Project No. 20-07 (Task 393)

Traffic Safety Countermeasures: Impacts on Pedestrian and Bicyclist Safety

Decision Tool User Guide

NCHRP Project 20-07 (Task 393)
MRIGlobal Project 111018

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
of
The National Academies of Sciences, Engineering, and Medicine

MRIGlobal
Kansas City, Missouri

June 2019

THIS PAGE LEFT INTENTIONALLY BLANK.

ACKNOWLEDGMENT OF SPONSORSHIP

This work was sponsored by one or more of the following as noted:

■ American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted in the **National Cooperative Highway Research Program,**

☐ Federal Transit Administration and was conducted in the **Transit Cooperative Research Program,**

☐ Federal Aviation Administration and was conducted in the **Airport Cooperative Research Program,**

☐ The National Highway Safety Administration and was conducted in the **Behavioral Traffic Safety Cooperative Research Program,**

which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

DISCLAIMER

THIS PAGE LEFT INTENTIONALLY BLANK.

Project No. 20-07 (Task 393)

Traffic Safety Countermeasures: Impacts on Pedestrian and Bicyclist Safety

Decision Tool User Guide

NCHRP Project 20-07 (Task 393)
MRIGlobal Project 111018

Prepared for

National Cooperative Highway Research Program

Transportation Research Board
of
The National Academies of Sciences, Engineering, and Medicine

by

Daniel J. Cook, Darren J. Torbic, and Jessica M. Hutton

MRIGlobal
Kansas City, MO

MRIGlobal

June 2019

THIS PAGE LEFT INTENTIONALLY BLANK.

Contents

Figures

Tables

THIS PAGE LEFT INTENTIONALLY BLANK.

Author Acknowledgement

Development of the decision tool described herein was performed under NCHRP Project 20-07 (Task 393), “Traffic Safety Countermeasures: Impacts on Pedestrian and Bicyclist Safety.” This user guide was prepared by Mr. Daniel J. Cook, Dr. Darren J. Torbic, and Ms. Jessica M. Hutton of MRIGlobal. Mr. Theodore A. Petritsch and Christopher B. Fellerhoff of Landis Evans + Partners were members of the research team and provided significant contributions to the development of the decision tool. For additional details on the research that went into the development of the decision tool to help planners, designers, and safety engineers identify tradeoffs in safety and mobility between motorists, pedestrians, and bicyclists that may arise from traffic safety countermeasures during countermeasure selection, refer to the final report from NCHRP Project 20-07 (Task 393), “Traffic Safety Countermeasures: Impacts on Pedestrian and Bicyclist Safety.”

Abstract

The objective of this research was to develop a decision tool and user guide to help planners, designers, and safety engineers identify tradeoffs in safety and mobility between motorists, pedestrians, and bicyclists that may arise from traffic safety countermeasures during countermeasure selection. The decision tool and user guide will help state and local highway agencies make more informed decisions as part of their roadway safety management process and Highway Safety Improvement Program (HSIP). The decision tool was designed with two primary purposes:

1. For a given classification of roadway or intersection configuration and traffic control type, the decision tool helps practitioners select a traffic safety countermeasure that addresses specific crash types or contributing factors, while also considering potential impacts on pedestrians and bicyclists.
2. If a designer or safety engineer has already identified an initial traffic safety countermeasure for potential implementation to address a specific crash pattern of interest or crash contributing factor, the decision tool can be used to identify alternative countermeasures that address the same crash pattern of interest or crash contributing factor, while also considering the potential impacts on pedestrians and bicyclists of the initial countermeasure and alternative countermeasures.

The decision tool was designed to help planners, designers, and safety engineers select countermeasures covering most types of roadway segments and intersections. The tool does not address countermeasures for freeways (i.e., limited access roads). The tool was designed to be consistent with the *Highway Safety Manual* (HSM) and Safety Analyst software. This User Guide describes the general work flow of the decision tool, the countermeasures included in the decision tool, step-by-step instructions on how to use the decision tool, guidance on interpreting the output tables, and two examples to demonstrate use of the decision tool.

Summary

The Highway Safety Improvement Program (HSIP) is a core Federal-aid program with the purpose to achieve a significant reduction in traffic fatalities and serious injuries on all public roads. The HSIP requires a data-driven, strategic approach to improving highway safety on all public roads with a focus on performance. The primary components of the HSIP process include planning, implementation, and evaluation. The planning component consists of processes for problem identification, countermeasure identification, and project prioritization. Most HSIP projects focus on improving motor vehicle safety, but agencies need a better understanding of how roadway safety countermeasures intended to improve motor vehicle safety impact pedestrians and bicyclists.

The objective of this research was to develop a decision tool and user guide to help planners, designers, and safety engineers identify tradeoffs in safety and mobility between motorists, pedestrians, and bicyclists that may arise from traffic safety countermeasures during countermeasure selection. The decision tool and user guide will help state and local highway agencies make more informed decisions as part of their roadway safety management process and HSIP. The decision tool was designed with two primary purposes:

1. For a given classification of roadway or intersection configuration and traffic control type, the decision tool will help practitioners select a traffic safety countermeasure that addresses specific crash types or contributing factors while also considering potential impacts on pedestrians and bicyclists.
2. If a designer or safety engineer has already identified an initial traffic safety countermeasure for potential implementation to address a specific safety concern, the decision tool can be used to identify alternative countermeasures that address the same safety concern while also considering the potential impacts on pedestrians and bicyclists of the initial countermeasure and the alternative countermeasures.

The decision tool was designed to help planners, designers, and safety engineers select countermeasures covering most types of roadway segments and intersections. Seventeen roadway segment and fourteen intersection countermeasures are included in the decision tool. The decision tool is a spreadsheet-based tool, implemented using Visual Basic for Applications (VBA) within Microsoft Excel. The tool is designed to be consistent with the *Highway Safety Manual* (HSM) and the AASHTOWare Safety Analyst software. This User Guide describes the general work flow of the decision tool, the countermeasures included in the decision tool, step-by-step instructions on how to use the decision tool, guidance on interpreting the output tables, and two examples to demonstrate its use.

Section 1. Introduction

1.1 Background

The Highway Safety Improvement Program (HSIP) is a core Federal-aid program under 23 U.S.C. 148. The purpose of the HSIP is to achieve a significant reduction in traffic fatalities and serious injuries on all public roads. The focus of most HSIP projects is on improving motor-vehicle safety; yet according to the Fatality Analysis Reporting System (FARS) data, pedestrian and bicyclist fatalities have been increasing and now account for more than 15 percent of all roadway fatalities (NHTSA, 2018). Thus, states may need to reconsider how they allocate funds to be consistent with concerns and areas of need such as pedestrian and bicycle safety. States also need to gain a better understanding of how roadway safety countermeasures intended to improve motor-vehicle safety may impact pedestrians and bicyclists.

Existing resources and tools such as the *Highway Safety Manual* (HSM) (AASHTO, 2010), the Crash Modification Factor (CMF) Clearinghouse, and the AASHTOWare Safety Analyst software can help highway agencies identify countermeasures to remedy certain types of crashes or crash patterns. Often, traffic safety countermeasures are selected, programmed, and installed to reduce the frequency and/or severity of motor-vehicle crashes without regard to potential impacts to pedestrians and bicyclists. Therefore, a decision tool to identify tradeoffs in safety, mobility, and other concerns between motorists, pedestrians, and bicyclists arising from traffic safety countermeasures during the countermeasure selection process will benefit agencies so that motor-vehicle countermeasures are not installed that unintentionally create safety, operational, mobility, or other concerns for pedestrians and bicyclists. At a minimum, the decision tool enables pedestrian and bicyclist concerns to be factored into the countermeasure selection process before selecting and programming a countermeasure for installation.

This user guide is intended to help practitioners use the decision tool to identify tradeoffs in safety and mobility between motorists, pedestrians, and bicyclists that may arise from traffic safety countermeasures during countermeasure selection. The decision tool is a spreadsheet-based tool, implemented using Visual Basic for Applications (VBA) within Microsoft Excel. The decision tool was designed with two primary purposes:

1. For a given classification of roadway or intersection configuration and traffic control type, the decision tool helps practitioners select a traffic safety countermeasure that addresses specific crash types or contributing factors, while also considering potential impacts on pedestrians and bicyclists.
2. If a designer or safety engineer has already identified an initial traffic safety countermeasure for potential implementation to address a specific crash pattern of interest or crash contributing factor, the decision tool can be used to identify alternative countermeasures that address the same crash pattern of interest or crash contributing factor, while also considering the potential impacts on pedestrians and bicyclists of the initial countermeasure and alternative countermeasures.

The decision tool was designed to help practitioners select countermeasures covering most types of roadway segments and intersections. The decision tool does not address countermeasures for freeways (i.e., limited access roads).

The decision tool is designed to be consistent with the HSM and Safety Analyst software. For example, the decision tool categorizes roadway segments and intersections according to similar categories used in the first edition of the HSM and the Safety Analyst software. In addition, the crash types and crash contributing factors incorporated in the decision tool are generally consistent with HSM Part B.

1.2 General Work Flow of the Decision Tool

The general steps of the decision tool are illustrated in Figure 1 and are described below.

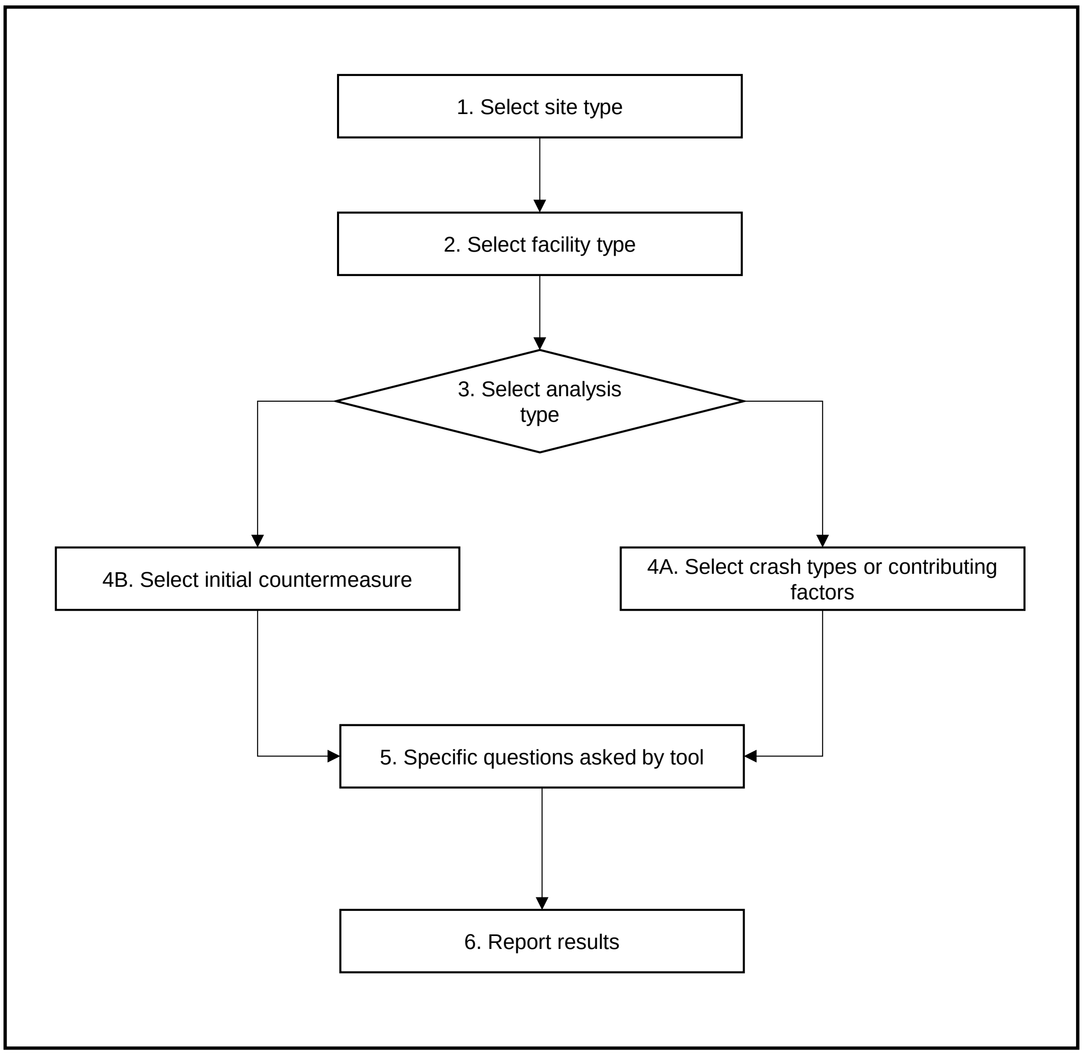


Figure 1. Framework for Decision Tool

Step 1: Select Site Type

In Step 1, the user selects the site type where a traffic safety countermeasure is being considered for implementation. Potential site types to select include roadway segments and intersections. The user can select only one site type to proceed to the next step.

Step 2: Select Facility Type

In Step 2, the user selects the specific facility type where the traffic safety countermeasure is being considered for implementation. Options include:

Roadway Segments

- Rural two-lane highway
- Rural multilane undivided highway
- Rural multilane divided highway
- Urban two-lane arterial
- Urban multilane undivided arterial
- Urban multilane divided arterial
- Urban one-way arterial

Intersections

- Rural three-leg minor-road stop control
- Rural three-leg all-way stop control
- Rural three-leg signalized
- Rural four-leg minor-road stop control
- Rural four-leg all-way stop control
- Rural four-leg signalized
- Urban three-leg minor-road stop control
- Urban three-leg all-way stop control
- Urban three-leg signalized
- Urban four-leg minor-road stop control
- Urban four-leg all-way stop control
- Urban four-leg signalized

Step 3: Select Analysis Type

In Step 3, the user selects from two options on how to proceed with the analysis. One option is to assess countermeasures that address certain contributing factors or crash types. The second option is to select an initial countermeasure and compare alternative countermeasures that remedy the same crash types or contributing factors.

Step 4A: Select Crash Types or Contributing Factors

If, in Step 3, the user selects to assess countermeasures that address certain contributing factors or crash types, then in Step 4A, the user selects certain crash types (up to a maximum of three) or contributing factors (up to a maximum of three) that a countermeasure is intended to address. Potential crash types and contributing factors options to select include:

Roadway Segments Crash Types

- Angle
- Head on
- Rear end
- Opposite-direction sideswipe
- Same-direction sideswipe

Intersections Crash Types

- Angle
- Head on
- Rear end
- Sideswipe
- Left turn

Roadway Segments
Crash Types

- Backing
- Run off the road
- Left turn
- Collisions at driveways
- Parking-related

Contributing Factors

- Excessive speed
- Inadequate lane width
- Inadequate shoulder width
- Inadequate median width
- Inadequate roadway geometry
- Inadequate sight distance
- Poor delineation
- Poor visibility
- Left-turning vehicles
- Unexpected lane changes
- Unexpected stops
- Large volume of through traffic
- Large volume of driveway traffic
- Improperly located driveway
- Inadequate gaps in traffic
- Misjudge speed of oncoming traffic
- Pedestrians on roadway
- Long distance to nearest crosswalk
- Driver has inadequate warning of mid-block crossings

Intersections
Crash Types

- Truck

Contributing Factors

- Conflict with right-turn-on-red vehicles
- Drivers running red light
- Drivers running STOP sign
- Excessive speed
- Inadequate gaps in traffic
- Inadequate lane width
- Inadequate roadway geometry
- Inadequate sight distance
- Inadequate signal timing
- Large number of turning vehicles
- Long crossing distance
- Misjudge speed of oncoming traffic
- Unexpected lane changes on approach
- Unexpected stops on approach

All countermeasures for the facility type of interest that may remedy the selected crash type(s) or address the selected contributing factor(s) are identified for further consideration in the analysis. In addition, all other countermeasures for the facility type of interest that do not necessarily address the selected crash type(s) or contributing factor(s) can also be considered in the analysis at the discretion of the user. From these countermeasures, the user selects the subset of the countermeasures to be considered for the analysis.

Step 4B: Select Initial Countermeasure

If, in Step 3, the users selects the option to analyze a certain countermeasure for potential implementation and compare it to alternative countermeasures that remedy the same crash types and/or contributing factors, then in Step 4B, the user selects an initial countermeasure from a list of countermeasures for the site type and facility type selected in the previous steps. Then, for the given countermeasure, alternative countermeasures are identified for further consideration in the analysis if they have either a crash type or a contributing factor in common with the initial countermeasure. Alternative countermeasures for the facility type of interest that do not have a crash type or contributing factor in common with the initial countermeasure can also be considered for the analysis at the discretion of the user. From these countermeasures, the user selects the subset of the countermeasures to be considered for the analysis.

Step 5: Specific Questions Asked by Tool

At the conclusion of Step 4, a list of countermeasures is identified for further analysis. Then, in Step 5, for each countermeasure, the user is asked a series of questions as appropriate about the attributes or characteristics of the site and how they would be impacted if the countermeasure was installed. Table 1 lists the series of diagnostic questions for roadway segments and applicable responses, and Table 2 lists the series of diagnostic questions for intersections and applicable responses.

The questions in Tables 1 and 2 are presented in a generalized format, as more specific questions are asked in the decision tool about the individual countermeasures. The questions are formulated to determine how installation of the countermeasure may likely impact specific parameters related to the safety or level of service, or in some other way impact pedestrians and bicyclists traveling along a roadway segment or crossing an intersection. The parameters included in the tool are related to parameters in the HSM methodology to predict pedestrian crashes at signalized intersections (AASHTO, 2010), the *Highway Capacity Manual* (HCM) (TRB, 2016) methodology to calculate pedestrian and bicycle level of service, the methodology developed by Carter et al. (2006) to calculate pedestrian and bicycle intersection safety indices, and other parameters relevant to pedestrian and bicycle operations and safety as determined by the research team. Parameters of interest included in the diagnostic questions and used to formulate the final output reports in the decision tool are as follows:

Roadway Segments

- Pedestrian travel time
- Pedestrian delay
- Bicyclist travel time
- Bike speed
- Motor vehicle speed
- Motor vehicle traffic volume
- Number of through lanes
- Lane width
- Overall pavement width
- Separation to pedestrian facility
- Crossing distance
- Separation to bikeway
- Pavement surface quality
- Driveway radii, turning speeds
- Left-turning conflicts
- Right-turning conflicts
- Visibility
- Conspicuity

Intersections

- Pedestrian travel time
- Pedestrian delay
- Bicyclist travel time
- Bicyclist delay
- Motor vehicle approach speed
- Number of through lanes
- Width of outside through lane
- Presence of bike lane
- Width of bicycle lane
- Width of paved outside shoulder
- Presence of on-street parking
- Width of parking lane
- Presence of raised median
- Number of lanes for bicyclist to cross to make a left turn
- Left-turn phasing
- Number of right-turn lanes on major approach

Roadway Segments	Intersections
	• Number of right-turn islands • Crosswalk length • Permitted-left-turn flow rate • Right-turn-on-red flow rate • Corner radius • Turning speeds • Cycle length • Walk duration • Motorist yielding rate • Visibility • Conspicuity

The decision tool has also been created to provide responses to questions that are readily apparent based on the countermeasure being considered. For example, there is no need to ask the user a question about how the treatment will affect the average lane width, when the countermeasure being considered is "Change lane width, widen" or "Change lane width, narrow". Some answers to questions are readily apparent so the decision tool has been developed with the logic to skip questions as appropriate.

Table 1. Roadway Segment Diagnostic Questions And Applicable Responses

Questions	Response 1	Response 2	Response 3	Response 4
How will the treatment effect the average lane width?	increase	decrease	no change	unknown
How will the treatment effect the separation width between the roadway and the bicycle facility?	increase	decrease	no change	unknown
How will the treatment effect the separation width between the roadway and the pedestrian facility?	increase	decrease	no change	unknown
How will the treatment effect the overall pavement width?	increase	decrease	no change	unknown
Due to the treatment, will a wider outside travel lane or a dedicated facility be provided for bicyclists?	yes	no	not applicable: bike facility already exists	unknown
Will a rideable space be provided for bikes away from or around the treatment?	yes: shoulders will need to be widened	yes: shoulders will not need to be widened	no	unknown
How will the treatment effect shoulder widths?	widen	narrow	no change	unknown
How will the treatment effect crossing distance?	increase	decrease	no change	unknown

Table 2. Intersection Diagnostic Questions and Applicable Responses

Questions	Response 1	Response 2	Response 3	Response 4	Response 5
How will treatment installation impact crosswalk length?	increase	decrease	no change	unknown	not applicable
How will treatment installation impact width of outside through lane?	increase	decrease	no change	unknown	not applicable
How will treatment installation impact width/presence of bicycle lane?	eliminate	decrease	no change	unknown	no existing bike lane
How will treatment installation impact width/presence of paved outside shoulder?	eliminate	narrow	widen / improve	no change	unknown
How will treatment installation impact width/presence of parking lane?	eliminate	decrease	no change	unknown	no existing parking lane
How will treatment installation impact presence of two-staged pedestrian crossing?	will add where previously did not exist	will remove previously existed	no change	unknown	not applicable
How will treatment installation impact signal cycle length?	increase	decrease	no change	unknown	not applicable
How will treatment installation impact pedestrian walk duration?	increase	decrease	no change	unknown	not applicable
How will treatment installation impact left-turn phasing?	change from permissive only to permissive/ protected	change from permissive only to protected only	change from permissive/protected to protected only	change from permissive/ protected to permissive only	no change
How will treatment installation impact width of through lanes?	will widen	will narrow	no change	unknown	not applicable
How will treatment installation change number of through lanes?	increase	decrease	no change	unknown	not applicable
How will treatment installation change the number of right-turn islands?	increase	decrease	no change	unknown	not applicable

In Step 6, the user is presented with the results of the diagnostic evaluation for each countermeasure, indicating the potential impacts on pedestrians and bicyclists if the countermeasure is installed. An output table is provided that addresses the potential impacts on pedestrians for each countermeasure included in the analysis, and a separate output table is provided showing the same information for bicyclists.

Table 3 presents the general format of an output report considering the potential impacts of countermeasures on pedestrians at roadway segments. A similar output report considering the potential impacts on bicyclists at roadway segments would also be generated. Depending on the site type being evaluated, one of three pairs of reports will be generated:

- Output reports considering the potential impacts of countermeasures on pedestrians and bicyclists at roadway segments
- Output reports considering the potential impacts of countermeasures on pedestrians and bicyclists at signalized intersections
- Output reports considering the potential impacts of countermeasures on pedestrians and bicyclists at stop-controlled intersections

Table 3. Sample Output Report: Potential Impacts on Pedestrians at Roadway Segments

Variable	Direction of Impact	Potential Impacts on Pedestrians at Roadway Segments
Travel time		Treatments that increase travel time for pedestrians can decrease compliance with the traffic control by pedestrians, encourage pedestrians to use undesired routes, and/or decrease pedestrian level of service.
Delay		Treatments that increase delay for crossing pedestrians can decrease compliance with the traffic control. Increased delay decreases pedestrian level of service.
Number of through lanes		As the number of through lanes increases, the availability for a suitable midblock crossing gap decreases, decreasing pedestrian level of service. Treatments that increase the number of through lanes that intersect the path of a crossing pedestrian increase crash exposure for pedestrians. It can also create situations where traffic in one lane blocks the view of crossing pedestrians for drivers in another lane.
Lane width		Treatments that increase lane width increase the midblock crossing distance for pedestrians and increase their travel time, decreasing pedestrian level of service. Increased lane width may also increase vehicle travel speeds. Pedestrian crashes become more severe as vehicle speeds increase. In addition, increased speeds reduce the available time for a driver to identify and react to the presence of a pedestrian.
Crossing distance		Treatments that increase the midblock crossing distance for pedestrians increase their exposure time to traffic.
Overall pavement width		Treatments that increase overall pavement width increase the midblock crossing distance for pedestrians and increase their travel time, decreasing pedestrian level of service. Increased pavement width may also increase vehicle travel speeds. Pedestrian crashes become more severe as vehicle speeds increase. In addition, increased speeds reduce the available time for a driver to identify and react to the presence of a pedestrian.
Separation to pedestrian facility		As the distance between motor vehicle lanes and the pedestrian facility increases, pedestrian comfort increases.
Motor vehicle speed		As motor vehicle speed increases, crashes with pedestrians become more severe. In addition, higher speeds give drivers less reaction time to detect and respond to the presence of a pedestrian.
Driveway radii, turning speeds		Treatments that increase turning speeds can make crashes with pedestrians more severe. This may be more of a concern where drivers' attention may not be on pedestrians, such as when making a left-turn into a driveway.
Traffic volumes		Treatments that increase vehicle volumes reduce available gaps for pedestrians to cross at midblock locations. Increased volumes may also decrease the comfort of pedestrians walking along the roadside. Increase traffic volumes increase pedestrian exposure to crashes.
Visibility		Treatments that block the view of pedestrians or cast them in shadows may result in drivers being surprised by their presence near a midblock crossing or driveway, and drivers may not have sufficient time to yield to the pedestrians.
Conspicuity		When pedestrians are not conspicuous, drivers may have difficulty identifying them in time to yield to them at a midblock crossing or at driveways.
Left-turning conflicts		Treatments that increase left-turning traffic onto driveways and other access points along the roadway segment create potential conflicts for pedestrians walking along the side of the road and increase crash exposure. The level of service methodology in the HCM for pedestrians walking along a roadway assumes that drivers yield to pedestrians before making turns, so turning volume is not a factor in pedestrian roadway segment LOS calculations. However, in reality, increases in turning movements may reduce the level of comfort of pedestrians walking along the roadway.
Right-turning conflicts		Treatments that increase right-turning traffic onto or out of driveways and other access points along the roadway segment create potential conflicts for pedestrians walking along the side of the road and increase crash exposure. The level of service methodology in the HCM for pedestrians walking along a roadway assumes that drivers yield to pedestrians before making turns, so turning volume is not a factor in pedestrian roadway segment LOS calculations. However, in reality, increases in turning movements may reduce the level of comfort of pedestrians walking along the roadway.

