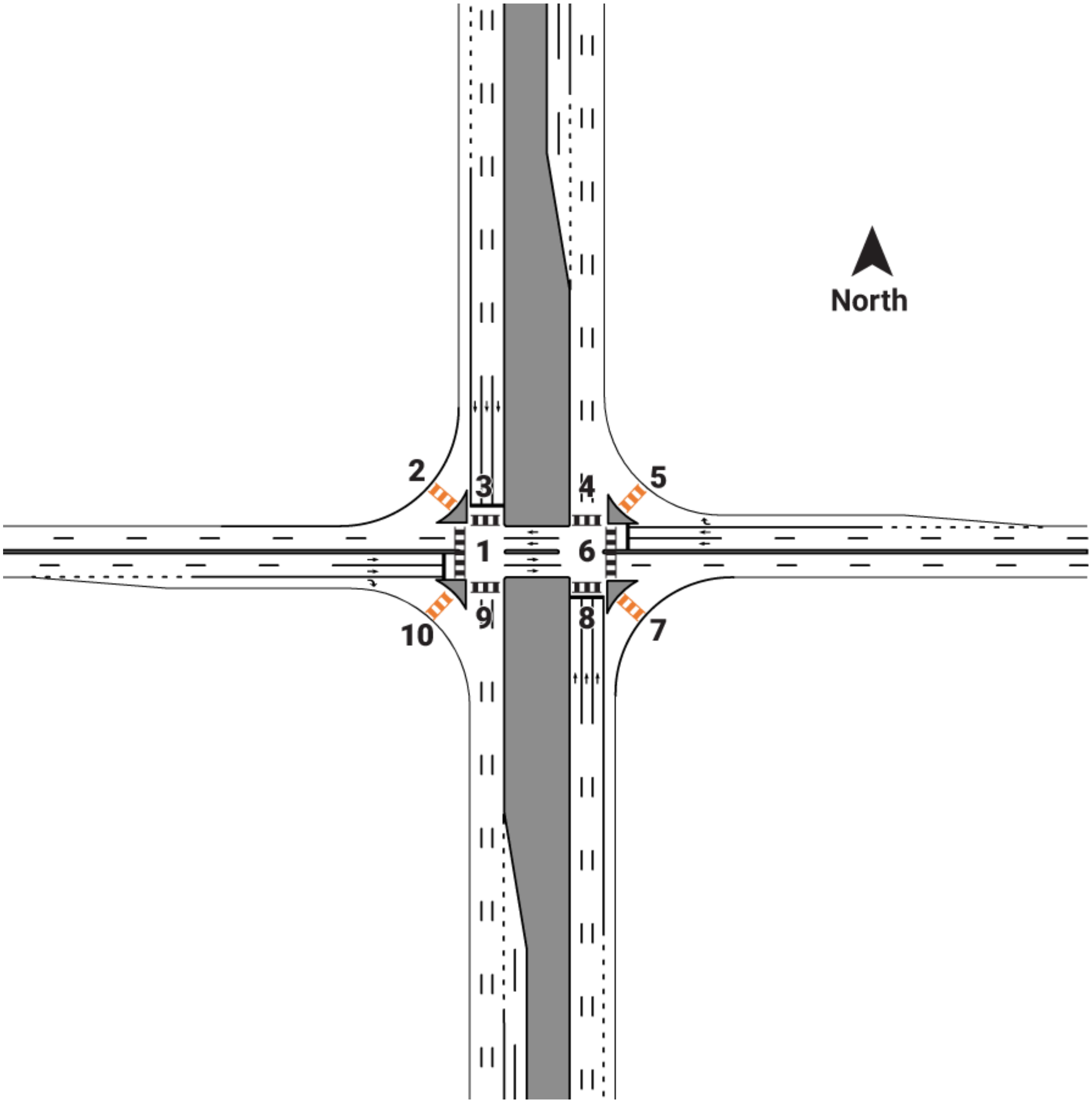


Figure C-28: Median U-Turn (N-S)

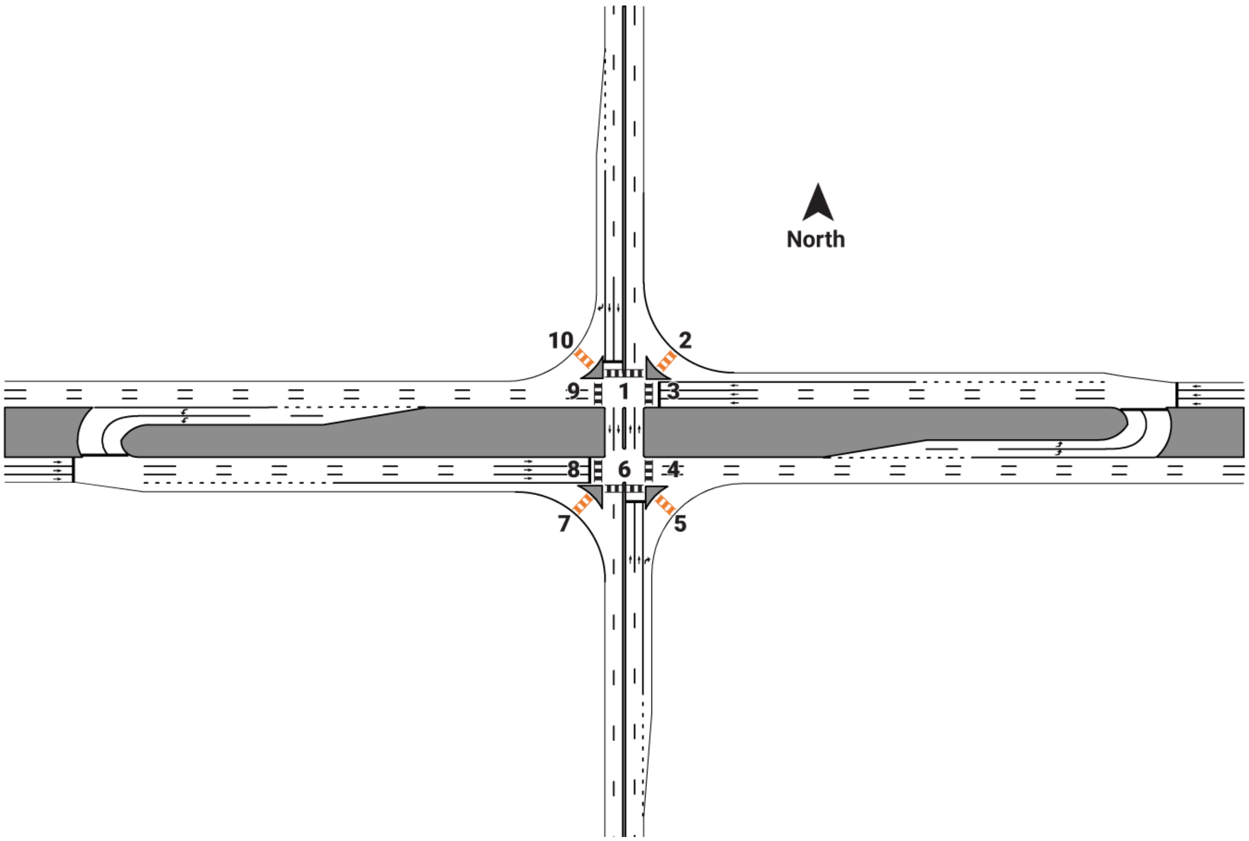


Figure C-29: Median U-Turn (E-W)

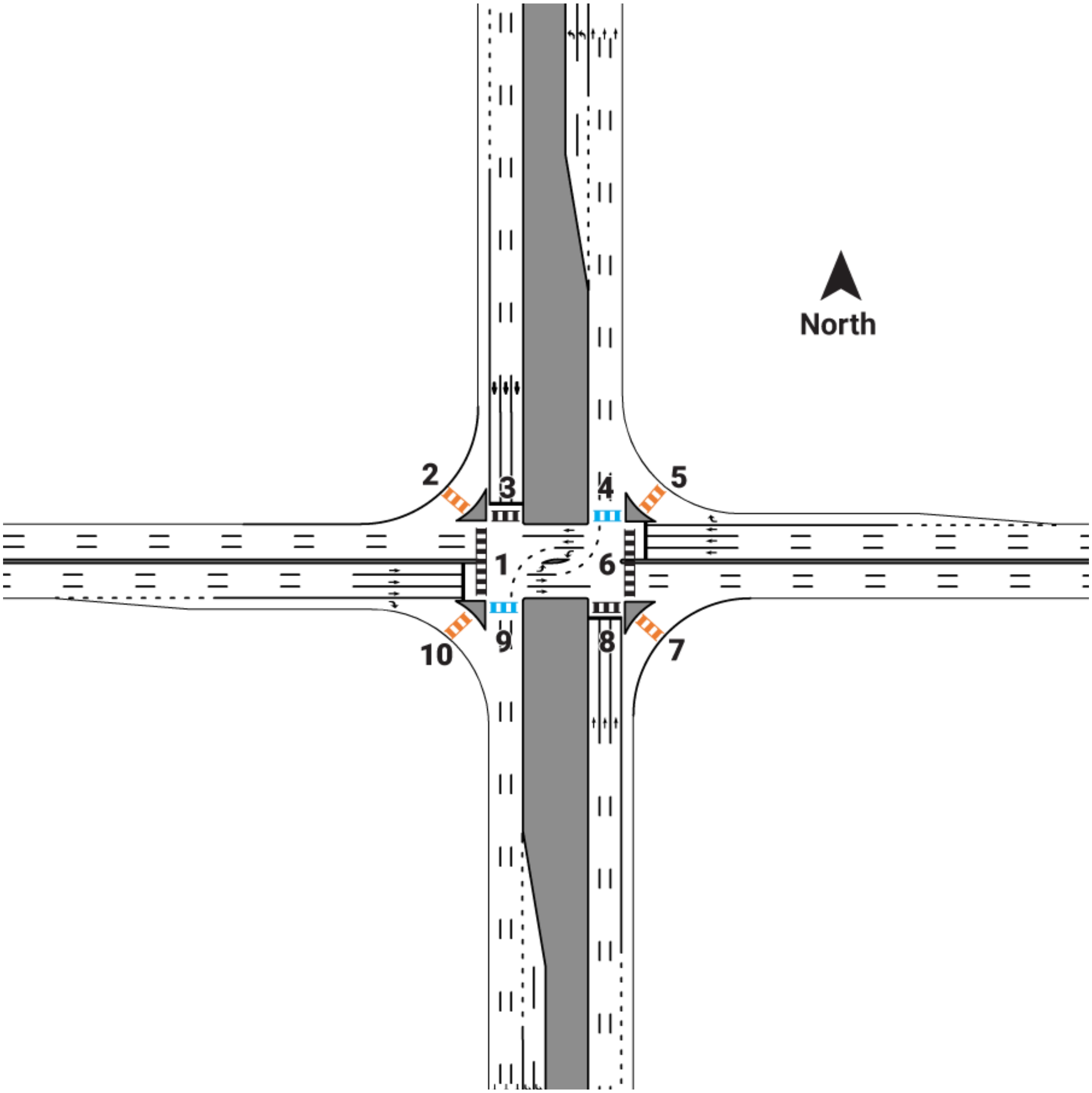


Figure C-30: Partial Median U-Turn (N-S)