Section 2.
Countermeasures in the Decision Tool

A total of 17 roadway-segment and 14 intersection countermeasures are included in the decision tool. For each countermeasure, information is provided for:

- The facility types where the countermeasure could be applied
- The primary collision types mitigated or remedied by the countermeasure
- Crash contributing factors that, if present, would lead one to consider the countermeasure for potential implementation
- The number of related CMFs included in the CMF Clearinghouse with 3-star quality ratings or above

Section 2.1 presents information for the roadway segment countermeasures, and Section 2.2 presents information for the intersection countermeasures.

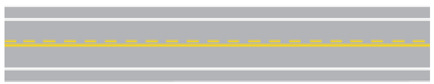
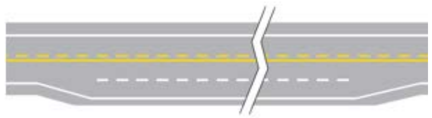
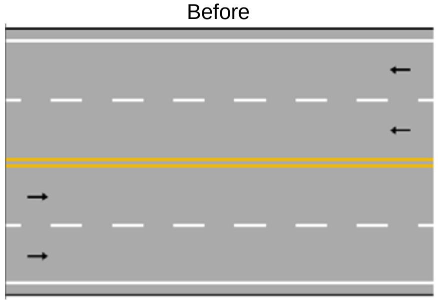
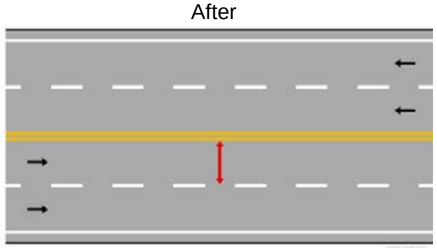
2.1 Roadway Segment Countermeasures in the Decision Tool

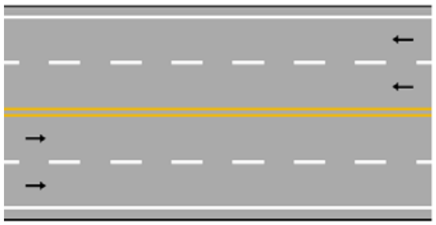
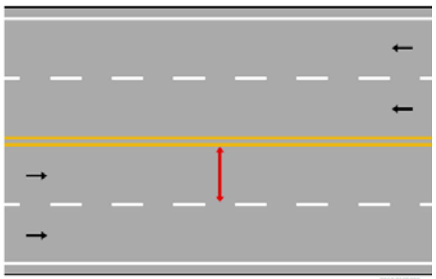
The roadway segment countermeasures incorporated into the decision tool are as follows:

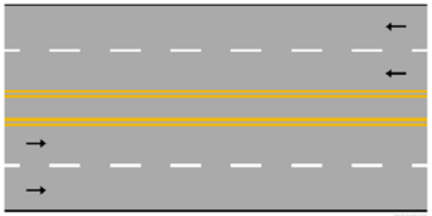
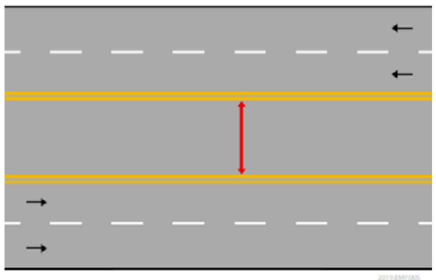
- Add auxiliary lane
- Change lane width, narrow
- Change lane width, widen
- Change median width
- Change number of lanes, reduce
- Change parking type
- Change shoulder width/type
- Convert a two-way left-turn (TWLTL) lane to a raised median
- Implement truck lane restrictions
- Install automated speed enforcement
- Install raised median
- Install shoulder rumble strips
- Install speed humps
- Install transverse rumble strips
- Reduce driveway density
- Reduce median opening density
- Reduce number of transit stops

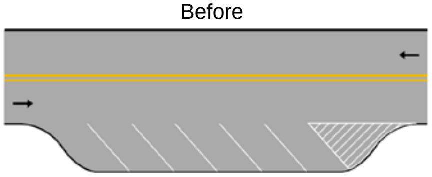
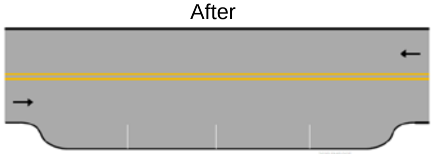
Table 4 illustrates common before and after conditions for each of the roadway segment countermeasures included in the decision tool. Because the countermeasures included in the decision tool address fairly common treatments, it is not feasible to illustrate all possible before conditions and the range of treatments and applications associated with each countermeasure in the after condition. Table 4 also provides the roadway types, crash types mitigated, and crash contributing factors associated with each of the roadway segment countermeasures and indicates the number of related CMFs in the CMF Clearinghouse with 3-star quality ratings or above for the given countermeasure, shown in parenthesis following the treatment name. A single countermeasure in the Clearinghouse may have multiple CMFs with varying star quality ratings that may apply to specific crash types, roadway types, and other conditions. The star quality rating of each CMF is based on the characteristics of the study that produced the CMF. When considering use of CMFs for prioritizing and selecting countermeasures for potential installation, it is important to understand the conditions to which the CMFs and treatments apply.

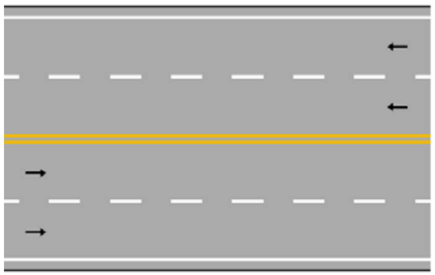
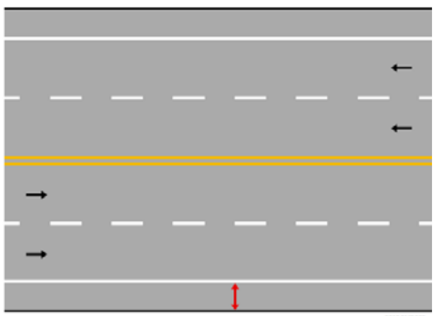
Table 4. Roadway Segment Countermeasures: Roadway Types, Crash Types, and Contributing Factors

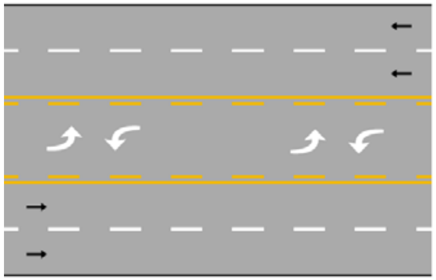
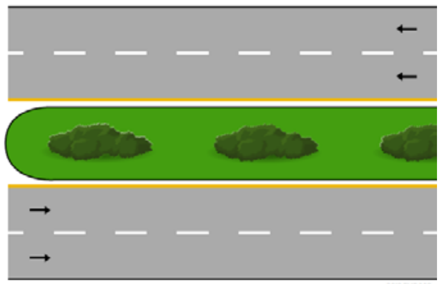
Treatment Name[a]	Roadway Types	Crash Types Mitigated	Contributing Factors
Add auxiliary lane (7)	Rural 2-lane highway	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed; inadequate roadway geometry
Before	Rural multilane undivided highway	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed; inadequate roadway geometry
	Rural multilane divided highway	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed; inadequate roadway geometry
After	Urban 2-lane arterial	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed; inadequate roadway geometry
	Urban multilane undivided arterial	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed; inadequate roadway geometry
	Urban multilane divided arterial	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed; inadequate roadway geometry
	Urban ane-way arterial	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed; inadequate roadway geometry
Change lane width, narrow (54)	Rural 2-lane highway	Opposite-direction sideswipe; same-direction sideswipe; head on; run off the road	Excessive speed; inadequate shoulder width
Before	Rural multilane undivided highway	Opposite-direction sideswipe; same-direction sideswipe; head on; run off the road	Excessive speed; inadequate shoulder width
	Rural multilane divided highway	Same-direction sideswipe; run off the road	Excessive speed; inadequate shoulder width; inadequate median width
	Urban 2-lane arterial	Opposite-direction sideswipe; same-direction sideswipe; head on; run off the road	Excessive speed; inadequate shoulder width
	Urban multilane undivided arterial	Opposite-direction sideswipe; same-direction sideswipe; head on; run off the road	Excessive speed; inadequate shoulder width
After	Urban multilane divided arterial	Same-direction sideswipe; run off the road	Excessive speed; inadequate shoulder width; inadequate median width
	Urban one-way arterial	Same-direction sideswipe; run off the road	Excessive speed; inadequate shoulder width

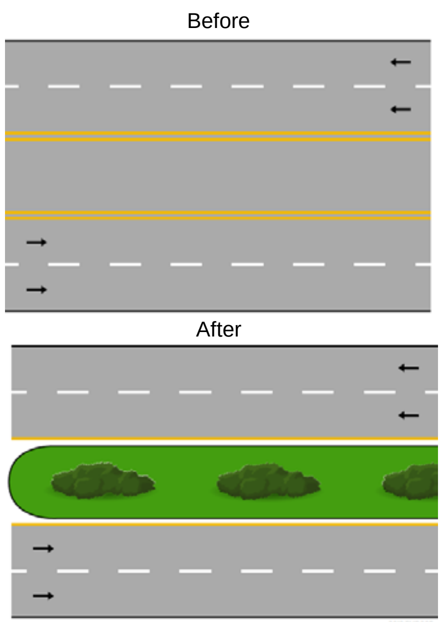
Treatment Name[a]	Roadway Types	Crash Types Mitigated	Contributing Factors
Change lane width, widen (16) Before  After 	Rural 2-lane highway	Opposite-direction sideswipe; same-direction sideswipe; head on; run off the road	Excessive speed; inadequate lane width
	Rural multilane undivided highway	Opposite-direction sideswipe; same-direction sideswipe; head on; run off the road	Excessive speed; inadequate lane width
	Rural multilane divided highway	Same-direction sideswipe; run off the road	Excessive speed; inadequate lane width
	Urban 2-lane arterial	Opposite-direction sideswipe; same-direction sideswipe; head on; run off the road	Excessive speed; inadequate lane width
	Urban multilane undivided arterial	Opposite-direction sideswipe; same-direction sideswipe; head on; run off the road	Excessive speed; inadequate lane width
	Urban multilane divided arterial	Same-direction sideswipe; run off the road	Excessive speed; inadequate lane width
	Urban one-way arterial	Same-direction sideswipe; run off the road	Excessive speed; inadequate lane width

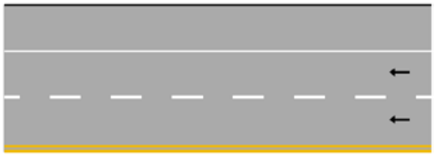
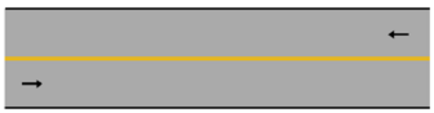
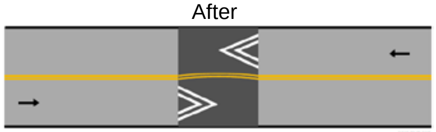
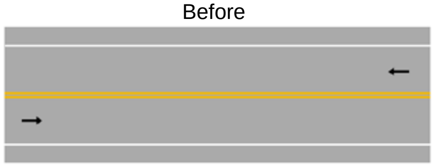
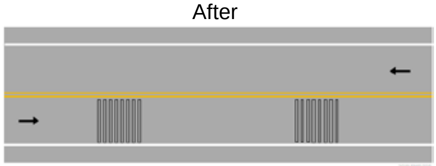
Treatment Name[a]	Roadway Types	Crash Types Mitigated	Contributing Factors
Change median width (40) Before 	Rural multilane divided highway	Head on	Inadequate median width; excessive speed
After 	Urban multilane divided arterial	Head on	Inadequate median width; excessive speed

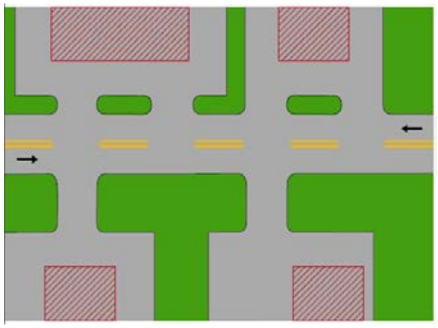
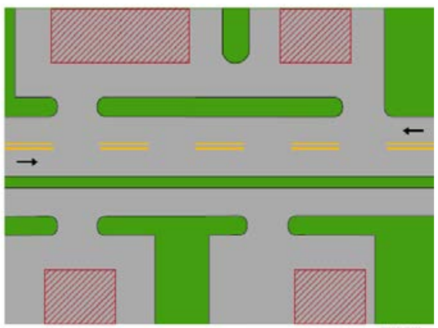
Treatment Name[a]	Roadway Types	Crash Types Mitigated	Contributing Factors
Change number of lanes, reduce (44) Before  After 	Rural multilane undivided highway	Same-direction sideswipe	Inadequate roadway geometry; inadequate shoulder width; excessive speed
	Rural multilane divided highway	Same-direction sideswipe	Inadequate roadway geometry; inadequate shoulder width; excessive speed
	Urban multilane undivided arterial	Same-direction sideswipe	Inadequate roadway geometry; inadequate shoulder width; excessive speed
	Urban multilane divided arterial	Same-direction sideswipe	Inadequate roadway geometry; inadequate shoulder width; excessive speed
	Urban one-way arterial	Same-direction sideswipe	Inadequate roadway geometry; inadequate shoulder width; excessive speed
Change parking type (10) Before  After 	Urban 2-lane arterial	Backing; rear end; parking-related	Unexpected stops; inadequate sight distance
	Urban multilane undivided arterial	Backing; rear end; parking-related	Unexpected stops; inadequate sight distance
	Urban multilane divided arterial	Backing; rear end; parking-related	Unexpected stops; inadequate sight distance
	Urban one-way arterial	Backing; rear end; parking-related	Unexpected stops; inadequate sight distance

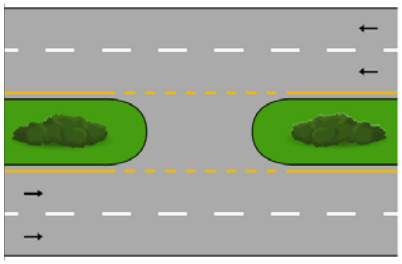
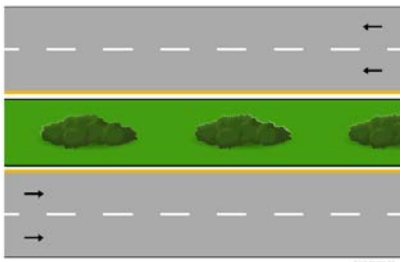
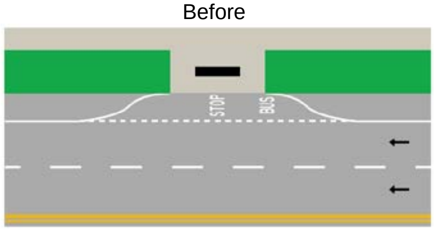
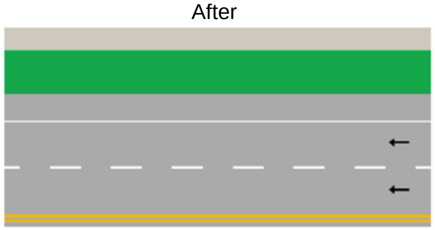
Treatment Name[a]	Roadway Types	Crash Types Mitigated	Contributing Factors
Change shoulder width / type (206) Before  After 	Rural 2-lane highway	Run off the road	Inadequate lane width; inadequate shoulder width; excessive speed
	Rural multilane undivided highway	Run off the road	Inadequate lane width; inadequate shoulder width; excessive speed
	Rural multilane divided highway	Run off the road	Inadequate lane width; inadequate shoulder width; excessive speed; inadequate median width
	Urban 2-lane arterial	Run off the road	Inadequate lane width; inadequate shoulder width; excessive speed
	Urban multilane undivided arterial	Run off the road	Inadequate lane width; inadequate shoulder width; excessive speed
	Urban multilane divided arterial	Run off the road	Inadequate lane width; inadequate shoulder width; excessive speed; inadequate median width
	Urban one-way arterial	Run off the road	Inadequate lane width; inadequate shoulder width; excessive speed

Treatment Name[a]	Roadway Types	Crash Types Mitigated	Contributing Factors
Convert a TWLTL to a raised median (8) Before  After 	Rural 2-lane highway	Head on; left turn; angle; opposite-direction sideswipe; same-direction sideswipe; collisions at driveways	Excessive speed; misjudge speed of oncoming traffic; inadequate sight distance; unexpected lane changes; inadequate lane width; left-turning vehicles; large volume of through traffic; large volume of driveway traffic
	Rural multilane undivided highway	Head on; left turn; angle; opposite-direction sideswipe; same-direction sideswipe; collisions at driveways	Excessive speed; misjudge speed of oncoming traffic; inadequate sight distance; unexpected lane changes; inadequate lane width ; left-turning vehicles; large volume of through traffic; large volume of driveway traffic
	Urban 2-lane arterial	Head on; left turn; angle; opposite-direction sideswipe; same-direction sideswipe; collisions at driveways	Excessive speed; misjudge speed of oncoming traffic; adequate sight distance; unexpected lane changes; inadequate lane width; left-turning vehicles; large volume of through traffic; large volume of driveway traffic
	Urban multilane undivided arterial	Head on; left turn; angle; opposite-direction sideswipe; same-direction sideswipe; collisions at driveways	Excessive speed; misjudge speed of oncoming traffic; inadequate sight distance; unexpected lane changes; inadequate lane width; left-turning vehicles; large volume of through traffic; large volume of driveway traffic
Implement truck lane restrictions (0) 	Rural multilane undivided highway	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed
	Rural multilane divided highway	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed
	Urban multilane undivided arterial	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed
	Urban multilane divided arterial	Same-direction sideswipe; rear end	Unexpected lane changes; excessive speed

Treatment Name[a]	Roadway Types	Crash Types Mitigated	Contributing Factors
Install automated speed enforcement (164) 	Rural 2-lane highway	Opposite-direction sideswipe; head on; run off the road	Excessive speed
	Rural multilane undivided highway	Opposite-direction sideswipe; head on; run off the road	Excessive speed
	Rural multilane divided highway	Run off the road	Excessive speed
	Urban 2-lane arterial	Opposite-direction sideswipe; head on; run off the road	Excessive speed
	Urban multilane undivided arterial	Opposite-direction sideswipe; head on; run off the road	Excessive speed
	Urban multilane divided arterial	Run off the road	Excessive speed
	Urban one-way arterial	Run off the road	Excessive speed
Install raised median (47) 	Rural 2-lane highway	Head on; left turn; angle; opposite-direction sideswipe; collisions at driveways	Excessive speed; misjudge speed of oncoming traffic; large volume of through traffic; unexpected crossing traffic; left-turning vehicles; large volume of driveway traffic; inadequate lane width; long distance to nearest crosswalk; inadequate median width
	Rural multilane undivided highway	Head on; left turn; angle; opposite-direction sideswipe; collisions at driveways	Excessive speed; misjudge speed of oncoming traffic; large volume of through traffic; unexpected crossing traffic; left-turning vehicles; large volume of driveway traffic; inadequate lane width; long distance to nearest crosswalk; inadequate median width
	Rural multilane divided highway	Head on; left turn; angle; opposite-direction sideswipe; collisions at driveways	Excessive speed; misjudge speed of oncoming traffic; large volume of through traffic; unexpected crossing traffic; left-turning vehicles; large volume of driveway traffic; inadequate lane width; long distance to nearest crosswalk; inadequate median width
	Urban 2-lane arterial	Head on; left turn; angle; opposite-direction sideswipe; collisions at driveways	Excessive speed; misjudge speed of oncoming traffic; large volume of through traffic; unexpected crossing traffic; left-turning vehicles; large volume of driveway traffic; inadequate lane width; long distance to nearest crosswalk; inadequate median width
	Urban multilane undivided arterial	Head on; left turn; angle; opposite-direction sideswipe; collisions at driveways	Excessive speed; misjudge speed of oncoming traffic; large volume of through traffic; unexpected crossing traffic; left-turning vehicles; large volume of driveway traffic; inadequate lane width; long distance to nearest crosswalk; inadequate median width
	Urban multilane divided arterial	Head on; left turn; angle; opposite-direction sideswipe; collisions at driveways	Excessive speed; misjudge speed of oncoming traffic; large volume of through traffic; unexpected crossing traffic; left-turning vehicles; large volume of driveway traffic; inadequate lane width; long distance to nearest crosswalk; inadequate median width

Treatment Name[a]	Roadway Types	Crash Types Mitigated	Contributing Factors
Install shoulder rumble strips (301) Before  After 	Rural 2-lane highway	Run off the road; opposite-direction sideswipe; head on	Excessive speed; inadequate lane width; inadequate shoulder width; poor delineation; poor visibility
	Rural multilane undivided highway	Run off the road; opposite-direction sideswipe; head on	Excessive speed; inadequate lane width; inadequate shoulder width; poor delineation; poor visibility
	Rural multilane divided highway	Run off the road; opposite-direction sideswipe; head on	Excessive speed; inadequate lane width; inadequate shoulder width; poor delineation; poor visibility; inadequate median width
	Urban 2-lane arterial	Run off the road; opposite-direction sideswipe; head on	Excessive speed; inadequate lane width; inadequate shoulder width; poor delineation; poor visibility
	Urban multilane undivided arterial	Run off the road; opposite-direction sideswipe; head on	Excessive speed; inadequate lane width; inadequate shoulder width; poor delineation; poor visibility
	Urban multilane divided arterial	Run off the road; opposite-direction sideswipe; head on	Excessive speed; inadequate lane width; inadequate shoulder width; poor delineation; poor visibility; inadequate median width
	Urban one-way arterial	Run off the road; opposite-direction sideswipe; head on	Excessive speed; inadequate lane width; inadequate shoulder width; poor delineation; poor visibility
Install speed humps (0) Before  After 	Rural 2-lane highway	Opposite-direction sideswipe; head on; run off the road	Excessive speed
	Urban 2-lane arterial	Opposite-direction sideswipe; head on; run off the road	Excessive speed
Install transverse rumble strips (2) Before  After 	Rural 2-lane highway	Run off the road; opposite-direction sideswipe; head on	Excessive speed
	Rural multilane undivided highway	Run off the road; opposite-direction sideswipe; head on	Excessive speed
	Rural multilane divided highway	Run off the road	Excessive speed
	Urban 2-lane arterial	Run off the road; opposite-direction sideswipe; head on	Excessive speed
	Urban multilane undivided arterial	Run off the road; opposite-direction sideswipe; head on	Excessive speed
	Urban multilane divided arterial	Run off the road	Excessive speed
	Urban one-way arterial	Run off the road	Excessive speed

Treatment Name[a]	Roadway Types	Crash Types Mitigated	Contributing Factors
Reduce driveway density (11) Before  After 	Rural 2-lane highway	Collisions at driveways; left turn; rear end; right turn	Misjudge speed of oncoming traffic; inadequate sight distance; left-turning vehicles; improperly located driveway; large volume of through traffic; large volume of driveway traffic; inadequate gaps in traffic
	Rural multilane undivided highway	Collisions at driveways; left turn; rear end; right turn	Misjudge speed of oncoming traffic; inadequate sight distance; left-turning vehicles; improperly located driveway; large volume of through traffic; large volume of driveway traffic; inadequate gaps in traffic
	Rural multilane divided highway	Collisions at driveways; left turn; rear end; right turn	Misjudge speed of oncoming traffic; inadequate sight distance; left-turning vehicles; improperly located driveway; large volume of through traffic; inadequate gaps in traffic
	Urban 2-lane arterial	Collisions at driveways; left turn; rear end; right turn	Misjudge speed of oncoming traffic; inadequate sight distance; left-turning vehicles; improperly located driveway; large volume of through traffic; large volume of driveway traffic; inadequate gaps in traffic
	Urban multilane undivided arterial	Collisions at driveways; left turn; rear end; right turn	Misjudge speed of oncoming traffic; inadequate sight distance; left-turning vehicles; improperly located driveway; large volume of through traffic; large volume of driveway traffic; inadequate gaps in traffic
	Urban multilane divided arterial	Collisions at driveways; left turn; rear end; right turn	Misjudge speed of oncoming traffic; inadequate sight distance; left-turning vehicles; improperly located driveway; large volume of through traffic; inadequate gaps in traffic
	Urban one-way arterial	Collisions at driveways; left turn; rear end; right turn	Misjudge speed of oncoming traffic; inadequate sight distance; left-turning vehicles; improperly located driveway; large volume of through traffic; large volume of driveway traffic; inadequate gaps in traffic

Treatment Name[a]	Roadway Types	Crash Types Mitigated	Contributing Factors
Reduce median opening density (3) Before  After 	Rural multilane divided highway	Collisions at driveways; left turn; rear end; right turn	Misjudge speed of oncoming traffic; inadequate sight distance; left-turning vehicles; improperly located driveway; large volume of through traffic; large volume of driveway traffic; inadequate gaps in traffic
	Urban multilane divided arterial	Collisions at driveways; left turn; rear end; right turn	Misjudge speed of oncoming traffic; inadequate sight distance; improperly located driveway; large volume of through traffic; large volume of driveway traffic; inadequate gaps in traffic
Reduce number of transit stops (0) Before  After 	Urban 2-lane arterial	Rear end	Excessive speed; inadequate sight distance; driver has inadequate warning of mid-block crossings; long distance to nearest crosswalk
	Urban multilane undivided arterial	Rear end	Excessive speed; misjudge speed of on-coming traffic; high traffic volume; unexpected crossing traffic; left-turning vehicles; large volume of driveway traffic; narrow lanes; long distance to nearest crosswalk
	Urban multilane divided arterial	Rear end	Excessive speed; misjudge speed of on-coming traffic; high traffic volume; unexpected crossing traffic; left-turning vehicles; large volume of driveway traffic; narrow lanes; long distance to nearest crosswalk
	Urban one-way arterial	Rear end	Excessive speed; misjudge speed of on-coming traffic; high traffic volume; unexpected crossing traffic; left-turning vehicles; large volume of driveway traffic; inadequate lane width; long distance to nearest crosswalk; narrow median

[a] The number in parentheses indicates the number of related CMFs included in the CMF Clearinghouse, with 3-star quality ratings or above, for the given countermeasure at the time of publication of this report.