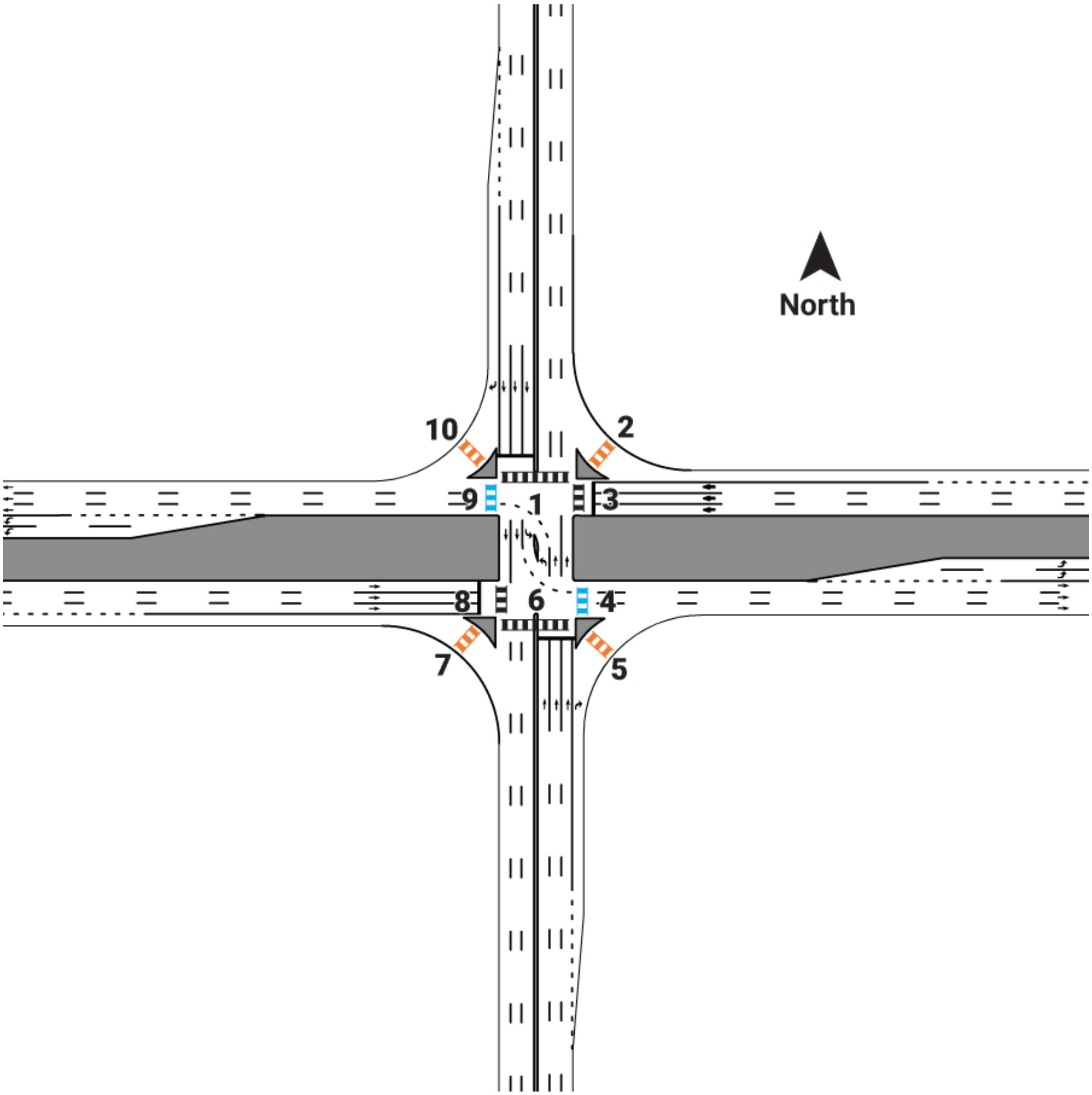


Figure C-31: Partial Median U-Turn (E-W)

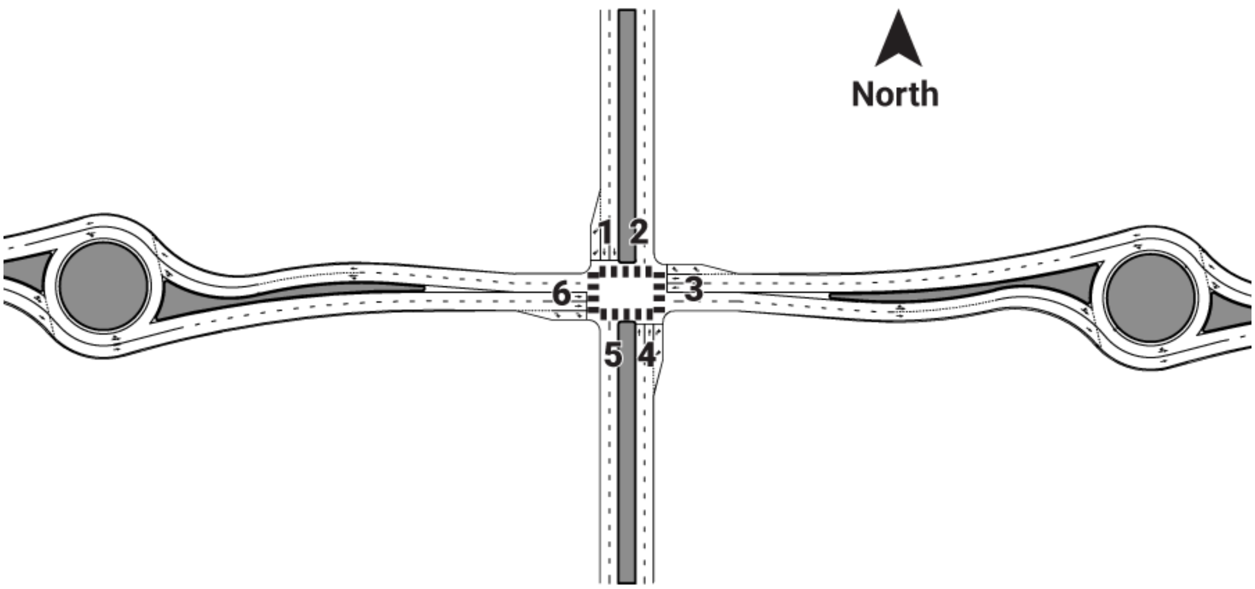


Figure C-32: Bowtie (N-S)

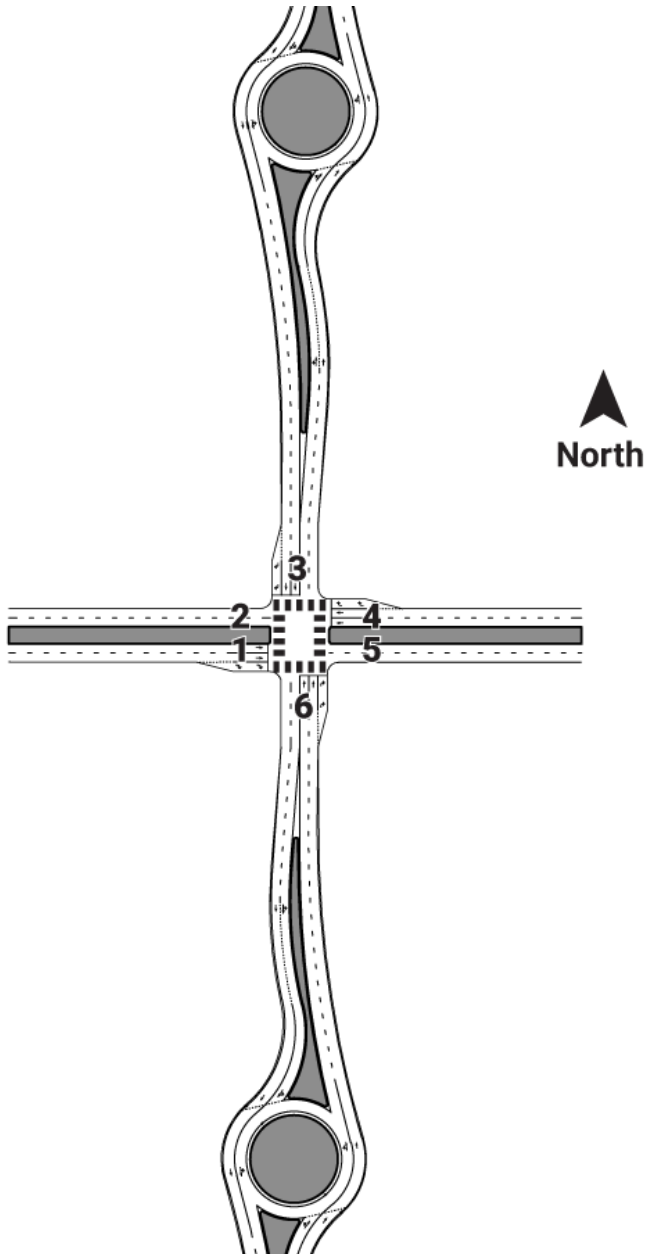


Figure C-33: Bowtie (E-W)

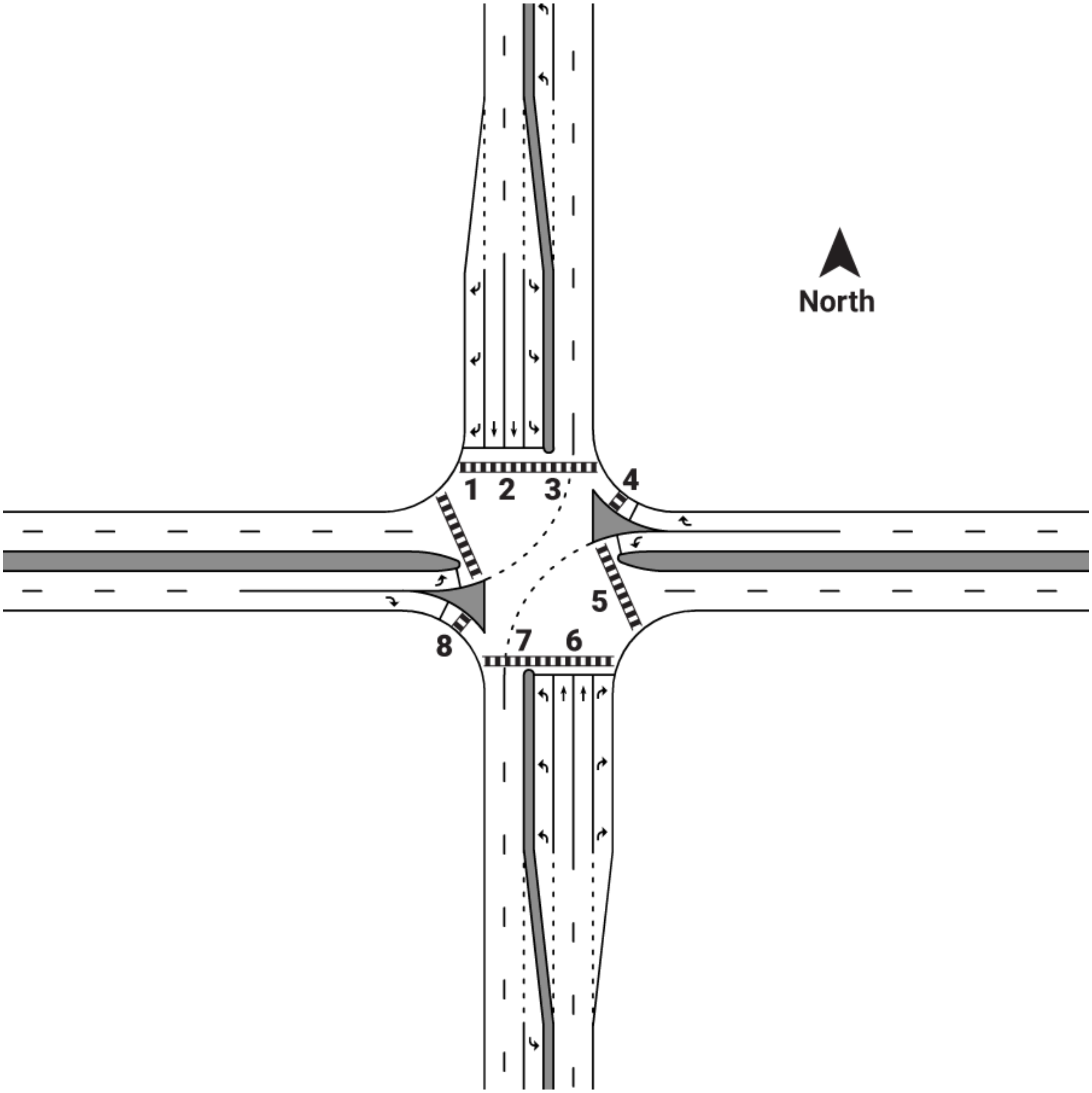


Figure C-34: Signalized Thru-Cut (N-S)