2.2 Intersection Countermeasures in the Decision Tool

The intersection countermeasures incorporated into the decision tool are as follows:

- Change lane width
- Change median width
- Change permissive/protected left-turn phasing
- Change shoulder width/type
- Increase corner radius
- Install curb extensions (bulb outs)
- Install dual left-turn lanes
- Install left-turn lane
- Install median
- Install right-turn lane
- Install roundabout
- Provide channelized left-turn lane
- Provide exclusive or concurrent right-turn phase
- Remove unwarranted signal

Table 5 illustrates common before and after conditions for each of the intersection countermeasures included in the decision tool. Because the countermeasures included in the decision tool address fairly common treatments, it is not feasible to illustrate all possible before conditions and the actual range of treatments and applications associated with each countermeasure in the after condition. Table 5 also provides the intersection types, crash types mitigated, and crash contributing factors associated with each of the intersection countermeasures and indicates the number of related CMFs in the CMF Clearinghouse with 3-star quality ratings or above for the given countermeasure, shown in parenthesis following the treatment name. A single countermeasure in the Clearinghouse may have multiple CMFs with varying star quality ratings that may apply to specific crash types, roadway types, and other conditions. The star quality rating of each CMF is based on the characteristics of the study that produced the CMF. When considering use of CMFs for prioritizing and selecting countermeasures for potential installation, it is important to understand the conditions to which the CMFs and treatments apply.

Table 5. Intersection Countermeasures: Intersection Types, Crash Types, and Contributing Factors

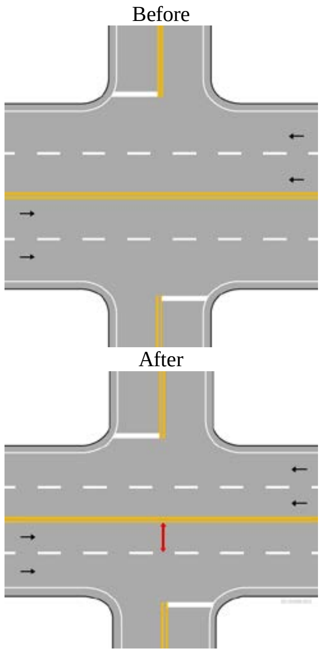
Treatment name[a]	Intersection type	Crash types mitigated	Contributing factors
Change lane width (0) 	Rural 3-leg minor-rd STOP	Sideswipes; rear-end	Inadequate lane width
	Rural 3-leg all-way STOP	Sideswipes; rear-end	Inadequate lane width
	Rural 3-leg signalized	Sideswipes; rear-end	Inadequate lane width
	Rural 4-leg minor-rd STOP	Sideswipes; rear-end	Inadequate lane width
	Rural 4-leg all-way STOP	Sideswipes; rear-end	Inadequate lane width
	Rural 4-leg signalized	Sideswipes; rear-end	Inadequate lane width
	Urban 3-leg minor-rd STOP	Sideswipes; rear-end	Inadequate lane width
	Urban 3-leg all-way STOP	Sideswipes; rear-end	Inadequate lane width
	Urban 3-leg signalized	Sideswipes; rear-end	Inadequate lane width
	Urban 4-leg minor-rd STOP	Sideswipes; rear-end	Inadequate lane width
	Urban 4-leg all-way STOP	Sideswipes; rear-end	Inadequate lane width
	Urban 4-leg signalized	Sideswipes; rear-end	Inadequate lane width

Table 5. Intersection Countermeasures: Intersection Types, Crash Types, and Contributing Factors (Continued)

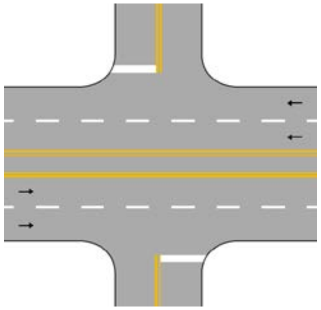
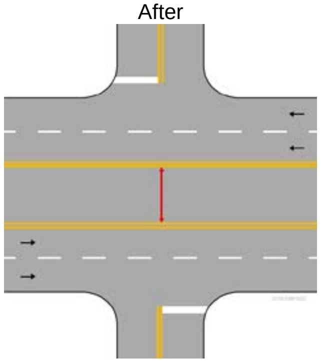
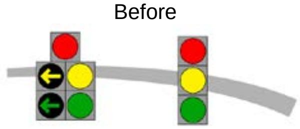
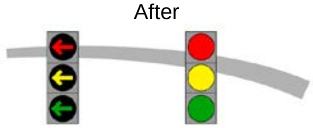
Treatment name[a]	Intersection type	Crash types mitigated	Contributing factors
Change median width (7) Before  After 	Rural 3-leg minor-rd STOP	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Rural 3-leg all-way STOP	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Rural 3-leg signalized	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Rural 4-leg minor-rd STOP	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Rural 4-leg all-way STOP	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Rural 4-leg signalized	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Urban 3-leg minor-rd STOP	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Urban 3-leg all-way STOP	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Urban 3-leg signalized	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Urban 4-leg minor-rd STOP	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Urban 4-leg all-way STOP	Left-turn	Inadequate roadway geometry; inadequate sight distance
	Urban 4-leg signalized	Left-turn	Inadequate roadway geometry; inadequate sight distance
Change permissive/protected left-turn phasing (36) Before  After 	Rural 3-leg signalized	Left-turn; angle	Inadequate gaps in traffic; inadequate signal timing; misjudge speed of oncoming traffic; inadequate sight distance
	Rural 4-leg signalized	Left-turn; angle	Inadequate gaps in traffic; inadequate signal timing; misjudge speed of oncoming traffic; inadequate sight distance
	Urban 3-leg signalized	Left-turn; angle	Inadequate gaps in traffic; inadequate signal timing; misjudge speed of oncoming traffic; inadequate sight distance
	Urban 4-leg signalized	Left-turn; angle	Inadequate gaps in traffic; inadequate signal timing; misjudge speed of oncoming traffic; inadequate sight distance

Table 5. Intersection Countermeasures: Intersection Types, Crash Types, and Contributing Factors (Continued)

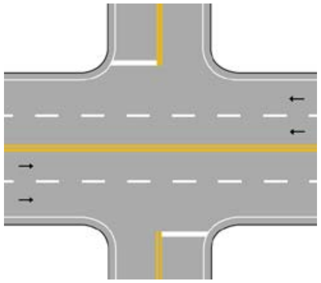
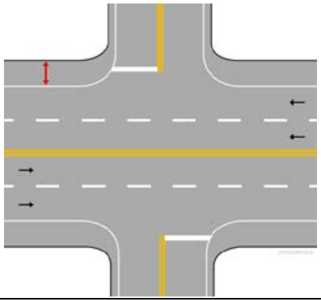
Treatment name[a]	Intersection type	Crash types mitigated	Contributing factors
Change shoulder width/type (5) Before  After 	Rural 3-leg minor-rd STOP	Angle; sideswipe	
	Rural 3-leg all-way STOP	Angle; sideswipe	
	Rural 3-leg signalized	Angle; sideswipe	
	Rural 4-leg minor-rd STOP	Angle; sideswipe	
	Rural 4-leg all-way STOP	Angle; sideswipe	
	Rural 4-leg signalized	Angle; sideswipe	
	Rural 3-leg minor-rd STOP	Truck crashes	Inadequate roadway geometry
	Rural 3-leg all-way STOP	Truck crashes	Inadequate roadway geometry
	Rural 3-leg signalized	Truck crashes	Inadequate roadway geometry
	Rural 4-leg minor-rd STOP	Truck crashes	Inadequate roadway geometry
	Rural 4-leg all-way STOP	Truck crashes	Inadequate roadway geometry
	Rural 4-leg signalized	Truck crashes	Inadequate roadway geometry
	Urban 3-leg minor-rd STOP	Truck crashes	Inadequate roadway geometry
	Urban 3-leg all-way STOP	Truck crashes	Inadequate roadway geometry
	Urban 3-leg signalized	Truck crashes	Inadequate roadway geometry
	Urban 4-leg minor-rd STOP	Truck crashes	Inadequate roadway geometry
	Urban 4-leg all-way STOP	Truck crashes	Inadequate roadway geometry

Table 5. Intersection Countermeasures: Intersection Types, Crash Types, and Contributing Factors (Continued)

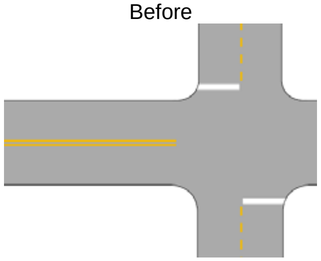
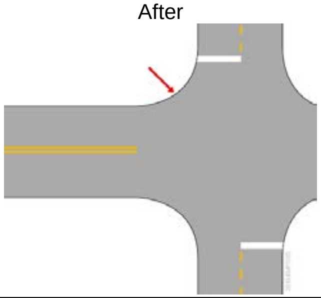
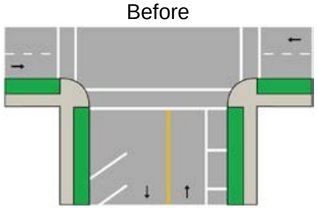
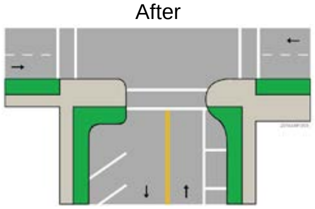
Treatment name[a]	Intersection type	Crash types mitigated	Contributing factors
Increase corner radius (0) Before  After 	Urban 4-leg signalized	Truck crashes	Inadequate roadway geometry
Install curb extensions (bulb outs) (0) Before  After 	Urban 3-leg minor-rd STOP	Rear-end	Inadequate sight distance; long crossing distance; excessive speed
	Urban 3-leg all-way STOP	Rear-end	Inadequate sight distance; long crossing distance; excessive speed
	Urban 3-leg signalized	Rear-end	Inadequate sight distance; long crossing distance; excessive speed
	Urban 4-leg minor-rd STOP	Rear-end	Inadequate sight distance; long crossing distance; excessive speed
	Urban 4-leg all-way STOP	Rear-end	Inadequate sight distance; long crossing distance; excessive speed
	Urban 4-leg signalized	Rear-end	Inadequate sight distance; long crossing distance; excessive speed

Table 5. Intersection Countermeasures: Intersection Types, Crash Types, and Contributing Factors (Continued)

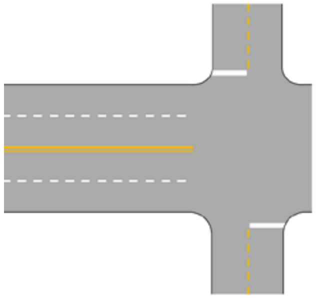
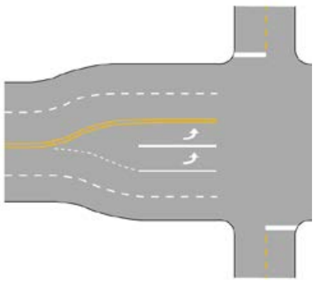
Treatment name[a]	Intersection type	Crash types mitigated	Contributing factors
Install dual left-turn lane (0)	Rural 3-leg signalized	Rear-end; left-turn	Inadequate signal timing; unexpected stops on approach
	Rural 4-leg signalized	Rear-end; left-turn	Inadequate signal timing; unexpected stops on approach
Before	Urban 3-leg signalized	Rear-end; left-turn	Inadequate signal timing; unexpected stops on approach
 After 	Urban 4-leg signalized	Rear-end; left-turn	Inadequate signal timing; unexpected stops on approach

Table 5. Intersection Countermeasures: Intersection Types, Crash Types, and Contributing Factors (Continued)

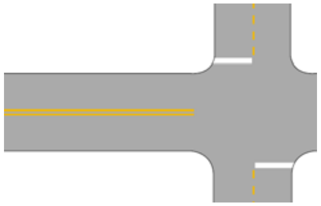
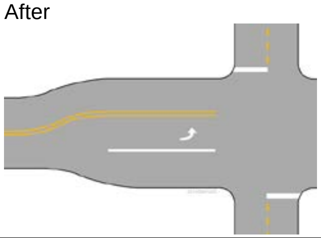
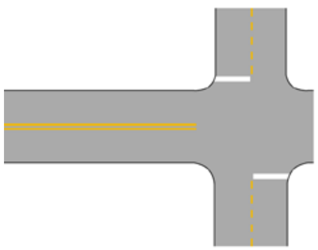
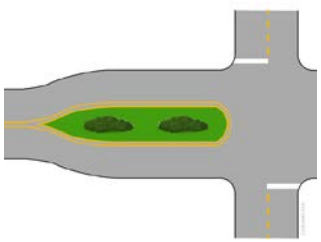
Treatment name[a]	Intersection type	Crash types mitigated	Contributing factors
Install left-turn lane (38) Before  After 	Rural 3-leg minor-rd STOP	Rear-end	Large number of turning vehicles; inadequate gaps in traffic; unexpected stops on approach
	Rural 3-leg signalized	Rear-end; left-turn	Inadequate signal timing; unexpected stops on approach
	Rural 4-leg minor-rd STOP	Rear-end	Large number of turning vehicles; inadequate gaps in traffic; unexpected stops on approach
	Rural 4-leg signalized	Rear-end; left-turn	Inadequate signal timing; unexpected stops on approach
	Urban 3-leg minor-rd STOP	Rear-end	Large number of turning vehicles; inadequate gaps in traffic; unexpected stops on approach
	Urban 3-leg signalized	Rear-end; left-turn	Inadequate signal timing; unexpected stops on approach
	Urban 4-leg minor-rd STOP	Rear-end	Large number of turning vehicles; inadequate gaps in traffic; unexpected stops on approach
	Urban 4-leg signalized	Rear-end; left-turn	Inadequate signal timing; unexpected stops on approach
Install median (3) Before  After 	Rural 3-leg minor-rd STOP	Head-on; sideswipe	Inadequate roadway geometry
	Rural 3-leg all-way STOP	Head-on; sideswipe	Inadequate roadway geometry
	Rural 3-leg signalized	Head-on; sideswipe	Inadequate roadway geometry
	Rural 4-leg minor-rd STOP	Head-on; sideswipe	Inadequate roadway geometry
	Rural 4-leg all-way STOP	Head-on; sideswipe	Inadequate roadway geometry
	Rural 4-leg signalized	Head-on; sideswipe	Inadequate roadway geometry
	Urban 3-leg minor-rd STOP	Head-on; sideswipe	Inadequate roadway geometry
	Urban 3-leg all-way STOP	Head-on; sideswipe	Inadequate roadway geometry
	Urban 3-leg signalized	Head-on; sideswipe	Inadequate roadway geometry
	Urban 4-leg minor-rd STOP	Head-on; sideswipe	Inadequate roadway geometry
	Urban 4-leg all-way STOP	Head-on; sideswipe	Inadequate roadway geometry
	Urban 4-leg signalized	Head-on; sideswipe	Inadequate roadway geometry

Table 5. Intersection Countermeasures: Intersection Types, Crash Types, and Contributing Factors (Continued)

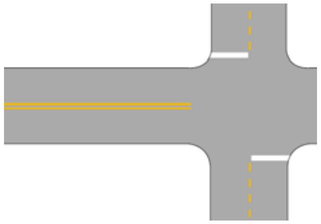
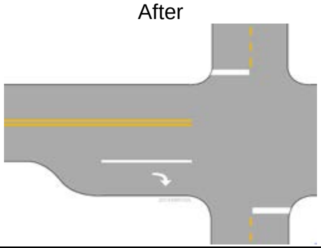
Treatment name[a]	Intersection type	Crash types mitigated	Contributing factors
Install right-turn lane (205) Before  After 	Rural 3-leg minor-rd STOP	Rear-end	Large number of turning vehicles; unexpected stops on approach
	Rural 3-leg signalized	Rear-end	Large number of turning vehicles; unexpected stops on approach
	Rural 4-leg minor-rd STOP	Rear-end	Large number of turning vehicles; unexpected stops on approach
	Rural 4-leg signalized	Rear-end	Large number of turning vehicles; unexpected stops on approach
	Urban 3-leg minor-rd STOP	Rear-end	Large number of turning vehicles; unexpected stops on approach
	Urban 3-leg signalized	Rear-end	Large number of turning vehicles; unexpected stops on approach
	Urban 4-leg minor-rd STOP	Rear-end	Large number of turning vehicles; unexpected stops on approach
	Urban 4-leg signalized	Rear-end	Large number of turning vehicles; unexpected stops on approach

Table 5. Intersection Countermeasures: Intersection Types, Crash Types, and Contributing Factors (Continued)

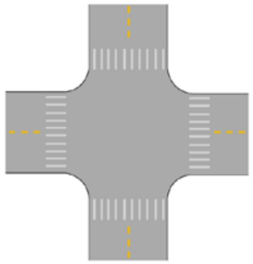
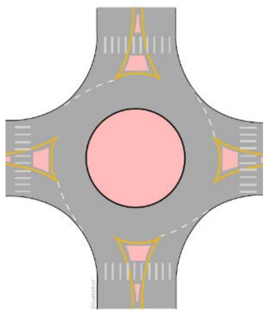
Treatment name[a]	Intersection type	Crash types mitigated	Contributing factors
Install roundabout (66) Before  After 	Rural 3-leg minor-rd STOP	Left-turn; angle; head-on	Inadequate sight distance; drivers running STOP sign; excessive speed; inadequate gaps in traffic
	Rural 3-leg all-way STOP	Angle	Drivers running STOP sign; excessive speed
	Rural 3-leg signalized	Left-turn; angle; head-on	Inadequate sight distance; drivers running red light; excessive speed; misjudge speed of oncoming traffic; inadequate signal timing; conflict with right-turn-on-red vehicles
	Rural 4-leg minor-rd STOP	Left-turn; angle; head-on	Inadequate sight distance; drivers running STOP sign; excessive speed; inadequate gaps in traffic
	Rural 4-leg all-way STOP	Angle	Drivers running STOP sign; excessive speed
	Rural 4-leg signalized	Left-turn; angle; head-on	Inadequate sight distance; drivers running red light; excessive speed; misjudge speed of oncoming traffic; inadequate signal timing; conflict with right-turn-on-red vehicles
	Urban 3-leg minor-rd STOP	Left-turn; angle; head-on	Inadequate sight distance; drivers running STOP sign; excessive speed; inadequate gaps in traffic
	Urban 3-leg all-way STOP	Angle	Drivers running STOP sign; excessive speed
	Urban 3-leg signalized	Left-turn; angle; head-on	Inadequate sight distance; drivers running red light; excessive speed; misjudge speed of oncoming traffic; inadequate signal timing; conflict with right-turn-on-red vehicles
	Urban 4-leg minor-rd STOP	Left-turn; angle; head-on	Inadequate sight distance; drivers running STOP sign; excessive speed; inadequate gaps in traffic
	Urban 4-leg all-way STOP	Angle	Drivers running STOP sign; excessive speed
	Urban 4-leg signalized	Left-turn; angle; head-on	Inadequate sight distance; drivers running red light; excessive speed; misjudge speed of oncoming traffic; inadequate signal timing; conflict with right-turn-on-red vehicles

Table 5. Intersection Countermeasures: Intersection Types, Crash Types, and Contributing Factors (Continued)

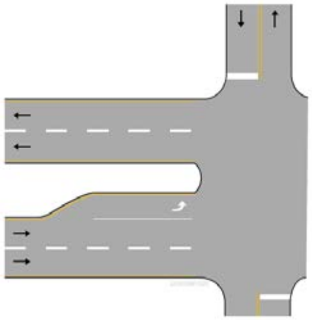
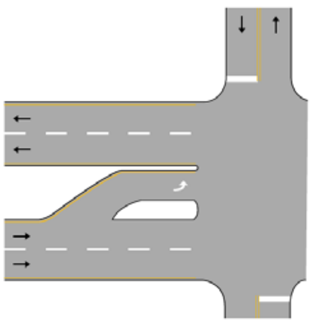
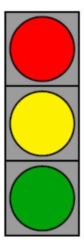
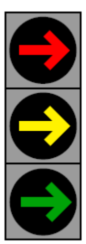
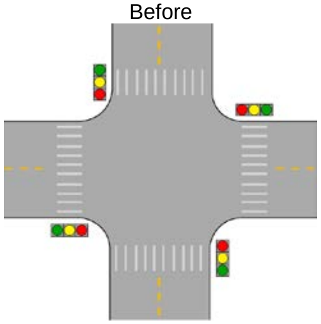
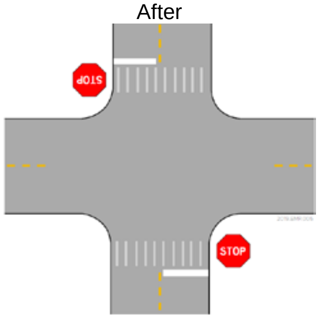
Treatment name[a]	Intersection type	Crash types mitigated	Contributing factors
Provide channelized left-turn lane (4)	Rural 3-leg minor-rd STOP	rear-end; sideswipe	Unexpected lane changes on approach
	Rural 3-leg signalized	rear-end; sideswipe	Unexpected lane changes on approach
	Rural 4-leg minor-rd STOP	rear-end; sideswipe	Unexpected lane changes on approach
Before  After 	Rural 4-leg signalized	rear-end; sideswipe	Unexpected lane changes on approach
Provide exclusive or concurrent right-turn phase (0)	Rural 3-leg signalized	Rear-end	Inadequate signal phasing
	Rural 4-leg signalized	Rear-end	Inadequate signal phasing
	Urban 3-leg signalized	Rear-end	Inadequate signal phasing
Before  After 	Urban 4-leg signalized	Rear-end	Inadequate signal phasing

Table 5. Intersection Countermeasures: Intersection Types, Crash Types, and Contributing Factors (Continued)

Treatment name[a]	Intersection type	Crash types mitigated	Contributing factors
Remove unwarranted signal (4)	Rural 3-leg signalized	Rear-end	Unexpected stops on approach; drivers running red light
	Rural 4-leg signalized	Rear-end	Unexpected stops on approach; drivers running red light
	Urban 3-leg signalized	Rear-end	Unexpected stops on approach; drivers running red light
Before  After 	Urban 4-leg signalized	Rear-end	Unexpected stops on approach; drivers running red light

[a] The number in parentheses indicates the number of related CMFs included in the CMF Clearinghouse, with 3-star quality ratings or above, for the given countermeasure at the time of publication of this report.