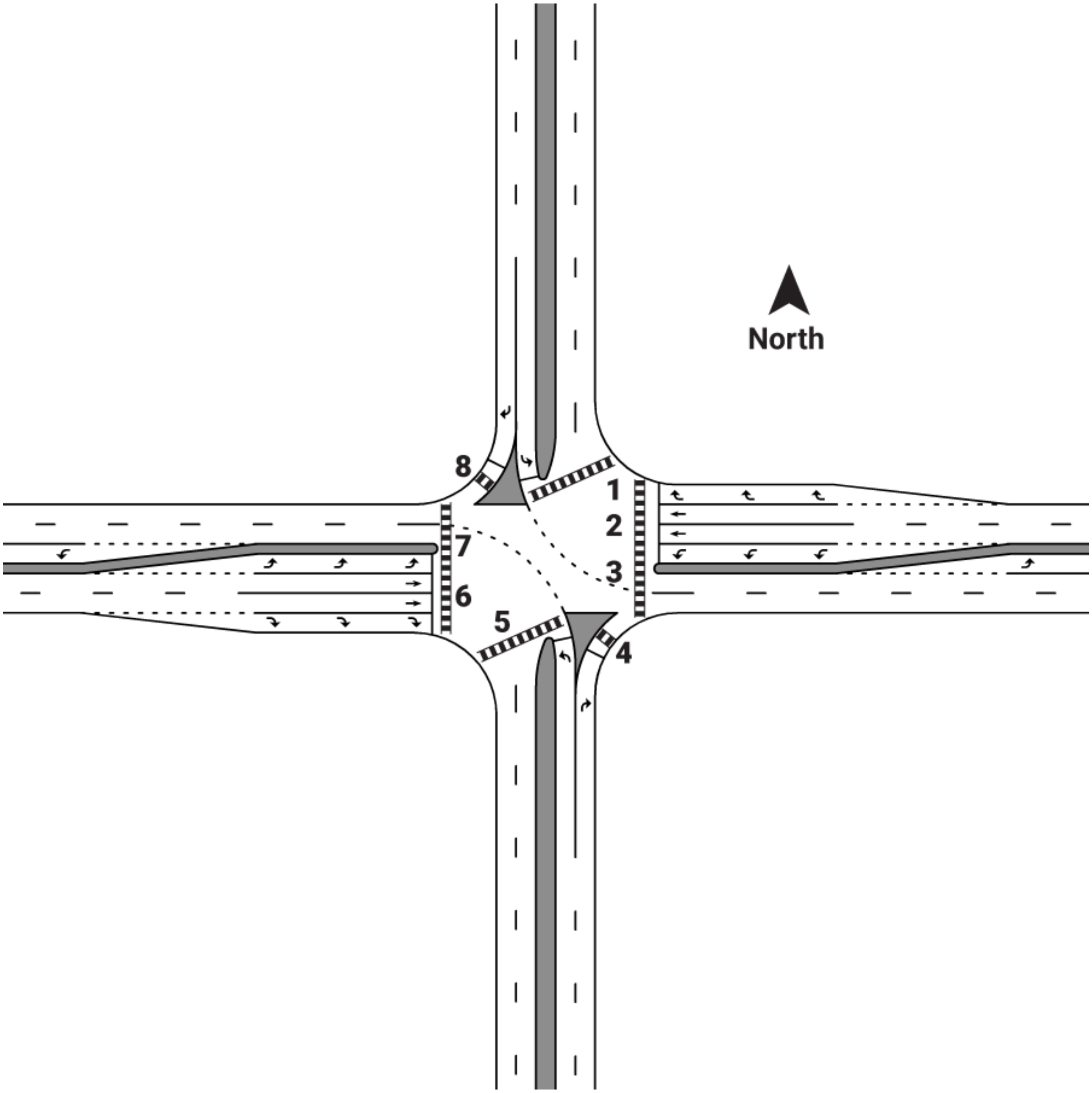


Figure C-35: Signalized Thru-Cut (E-W)

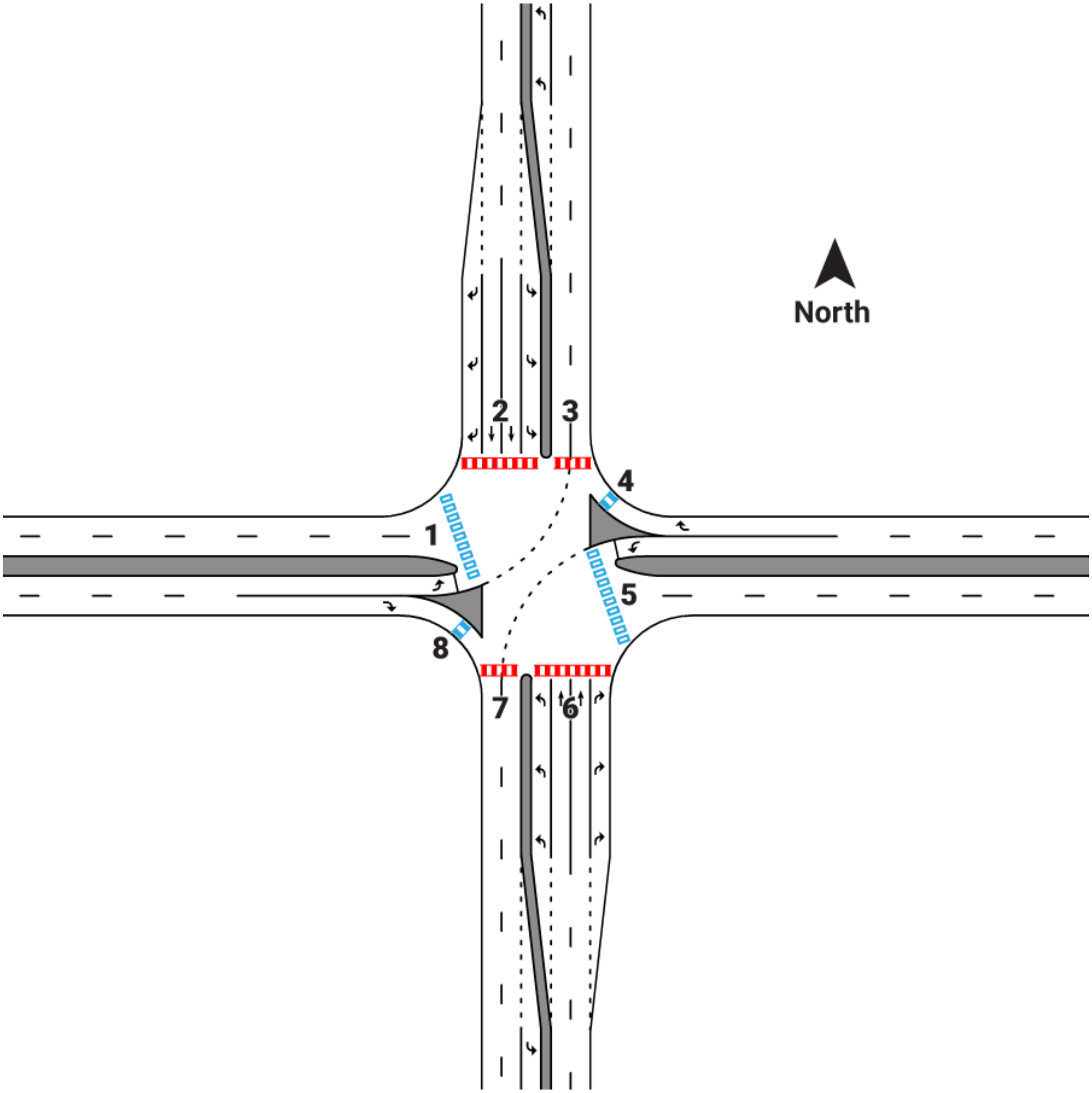


Figure C-36: Unsignalized Thru-Cut (N-S)

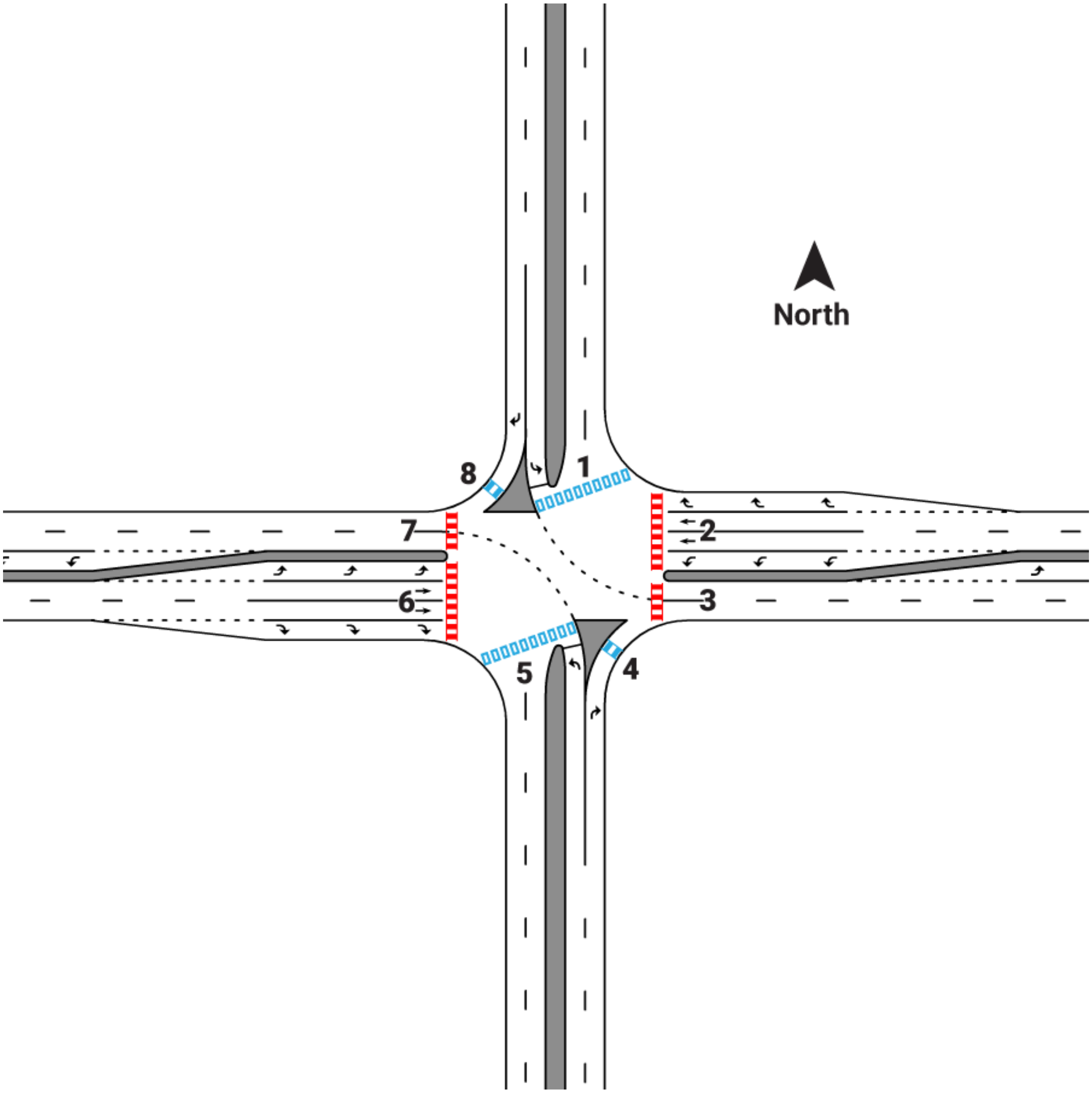


Figure C-37: Unsignalized Thru-Cut (E-W)

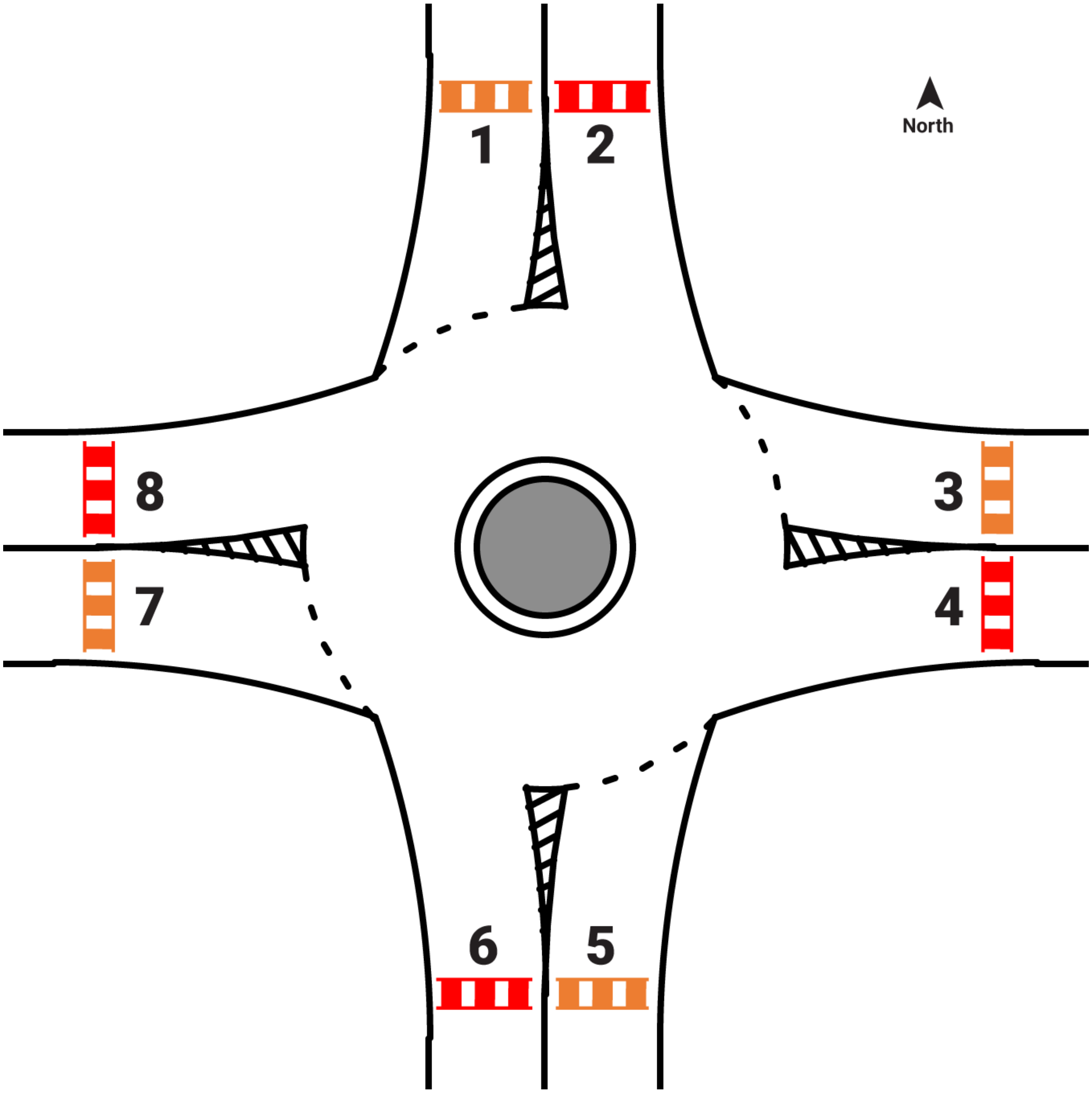


Figure C-38: Mini and Single-Lane Roundabout

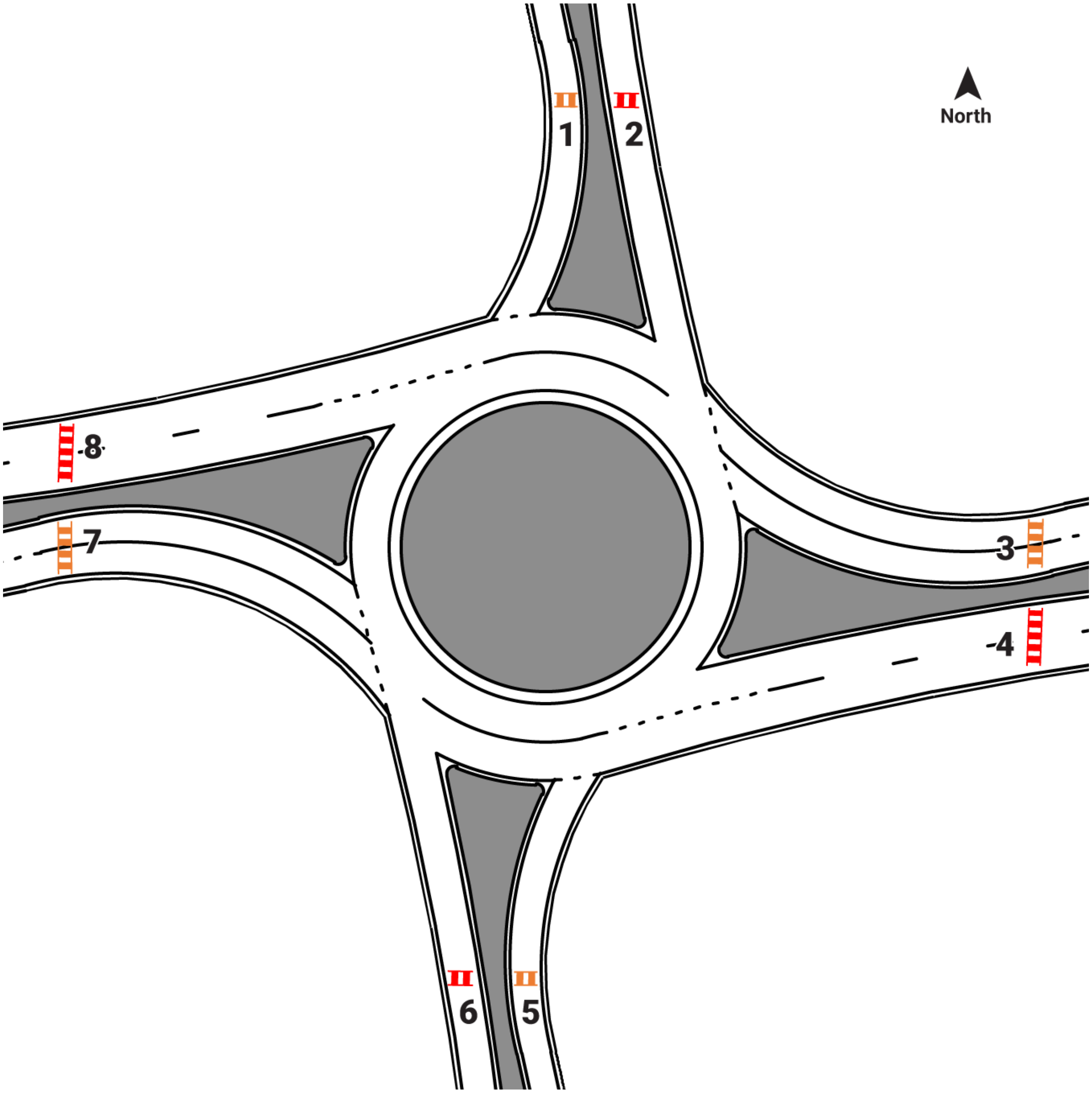


Figure C-39: 1NS X 2 EW Roundabout

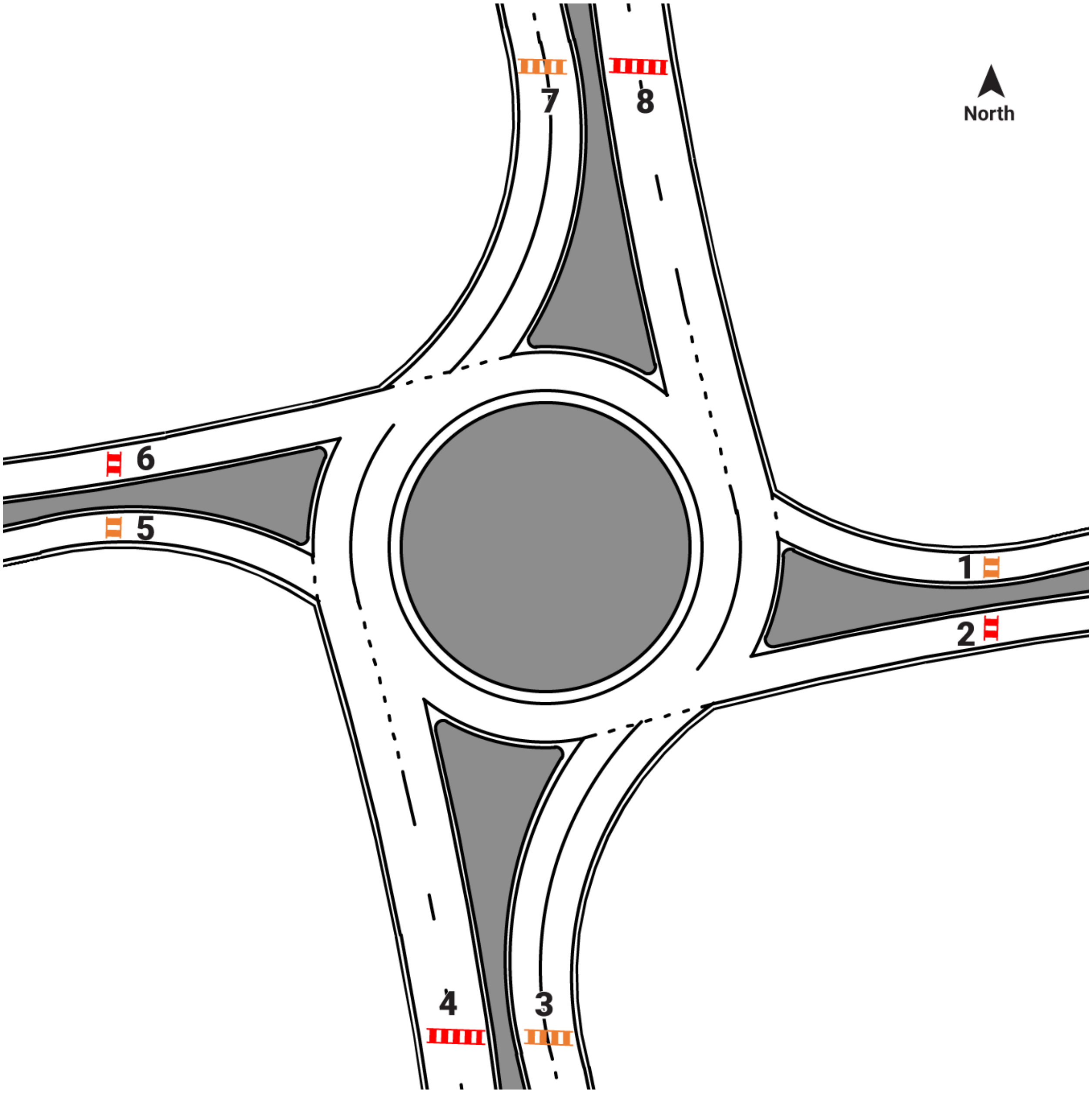


Figure C-40: 2NS X 1EW Roundabout

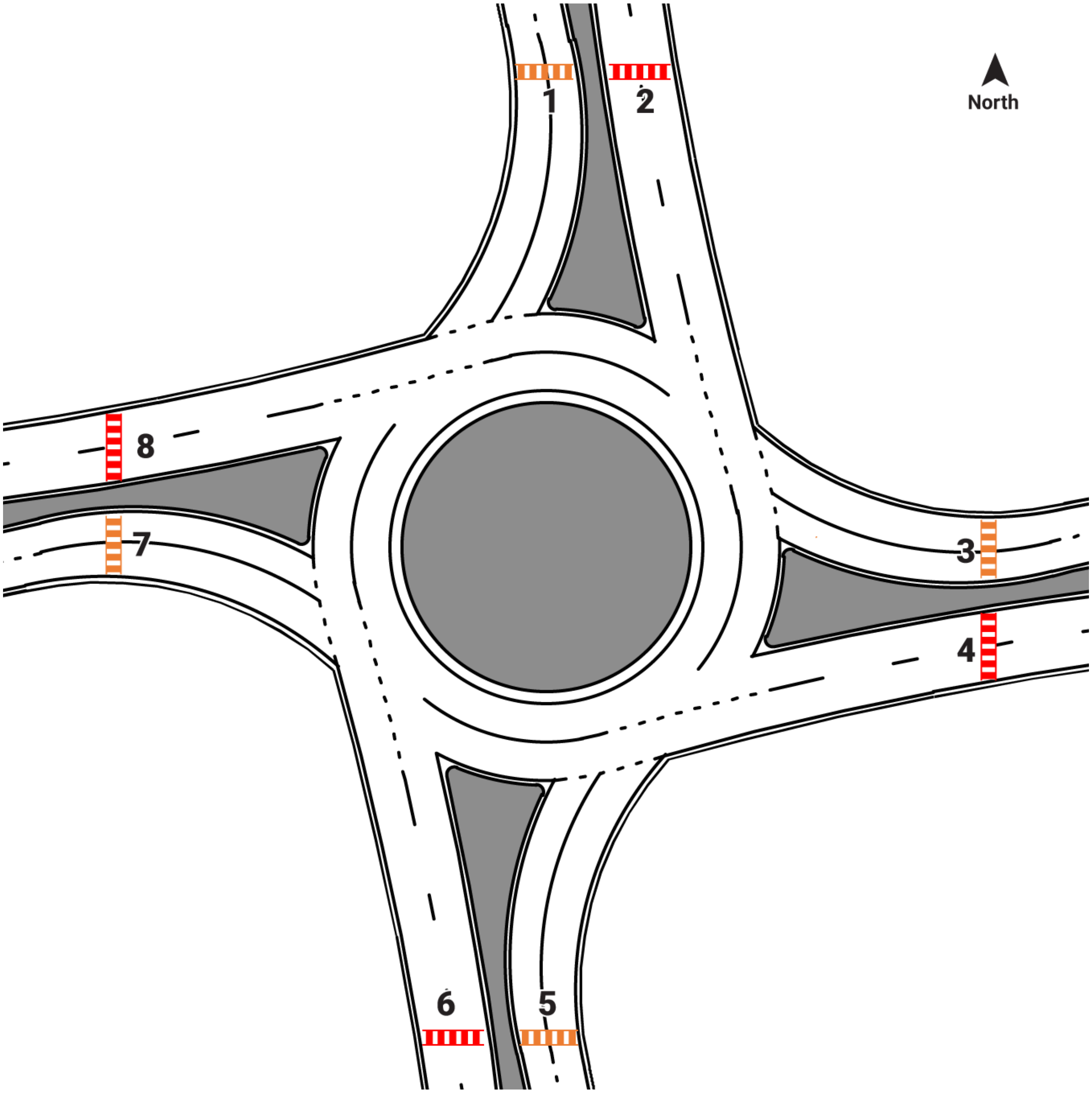