Section 3.
Using the Decision Tool

This section describes, step-by-step, how a practitioner uses the decision tool during the countermeasure selection process to identify tradeoffs in safety and mobility between motorists, pedestrians, and bicyclists that may arise from implementation of traffic safety countermeasures. The decision tool is a spreadsheet-based tool, implemented using Visual Basic for Applications (VBA) within Microsoft Excel.

3.1 To Start

To begin a new analysis, navigate to the Home worksheet, which is shown in Figure 2.

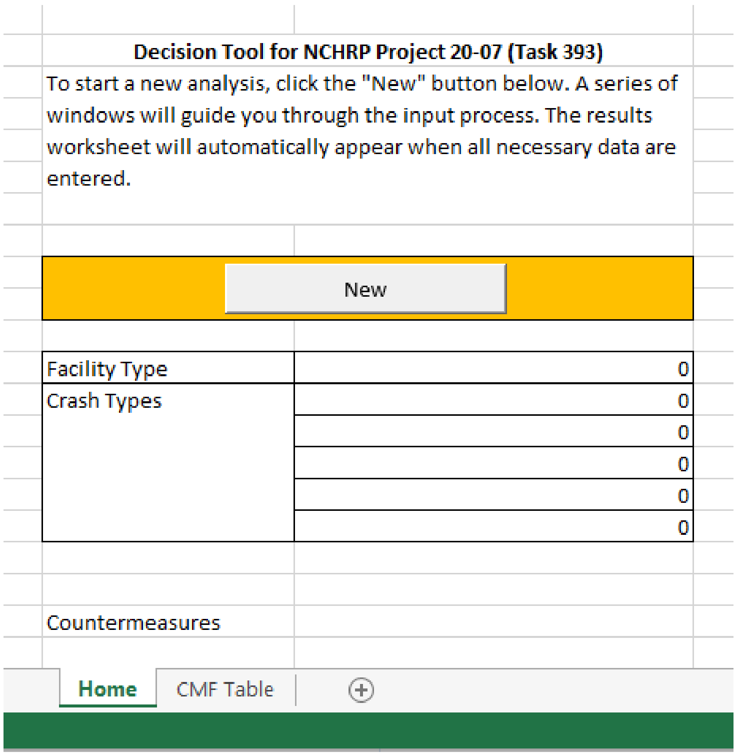


Figure 2. Home Worksheet of the Decision Tool

3.2 New Analysis

To start a new analysis, click the “New” button on the Home worksheet. You will be shown a series of input windows. All possible input windows that may appear are provided below. You may not see some of these windows depending on the particular analysis.

3.2.1 Site Type

The first input window (Figure 3) will appear, prompting you to select the site type of the location at which you are considering implementing a traffic safety countermeasure to reduce the frequency and/or severity of motor-vehicle crashes (i.e., crashes that are not pedestrian or bicycle related). Once you have selected “Road Segment” or “Intersection,” click the Next button to proceed. Otherwise click the Cancel button.

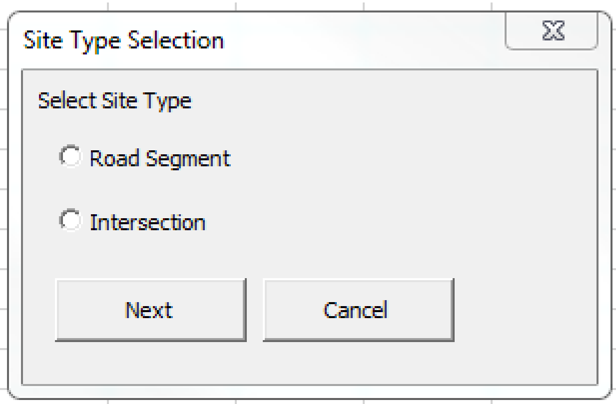


Figure 3. Site Type Selection Window

3.2.2 Facility Type

Next, select the facility type to which the analysis applies. The facility type selection window is shown in Figure 4. Use the dropdown menu to select the facility type. If the site you are evaluating has a facility type that is not listed, the tool does not support evaluation of that facility type. You have two options in this situation. You can either cancel the analysis, or select the facility type that most resembles the site type of interest. If you need to go back and change the site type, click the Back button. You can click the Cancel button to end the analysis. Once you have selected the facility type from the dropdown menu, click the Next button to proceed.

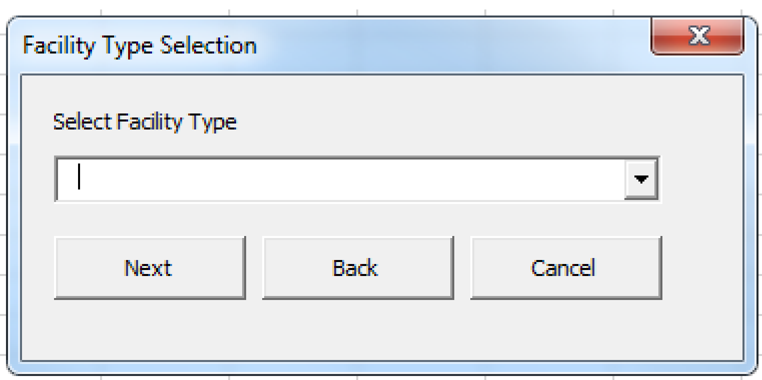


Figure 4. Facility Type Selection Window

3.2.3 Analysis Type

After selecting the facility type, you will be prompted to choose an analysis type. The Analysis Type Selection box is shown in Figure 5. The two options are as follows:

- **Prioritize countermeasures to address contributing factors or specific crash types:** Select this option when you want the tool to suggest countermeasures for specific crash types or crash contributing factors. You will select these crash types or contributing factors in a later step.
- **Identify alternative countermeasures:** Select this option when you have identified a potential countermeasure for your site and would like to consider alternative countermeasures that address similar contributing factors and crash types. You will select the initial countermeasure in a later step.

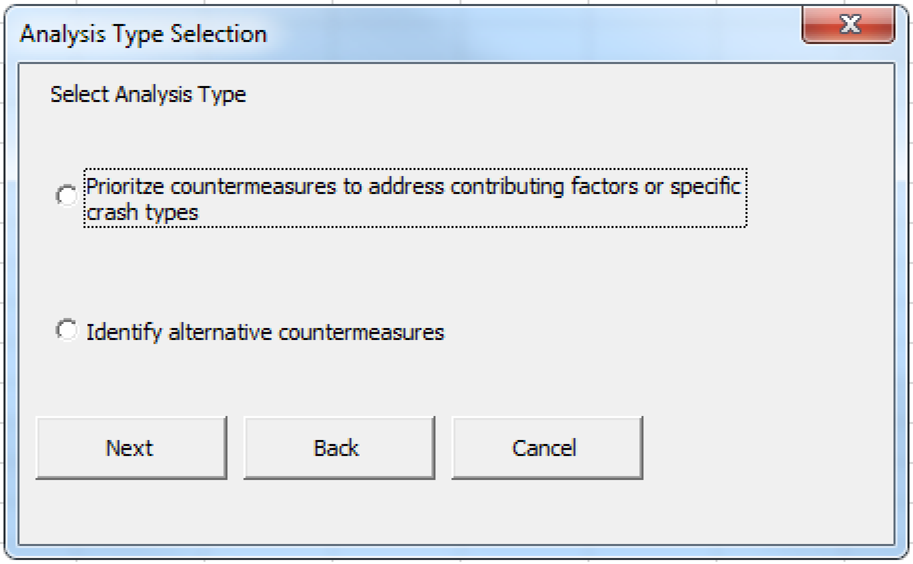


Figure 5. Analysis Type Selection Window

If you selected “Prioritize countermeasures to address contributing factors or specific crash types” in the window shown in Figure 5, another input window will appear (Figure 6). You can either select specific contributing factors or specific crash types as input into the analysis. Once you have chosen an option, click the Next button. Click the Back button to return to the analysis type selection window or click cancel to end the analysis.

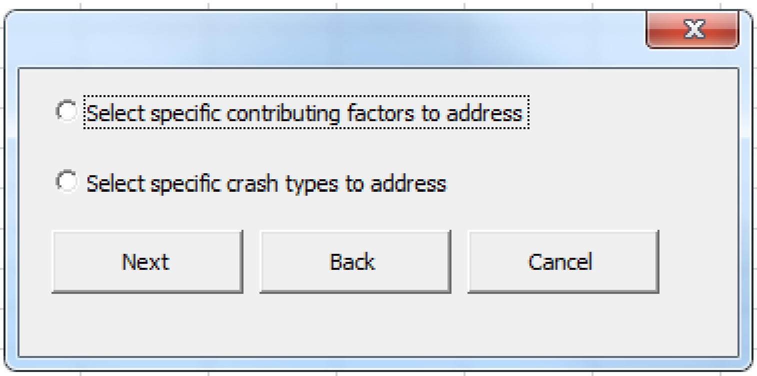


Figure 6. Contributing Factors-Crash Types Input Window

3.2.4 Contributing Factor Selection

If you selected “Select specific contributing factors to address” in the window shown in Figure 6, another input window will appear (Figure 7). You can select up to three contributing factors using the dropdown menus. The decision tool will report the countermeasures that address any of the selected contributing factors in a later step.

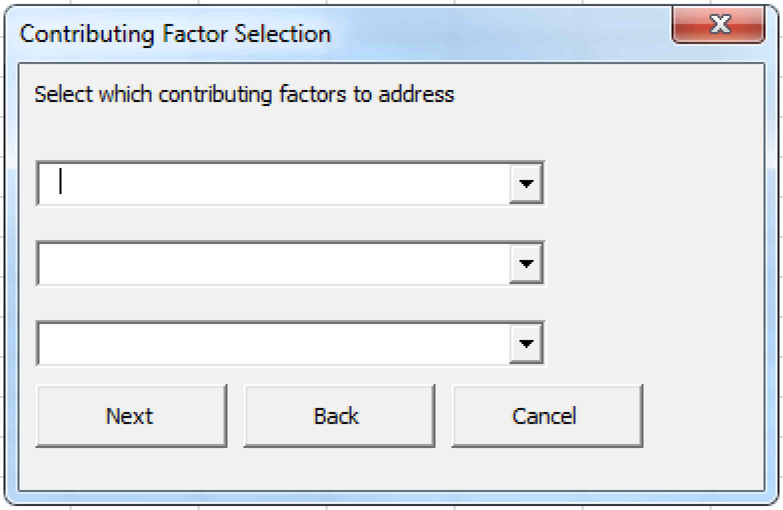


Figure 7. Contributing factor selection window

3.2.5 Crash Type Selection

If you selected "Select specific crash types to address" in the window shown in Figure 6, another input window will appear (Figure 8). You can select up to three crash types using the dropdown menus. The decision tool will report the countermeasures that address the selected crash types in a later step.

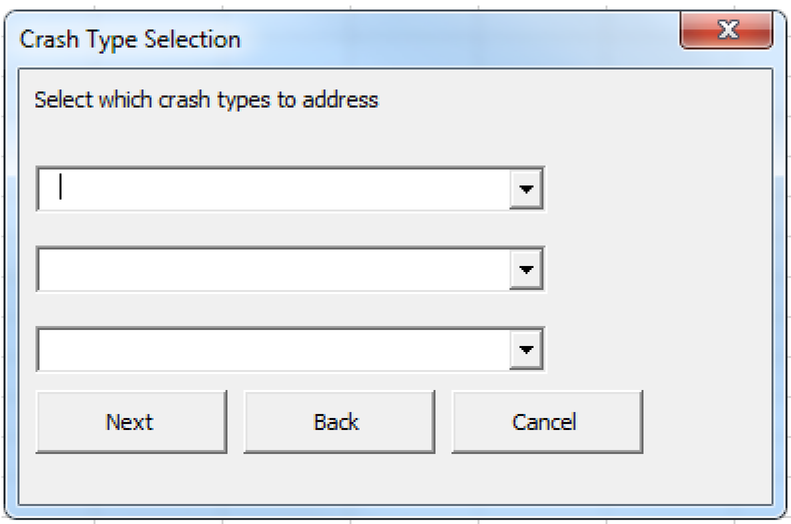


Figure 8. Crash Type Selection Window

3.2.6 Initial Countermeasure Selection

If you selected "Identify alternative countermeasures" in the window shown in Figure 5, another input window will appear (Figure 9). Select an initial traffic safety countermeasure for potential implementation using the dropdown menu. The decision tool will then report the countermeasures that have similar contributing factors or crash types as the initial countermeasure chosen in a subsequent step.

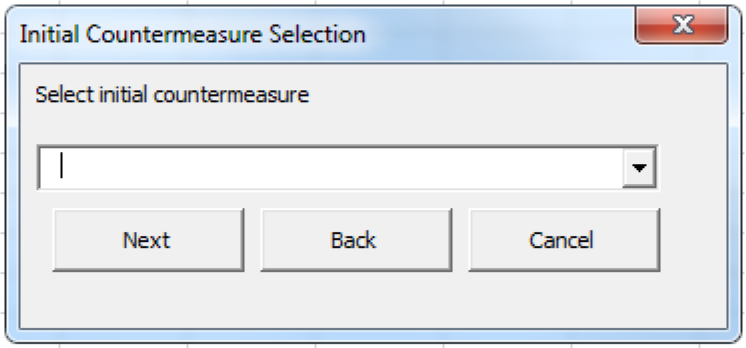


Figure 9. Initial Countermeasure Selection Window

3.2.7 Final Countermeasure Selection

Clicking the Next button in the previous three selection windows (Figures 7 through 9) leads to the final countermeasure selection window (Figure 10). This window shows alternative countermeasures that meet the criteria selected in the previous step as indicated by a check in the selection box next to the respective countermeasure. Alternatively, countermeasures that did not meet the selection criteria but are applicable to the facility type of interest can also be considered for the analysis. The countermeasures that did not meet the screening criteria are initially shown on this countermeasure selection window with an empty selection box next to the respective countermeasure. Before proceeding, you should select the subset of countermeasures by checking or unchecking the selection boxes that you want to view the potential operational and safety impacts to pedestrians and bicyclists. Then click the Next button.

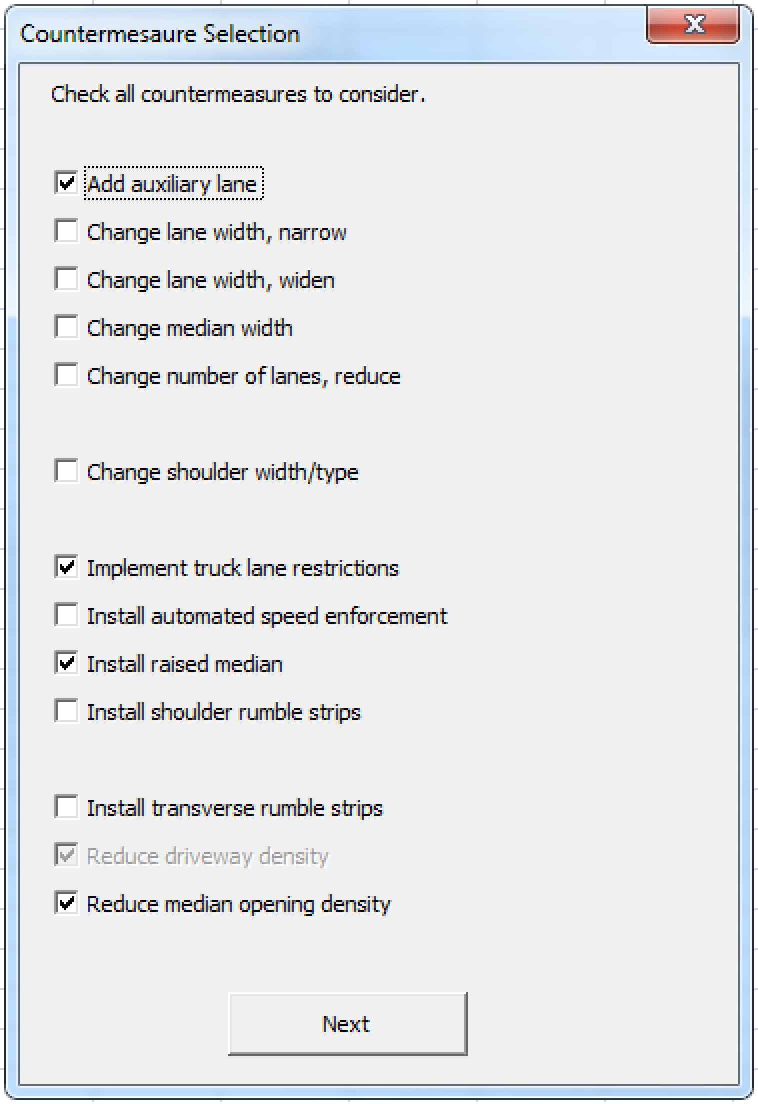


Figure 10. Final Countermeasure Selection Window

3.2.8 Additional Questions

It may be necessary for you to answer additional questions posed by the decision tool to determine the pedestrian and bicycle operational and safety impacts of the countermeasures selected in the previous step. Figure 11 shows an example of a question. For each question asked, use the dropdown menu to select the answer.

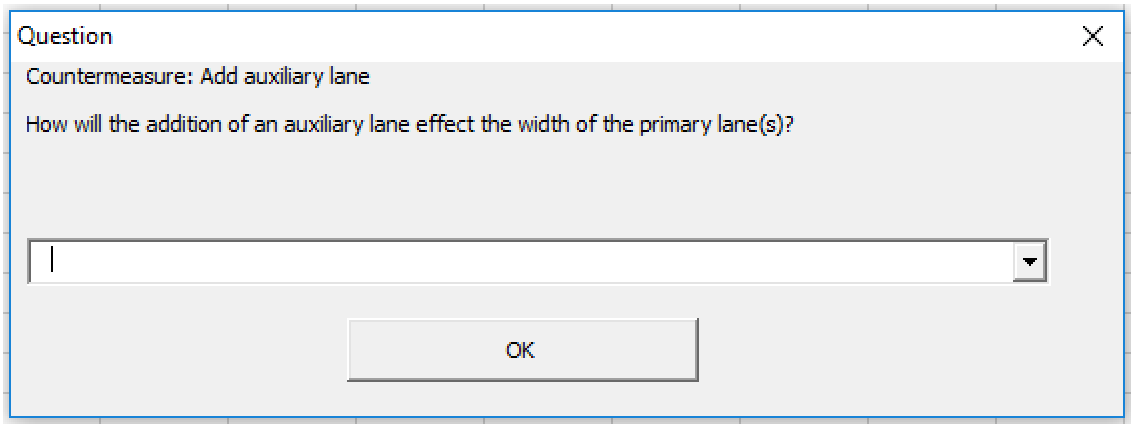


Figure 11. Example of Question

3.2.9 Results

For each countermeasure selected in Figure 10, a pedestrian impact table and a bicyclist impact table are created in their own worksheets. Table 6 shows the header of an example bicycle impact table taking into consideration three potential countermeasures: (a) converting a TWLTL to a raised median, (b) installing a raised median, and (c) reducing the driveway density. Section 4 provides more information on these impact tables and how the information they provide should be interpreted.

Table 6. Example of Bicycle Impact Table

	Direction of Impact			
Variable	**Convert a TWLTL to a raised median**	**Install raised median**	**Reduce driveway density**	**Potential impacts on bicyclists at roadway segments**
Travel time	no change	no change	decrease	Treatments that increase travel time for bicyclists can decrease compliance with the traffic control by bicyclists and encourage bicyclists to use undesired routes.
Number of through lanes	no change	no change	no change	As the number of through travel lanes increase, it becomes more difficult for bicyclists to cross lanes of traffic to make turns. Treatments that increase the number of lanes that intersect the path of through-moving or crossing cyclist increase crash exposure for cyclists. It can also create situations where traffic in one lane blocks the view of bicyclists for drivers in another lane.
Lane width	no change	no change	no change	Treatments that provide wider lanes, especially outside lanes, may provide more room for bicycles to share with vehicles, increasing bicycle level of service. However, narrow lanes may allocate space for dedicated bike lanes, or buffer lanes between bikes and motor vehicles or bikes and parking lanes.

On the Home worksheet, you can view the inputs selected for the analysis. For example, looking at the screenshot of the Home worksheet shown in Figure 12, the analysis was conducted for an urban multilane undivided arterial. The user selected “convert a TWLTL to a raised median” as an initial countermeasure. Then, based on the countermeasures reported back to the user, one additional countermeasure was manually selected by the user for further consideration: reduce driveway density.

Facility Type	Seg/Urb; Multilane undivided
Initial Countermeasure	Convert a TWLTL to a raised median
Countermeasures	Convert a TWLTL to a raised median
	Reduce driveway density

Figure 12. Analysis Inputs Shown on Home Worksheet

Section 4. Interpretation of Results

The decision tool provides results in the form of tables that describe the potential impacts on pedestrians and bicyclists of the countermeasures of interest. Each results table is generated on its own tab in the tool, and tabs are assigned the names “Ped Results” and “Bike Results”. Section 4.1 describes how the information in these tables should be interpreted. The decision tool also provides a tab called “CMF Table” after the two results tables. Section 4.2 describes the information provided in this tab and how it can be used to aid in treatment selection. Section 4.3 provides two examples to demonstrate use of the decision tool.

4.1 Interpreting Results Tabs

The results tables generated in the decision tool include at least three columns of information: one column containing the variables relevant to pedestrian or bicyclist level of service and safety, one column for each countermeasure included in the analysis describing the direction of impact that the treatment would likely have on the related variables, and a final column with a description of that impact. Table 7 and Table 8 show example results tables that were generated taking into consideration how two treatments, “Reduce driveway density” and “Install raised median,” may impact pedestrians and bicyclists if installed along an urban, two-lane, arterial roadway segment. These example tables are shown here to demonstrate how the results tables can be interpreted.

The first column of the output tables lists the variables related to pedestrian or bicyclist level of service or safety. These variables were chosen for inclusion in the output tables as they are related to:

- Variables in the HSM methodology to predict pedestrian crashes at signalized intersections (AASHTO, 2010);
- Variables in the *Highway Capacity Manual* Level of Service methodology for that mode (pedestrian or bicycle) and that facility type (TRB, 2016);
- Variables in the methodology to calculate pedestrian and bicycle intersection safety indices (Carter et al., 2006); and
- Variables likely to impact pedestrian and/or bicyclist operations and/or safety as determined by the research team.

The variables shown in each table are specific to the mode for which the table has been generated. For example, in Table 7, the variable “Travel time” refers to travel time for pedestrians along the roadway segment, while in Table 8, the same variable refers to travel time for the bicyclist along the roadway segment. While many of the variables are the same across both modes of travel, some variables are unique to one mode or the other. For example, “Walk duration” is included for pedestrians at signalized intersections, but not for bicyclists.

The next column (or multiple columns) of the output tables, under the general heading “Direction of Impact”, indicates how the implementation of the specific treatment is likely to impact the variables shown in the first column. The “Direction of Impact” is determined either automatically by the decision tool, in cases where the direction is generally consistent for the given treatment (i.e., the direction is not likely to change based on the specifics of the treatment implementation), or from responses to questions answered by the user regarding specifics of the treatment implementation. The tool prompts the user with such questions in cases where a given treatment is very general, has no typical implementation, or is often implemented in conjunction with other changes to the roadway. As shown in Table 7, the treatment "Reduce driveway density" is expected to increase motor-vehicle speeds (which increases the severity of pedestrian crashes), but decrease left- and right-turning conflicts for pedestrians (which reduces the likelihood of crashes). The treatment is also expected to increase conspicuity of pedestrians, most likely by reducing the locations where pedestrians may be hidden from view of motorists by vehicles stopped in driveways. Most other variables are expected to remain unchanged based on the implementation of this treatment. The results for bicyclists, shown in Table 8, are similar; this particular treatment is expected to have the same general impacts on bicyclists as it does on pedestrians, with the addition of increasing speed for bicyclists and, therefore, reducing their travel time.

Table 7. Example Results Table for the Countermeasures "Reduce Driveway Density" and "Install Raised Median" for Pedestrians on an Urban Two-Lane Arterial

Variable	Direction of Impact		Potential impacts on pedestrians at roadway segments
	Reduce driveway density	Install raised median	
Travel time	no change	increase	Treatments that increase travel time for pedestrians can decrease compliance with the traffic control by pedestrians, encourage pedestrians to use undesired routes, and/or decrease pedestrian level of service.
Delay	no change	increase	Treatments that increase delay for crossing pedestrians can decrease compliance with the traffic control. Increased delay decreases pedestrian level of service.
Number of through lanes	no change	no change	As the number of through lanes increases, the availability for a suitable midblock crossing gap decreases, decreasing pedestrian level of service. Treatments that increase the number of lanes that intersect the path of a crossing pedestrian increase crash exposure for pedestrians. It can also create situations where traffic in one lane blocks the view of crossing pedestrians for drivers in another lane.
Lane width	no change	no change	Treatments that increase lane width increase the midblock crossing distance for pedestrians and increase their travel time, decreasing pedestrian level of service. Increased lane width may also increase vehicle travel speeds. Pedestrian crashes become more severe as vehicle speeds increase. In addition, increased speeds reduce the available time for a driver to identify and react to the presence of a pedestrian.
Crossing distance	no change	no change	Treatments that increase the midblock crossing distance for pedestrians increase their exposure time to traffic.
Overall pavement width	no change	no change	Treatments that increase overall pavement width increase the midblock crossing distance for pedestrians and increase their travel time, decreasing pedestrian level of service. Increased pavement width may also increase vehicle travel speeds. Pedestrian crashes become more severe as vehicle speeds increase. In addition, increased speeds reduce the available time for a driver to identify and react to the presence of a pedestrian.
Separation to pedestrian facility	no change	no change	As the distance between motor vehicle lanes and the pedestrian facility increases, pedestrian comfort increases.
Motor vehicle speed	increase	Increase	As motor vehicle speed increases, crashes with pedestrians become more severe. In addition, higher speeds give drivers less reaction time to detect and respond to the presence of a pedestrian.
Driveway radii, turning speeds	no change	no change	Treatments that increase turning speeds can make crashes with pedestrians more severe. This may be more of a concern where drivers' attention may not be on pedestrians, such as when making a left-turn into a driveway.

Table 7. Example Results Table for the Countermeasures “Reduce Driveway Density” and “Install Raised Median” for Pedestrians on an Urban Two-Lane Arterial (Continued)

Variable	Direction of Impact		Potential impacts on pedestrians at roadway segments
	Reduce driveway density	Install raised median	
Traffic volumes	no change	no change	Treatments that increase vehicle volumes reduce available gaps for pedestrians to cross at midblock locations. Increased volumes may also decrease the comfort of pedestrians walking along the roadside. Increase traffic volumes increase pedestrian exposure to crashes.
Visibility	no change	no change	Treatments that block the view of pedestrians or cast them in shadows may result in drivers being surprised by their presence near a midblock crossing or driveway, and drivers may not have sufficient time to yield to the pedestrians.
Conspicuity	increase	Increase	When pedestrians are not conspicuous, drivers may have difficulty identifying them in time to yield to them at a midblock crossing or at driveways.
Left-turning conflicts	decrease	decrease	Treatments that increase left-turning traffic onto driveways and other access points along the roadway segment create potential conflicts for pedestrians walking along the side of the road and increase crash exposure. The level of service methodology in the HCM for pedestrians walking along a roadway assumes that drivers yield to pedestrians before making turns, so turning volume is not a factor in pedestrian roadway segment LOS calculations. However, in reality, increases in turning movements may reduce the level of comfort of pedestrians walking along the roadway.
Right-turning conflicts	decrease	increase	Treatments that increase right-turning traffic onto or out of driveways and other access points along the roadway segment create potential conflicts for pedestrians walking along the side of the road and increase crash exposure. The level of service methodology in the HCM for pedestrians walking along a roadway assumes that drivers yield to pedestrians before making turns, so turning volume is not a factor in pedestrian roadway segment LOS calculations. However, in reality, increases in turning movements may reduce the level of comfort of pedestrians walking along the roadway.

Table 8. Example Results Table for the Countermeasures “Reduce Driveway Density” and “Install Raised Median” for Bicyclists on an Urban Two-Lane Arterial

Variable	Direction of Impact		Potential impacts on bicyclists at roadway segments
	Reduce driveway density	Install raised median	
Travel time	decrease	no change	Treatments that increase travel time for bicyclists can decrease compliance with the traffic control by bicyclists and encourage bicyclists to use undesired routes.
Number of through lanes	no change	no change	As the number of through travel lanes increase, it becomes more difficult for bicyclists to cross lanes of traffic to make turns. Treatments that increase the number of lanes that intersect the path of through-moving or crossing cyclist increase crash exposure for cyclists. It can also create situations where traffic in one lane blocks the view of bicyclists for drivers in another lane.
Lane width	no change	no change	Treatments that provide wider lanes, especially outside lanes, may provide more room for bicycles to share with vehicles, increasing bicycle level of service. However, narrow lanes may allocate space for dedicated bike lanes, or buffer lanes between bikes and motor vehicles or bikes and parking lanes.
Overall pavement width	no change	no change	Treatments that provide wider pavement width can provide more allocated space for bicyclists in terms of wider shared lanes, dedicated bike lanes, and buffer lanes, increasing bicycle level of service.
Separation to bikeway	no change	no change	As the distance between motor vehicle lanes and the bikeway increases, bicyclist comfort and bicycle level of service increase.
Crossing distance	no change	no change	Treatments that increase the midblock crossing distance for bicyclists increase their exposure time to traffic.
Motor vehicle speed	increase	Increase	As motor vehicle speed increases, crashes with bicyclists become more severe. In addition, higher speeds give drivers less reaction time to detect and respond to the presence of a bicyclist.

Table 8. Example Results Table for the Countermeasures “Reduce Driveway Density” and “Install Raised Median” for Bicyclists on an Urban Two-Lane Arterial (Continued)

Variable	Direction of Impact		Potential impacts on bicyclists at roadway segments
	Reduce driveway density	Install raised median	
Bike speed	increase	no change	Treatments that allow faster bike speeds reduce travel time for bicyclists.
Driveway radii, turning speeds	no change	no change	Treatments that increase turning speeds can make crashes with bicyclists more severe. This may be more of a concern where drivers' attention may not be on bicyclists, such as when making a left-turn into a driveway.
Traffic volumes	no change	no change	Treatments that increase vehicle volumes make passing maneuvers more difficult because drivers are less likely to be able to cross into the adjacent lane to give the bicyclist more space. In addition, increased volume in the shared lane or in the lane adjacent to the bike lane may decrease bicyclists’ comfort, decreasing bicycle level of service. Treatments that increase motor vehicle traffic volumes also increase crash exposure for bicyclists.
Visibility	no change	no change	Treatments that block the view of bicyclists or cast them in shadows may result in drivers being surprised by their presence near a midblock crossing or driveway or along the roadway, and drivers may not have sufficient time to yield to the bicyclists.
Conspicuity	increase	Increase	When bicyclists are not conspicuous, drivers may have difficulty identifying them in time to yield to them at midblock crossings, at driveways, or along roadways.
Pavement surface quality	no change	no change	Treatments that improve surface quality increase bicyclists’ comfort and bicycle level of service. Improved surface quality can also reduce the likelihood of bicyclists losing control and crashing in or near motor vehicle traffic.
Left-turning conflicts	decrease	decrease	Treatments that increase left-turning traffic onto driveways and other access points along the roadway segment create potential conflicts for bicyclists riding along the side of the road and increase crash exposure. The level of service methodology in the HCM for bicyclists riding along a roadway assumes that drivers yield to bicyclists before making turns, so turning volume is not a factor in bicycle roadway segment LOS calculations. However, in reality, increases in turning movements may reduce the level of comfort of bicyclists riding along the roadway.
Right-turning conflicts	decrease	increase	Treatments that increase right-turning traffic onto or out of driveways and other access points along the roadway segment create potential conflicts for cyclists riding along the side of the road and increase crash exposure. The level of service methodology in the HCM for bicyclists riding along a roadway assumes that drivers yield to bicyclists before making turns, so turning volume is not a factor in bicycle roadway segment LOS calculations. However, in reality, increases in turning movements may reduce the level of comfort of bicyclists riding along the roadway.

The last column of the table, “Potential impacts on pedestrians (bicyclists) at roadway segments,” describes how each variable impacts safety and/or operations (level of service) for pedestrians (or bicyclists). The descriptions are general in nature—they do not change based on the specific countermeasure being considered. The descriptions also remain the same regardless of the direction of impact shown in the treatment column. However, the descriptions for each variable are specific to the facility type (roadway segments, signalized intersections, stop-controlled intersections) and the mode (pedestrian or bicyclist).

The descriptions are intended to give the user information to consider during countermeasure selection. In general, the descriptions are written assuming installation of the countermeasure will “increase” the variable of interest. For example, Table 7 refers to the potential impacts on pedestrians at roadway segments, assuming the countermeasure “Reduce driveway density” was being considered for implementation. If this countermeasure (i.e., reduce driveway density) is installed, the output table from the decision tool states, “Treatments that increase travel time for pedestrians can decrease compliance with the traffic control by pedestrians, encourage pedestrians to use undesired routes, and/or decrease pedestrian level of service.” Thus, the output table describes the potential impacts on pedestrians based on an “increase” in travel time for pedestrians, indicating that an increase in pedestrian travel time can

- Decrease compliance with the traffic control by pedestrians
- Encourage pedestrians to use undesirable routes
- Decrease pedestrian level of service

Thus, when the “Direction of Impact” column for travel time shows an “increase,” the decision tool describes the likely impact on pedestrians. Alternatively, when the “Direction of Impact” column shows a “decrease,” in general it can be assumed that installation of the countermeasure would have an opposite effect as described. For example, installation of a countermeasure that “decreases” pedestrian travel time would likely

- increase compliance with the traffic control by pedestrians
- encourage pedestrians to use desirable routes
- increase pedestrian level of service

When the “Direction of Impact” column shows “no change,” it can be assumed that installation of the countermeasure would not impact the variable of interest.

In some cases, an increase in the “Direction of Impact” of a variable of interest would be viewed as a desirable effect on pedestrians or bicyclists. For example, installation of a countermeasure that would result in an increase in “Separation to pedestrian facility” along a roadway segment would increase pedestrian comfort, which would be considered desirable from the perspective of a pedestrian. However, a treatment that “increases” the “Overall pavement width” along a roadway segment would increase the midblock crossing distance for pedestrians and increase their travel time, decreasing pedestrian level of service, which would be considered undesirable from the perspective of a pedestrian. Thus, it should not be assumed that installation of a countermeasure resulting in an increase or a decrease of a particular variable would necessarily result in a desirable or undesirable impact on pedestrians or bicyclists; it is very much dependent upon the variable of interest. The “Potential impacts” column provides information to help the user interpret whether the direction of impact is desirable or undesirable for pedestrians or bicyclists.

In many cases, a potential undesirable impact of a treatment can be avoided or mitigated during the design or implementation of the countermeasure, or by including additional treatments. For example, reducing driveway density can have an undesirable effect from the perspective of pedestrians and bicyclists of increasing motor-vehicle speeds. However, this impact may be offset by narrowing lanes, altering the landscape, or including other traffic calming devices. The goal of the decision tool is to make traffic engineers and designers aware of the potential impacts of the countermeasures they are considering, not simply to discourage the use of specific treatments, but to encourage the mitigation of potential undesirable impacts on pedestrians and bicyclists before treatments are implemented.

4.2 Interpreting Countermeasure CMFs

The decision tool also includes a static tab called "CMF Table," which appears after the results tabs for all the countermeasures included in the analysis. Figure 13 shows the first several rows of the CMF Table (split in half and stacked to fit the page). The CMF table provides all the information for three-, four-, and five-star crash modification factors (CMFs) available in the CMF Clearinghouse (http://www.cmfclearinghouse.org) for the countermeasures included in the decision tool.

The CMF Clearinghouse is a database of crash modification factors that is regularly updated as new research produces CMFs for various crash countermeasures and roadway and intersection treatments. The database includes information about the treatment, the facility specifications or conditions, the study design, the crash and severity types to which the CMF applies, and the crash modification factor or function developed in the research. For any given treatment, there may be multiple CMFs; often one research project will develop specific CMFs for facility types, crash types, or severity levels, but CMFs for the same treatment and conditions may also come from multiple studies. In addition, a single category of treatment may have several CMFs by more specific names in the Clearinghouse. An example of this is described below.

Every CMF in the Clearinghouse is given a star rating based on the reliability of the results. Reliability is determined by the CMF's study design, sample size, and standard deviation. The most reliable CMFs have a five-star rating, while the least reliable have a one-star rating.

To develop the CMF table provided in the decision tool, the CMF Clearinghouse was scanned for all 3- to 5-star CMFs that may fall under each of the countermeasures in the decision tool. Table 9 lists all of the 3- to 5- star CMFs from the CMF Clearinghouse that were categorized under the "Change permissive / protected left-turn phasing" countermeasure in the decision tool.

The number to the left of the treatment name indicates the CMF number in the Clearinghouse. This list shows that each of the specific treatment names can have multiple CMFs. For example, there are four 3- to 5-star CMFs for "Change permissive left-turn phasing to protected/ permissive." A review of the full CMF Table provided in the decision tool shows that these four CMFs apply to the following four crash and severity conditions: all crash types and all severity levels (CMF ID 4268), all crash types for fatal-and-injury crashes (CMF ID 4269), left-turn crashes all severities (CMF ID 4270), and rear-end crashes all severities (CMF ID 4270). The information available for all 31 of the CMFs shown in the list above is included in the CMF Table in the decision tool. For some countermeasures in the decision tool, no reliable CMFs were identified in the CMF Clearinghouse. For these treatments, the CMF Table in the decision tool is blank for all columns beyond Column B.

The CMF table is provided in the decision tool to help the user assess the likely impact on crashes of the countermeasure(s) being considered in the analysis. Because many of the countermeasures have a number of available CMFs, the user can scan the table for the CMFs most relevant to the facility, crash type, severity level, or other conditions of the sites being evaluated for improvement. Some countermeasures have CMFs specifically for pedestrian and/or bicycle crashes, but this is rare. In general, the likely crash impact on pedestrians and bicyclists of vehicle-focused countermeasures (including those available in the decision tool) has not yet been quantified by research.

Segments / Intersections	Countermeasure Title Used in NCHRP 20-07 (Task 393)	CMF ID	Countermeasure	Countermeasure Category	Countermeasure Subcategory	Roadway Type	Area Type	Number of Lanes	Crash Type
Intersection	Change lane width								
Intersection	Change median width	298	Increase intersection median width by 3 ft increments	Access management	None	Not Specified	Rural		Multiple vehicle
Intersection	Change median width	299	Increase intersection median width by 3 ft increments	Access management	None	Not Specified	Urban and Suburban		Multiple vehicle
Intersection	Change median width	300	Increase intersection median width by 3 ft increments	Access management	None	Not Specified	Urban and Suburban		Multiple vehicle
Intersection	Change median width	301	Increase intersection median width by 3 ft increments	Access management	None	Not Specified	Urban and Suburban		Multiple vehicle
Intersection	Change median width	302	Increase intersection median width by 3 ft increments	Access management	None	Not Specified	Rural		Multiple vehicle
Intersection	Change median width	303	Increase intersection median width by 3 ft increments	Access management	None	Not Specified	Urban and Suburban		Multiple vehicle
Intersection	Change median width	304	Increase intersection median width by 3 ft increments	Access management	None	Not Specified	Urban and Suburban		Multiple vehicle
Intersection	Change number of through lanes	2950	Change number of lanes on major road of a 4-leg signalized intersecti	Intersection geometry	Other	Not Specified	Urban		All
Intersection	Change number of through lanes	2955	Change number of lanes on minor road of a 4-leg signalized intersecti	Intersection geometry	Other	Not Specified	Urban		All
Intersection	Change number of through lanes	2961	Change number of lanes on minor road of a signalized T intersection (	Intersection geometry	Other	Not Specified	Urban		All
Intersection	Change permissive / protected left-turn phasing	333	Change from permitted or permitted-protected to protected	Intersection traffic control	Signal phasing or timing	Not specified	Urban		Angle
Intersection	Change permissive / protected left-turn phasing	334	Change from permitted or permitted-protected to protected	Intersection traffic control	Signal phasing or timing	Not specified	Urban		All
Intersection	Change permissive / protected left-turn phasing	335	Change from permitted to protected on minor approach	Intersection traffic control	Signal phasing or timing	Not specified	Urban		Angle
Intersection	Change permissive / protected left-turn phasing	339	Change from permitted-protected to protected on major approach	Intersection traffic control	Signal phasing or timing	Not specified	Urban		Angle
Intersection	Change permissive / protected left-turn phasing	340	Change from permitted-protected to protected on major approach	Intersection traffic control	Signal phasing or timing	Not specified	Urban		All
Intersection	Change permissive / protected left-turn phasing	337	Change from permitted-protected to protected on minor approach	Intersection traffic control	Signal phasing or timing	Not specified	Urban		Angle
Intersection	Change permissive / protected left-turn phasing	4578	Change left-turn phase from permissive to protected/permissive or per	Intersection traffic control	Signal phasing or timing	Not specified	Urban		Left turn
Intersection	Change permissive / protected left-turn phasing	4576	Change left-turn phase to protected phasing on one or more approach	Intersection traffic control	Signal phasing or timing	Not specified	Urban		Left turn
Intersection	Change permissive / protected left-turn phasing	4577	Change left-turn phase to protected phasing on one or more approach	Intersection traffic control	Signal phasing or timing	Not specified	Urban		All
Intersection	Change permissive / protected left-turn phasing	4268	Change permissive left-turn phasing to protected/permissive	Intersection traffic control	Signal phasing or timing	Not specified	Urban		All
Intersection	Change permissive / protected left-turn phasing	4269	Change permissive left-turn phasing to protected/permissive	Intersection traffic control	Signal phasing or timing	Not specified	Urban		All
Intersection	Change permissive / protected left-turn phasing	4270	Change permissive left-turn phasing to protected/permissive	Intersection traffic control	Signal phasing or timing	Not specified	Urban		Left turn
Intersection	Change permissive / protected left-turn phasing	4271	Change permissive left-turn phasing to protected/permissive	Intersection traffic control	Signal phasing or timing	Not specified	Urban		Rear end

Crash Severity	CRF	CMF	Star Quality Rating	Adjusted Standard Error of CRF	Unadjusted Standard Error of CRF	Adjusted Standard Error of CMF	Unadjusted Standard Error of CMF	Included in First Edition of Highway Safety Manual	Type of Study Methodology	Intersection Related	Intersection Type	Intersection Geometry	Traffic Control Type	Speed Limit (mph)
All	4	0.96	5	2	1	0.02	0.01	bold caret	Regression cross-section	yes	Roadway/roadway (not interchange	4-leg	Stop-controlled	
All	-6	1.06	5	1	1	0.01	0.01	bold	Regression cross-section	yes	Roadway/roadway (not interchange	4-leg	Stop-controlled	
All	-3	1.03	5	1	1	0.01	0.01	bold	Regression cross-section	yes	Roadway/roadway (not interchange	3-leg	Stop-controlled	
All	-3	1.03	5	1	1	0.01	0.01	bold	Regression cross-section	yes	Roadway/roadway (not interchange	4-leg	Signalized	
Fatal,Serious Injury	4	0.96	5	2	1	0.02	0.01	bold caret	Regression cross-section	yes	Roadway/roadway (not interchange	4-leg	Stop-controlled	
Fatal,Serious Injury	-5	1.05	5	2	1	0.02	0.01	bold	Regression cross-section	yes	Roadway/roadway (not interchange	4-leg	Stop-controlled	
Fatal,Serious Injury	-3	1.03	5	1	1	0.01	0.01	bold	Regression cross-section	yes	Roadway/roadway (not interchange	4-leg	Signalized	
All	http://ww	http://www	3					no	Regression cross-section	yes	Not specified	4-leg	Signalized	
All	http://ww	http://www	3					no	Regression cross-section	yes	Not specified	4-leg	Signalized	
All	http://ww	http://www	3					no	Regression cross-section	yes	Not specified	3-leg	Signalized	
All	99	0.01	5	3	1	0.03	0.01	no	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	Not specified	Signalized	
All	1	0.99	3	13	7	0.13	0.07	no	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	Not specified	Signalized	
All	99	0.01	5	2	1	0.02	0.01	no	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	Not specified	Signalized	
All	99	0.01	5	2	1	0.02	0.01	no	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	Not specified	Signalized	
All	42	0.58	3	34	19	0.34	0.19	no	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	Not specified	Signalized	
All	97	0.04	4	8	4	0.08	0.04	no	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	Not specified	Signalized	
Fatal,Serious injury	16	0.84	5		2		0.02	yes	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	4-leg	Signalized	
All	99	0.01	5		1		0.01	yes	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	3-leg,4-leg	Signalized	
All	6	0.94	3		10		0.1	yes	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	3-leg,4-leg	Signalized	
All	-3.1	1.031	4		2.2		0.022	no	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	4-leg	Signalized	
Fatal,Serious injury	3.8	0.962	4		3.5		0.035	no	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	4-leg	Signalized	
All	13.8	0.862	4		5		0.05	no	Before/after using empirical Bayes or full Bayes	yes	Roadway/roadway (not interchange	4-leg	Signalized	

Figure 13. CMF Table Provided in Decision Tool (First Several Rows Covering Four Intersection Treatments)

Table 9. CMFs from the Clearinghouse Categorized under "Change Permissive / Protected Left-Turn Phasing" in the Decision Tool

CMF ID		Countermeasure Description
333		Change from permitted or permitted-protected to protected
334		Change from permitted or permitted-protected to protected
335		Change from permitted to protected on minor approach
339		Change from permitted-protected to protected on major approach
340		Change from permitted-protected to protected on major approach
337		Change from permitted-protected to protected on minor approach
4578		Change left-turn phase from permissive to protected/permissive or permissive/protected phasing on one or more approaches
4576		Change left-turn phase to protected phasing on one or more approaches
4577		Change left-turn phase to protected phasing on one or more approaches
4268		Change permissive left-turn phasing to protected/permissive
4269		Change permissive left-turn phasing to protected/permissive
4270		Change permissive left-turn phasing to protected/permissive
4271		Change permissive left-turn phasing to protected/permissive
2251		Change permitted to protected/permitted or permitted/protected
4168		Changing left turn phasing on more than one approach from permissive to protected-permissive
4169		Changing left turn phasing on more than one approach from permissive to protected-permissive
4170		Changing left turn phasing on more than one approach from permissive to protected-permissive
4171		Changing left turn phasing on more than one approach from permissive to protected-permissive
4164		Changing left turn phasing on one approach from permissive to protected-permissive
4165		Changing left turn phasing on one approach from permissive to protected-permissive
4166		Changing left turn phasing on one approach from permissive to protected-permissive
4167		Changing left turn phasing on one approach from permissive to protected-permissive
348		Protected/Permitted to Permitted / Protected
345		Protected to protected/permissive left-turn operations
2326		Protected/permissive to protected-only left turn phasing
2327		Protected/permissive to protected-only left turn phasing
2328		Protected/permissive to protected-only left turn phasing
2252		Replace permissive with protected
2253		Replace permissive with protected
2016		Lag-lag to lead-lag left turn phasing
2017		Lag-lag to lead-lead left turn phasing
350		Leading protected to lagging protected exclusive left-turn operations
2018		Lead-lead to lag-lag, protected-only left-turn phasing
2020		Lead-lead to lead-lag, protected/permissive left turn phasing
2019		Lead-lead to lead-lag, protected-only left turn phasing
3945		Left turn phase improvement

4.3 Examples of How to Use the Decision Tool

This section provides two examples of how to use the decision tool to identify tradeoffs in safety and mobility between motorists, pedestrians, and bicyclists that may arise from traffic safety countermeasures during countermeasure selection. The examples demonstrate the two types of functionality for which the decision tool was designed:

1. For a given classification of roadway or intersection configuration and traffic control type, the decision tool helps practitioners select a traffic safety countermeasure that addresses specific crash types or contributing factors, while also considering potential impacts on pedestrians and bicyclists.