Figure C-41: 2X2 Roundabout

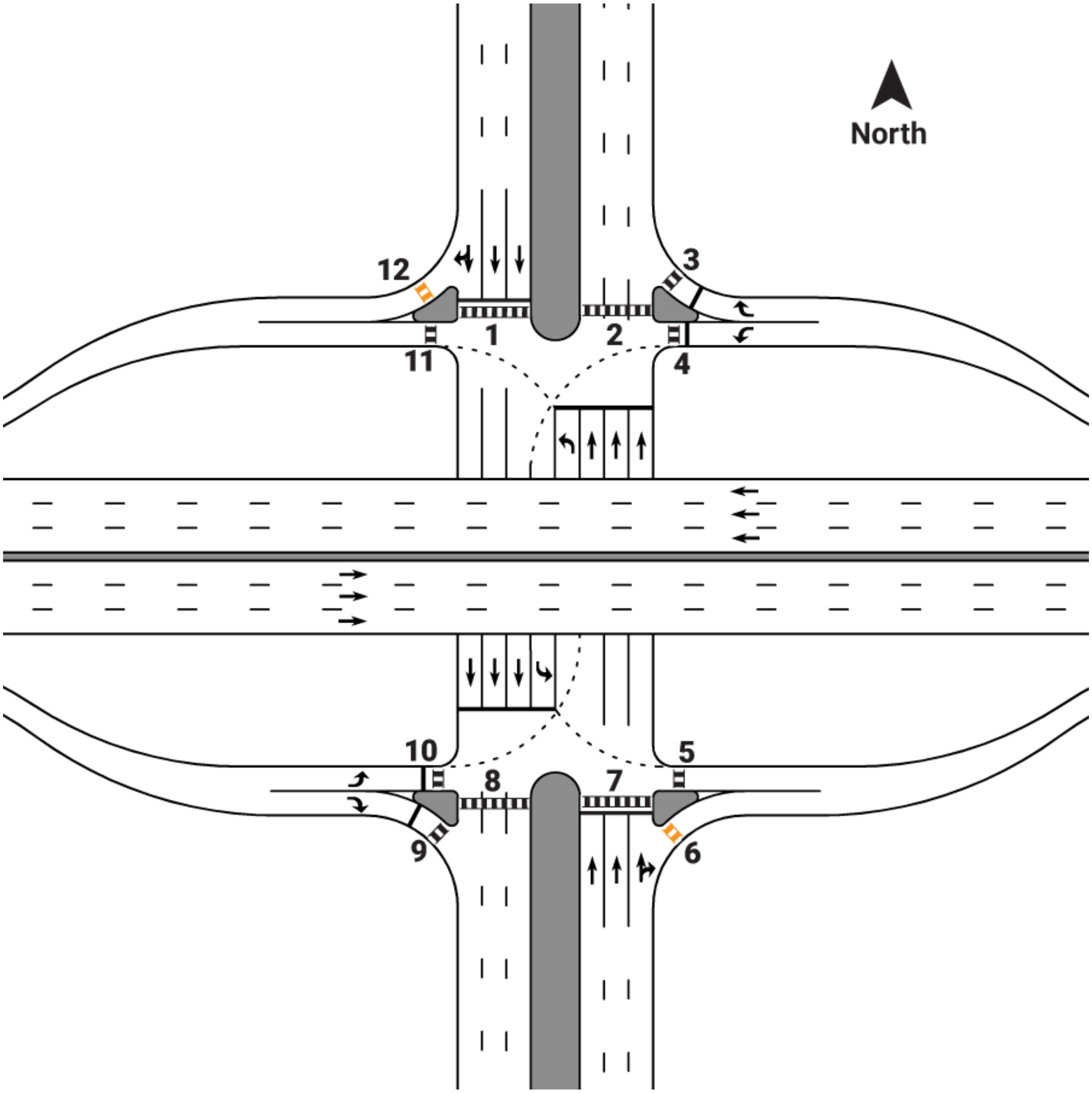


Figure C-42: Diamond (N-S)

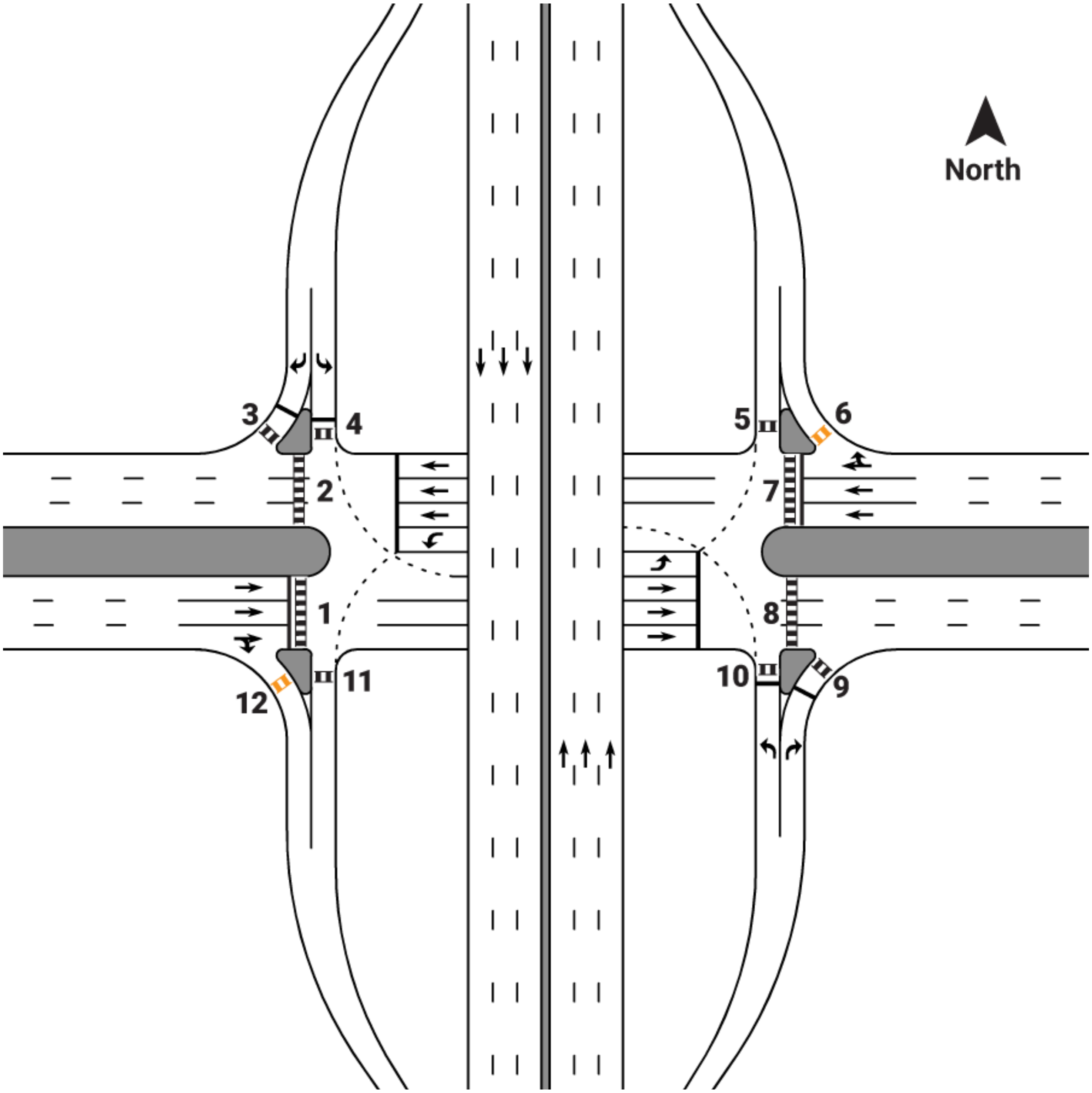


Figure C-43: Diamond (E-W)

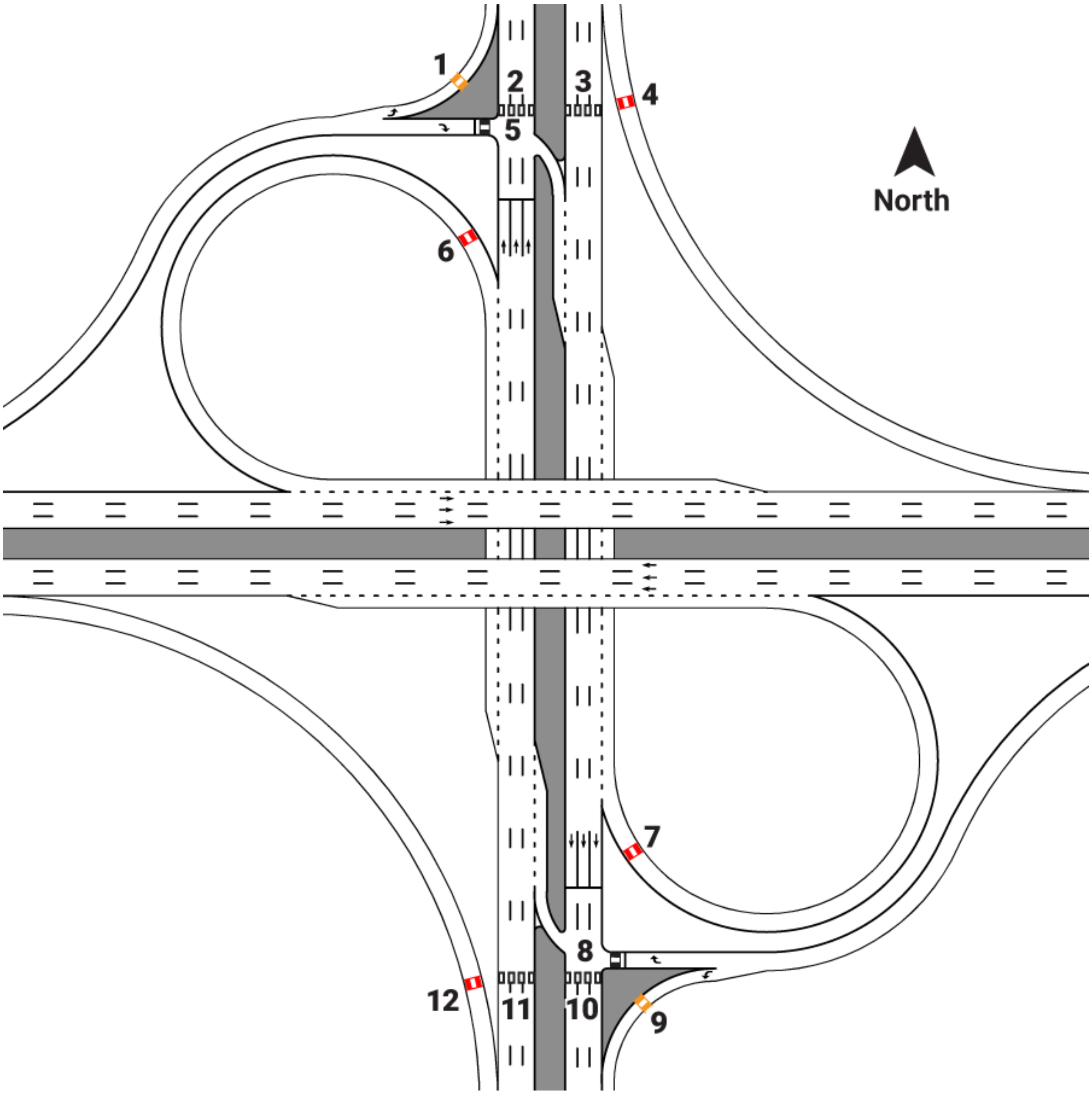


Figure C-44: Partial Cloverleaf B (N-S)