2. If a designer or safety engineer has already identified an initial traffic safety countermeasure for potential implementation to address a specific crash pattern of interest or crash contributing factor, the decision tool can be used to identify alternative countermeasures that address the same crash pattern of interest or crash contributing factor, while also considering the potential impacts on pedestrians and bicyclists of the initial countermeasure and alternative countermeasures.

Example 1: A section of an urban, four-lane, undivided arterial is experiencing a high frequency of crashes. After a diagnostic review of the crashes, it was determined that a large volume of driveway traffic and left-turning vehicles were the two primary contributing factors to the crashes. What countermeasures could potentially be installed to remedy the types of crashes that are occurring on this section of roadway, and what potential impact might these countermeasures have on pedestrians and bicyclists?

Solution:

Step 1: Select Site Type

From the Home Tab, the user selects "New" to begin the analysis. The first input window prompts the user to select the site type for the analysis (Figure 14). "Road Segment" is selected, and the "Next" button is clicked to proceed.

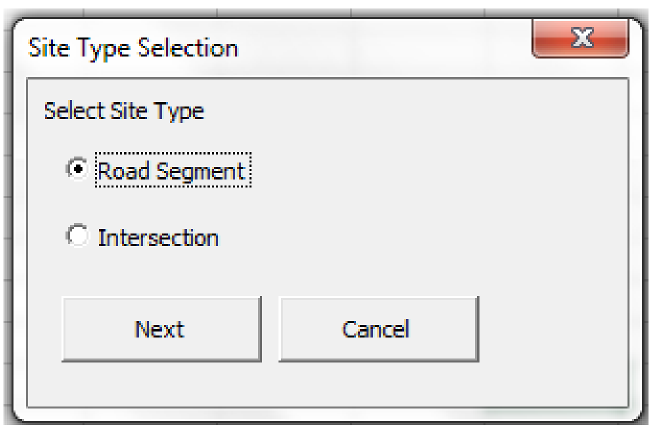


Figure 14. Example 1—Site Type Selection Input Window

Step 2: Select Facility Type

On the next input window, the user selects the facility type to which the analysis applies (Figure 15). From the dropdown menu, "Seg/Urb; Multilane undivided" is selected, and the "Next" button is clicked to proceed.

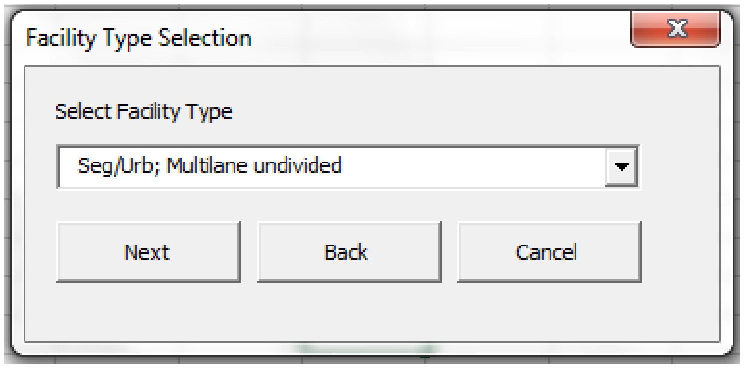


Figure 15. Example 1—Facility Type Selection Input Window

Step 3: Select Analysis Type

On the next input window, the user is prompted to choose an analysis type from two options (Figure 16). “Prioritize countermeasures to address contributing factors or specific crash types” is selected, and the “Next” button is clicked to proceed.

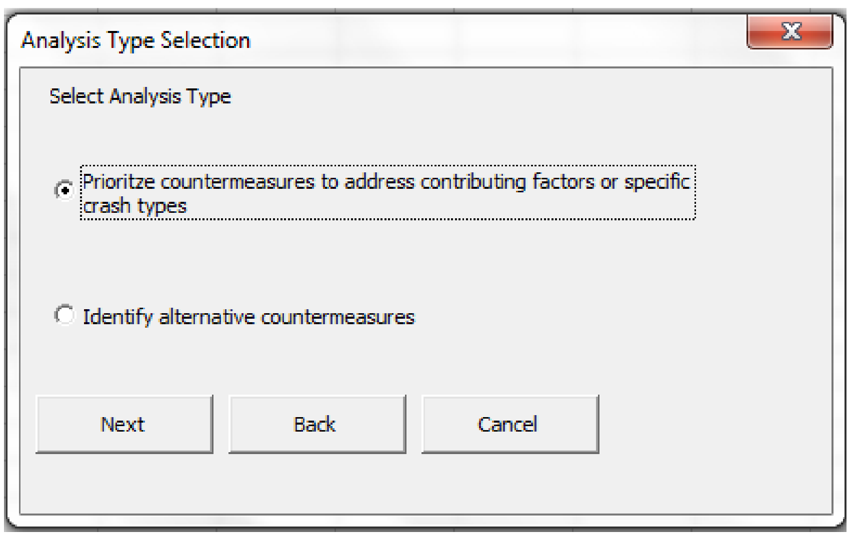


Figure 16. Example 1—Analysis Type Selection Input Window

Step 4: Select Crash Types or Contributing Factors

Based on the selection from the previous screen in Step 3, the user has the option to assess countermeasures that address certain contributing factors or crash types (Figure 17). As indicated in the problem statement, the diagnostic review of the segment revealed several contributing factors to the crashes. Hence in Step 4, “Select specific contributing factors to address” is selected for the analysis, and the “Next” button is clicked to proceed.

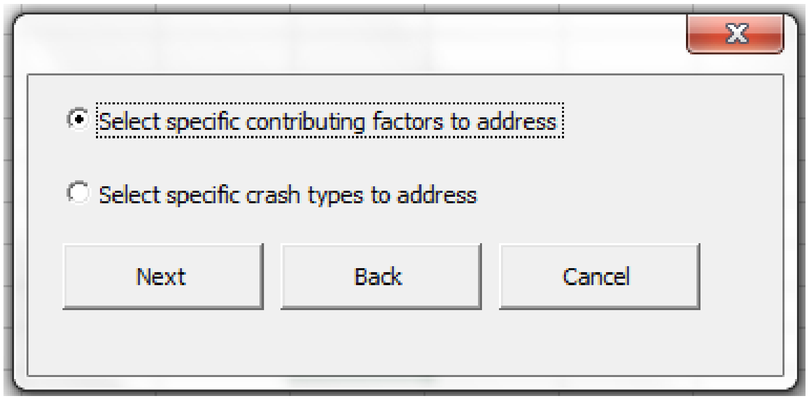


Figure 17. Example 1—Contributing Factors or Crash Types Selection Input Window

On the next input window, the user is prompted to select up to three contributing factors for the analysis (Figure 18). From the dropdown menus, “Large volume of driveway traffic” and “Left-turning vehicles” are selected, and the “Next” button is clicked to proceed.

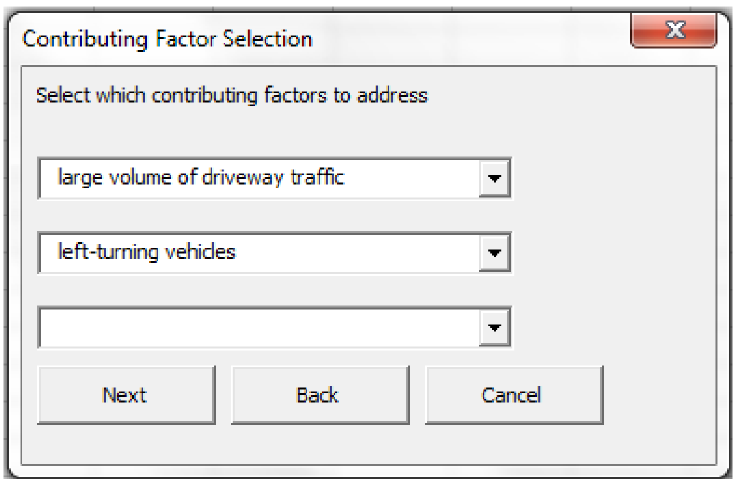


Figure 18. Example 1—Contributing Factors Selection Input Window

On the next input window, the decision tool indicates that three countermeasures address at least one of the two contributing factors identified for the analysis, including (Figure 19):

- Convert a TWLTL to a raised median
- Install raised median
- Reduce driveway density

Additional countermeasures applicable to the facility type of interest are also included on the input window for consideration in the analysis. The problem statement indicates that the roadway segment under investigation is a 4-lane undivided section of roadway, so the first countermeasure that met the selection criteria “Convert a TWLTL to a raised median” can be immediately ruled out of consideration from the analysis as not being applicable. The other two countermeasures that met the selection criteria (i.e., “Install raised median” and “Reduce driveway density”) are selected for the analysis (Figure 20), and the “Next” button is clicked to proceed.

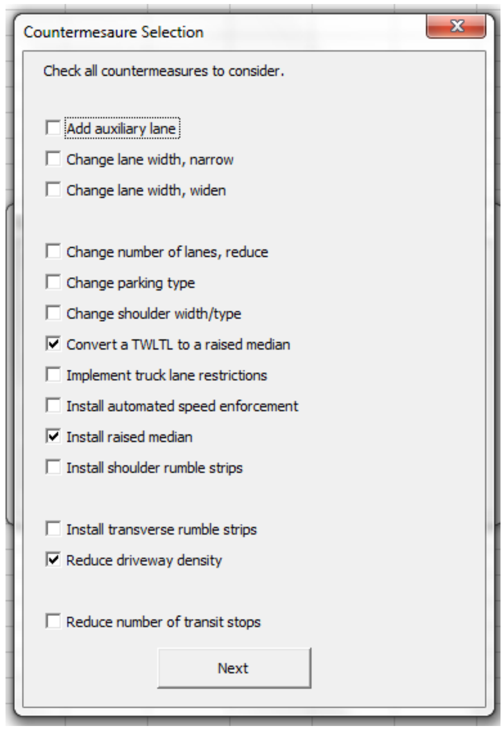


Figure 19. Example 1—Countermeasure Selection Input Window

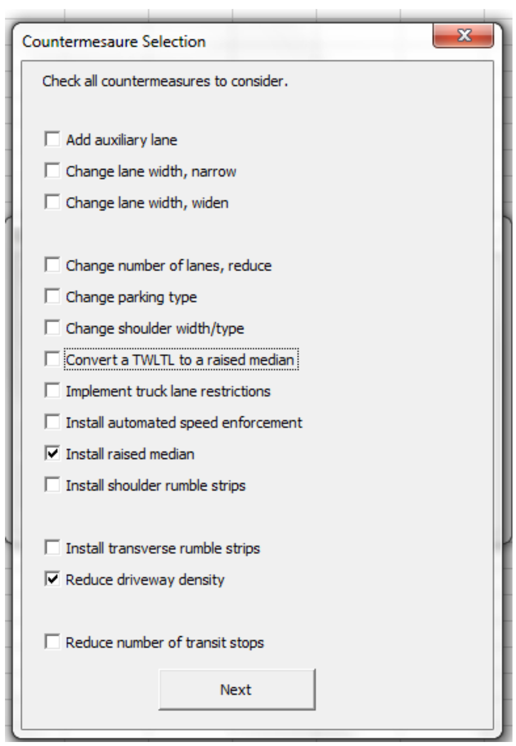


Figure 20. Example 1—Countermeasure Selection Input Window (Final Selection)

Step 5: Specific Questions Asked by Tool

By selecting “Install raised median” and “Reduce driveway density”, the decision tool automatically formulates responses to the series of diagnostic questions related to these specific countermeasures, so there is no need to provide any responses to questions posed by the decision tool for this analysis.

Step 6: Report Results

In this final step, the user is presented with the results of the diagnostic evaluation for each countermeasure considered in the analysis, indicating the potential impacts on pedestrians and bicyclists if the countermeasure is installed. Separate output tables are provided considering the potential impacts on pedestrians (Ped Results) and bicyclists (Bike Results). Table 10 presents the output table listing the potential impacts on pedestrians taking into considering the installation of a raised median and reducing the driveway density along the segment. Table 11 presents the corresponding output table listing the potential impacts on bicyclists.

Interpretation of Results

When interpreting the results, the user or analyst should first review the output tables for validity of the results. Each potential site where safety improvements are being considered is unique, and assumptions have been made to estimate the “Direction of Impact” of the individual countermeasures on pedestrians and bicyclists. In particular, it is assumed that no other changes or improvements to a site are made except the countermeasure under consideration, unless otherwise specified by the user in response to the diagnostic questions. However, this assumption may not always be true. Often when countermeasures are implemented or installed at a site, multiple changes are made to site characteristics and/or geometrics. In addition, the countermeasures included in the decision tool address fairly common treatments. It is not feasible to take into consideration all possible conditions and the range of treatments and applications associated with each countermeasure when estimating the “Direction of Impact” of the individual countermeasures on pedestrians and bicyclists. Therefore, for each variable included on the output table, the user should review the estimated “Direction of Impact” of the individual countermeasures on pedestrians and bicyclists taking into consideration the current conditions of the actual site and the most likely conditions of the site if the countermeasures under consideration were to be installed or implemented, and as necessary update the estimated “Direction of Impact” for a given variable with the primary options being “increase”, “decrease”, or “no change”.

Table 10. Example 1 - Output Table from Decision Tool Listing Potential Impacts on Pedestrians at Roadway Segments

	Direction of Impact		
Variable	**Install raised median**	**Reduce driveway density**	**Potential impacts on pedestrians at roadway segments**
Travel time	increase	no change	Treatments that increase travel time for pedestrians can decrease compliance with the traffic control by pedestrians, encourage pedestrians to use undesired routes, and/or decrease pedestrian level of service.
Delay	increase	no change	Treatments that increase delay for crossing pedestrians can decrease compliance with the traffic control. Increased delay decreases pedestrian level of service.
Number of through lanes	no change	no change	As the number of travel lanes increase, the availability for a suitable midblock crossing gap decreases, decreasing pedestrian level of service. Treatments that increase the number of lanes that intersect the path of a crossing pedestrian increase crash exposure for pedestrians. It can also create situations where traffic in one lane blocks the view of crossing pedestrians for drivers in another lane.
Lane width	no change	no change	Treatments that increase lane width increase the midblock crossing distance for pedestrians and increase their travel time, decreasing pedestrian level of service. Increased lane width may also increase vehicle travel speeds. Pedestrian crashes become more severe as vehicle speeds increase. In addition, increased speeds reduce the available time for a driver to identify and react to the presence of a pedestrian.
Crossing distance	no change	no change	Treatments that increase the midblock crossing distance for pedestrians increase their exposure time to traffic.
Overall pavement width	no change	no change	Treatments that increase overall pavement width increase the midblock crossing distance for pedestrians and increase their travel time, decreasing pedestrian level of service. Increased pavement width may also increase vehicle travel speeds. Pedestrian crashes become more severe as vehicle speeds increase. In addition, increased speeds reduce the available time for a driver to identify and react to the presence of a pedestrian.
Separation to pedestrian facility	no change	no change	As the distance between motor vehicle lanes and the pedestrian facility increases, pedestrian comfort increases.
Motor vehicle speed	increase	increase	As motor vehicle speed increases, crashes with pedestrians become more severe. In addition, higher speeds give drivers less reaction time to detect and respond to the presence of a pedestrian.
Driveway radii, turning speeds	no change	no change	Treatments that increase turning speeds can make crashes with pedestrians more severe. This may be more of a concern where drivers' attention may not be on pedestrians, such as when making a left-turn into a driveway.
Traffic volumes	no change	no change	Treatments that increase vehicle volumes reduce available gaps for pedestrians to cross at midblock locations. Increased volumes may also decrease the comfort of pedestrians walking along the roadside. Increase traffic volumes increase pedestrian exposure to crashes.
Visibility	no change	no change	Treatments that block the view of pedestrians or cast them in shadows may result in drivers being surprised by their presence near a midblock crossing or driveway, and drivers may not have sufficient time to yield to the pedestrians.
Conspicuity	increase	increase	When pedestrians are not conspicuous, drivers may have difficulty identifying them in time to yield to them at a midblock crossing or at driveways.
Left turning conflicts	decrease	decrease	Treatments that increase left-turning traffic onto driveways and other access points along the roadway segment create potential conflicts for pedestrians walking along the side of the road and increase crash exposure. The level of service methodology in the HCM for pedestrians walking along a roadway assumes that drivers yield to pedestrians before making turns, so turning volume is not a factor in pedestrian roadway segment LOS calculations. However, in reality, increases in turning movements may reduce the level of comfort of pedestrians walking along the roadway.
Right turning conflicts	increase	decrease	Treatments that increase right-turning traffic onto or out of driveways and other access points along the roadway segment create potential conflicts for pedestrians walking along the side of the road and increase crash exposure. The level of service methodology in the HCM for pedestrians walking along a roadway assumes that drivers yield to pedestrians before making turns, so turning volume is not a factor in pedestrian roadway segment LOS calculations. However, in reality, increases in turning movements may reduce the level of comfort of pedestrians walking along the roadway.

Table 11. Example 1 - Output Table from Decision Tool Listing Potential Impacts on Bicyclists at Roadway Segments

Variable	Direction of Impact: Install raised median	Direction of Impact: Reduce driveway density	Potential impacts on bicyclists at roadway segments
Travel time	no change	decrease	Treatments that increase travel time for bicyclists can decrease compliance with the traffic control by bicyclists and encourage bicyclists to use undesired routes.
Number of through lanes	no change	no change	As the number of through travel lanes increase, it becomes more difficult for bicyclists to cross lanes of traffic to make turns. Treatments that increase the number of lanes that intersect the path of through-moving or crossing cyclist increase crash exposure for cyclists. It can also create situations where traffic in one lane blocks the view of bicyclists for drivers in another lane.
Lane width	no change	no change	Treatments that provide wider lanes, especially outside lanes, may provide more room for bicycles to share with vehicles, increasing bicycle level of service. However, narrow lanes may allocate space for dedicated bike lanes, or buffer lanes between bikes and motor vehicles or bikes and parking lanes.
Overall pavement width	no change	no change	Treatments that provide wider pavement width can provide more allocated space for bicyclists in terms of wider shared lanes, dedicated bike lanes, and buffer lanes, increasing bicycle level of service.
Separation to bikeway	no change	no change	As the distance between motor vehicle lanes and the bikeway increases, bicyclist comfort and bicycle level of service increase.
Crossing distance	no change	no change	Treatments that increase the midblock crossing distance for bicyclists increase their exposure time to traffic.
Motor vehicle speed	increase	increase	As motor vehicle speed increases, crashes with bicyclists become more severe. In addition, higher speeds give drivers less reaction time to detect and respond to the presence of a bicyclist.
Bike speed	no change	increase	Treatments that allow faster bike speeds reduce travel time for bicyclists.
Driveway radii, turning speeds	no change	no change	Treatments that increase turning speeds can make crashes with bicyclists more severe. This may be more of a concern where drivers' attention may not be on bicyclists, such as when making a left-turn into a driveway.
Traffic volumes	no change	no change	Treatments that increase vehicle volumes make passing maneuvers more difficult because drivers are less likely to be able to cross into the adjacent lane to give the bicyclist more space. In addition, increased volume in the shared lane or in the lane adjacent to the bike lane may decrease bicyclists' comfort, decreasing bicycle level of service. Treatments that increase motor vehicle traffic volumes also increase crash exposure for bicyclists.
Visibility	no change	no change	Treatments that block the view of bicyclists or cast them in shadows may result in drivers being surprised by their presence near a midblock crossing or driveway or along the roadway, and drivers may not have sufficient time to yield to the bicyclists.
Conspicuity	increase	increase	When bicyclists are not conspicuous, drivers may have difficulty identifying them in time to yield to them at midblock crossings, at driveways, or along roadways.
Pavement surface quality	no change	no change	Treatments that improve surface quality increase bicyclists' comfort and bicycle level of service. Improved surface quality can also reduce the likelihood of bicyclists losing control and crashing in or near motor vehicle traffic.
Left turning conflicts	decrease	decrease	Treatments that increase left-turning traffic onto driveways and other access points along the roadway segment create potential conflicts for bicyclists riding along the side of the road and increase crash exposure. The level of service methodology in the HCM for bicyclists riding along a roadway assumes that drivers yield to bicyclists before making turns, so turning volume is not a factor in bicycle roadway segment LOS calculations. However, in reality, increases in turning movements may reduce the level of comfort of bicyclists riding along the roadway.
Right turning conflicts	increase	decrease	Treatments that increase right-turning traffic onto or out of driveways and other access points along the roadway segment create potential conflicts for cyclists riding along the side of the road and increase crash exposure. The level of service methodology in the HCM for bicyclists riding along a roadway assumes that drivers yield to bicyclists before making turns, so turning volume is not a factor in bicycle roadway segment LOS calculations. However, in reality, increases in turning movements may reduce the level of comfort of bicyclists riding along the roadway.

Assuming review of the output tables indicated valid results, based on Table 10, installation of a raised median could potentially:

- Increase the travel time for pedestrians,
- Increase delay for pedestrians,
- Have no effect on number of through lanes,
- Have no effect on lane width,
- Have no effect on crossing distance,
- Have no effect on overall pavement width,
- Have no effect on separation to pedestrians,
- Increase motor vehicle speed,
- Have no effect on driveway radii, turning speeds,
- Have no effect on traffic volumes,
- Have no effect on visibility of pedestrians,
- Increase the conspicuity of pedestrians,
- Decrease left-turning conflicts with pedestrians, and
- Increase right-turning conflicts with pedestrians.

Also based on Table 10, reducing the driveway density could potentially:

- Have no effect on travel time for pedestrians,
- Have no effect on delay for pedestrians,
- Have no effect on number of through lanes,
- Have no effect on lane width,
- Have no effect on crossing distance,
- Have no effect on overall pavement width,
- Have no effect on separation to pedestrians,
- Increase motor vehicle speed,
- Have no effect on driveway radii, turning speeds,
- Have no effect on traffic volumes,
- Have no effect on visibility of pedestrians,
- Increase the conspicuity of pedestrians,
- Decrease left-turning conflicts with pedestrians, and
- Decrease right-turning conflicts with pedestrians.

In summary, the variables most directly related to pedestrian level of service and/or safety that could potentially be affected by installation of the two countermeasures being considered in this example are as follows:

Install raised median:

- Travel time
- Delay
- Motor vehicle speed
- Conspicuity
- Left-turning conflicts
- Right-turning conflicts

Reduce driveway density:

- Motor vehicle speed
- Conspicuity
- Left-turning conflicts
- Right-turning conflicts

Thus, the potential impacts on pedestrians along a section of an urban, four-lane, undivided arterial, due to installation of a raised median, are as follows:

- By increasing travel time for pedestrians, this treatment may decrease compliance with the traffic control by pedestrians, encourage pedestrians to use undesired routes, and/or decrease pedestrian level of service.
- By increasing delay for crossing pedestrians, this treatment may decrease compliance with the traffic control. Increased delay also decreases pedestrian level of service.
- By increasing motor vehicle speeds, crashes with pedestrians may become more severe. In addition, higher speeds give drivers less reaction time to detect and respond to the presence of a pedestrian.
- By increasing the conspicuity of pedestrians, drivers may have less difficulty identifying pedestrians in time to yield to them at a midblock crossing or at driveways.
- By decreasing left-turning conflicts, this treatment may create less potential conflicts for pedestrians walking along the side of the road and decrease crash exposure. The level of service methodology in the HCM for pedestrians walking along a roadway assumes that drivers yield to pedestrians before making turns, so turning volume is not a factor in pedestrian roadway segment LOS calculations. However, in reality, decreases in left-turning movements along the roadway may improve the level of comfort of pedestrians walking along the roadway.
- By increasing right-turning conflicts, this treatment may create potential conflicts for pedestrians walking along the side of the road and increase crash exposure. The level of service methodology in the HCM for pedestrians walking along a roadway assumes that drivers yield to pedestrians before making turns, so turning volume is not a factor in pedestrian roadway segment LOS calculations. However, in reality, increases in right-turning movements may reduce the level of comfort of pedestrians walking along the roadway.

Correspondingly, the potential impacts on pedestrians along a section of an urban, four-lane, undivided arterial, due to reduction of driveway density, are as follows:

- By increasing motor vehicle speeds, crashes with pedestrians may become more severe. In addition, higher speeds give drivers less reaction time to detect and respond to the presence of a pedestrian.
- By increasing the conspicuity of pedestrians, drivers may have less difficulty identifying pedestrians in time to yield to them at a midblock crossing or at driveways.
- By decreasing left-turning conflicts, this treatment may create less potential conflicts for pedestrians walking along the side of the road and decrease crash exposure. The level of service methodology in the HCM for pedestrians walking along a roadway assumes that drivers yield to pedestrians before making turns, so turning volume is not a factor in pedestrian roadway segment LOS calculations. However, in reality, decreases in left-turning movements along the roadway may improve the level of comfort of pedestrians walking along the roadway.
- By decreasing right-turning conflicts, this treatment may create less potential conflicts for pedestrians walking along the side of the road and decrease crash exposure. The level of

service methodology in the HCM for pedestrians walking along a roadway assumes that drivers yield to pedestrians before making turns, so turning volume is not a factor in pedestrian roadway segment LOS calculations. However, in reality, decreases in right-turning movements along the roadway may improve the level of comfort of pedestrians walking along the roadway.

Then, based on Table 11, installation of a raised median could potentially:

- Have no effect on travel time for bicyclists,
- Have no effect on number of through lanes,
- Have no effect on lane width,
- Have no effect on overall pavement width,
- Have no effect on separation to bikeway,
- Have no effect on crossing distance,
- Increase motor vehicle speed,
- Have no effect on bike speed,
- Have no effect on driveway radii, turning speeds,
- Have no effect on traffic volumes,
- Have no effect on visibility of bicyclists,
- Increase the conspicuity of bicyclists,
- Have no effect on pavement surface quality,
- Decrease left-turning conflicts with bicyclists, and
- Increase right-turning conflicts with bicyclists.

Also based on Table 11, reducing the driveway density could potentially:

- Decrease travel time for bicyclists,
- Have no effect on number of through lanes,
- Have no effect on lane width,
- Have no effect on overall pavement width,
- Have no effect on separation to bikeway,
- Have no effect on crossing distance,
- Increase motor vehicle speed,
- Increase bike speed,
- Have no effect on driveway radii, turning speeds,
- Have no effect on traffic volumes,
- Have no effect on visibility of bicyclists,
- Increase the conspicuity of bicyclists,
- Have no effect on pavement surface quality,
- Decrease left-turning conflicts with bicyclists, and
- Decrease right-turning conflicts with bicyclists.

In summary, the variables most directly related to bicyclist level of service and/or safety that could potentially be affected by installation of the two countermeasures being considered in this example are as follows:

Install raised median:

- Motor vehicle speed
- Conspicuity
- Left-turning conflicts
- Right-turning conflicts

Reduce driveway density:

- Travel time
- Motor vehicle speed
- Bike speed
- Conspicuity
- Left-turning conflicts
- Right-turning conflicts

Thus, the potential impacts on bicyclists along a section of an urban, four-lane, undivided arterial, due to installation of a raised median, are as follows:

- By increasing motor vehicle speeds, crashes with bicyclists may become more severe. In addition, higher speeds give drivers less reaction time to detect and respond to the presence of a bicyclist.
- By increasing the conspicuity of bicyclists, drivers may have less difficulty identifying bicyclists in time to yield to them at midblock crossings, at driveways, or along roadways.
- By decreasing left-turning conflicts, this treatment may create fewer potential conflicts for bicyclists riding along the side of the road and decrease crash exposure. The level of service methodology in the HCM for bicyclists riding along a roadway assumes that drivers yield to bicyclists before making turns, so turning volume is not a factor in bicycle roadway segment LOS calculations. However, in reality, decreases in left-turning movements may improve the level of comfort of bicyclists riding along the roadway.
- By increasing right-turning conflicts, this treatment may create potential conflicts for bicyclists riding along the side of the road and increase crash exposure. The level of service methodology in the HCM for bicyclists riding along a roadway assumes that drivers yield to bicyclists before making turns, so turning volume is not a factor in bicycle roadway segment LOS calculations. However, in reality, increases in right-turning movements may reduce the level of comfort of bicyclists riding along the roadway.

Correspondingly, the potential impacts on bicyclists along a section of an urban, four-lane, undivided arterial, due to reduction of driveway density, are as follows:

- By decreasing travel time for bicyclists, this treatment may increase compliance with the traffic control by bicyclists and encourage bicyclists to use desired routes.
- By increasing motor vehicle speeds, crashes with bicyclists may become more severe. In addition, higher speeds give drivers less reaction time to detect and respond to the presence of a bicyclist.
- By increasing the conspicuity of bicyclists, drivers may have less difficulty identifying bicyclists in time to yield to them at midblock crossings, at driveways, or along roadways.

- By decreasing left-turning conflicts, this treatment may create less potential conflicts for bicyclists riding along the side of the road and decrease crash exposure. The level of service methodology in the HCM for bicyclists riding along a roadway assumes that drivers yield to bicyclists before making turns, so turning volume is not a factor in bicycle roadway segment LOS calculations. However, in reality, decreases in left-turning movements may improve the level of comfort of bicyclists riding along the roadway.
- By decreasing right-turning conflicts, this treatment may create less potential conflicts for bicyclists riding along the side of the road and decrease crash exposure. The level of service methodology in the HCM for bicyclists riding along a roadway assumes that drivers yield to bicyclists before making turns, so turning volume is not a factor in bicycle roadway segment LOS calculations. However, in reality, decreases in right-turning movements may improve the level of comfort of bicyclists riding along the roadway.

Based on the output results, the two countermeasures considered in this analysis: (a) installing a raised median and (b) reduce driveway density, would have very similar potential impacts on pedestrians and bicyclists with a few exceptions:

- Installing a raised median could increase travel time and delay for pedestrians compared to reducing the driveway density which would have no effect on travel time and delay for pedestrians;
- Installing a raised median could decrease travel time for bicyclists compared to reducing the driveway density which would have no effect on travel time for bicyclists; and
- Installing a raised median could increase right-turning conflicts for pedestrians and bicyclists compared to reducing the driveway density which could decrease right-turning conflicts for pedestrians and bicyclists.

Otherwise, both treatments would be expected to impact pedestrians and bicyclists in similar fashion. Based on interpretation of the output, it would be up to the decision of the user to determine and/or select one or the other treatment for potential implementation. To potentially help with the decision, the CMF Table tab in the decision tool includes 47 CMFs for “Install raised median” and 8 CMFs for “Reduce driveway density” that may be applicable to an urban, four-lane, undivided arterial. Other factors that may be considered in selecting one or the other treatment for implementation include the context of the site and level of pedestrian and bicyclist activity or exposure along the roadway segment.

This example demonstrates how the decision tool can be used to help select a traffic safety countermeasure that addresses specific contributing factors, while also considering potential impacts on pedestrians and bicyclists. With only a few minor input adjustments in Step 4, this example also demonstrates how the decision tool can be used to help select a traffic safety countermeasure that addresses a specific crash type, while also considering potential impacts on pedestrians and bicyclists.

Example 2: A rural, four-leg signalized intersection is experiencing a high frequency of left-turn-related crashes. On the major-road approaches, two lanes approach the intersection from both directions. The outside lanes are shared-through-right lanes, and the inside lanes are shared-through-left lanes. Currently, the signal operates with permissive left-turn phasing for the major-road approaches. The agency responsible for the intersection is initially considering installing left-turn lanes at the intersection on both major-road approaches. What other countermeasures could the agency consider as alternatives to installing left-turn lanes on the major-road approaches, and what potential impact might these countermeasures have on pedestrians and bicyclists?

Solution:

Step 1: Select Site Type

From the Home Tab, the user selects “New” to begin the analysis. The first input window prompts the user to select the site type for the analysis (Figure 21). “Intersection” is selected, and the “Next” button is clicked to proceed.

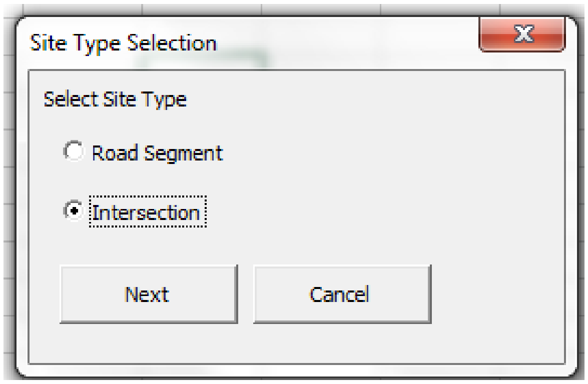


Figure 21. Example 2 – Site Type Selection Input Window

Step 2: Select Facility Type

On the next input window, the user selects the facility type to which the analysis applies (Figure 22). From the dropdown menu, “Int/Rur; 4-leg signalized” is selected, and the “Next” button is clicked to proceed.

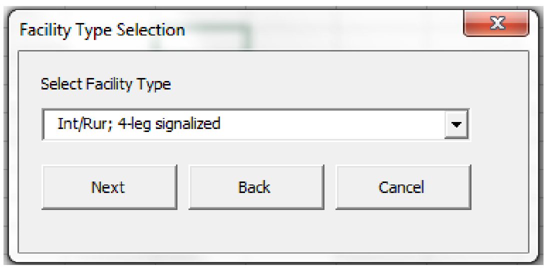


Figure 22. Example 2 – Facility Type Selection Input Window

Step 3: Select Analysis Type

On the next input window, the user is prompted to choose an analysis type from two options (Figure 23). “Identify alternative countermeasures” is selected, and the “Next” button is clicked to proceed.

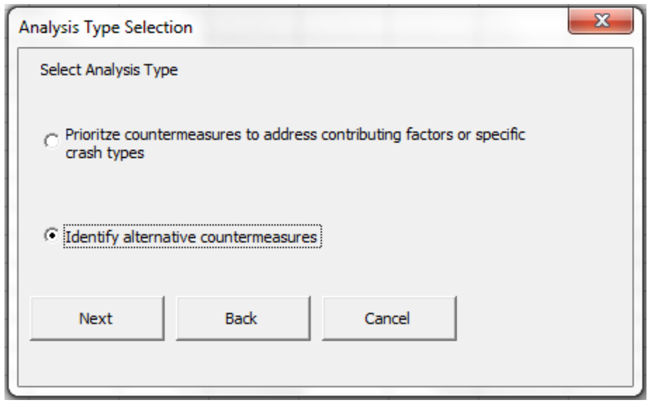


Figure 23. Example 2 – Analysis Type Selection Input Window

Step 4: Select Initial Countermeasure

By selecting “Identify alternative countermeasures” in Step 3, then the user selects an initial countermeasure for the analysis from a list of countermeasures for the site type and facility type of interest. Hence, “Install left-turn lane” is selected for the analysis (Figure 24); and the “Next” button is clicked to proceed.

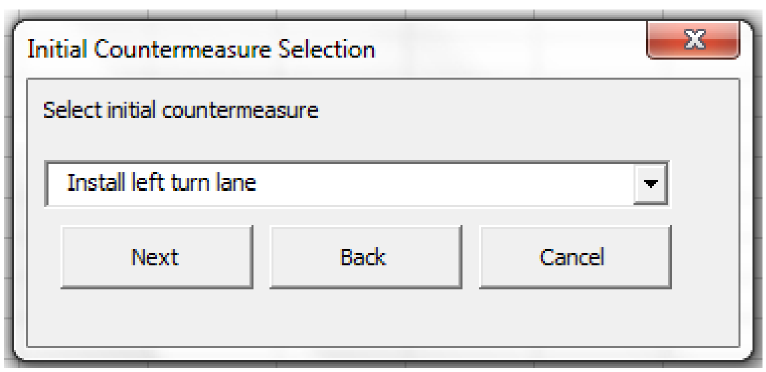


Figure 24. Example 2 – Initial Countermeasure Selection Input Window

On the next input window, for the given countermeasure, alternative countermeasures are identified for further consideration in the analysis if they have either a crash type or a contributing factor in common with the initial countermeasure for the facility type of interest (see Figure 25). In addition, alternative countermeasures for the facility type of interest that do not have a crash type or contributing factor in common with the initial countermeasure can also be considered for the analysis at the discretion of the user, but these countermeasures are not initially identified for inclusion in the analysis. The user selects the subset of alternative countermeasures for consideration in the analysis by checking or unchecking the respective boxes of the alternative countermeasures. For this example, nine countermeasures have a crash type or contributing factor in common with the initial countermeasures (i.e., Install left-turn lane), so these countermeasures are initially identified for inclusion in the analysis; while three additional countermeasures could also be selected for further consideration in the analysis based on being a countermeasure applicable to the facility type of interest (i.e., Int/Rur; 4-leg signalized).

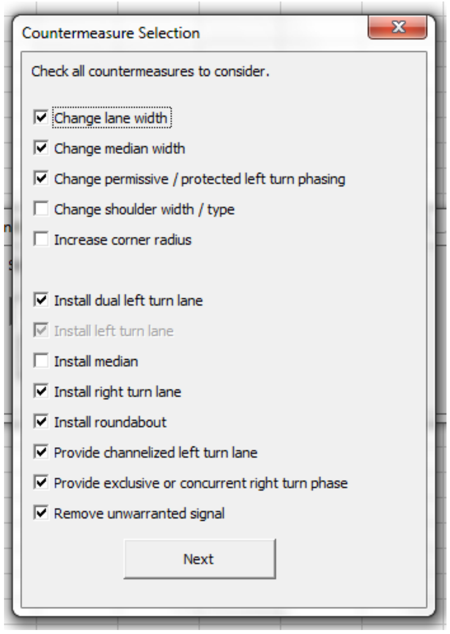


Figure 25. Example 2 – Countermeasure Selection Input Window

For this example, one alternative countermeasure, "Change permissive/protected left-turn phasing", is selected for further consideration in the analysis, in addition to the initial countermeasure (i.e., Install left-turn lane) (see Figure 26). The "Next" button is clicked to proceed to subsequent steps.

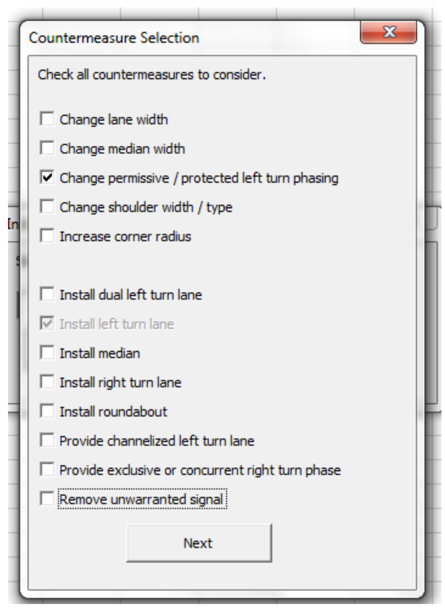


Figure 26. Example 2 – Countermeasure Selection Input Window (Final Selection)

Step 5: Specific Questions Asked by Tool

By selecting “Install left-turn lane” and “Change permissive/protected left turn phasing” for the analysis, the decision tool formulates a series of diagnostic questions related to these specific countermeasures for the user to respond to using dropdown menus. The decision tool also makes some assumptions about how the countermeasures of interest may impact particular variables related to pedestrian and bicycle level of service and safety.

Figure 27 through Figure 34 illustrate the series of diagnostic questions from the decision tool related to installing a left-turn lane at a rural, 4-leg signalized intersection and the respective responses used for this example. As illustrated in Figure 27 through Figure 34, the particular countermeasure to which the question applies (i.e., Install left-turn lane) is provided at the top left portion of the input window. The series of diagnostic questions related to installing a left-turn lane at a rural, 4-leg signalized intersection and the respective responses used for this example are summarized as follows:

Countermeasure: Install left-turn lane

- How will installation of a left-turn lane impact left-turn phasing?
  Response: change from permissive only to permissive/protected
- How will installation of a left-turn lane impact crosswalk length?
  Response: increase
- How will installation of a left-turn lane impact width of the outside through lane?
  Response: no change
- How will installation of a left-turn lane impact width of a bicycle lane?
  Response: no existing bike lane
- How will installation of a left-turn lane impact the width of the paved outside shoulder?
  Response: narrow
- How will installation of a left-turn lane impact the width or presence of a parking lane?
  Response: no existing parking lane
- How will installation of a left-turn lane impact signal cycle length?
  Response: increase
- How will installation of a left-turn lane impact pedestrian walk duration?
  Response: no change

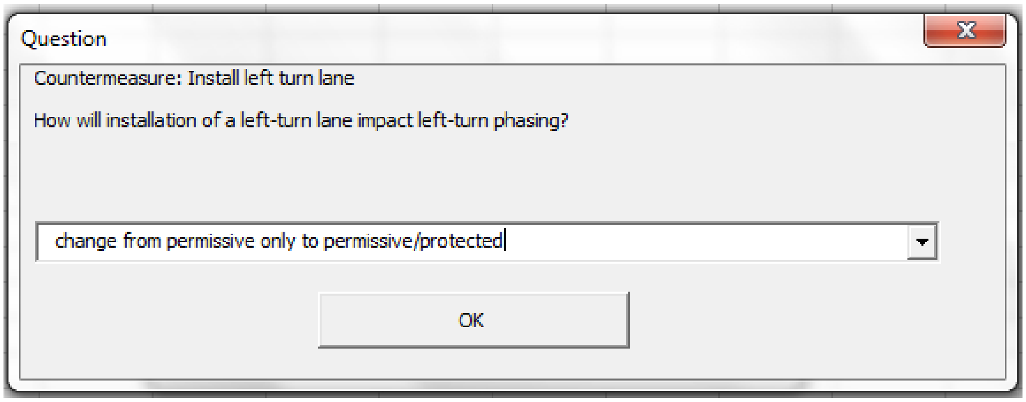


Figure 27. Example 2 – Diagnostic Question for Install Left-Turn Lane Related to Left-Turn Phasing

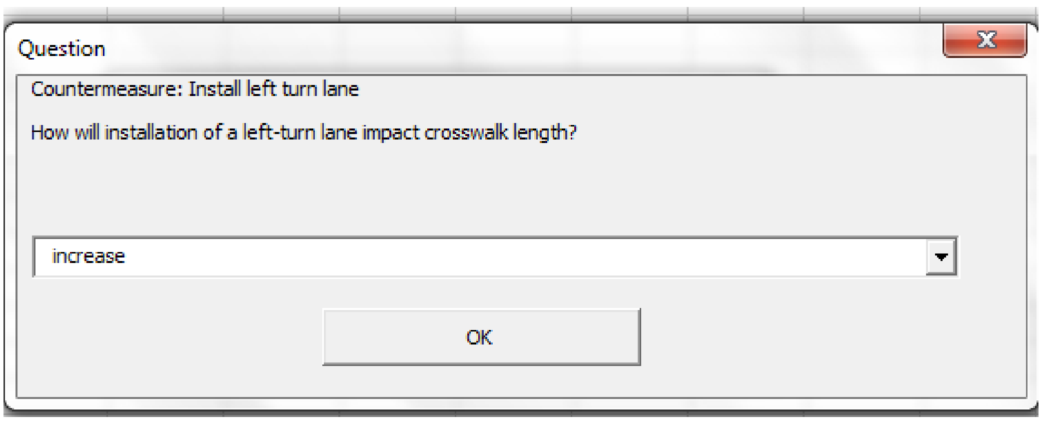


Figure 28. Example 2 – Diagnostic Question for Install Left-Turn Lane Related to Crosswalk Length

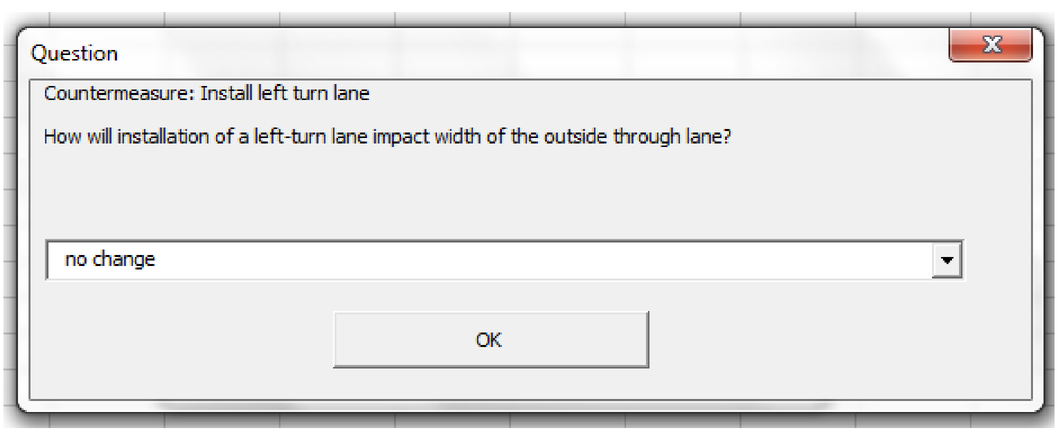


Figure 29. Example 2 – Diagnostic Question for Install Left-Turn Lane Related to Width of Outside Through Lane

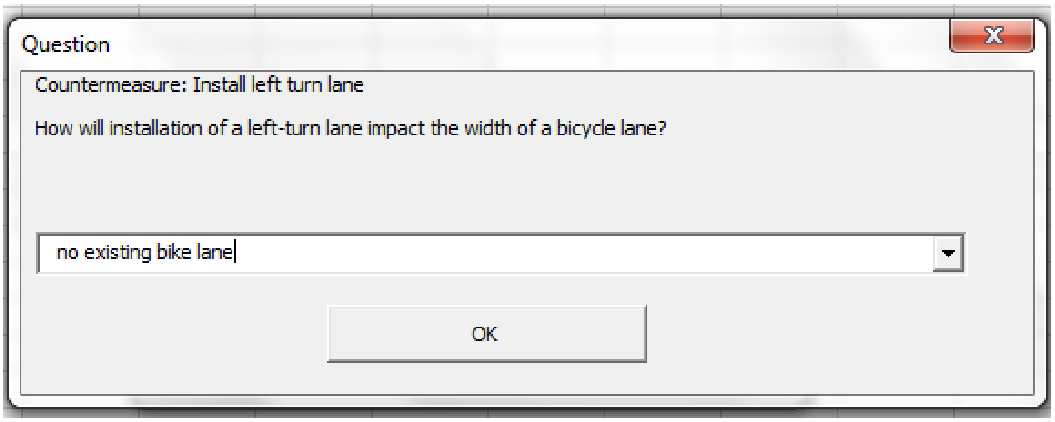


Figure 30. Example 2 – Diagnostic Question for Install Left-Turn Lane Related to Width of Bicycle Lane

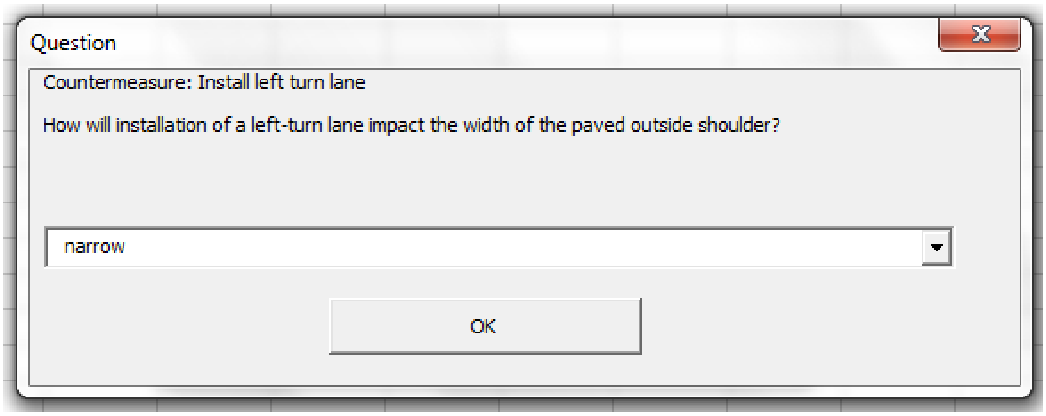


Figure 31. Example 2 – Diagnostic Question for Install Left-Turn Lane Related to Width of Paved Outside Shoulder