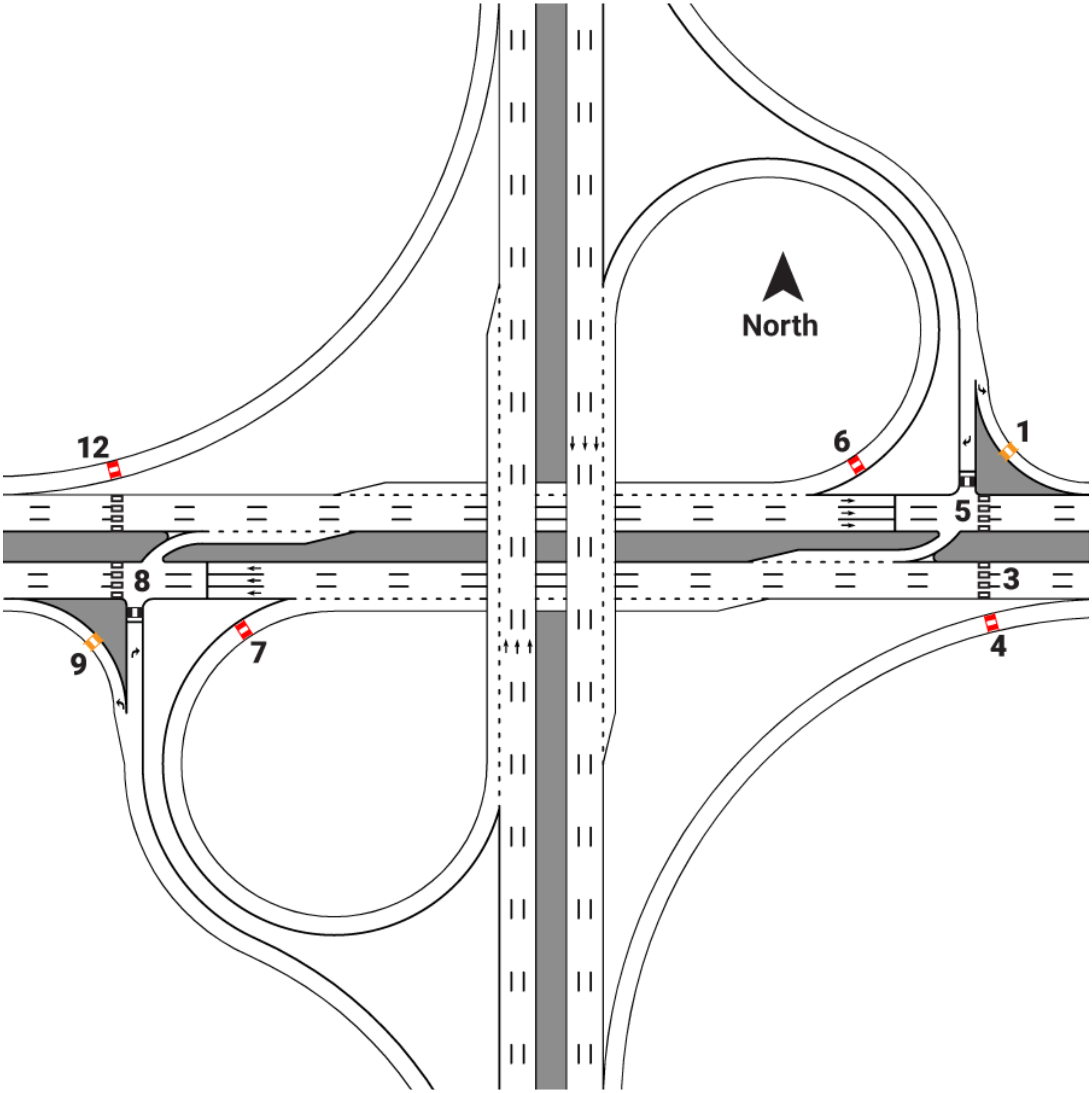


Figure C-45: Partial Cloverleaf B (E-W)

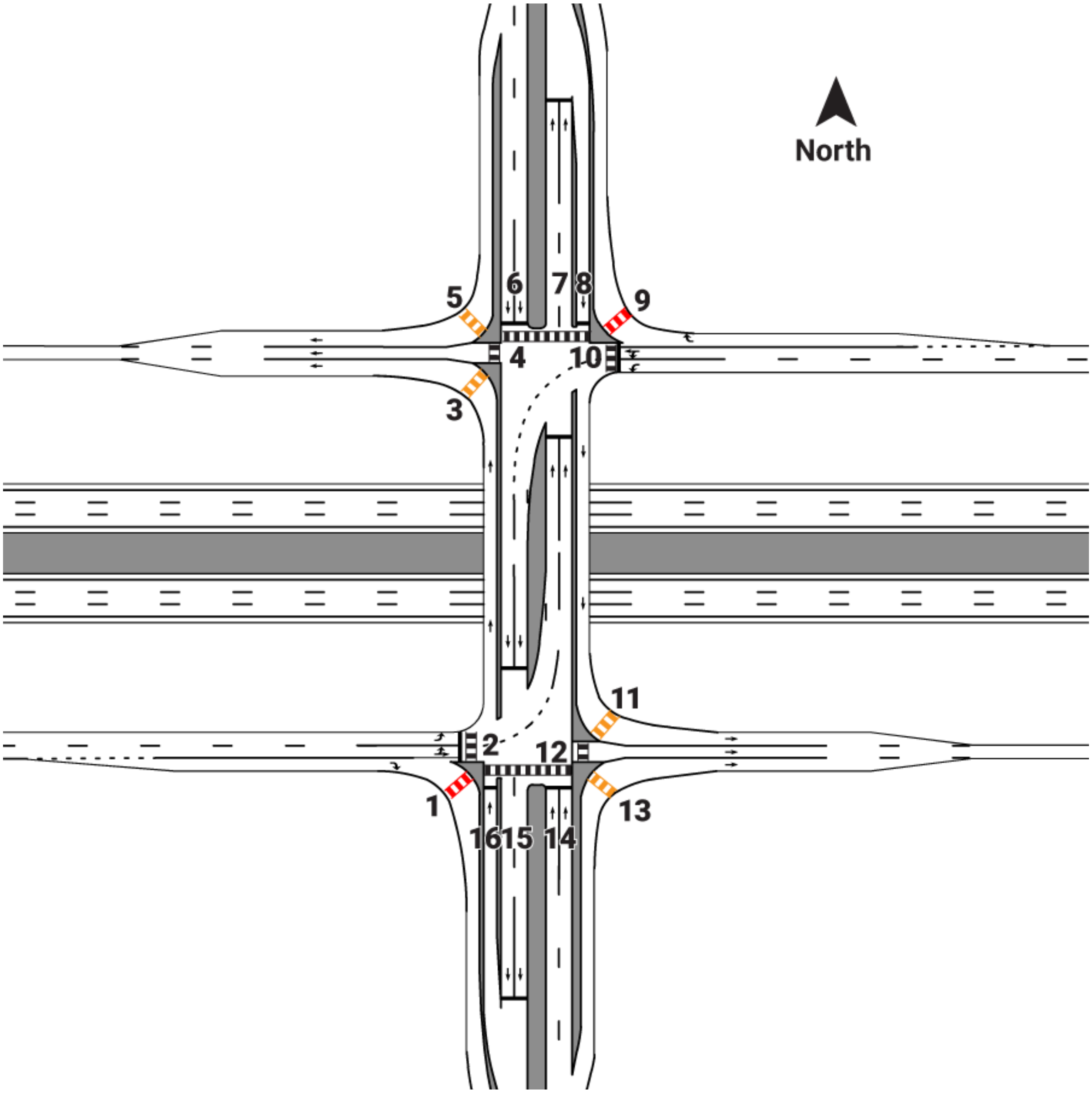


Figure C-46: Displaced Left Turn Interchange (N-S)

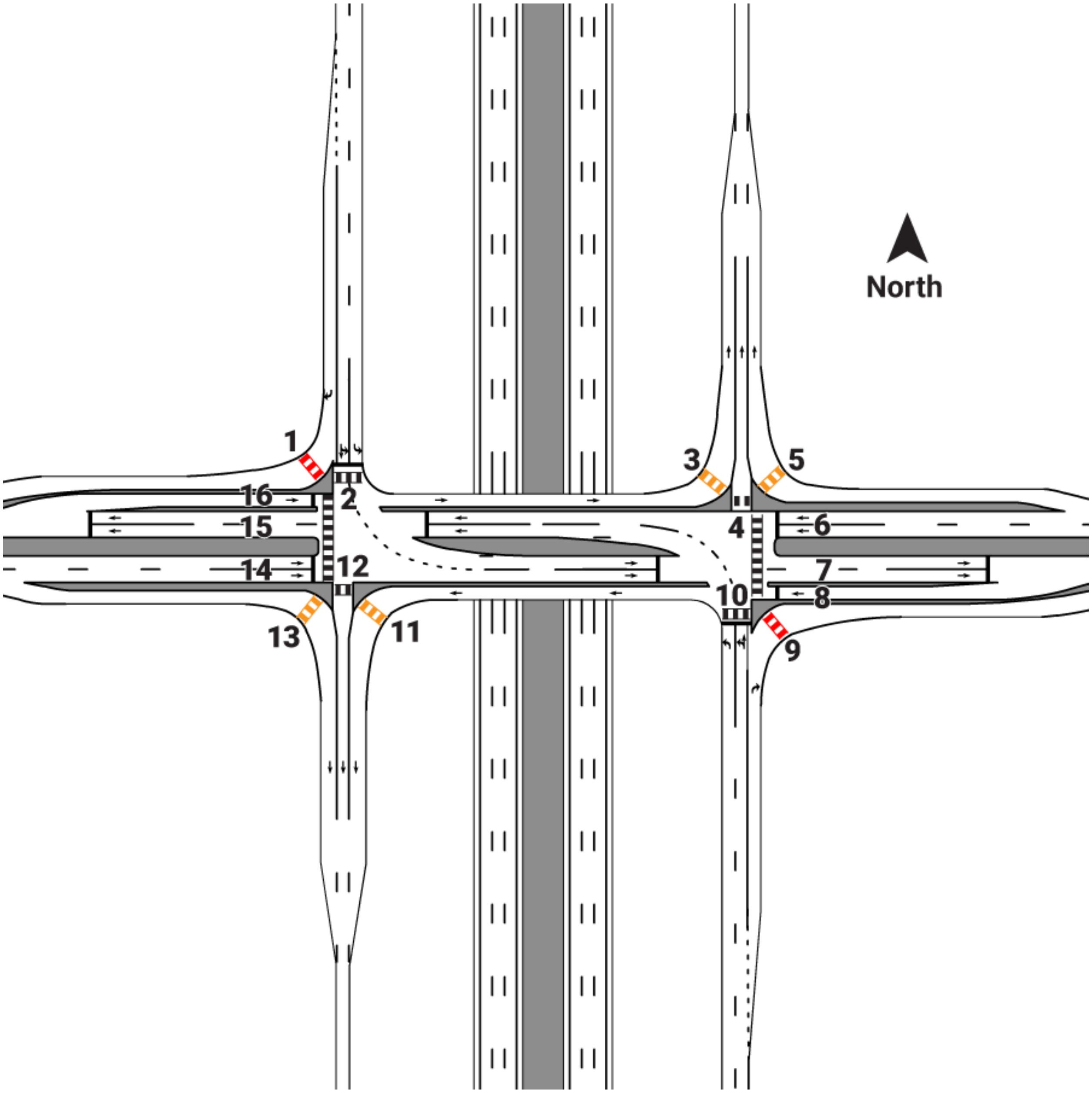


Figure C-47: Displaced Left Turn Interchange (E-W)

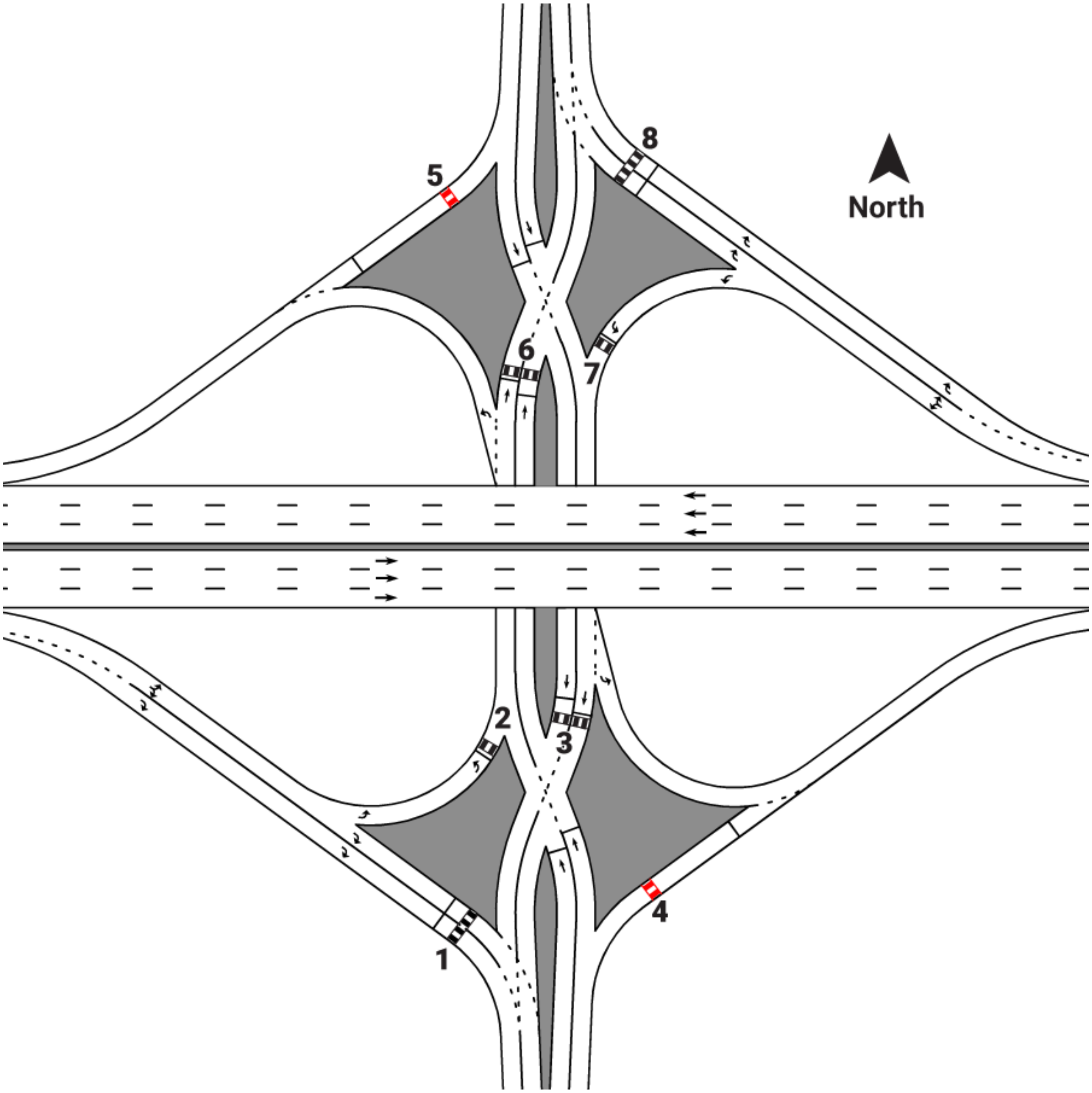


Figure C-48: Diverging Diamond (N-S)

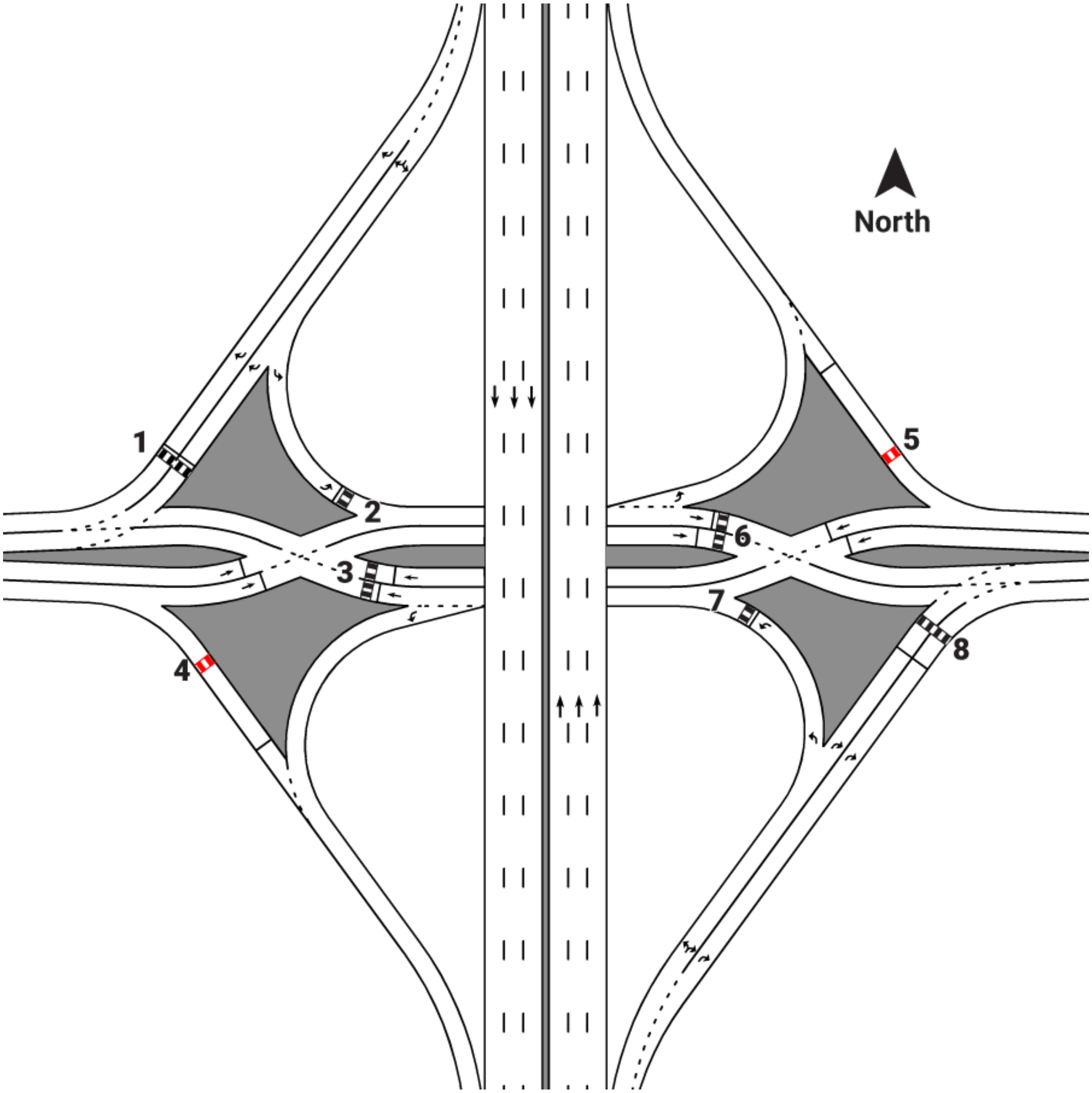


Figure C-49: Diverging Diamond (E-W)

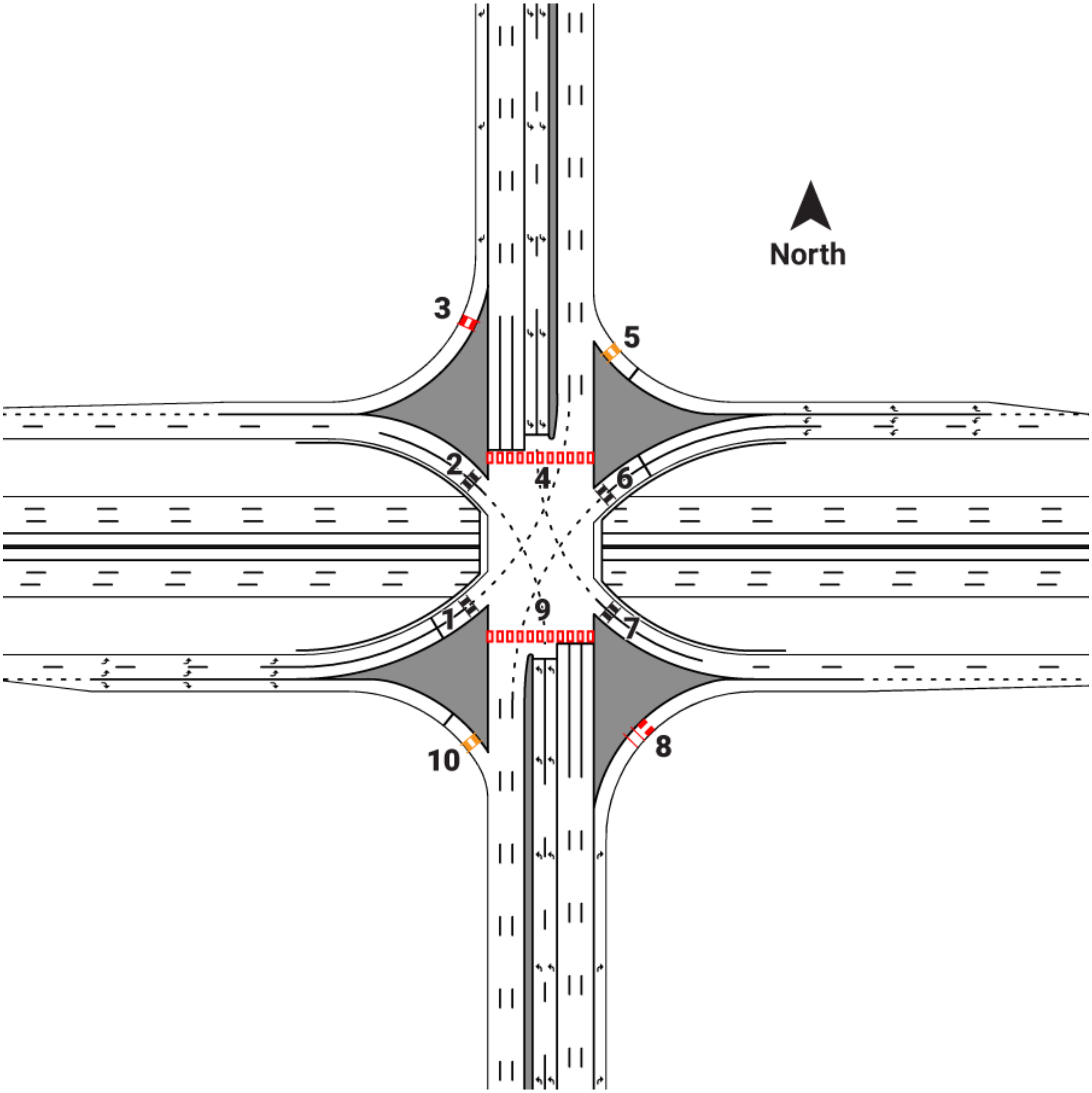


Figure C-50: Single Point Diamond (N-S)

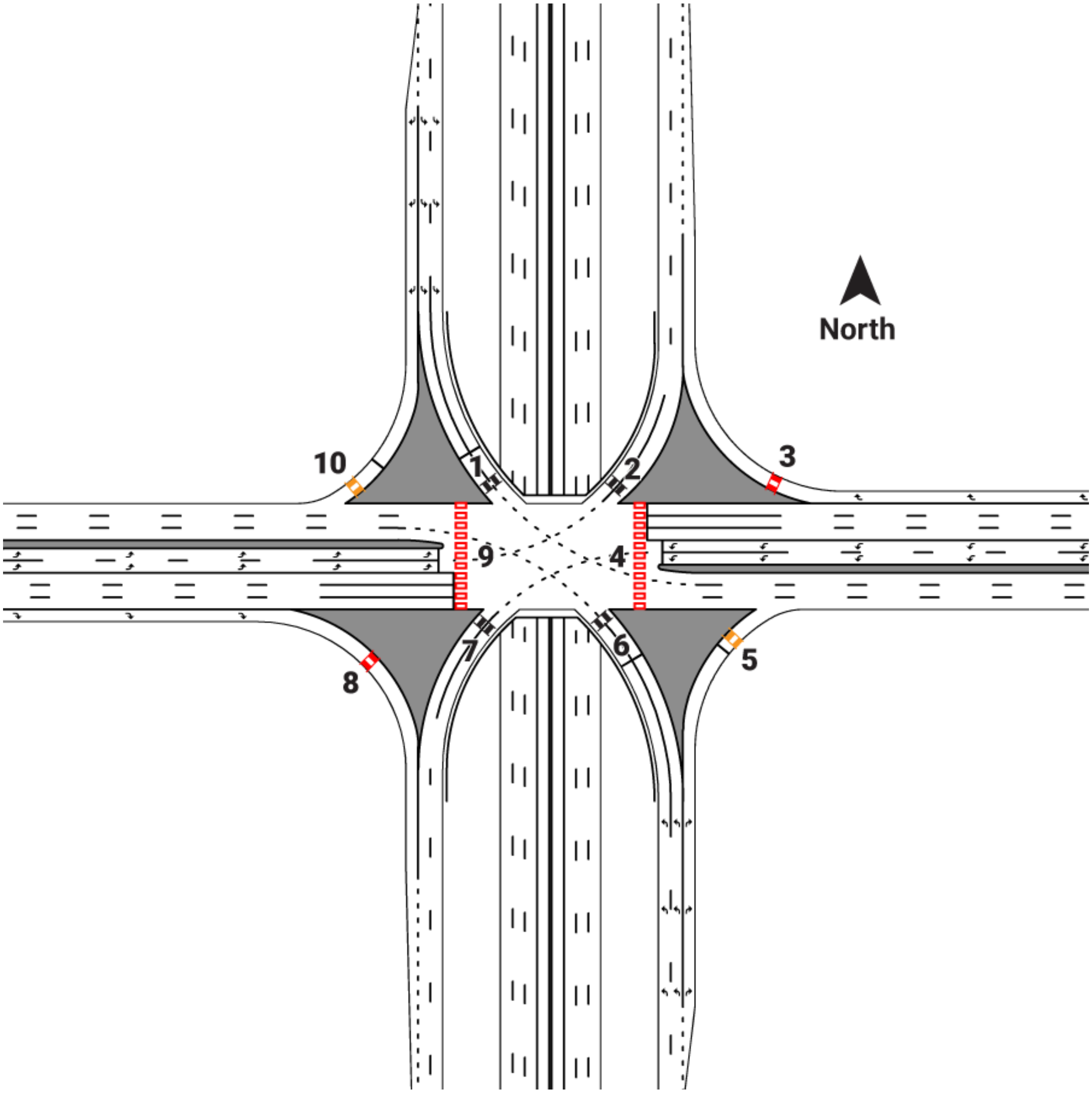


Figure C-51: Single Point Diamond (E-W)

C.4 References

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APPENDIX D
SAFETY EVALUATION METHODS – SOURCES AND ASSUMAPTIONS

CONTENTS

LIST OF TABLES

D.1 Crash Prediction Method Sources

Table D-1: Crash Prediction Method Sources for At-Grade Intersections

Control	Facility Type	# legs	1 way/ 2 way	# of lanes	Source of Crash Prediction Method
Traffic Signal	Rural Two-Lane Highway	3 leg	-	-	SPF from NCHRP 17-68
		4 leg	-	-	SPF from HSM
	Rural Multilane Highway	3 leg	-	-	SPF from NCHRP 17-68
		4 leg	-	-	SPF from HSM
	Urban and Suburban Arterial	3 leg	2x2	≤5	SPF from HSM
		4 leg	2x2	≤5	SPF from HSM
		3 leg	2x2	6+	SPF from NCHRP 17-58
		4 leg	2x2	6+	SPF from NCHRP 17-58
		3 leg	1x2	-	SPF from NCHRP 17-58
		4 leg	1x2	-	SPF from NCHRP 17-58
		3 leg	1x1	-	SPF from NCHRP 17-58
		4 leg	1x1	-	SPF from NCHRP 17-58
	High Speed Urban and Suburban Arterial	3 leg	-	-	SPF from NCHRP 17-68
		4 leg	-	-	SPF from NCHRP 17-68
Minor Road Stop Control	Rural Two-Lane Highway	3 leg	-	-	SPF from HSM
		4 leg	-	-	SPF from HSM
	Rural Multilane Highway	3 leg	-	-	SPF from HSM
		4 leg	-	-	SPF from HSM
	Urban and Suburban Arterial	3 leg	2x2	≤5	SPF from HSM
		4 leg	2x2	≤5	SPF from NCHRP HSM
		3 leg	2x2	6+	SPF from NCHRP 17-58
		4 leg	2x2	6+	SPF from NCHRP 17-58
		3 leg	1x2	-	SPF from NCHRP 17-58
		4 leg	1x2	-	SPF from NCHRP 17-58
		3 leg	1x1	-	SPF from NCHRP 17-58
		4 leg	1x1	-	SPF from NCHRP 17-58
	High Speed Urban and Suburban Arterial	3 leg	-	-	SPF from NCHRP 17-68
		4 leg	-	-	SPF from NCHRP 17-68
All-Way Stop	Rural Two-Lane Highway	4 leg	-	-	SPF from NCHRP 17-68
	Urban and Suburban Arterial	3 leg	-	-	SPF from NCHRP 17-68
		4 leg	-	-	SPF from NCHRP 17-68
Roundabout	1-lane roundabout	3 leg	-	-	SPF from NCHRP 17-68
		4 leg	-	-	SPF from NCHRP 17-68
	2-lane roundabout	3 leg	-	-	SPF from NCHRP 17-68
		4 leg	-	-	SPF from NCHRP 17-68
Partial Displaced Left Turn (PDLT)		-	-	-	CMF - 0.88 (Total Crashes)

Control	Facility Type	# legs	1 way/ 2 way	# of lanes	Source of Crash Prediction Method
Full Median U-Turn (MUT)		-	-	-	CMF 0.63 (Total Crashes) 0.76 (Injury Crashes)
Signalized Restricted Crossing U-Turn (RCUT)		-	-	-	SPF developed in Florida
Unsignalized Restricted Crossing U-Turn (RCUT)		-	-	-	SPF developed in Florida
Continuous Green-T Intersection		-	-	-	CMF - 0.96 (Total Crashes) 0.85 (FI Crashes)
Jughandle		-	-	-	CMF - 0.74 (FI Crashes)

Table D-2: Crash Prediction Method Sources for Ramp Terminal Intersections

Control	Ramp and Intersection Type	Source of Crash Prediction and Status
Conventional Traffic Signal	Three-leg terminals with diagonal exit ramp (D3ex)	SPF from HSM Supplement
	Three-leg terminals with diagonal entrance ramp (D3en)	SPF from HSM Supplement
	Four-leg terminals with diagonal ramps (D4)	SPF from HSM Supplement
	Four-leg terminals at four-quadrant parclo A (A4)	SPF from HSM Supplement
	Four-leg terminals at four-quadrant parclo B (B4)	SPF from HSM Supplement
	Three-leg terminals at two-quadrant parclo A (A2)	SPF from HSM Supplement
	Three-leg terminals at two-quadrant parclo B (B2)	SPF from HSM Supplement
Crossover Traffic Signal (of Diverging Diamond Interchange)	-	CMF – 0.23 to 1.03 (Total Crashes), varying by Crossroad Speed Limit 0.23 to 0.80 (FI Crashes), varying by Crossroad Speed Limit
Single-Point Diamond Traffic Signal	-	SPF from 17-68
Signalized Tight Diamond	-	SPF from 17-68
Minor Road (Ramp) Stop	Three-leg terminals with diagonal exit ramp (D3ex)	SPF from HSM Supplement
	Three-leg terminals with diagonal entrance ramp (D3en)	SPF from HSM Supplement
	Four-leg terminals with diagonal ramps (D4)	SPF from HSM Supplement
	Four-leg terminals at four-quadrant parclo A (A4)	SPF from HSM Supplement
	Four-leg terminals at four-quadrant parclo B (B4)	SPF from HSM Supplement
	Three-leg terminals at two-quadrant parclo A (A2)	SPF from HSM Supplement
	Three-leg terminals at two-quadrant parclo B (B2)	SPF from HSM Supplement
Roundabout	1-lane roundabout with 3 legs	SPF from NCHRP 17-70
	1-lane roundabout with 4 legs	SPF from NCHRP 17-70
	2-lane roundabout with 3 legs	SPF from NCHRP 17-70
	2-lane roundabout with 4 legs	SPF from NCHRP 17-70

D.2 Assumptions for the SSI Method

Table D-3 and **Table D-4** present the assumptions made in the SSI method calculations for at-grade and ramp terminal intersection control strategies, respectively. These are the default assumptions made in the FDOT SPICE tool for each intersection strategy. There are several overarching assumptions that apply across multiple control strategies:

- The calculations assume that intersection approaches have medians, channelizing islands, and/or nonmotorized refuge points only when those features are inherent to the design of the intersection alternative.
- The calculations do not consider U-turn movements unless they are an inherent part of the intersection design (such as in an RCUT or MUT intersection).
- The calculations do not consider exit ramp-to-entrance ramp through movements at ramp terminal intersections.
- Where left turn or exclusive pedestrian phasing is modifiable, as noted in **Table D-3** and **Table D-4**, the default assumption is protected left turn phasing without exclusive pedestrian phasing.

Table D-3: SSI Assumptions for At-Grade Intersection Control Strategies

At-Grade Intersection Control Strategy	SSI Considerations
Two-way stop-control	• Presence of median opening adequate to store vehicles for two-stage crossing is modifiable on SSI Input sheet. • Presence of major- or minor-street median serving as pedestrian refuge island is modifiable on SSI Input sheet.
All-way stop-control	• Presence of median opening adequate to store vehicle for two-stage crossing is modifiable on SSI Input sheet. • Presence of major or minor street median serving as pedestrian refuge island is modifiable on SSI Input sheet.
Signalized Control	• Presence of street median opening adequate to store vehicle for two-stage crossing is modifiable on SSI Input sheet. • Presence of major- or minor-street median serving as pedestrian refuge island is modifiable on SSI Input sheet. • Left turn phasing operation is modifiable on SSI Input sheet.

At-Grade Intersection Control Strategy	SSI Considerations
Roundabout	• Three roundabout entry geometries considered: 1x1 Roundabout (1 lane in each direction on all approaches), 2x1 Roundabout (2 lanes in each direction on major road, which yield to one circulating lane; 1 lane in each direction on minor road, which yield to two circulating lanes), and 2x2 Roundabout (2 lanes in each direction on all approaches, yielding to two circulating lanes). • All approaches have splitter islands/pedestrian refuge islands. • All approaches operate under yield control. • Indirect Paths (out of direction travel) adjustment is applied to all nonmotorized movements due to footprint and placement of crosswalks.
Median U-Turn (MUT)	• All approaches have medians/pedestrian refuge islands. • All direct left turns are removed from intersection. • U-turn movements operate under traffic signal control.
Bowtie	• Presence of median opening adequate to store vehicle for two-stage crossing is modifiable on SSI Input sheet. • Presence of major or minor street median serving as pedestrian refuge island is modifiable on SSI Input sheet.
Signalized Restricted Crossing U-Turn (RCUT) or Superstreet	• All approaches have medians/pedestrian refuge islands. • Z-type pedestrian crossing pattern is utilized. • Indirect Paths (out of direction travel) adjustment is applied to nonmotorized road users crossing major street. • U-turn movements operate under traffic signal control.
Unsignalized RCUT or J-Turn	• All approaches have medians/pedestrian refuge islands. • Z-type pedestrian crossing pattern is utilized. • Indirect Paths (out of direction travel) adjustment applied to nonmotorized road users crossing major street. • U-turn movements operate under stop control.
Jughandle	• Though other configurations are possible, the most common type–the forward jughandle–is assumed. • For left turns at the main intersection which are not redirected, phasing operation is modifiable on SSI input sheet. • Presence of median opening adequate to store vehicle for two-stage crossing is modifiable on SSI Input sheet. • Presence of major or minor street median serving as pedestrian refuge island is modifiable on SSI Input sheet.

At-Grade Intersection Control Strategy	SSI Considerations
Displaced Left-Turn	• Two DLT alternatives considered: partial DLT (PDLT), displaced left turns on major street approaches only) and full DLT (displaced left turns on all four approaches). • All approaches have medians/pedestrian refuge islands and right turns are all channelized. • Indirect Paths (out of direction travel) adjustment is applied to all nonmotorized conflict points (due to channelized right turns); Non-Intuitive Motor Vehicle Movements adjustment is applied to nonmotorized conflict points along nonmotorized movements that cross approaches with displaced left turns (i.e., all nonmotorized conflict points for full DLT). • For PDLT, minor street left turn phasing operation is modifiable on SSI input sheet.
Continuous Green T	• Nonmotorized movements crossing the continuous through movement on the major road are protected through user actuated signal control. • Major road approach without continuous movement has median that provides refuge to nonmotorized users. • Presence of median opening adequate to store vehicle for two-stage crossing is modifiable on SSI Input sheet. • Presence of major or minor street median serving as pedestrian refuge island is modifiable on SSI Input sheet.
Quadrant Roadway (QR)	• Though it is possible for other configurations, such as having QR in two quadrants or having roundabouts serve as the secondary intersections, a single QR with signalized T-intersections is assumed. • Presence of median opening adequate to store vehicle for two-stage crossing is modifiable on SSI Input sheet. • Presence of major- or minor-street median serving as pedestrian refuge island is modifiable on SSI Input sheet. • Phasing operation for left turns onto auxiliary road is modifiable on SSI input sheet. • Analysis for exclusive pedestrian phasing at auxiliary intersections is available on SSI input page in SPICE and QR tab in CAP-X.
Signalized Thru-Cut	• All approaches have medians/pedestrian refuge islands. • U-turn movements operate under traffic signal control. • Left turns from the major road operate under protected phasing. • Analysis for exclusive pedestrian phasing is available on SSI input page in SPICE and QR tab in CAP-X.
Unsignalized Thru-Cut	• All approaches have medians/pedestrian refuge islands. • Stop control is present on minor road approaches. • U-turn movements operate under stop control.

Table D- 4: SSI Assumptions for Ramp Terminal Intersection Control Strategies

Ramp Terminal Intersection Control Strategy	SSI Considerations
Signalized Diamond	• Presence of cross-street median serving as pedestrian refuge island is modifiable on the SSI Input sheet. • Nonmotorized user paths across the cross-street are located outside the ramp legs. • Left-turn phasing operation from the arterial is modifiable on SSI input sheet.
Diverging Diamond	• Nonmotorized users travel using the centerline median island. • Indirect Paths (out of direction travel) adjustment is applied to all nonmotorized conflict points. • Non-Intuitive Motor Vehicle Movements adjustment is applied to all nonmotorized conflict points. • All signal-controlled movements are protected.
Single Point Diamond	• Nonmotorized user paths across the cross-street are located just outside the single point intersection. • Analysis for exclusive pedestrian phasing is available on SSI input sheet in SPICE and Single Point tab in CAP-X. • The on- and off-ramp pedestrian crossings feature refuge islands. • Presence of cross-street median serving as pedestrian refuge island is modifiable on SSI Input sheet. • Indirect Paths (out of direction travel) adjustment is applied to nonmotorized movements crossing the cross-street.
Unsignalized Diamond	• No median present, or if present, the median is inadequate to store vehicle for two-stage crossing. • No approaches have pedestrian refuge islands. • Nonmotorized user paths across the cross-street are located outside the ramp legs.
Roundabout	• Three roundabout entry geometries considered: 1x1 Roundabout (1 lane in each direction on all approaches), 2x1 Roundabout (2 lanes in each direction on major road, yielding to one circulating lane; 1 lane in each direction on minor road, yielding to two circulating lanes), and 2x2 Roundabout (2 lanes in each direction on all approaches, yielding to two circulating lanes). • Cross-street approaches have splitter islands/pedestrian refuge islands. • All approaches operate under yield control. • Indirect Paths (out of direction travel) adjustment is applied to all nonmotorized movements due to footprint and placement of crosswalks.
Signalized Tight Diamond	• Presence of cross-street median and channelized turning island serving as pedestrian refuge island is modifiable on SSI Input sheet. • Left turns onto ramps operate under protected signal phasing.