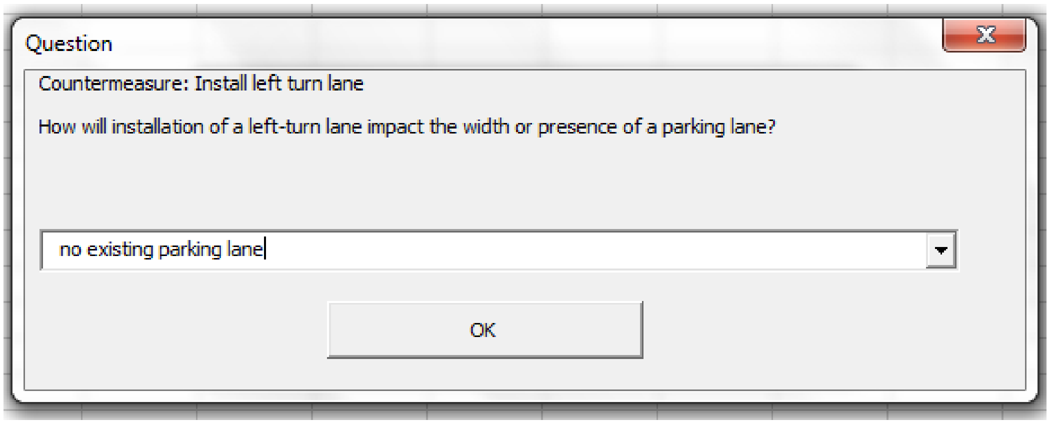


Figure 32. Example 2 – Diagnostic Question for Install Left-Turn Lane Related to Width or Presence of Parking Lane

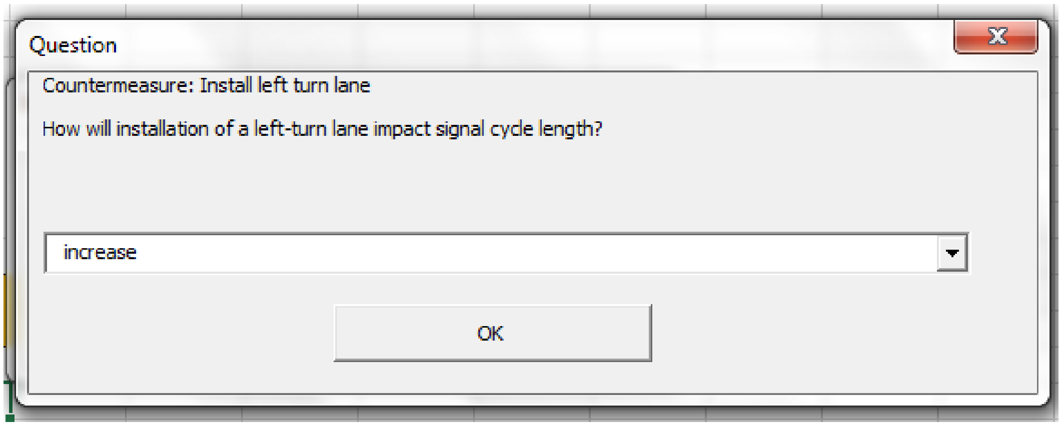


Figure 33. Example 2 – Diagnostic Question for Install Left-Turn Lane Related to Signal Cycle Length

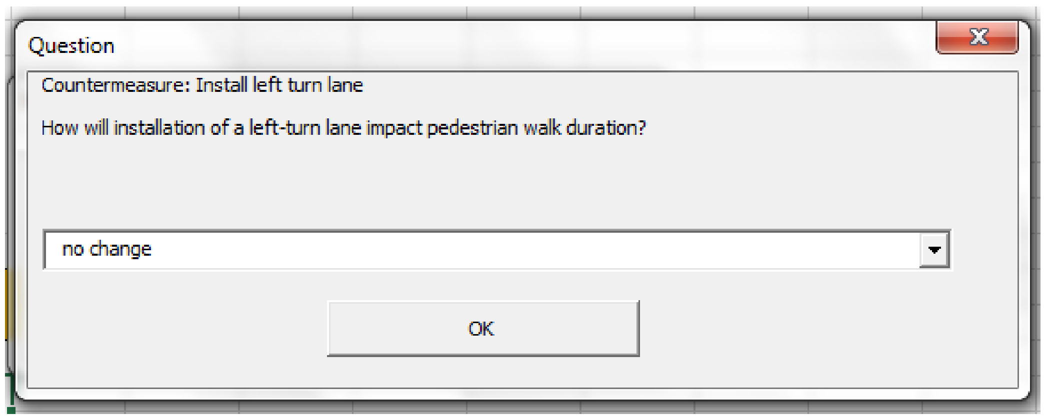


Figure 34. Example 2 – Diagnostic Question for Install Left-Turn Lane Related to Walk Duration

Three diagnostic questions related to the countermeasure "Change permissive/protected left-turn phasing" applicable at a rural, 4-leg signalized intersection are provided in the decision tool. The respective questions and responses used for this example are summarized as follows:

Countermeasure: Change permissive/protected left-turn phasing

- How will changing permissive/protected left-turn phasing impact left-turn phasing?
  Response: change from permissive only to permissive/protected
- How will changing permissive/protected left-turn phasing impact signal cycle length?
  Response: increase
- How will changing permissive/protected left-turn phasing impact pedestrian walk duration?
  Response: no change

Step 6: Report Results

In this final step, the user is presented with the results of the diagnostic evaluation for each countermeasure considered in the analysis, indicating the potential impacts on pedestrians and bicyclists if the countermeasure is installed. Separate output tables are provided considering the potential impacts on pedestrians (Ped Results) and bicyclists (Bike Results). Table 12 presents the output table listing the potential impacts on pedestrians taking into considering installation of a left-turn lane and changing permissive/protected left-turn phasing. Table 13 presents the corresponding output table listing the potential impacts on bicyclists.

Table 12. Example 2 - Output Table from Decision Tool Listing Potential Impacts on Pedestrians at Signalized Intersections

	Direction of Impact		
Variable	**Install left-turn lane**	**Change permissive/protected left-turn phasing**	**Potential impacts on pedestrians at signalized intersections**
Travel time	Increase	increase	Treatments that increase travel time for pedestrians may reduce compliance with traffic control by pedestrians, discourage pedestrians from using their intended travel path, and/or decrease pedestrian level of service.
Walk duration	no change	no change	Treatments that reduce the length of the duration of the WALK indication may not adequately accommodate seniors, people requiring mobility assistance devices, and young children.
Number of through lanes	no change	no change	Treatments that increase the number of through lanes a pedestrian must cross may increase their travel time across the intersection and decrease their level of service. Increasing the number of through lanes being crossed also increases the number of potential conflict points for crossing pedestrians and the potential for pedestrians being involved in a crash. In addition, a vehicle in one lane may block the view of the crossing pedestrian from vehicles in adjacent lanes.
Number of RTL on major approach	no change	no change	Each additional right-turn lane adds a conflict point for crossing pedestrians, lengthens the crossing distance, and increases the potential for pedestrians being involved in a crash. Where right-turn-on-red is permitted, drivers may be looking to the left for oncoming traffic and not see pedestrians crossing from the right.
Number of right turn islands	no change	no change	Treatments that provide right-turn islands give pedestrians a refuge location between crossing right-turning traffic and crossing through traffic. This allows the pedestrian to cross the right-turn lane any time there is a sufficient gap, and then wait for a green light to cross through traffic. Right-turn islands increase pedestrian level of service.
Right-turn-on-red flow rate	no change	no change	Treatments that increase the number of vehicles turning right on a red signal indication reduce opportunities for pedestrians to find a sufficient gap to cross during their allocated green time and may increase delay for pedestrians. As right-turn-on-red flow rate increases, pedestrian level of service decreases.
Crosswalk length	Increase	no change	Treatments that increase the length of the crosswalk result in longer crossing times and decreased pedestrian level of service. If crosswalk length increases because one or more lanes is added at the intersection approach, the number of potential conflict points for crossing pedestrians and the potential for pedestrians to be involved in a crash also increase.
Cycle length	Increase	increase	Longer cycle lengths create longer wait times for pedestrians, increase their delay, decrease their level of service, and may lead to less compliance with traffic control (pedestrians crossing during a Don't Walk phase).
Left-turn phasing	Change from permissive only to permissive/protected	Change from permissive only to permissive/protected	Permissive left-turn indications can create conflicts between pedestrians crossing legally on a green indication, and left-turn vehicles turning legally during a gap in oncoming traffic. It can be difficult for drivers to assess gaps, while also being aware of potential crossing pedestrians from both sides of the street.
Permitted-left-turn flow rate	decrease	decrease	Treatments that increase the number of vehicles turning left on a green ball or flashing yellow signal indication reduce opportunities for pedestrians to find a sufficient gap to cross during their allocated green time and may increase delay. As permitted-left-turn flow rate increases, pedestrian level of service decreases.
Motor vehicle approach speed	no change	no change	Treatments that increase the mid-segment 85th percentile speed reduce pedestrian level of service. In addition, increased speeds reduce the available time for a driver to identify and react to the presence of a pedestrian, and pedestrian crashes tend to be more severe as vehicle speeds increase.

Table 12. Example 2 - Output Table from Decision Tool Listing Potential Impacts on Pedestrians at Signalized Intersections (Continued)

	Direction of Impact		
Variable	**Install left-turn lane**	**Change permissive/protected left-turn phasing**	**Potential impacts on pedestrians at signalized intersections**
Corner radius	no change	no change	Treatments that increase the corner radius can help right-turning vehicles make smoother and quicker right turns. However, these larger radii often create a longer crossing for pedestrians, increasing their crossing time and decreasing their level of service.
Turning speeds	Increase	increase	Treatments that increase turning speeds can make crashes with pedestrians more severe. This may be more of a concern where drivers' attention may not be on crossing pedestrians, such as during right-turn-on-red and permissive left-turn maneuvers.
Visibility	no change	no change	Treatments that block the view of pedestrians or cast them in shadows may result in drivers being surprised by their presence in the intersection, and drivers may not have sufficient time to yield to the pedestrians.
Conspicuity	no change	no change	When pedestrians are not conspicuous, drivers may have difficulty identifying them in time to yield to them at an intersection.

Table 13. Example 2 - Output Table from Decision Tool Listing Potential Impacts on Bicyclists at Signalized Intersections

	Direction of Impact		
Variable	**Install left-turn lane**	**Change permissive/protected left-turn phasing**	**Potential impacts on bicyclists at signalized intersections**
Travel time	increase	increase	Treatments that increase travel time for bicyclists may reduce compliance with traffic control by bicyclists and discourage bicyclists from using their intended travel path.
Delay	increase	increase	Treatments that increase delay for bicyclists at the intersection may reduce compliance with traffic control.
Number of through lanes	no change	no change	Treatments that increase the number of through lanes a bicyclist must cross may increase their travel time across the intersection. Increasing the number of through lanes being crossed also increases the number of potential conflict points for crossing bicyclists. In addition, a vehicle in one lane may block the view of the crossing bicyclist from vehicles in adjacent lanes.
Width of outside through lane	no change	no change	Treatments that widen the outside through lane provide bicyclists more space to ride alongside motor vehicles through the intersection and increase bicycle level of service. It also allows bicyclists more space to move to the front of queued vehicles at a signal to prepare to make a turning maneuver from a position that is more visible to motor vehicle drivers. This positioning allows bicyclists to reduce their delay and increases bicycle level of service. Conversely, narrow outside lanes make it difficult for bicyclists to position themselves alongside motor vehicles.
Presence of bike lane	no existing bike lane	no change	Providing a bike lane makes drivers more aware of the potential presence of a bicycle and encourages drivers and bicyclists to stay in the pavement width allocated to them, increasing bicycle level of service and reducing the likelihood of a crash.

Table 13. Example 2 - Output Table from Decision Tool Listing Potential Impacts on Bicyclists at Signalized Intersections (Continued)

	Direction of Impact		
Variable	**Install left-turn lane**	**Change permissive/protected left-turn phasing**	**Potential impacts on bicyclists at signalized intersections**
Width of bicycle lane	no existing bike lane	no change	Treatments that provide or widen a bicycle lane at the intersection provide bicycles more space to ride alongside motor vehicles through the intersection and increase bicycle level of service. These treatments also allow bicyclists more space to move to the front of queued vehicles at a signal to prepare to make a turning maneuver from a position that is more visible to motor vehicle drivers. This positioning allows bicyclists to reduce their delay and increases bicycle level of service. Conversely, removing or narrowing the bicycle lane makes it difficult for bicyclists to position themselves alongside motor vehicles.
Width of paved outside shoulder	narrow	no change	Treatments that provide or widen a paved outside shoulder at the intersection provide bicyclists more space to ride alongside motor vehicles through the intersection and increase bicycle level of service. These treatments also allow bicyclists more space to move to the front of queued vehicles at a signal to prepare to make a turning maneuver from a position that is more visible to motor vehicle drivers. This positioning allows bicyclists to reduce their delay and increases bicycle level of service. Conversely, removing or narrowing a paved outside shoulder makes it difficult for bicyclists to position themselves alongside motor vehicles.
Presence of on-street parking, major approach	no existing parking lane	no change	The presence of on-street parking can create conflicts at intersections, as vehicles must cross the path of the bicyclist to enter and exit parking spaces while bicyclists are trying to position themselves for their desired movement through the intersection. In addition, parked vehicles can block the view of crossing bicyclists from drivers. Finally parked vehicles can result in dooring crashes.
Width of parking lane	no existing parking lane	no change	Treatments that widen the parking lane provide bicycles more space to ride alongside motor vehicles through the intersection if the parking lane is not occupied.
Cycle length	increase	increase	Longer cycle lengths create longer wait times for bicyclists and may lead to less compliance with traffic control (i.e., bicyclists crossing during a red signal).
Left-turn phasing	change from permissive only to permissive/protected	change from permissive only to permissive/protected	Permissive left-turn indications can create conflicts between through bicyclists and opposing left-turn vehicles. Bicyclists may be less conspicuous than oncoming vehicles and go unnoticed by turning drivers assessing gaps.
Number of lanes for bicyclist to cross to make left turn	increase	no change	Adding through lanes requires a bicyclist, generally traveling on the right side of through traffic, to cross additional lanes of traffic to make a left turn. Each lane creates a new potential conflict point for the bicyclist, and a new opportunity for the bicyclist to be hidden from view of drivers in one lane of traffic by vehicles in an adjacent lane of traffic.
Number of right-turn lanes on major approach	no change	no change	Generally, vehicles must pass through the path of bicyclists (traveling either in a bike lane or in the right-most through lane) to access a right turn lane. Each additional right-turn lane adds complexity to the maneuver and increases the number of potential conflicts both the bicyclist and driver must be aware of.
Turning speeds	Increase	increase	Treatments that increase motor vehicle turning speeds can make crashes with bicyclists more severe. This may be more of a concern where drivers' attention may not be on approaching bicyclists, such as during right-turn-on-red and permissive left-turn maneuvers.
Visibility	no change	no change	Treatments that block the view of bicyclists may result in drivers being surprised by their presence in the intersection, and drivers may not have sufficient time to yield to the bicyclists.
Conspicuity	no change	no change	When bicyclists are not conspicuous, drivers may have difficulty identifying them in time to yield to them, or move over to give them space, at an intersection.

Interpretation of Results

When interpreting the results, the user should first review the output tables for validity of the results. Each potential site where safety improvements are being considered is unique, and assumptions have been made to estimate the "Direction of Impact" of the individual countermeasures on pedestrians and bicyclists. For each variable included on the output table, the user should review the estimated "Direction of Impact" of the individual countermeasures on pedestrians and bicyclists taking into consideration the current conditions of the actual site and the most likely conditions of the site if the countermeasures under consideration were to be installed or implemented, and as necessary update the estimated "Direction of Impact" for a given variable, with the primary options being "increase", "decrease", or "no change".

Assuming review of the output tables indicated valid results, based on Table 12, installation by itself of each countermeasure included in the analysis could potentially impact pedestrians as follows:

Countermeasure: Install left-turn lane

- Increase travel time for pedestrians,
- Have no effect on walk duration for pedestrians,
- Have no effect on number of through lanes,
- Have no effect on number of right-turn lanes on the major road approach,
- Have no effect on number of right-turn islands,
- Have no effect on right-turn-on-red flow rate,
- Increase crosswalk length,
- Increase cycle length,
- Change left-turn phasing from permissive only to permissive/protected,
- Decrease permitted-left-turn flow rate,
- Have no effect on motor vehicle approach speed,
- Have no effect on corner radius,
- Increase turning speeds,
- Have no effect on visibility of pedestrians, and
- Have no effect on conspicuity of pedestrians.

Countermeasure: Change permissive/protected left-turn phasing

- Increase travel time for pedestrians,
- Have no effect on walk duration for pedestrians,
- Have no effect on number of through lanes,
- Have no effect on number of right-turn lanes on the major road approach,
- Have no effect on number of right-turn islands,
- Have no effect on right-turn-on-red flow rate,
- Have no effect on crosswalk length,
- Increase cycle length,
- Change left-turn phasing from permissive only to permissive/protected,
- Decrease permitted-left-turn flow rate,
- Have no effect on motor vehicle approach speed,
- Have no effect on corner radius,

- Increase turning speeds,
- Have no effect on visibility of pedestrians, and
- Have no effect on conspicuity of pedestrians.

In summary, the variables most directly related to pedestrian level of service and/or safety that could potentially be affected by implementation of the two countermeasures being considered in this example are as follows:

Install left-turn lane:

- Travel time
- Crosswalk length
- Cycle length
- Left-turn phasing
- Permitted-left-turn flow rate
- Turning speeds

Change permissive/protected left-turn phasing:

- Travel time
- Cycle length
- Left-turn phasing
- Permitted-left-turn flow rate
- Turning speeds

For the most part, both countermeasures considered in this analysis, if implemented by themselves, would likely impact pedestrians in a similar fashion as follows:

- By increasing travel time for pedestrians, these treatments may decrease compliance with the traffic control by pedestrians, encourage pedestrians to use undesired routes, and/or decrease pedestrian level of service.
- By increasing the cycle length, these treatments may create longer wait times for pedestrians, increase their delay, decrease their level of service, and lead to less compliance with traffic control (pedestrians crossing during a Don't Walk phase).
- By changing the left-turning phasing from permissive only to permissive/protected, these treatments may decrease the number of conflicts between pedestrians crossing legally on a green indication, and left-turn vehicles turning legally during a gap in oncoming traffic. It can be difficult for drivers to assess gaps, while also being aware of potential crossing pedestrians from both sides of the street.
- By decreasing the permitted left-turn flow rate, the treatments may decrease the number of vehicles turning left on a green ball or flashing yellow signal indication, improving opportunities for pedestrians to find a sufficient gap to cross during their allocated green time and decreasing delay. As permitted-left-turn flow rate decreases, pedestrian level of service increases and pedestrian exposure to left-turning vehicles decreases.
- By increasing turning speeds, these treatments can make crashes with pedestrians more severe. This may be more of a concern where drivers' attention may not be on crossing pedestrians, such as during right-turn-on-red and permissive left-turn maneuvers.

How the two countermeasures considered in this analysis, if implemented by themselves, would likely impact pedestrians differently from the other countermeasure are as follows:

- Installing a left-turn lane is expected to increase the crosswalk length; and by increasing the crosswalk length, installing a left-turn lane may result in longer crossing times and decreased pedestrian level of service. For this treatment, increasing the length of the crosswalk also involves crossing additional lanes of traffic which will increase the number of potential conflict points for crossing pedestrians and the potential for pedestrians to be involved in a crash.

- Changing the permissive/protected left-turn phasing is not expected to affect the crosswalk length.

Then, based on Table 13, implementation by itself of each countermeasure included in the analysis could potentially impact bicyclists as follows:

Countermeasure: Install left-turn lane

- Increase <u>travel time</u> for bicyclists,
- Increase <u>delay</u> for bicyclists,
- Have no effect on <u>number of through lanes</u>,
- Have no effect on <u>width of the outside through lane</u>,
- Have no effect on <u>presence of a bike lane</u>,
- Have no effect on <u>width of a bike lane</u>,
- Narrow <u>width of the paved outside shoulder</u>,
- Have no effect on <u>presence of on street parking</u>,
- Have no effect on <u>width of a parking lane</u>,
- Increase <u>cycle length</u>,
- Change left-turn phasing <u>from permissive only to permissive/protected</u>,
- Increase <u>number of lanes for a bicyclist to cross to make a left turn</u>,
- Have no effect on <u>number of right-turn lanes</u>,
- Increase <u>turning speeds</u>,
- Have no effect on <u>visibility</u> of bicyclists, and
- Have no effect on <u>conspicuity</u> of bicyclists.

Countermeasure: Change permissive/protected left-turn phasing

- Increase <u>travel time</u> for bicyclists,
- Increase <u>delay</u> for bicyclists,
- Have no effect on <u>number of through lanes</u>,
- Have no effect on <u>width of the outside through lane</u>,
- Have no effect on <u>presence of a bike lane</u>,
- Have no effect on <u>width of a bike lane</u>,
- Have no effect on <u>width of the paved outside shoulder</u>,
- Have no effect on <u>presence of on-street parking</u>,
- Have no effect on <u>width of a parking lane</u>,
- Increase <u>cycle length</u>,
- Change left-turn phasing <u>from permissive only to permissive/protected</u>,
- Have no effect on <u>number of lanes for a bicyclist to cross to make a left turn</u>,
- Have no effect on <u>number of right-turn lanes</u>,
- Increase <u>turning speeds</u>,
- Have no effect on <u>visibility</u> of bicyclists, and
- Have no effect on <u>conspicuity</u> of bicyclists.

In summary, the variables most directly related to bicyclist level of service and/or safety that could potentially be affected by implementation of the two countermeasures being considered in this example are as follows:

Install left-turn lane:

- Travel time
- Delay
- Width of paved outside shoulder
- Cycle length
- Left-turn phasing
- Number of lanes for bicyclist to cross to make a left turn
- Turning speeds

Change permissive/protected left-turn phasing:

- Travel time
- Delay
- Cycle length
- Left-turn phasing
- Turning speeds

For the most part, both countermeasures considered in this analysis, if implemented by themselves, would likely impact bicyclists in a similar fashion as follows:

- By increasing travel time for bicyclists, these treatments may reduce compliance with traffic control by bicyclists and discourage bicyclists from using their intended travel path.
- By increasing delay for bicyclists, these treatments that may reduce compliance with traffic control by bicyclists.
- By increasing the cycle length, these treatments may create longer wait times for bicyclists and lead to less compliance with traffic control (i.e., bicyclists crossing during a red signal).
- By changing the left-turning phasing from permissive only to permissive/protected, these treatments may reduce the number of conflicts between through bicyclists and opposing left-turn vehicles. Bicyclists may be less conspicuous than oncoming vehicles and go unnoticed by turning drivers assessing gaps.
- By increasing turning speeds, these treatments may make crashes with bicyclists more severe. This may be more of a concern where drivers' attention may not be on approaching bicyclists, such as during right-turn-on-red and permissive left-turn maneuvers.

How the two countermeasures considered in this analysis, if implemented by themselves, would likely impact bicyclists differently from the other countermeasure are as follows:

- Installing a left-turn lane is expected to narrow the width of the paved outside shoulder; as such this treatment may provide bicyclists less space to ride alongside motor vehicles through the intersection and decrease bicycle level of service. Narrowing a paved outside shoulder makes it difficult for bicyclists to position themselves alongside motor vehicles at the intersection.
- Installing a left-turn lane is also expected to increase the number of lanes for bicyclists to cross to make a left turn. Each lane bicyclists must cross creates a new potential conflict point for bicyclists, and a new opportunity for bicyclists to be hidden from view of drivers in one lane of traffic by vehicles in an adjacent lane of traffic.

- Changing the permissive/protected left-turn phasing is not expected to affect the width of the paved outside shoulder or the number of lanes for bicyclists to cross to make a left turn.

Based on this interpretation of the output, it would be up to the decision of the user to determine and/or select one or the other treatment for potential implementation. To potentially help with the decision, the CMF Table tab in the decision tool includes 38 CMFs for “Install left-turn lane”. However, none of the CMFs for “Install left-turn lane” is applicable to rural, 4-leg signalized intersections, so the CMF Table in the decision tool does not necessarily provide additional help with this countermeasure. On the other hand, the CMF Table includes 11 CMFs for “Change permissive/protected left-turn phasing” that may be applicable to a rural, 4-leg signalized intersection. Other factors that may be considered in selecting one or the other treatment for potential implementation include the context of the site and level of pedestrian and bicyclist activity or exposure at the intersection.

Section 5. References

American Association State Highway and Transportation Officials (AASHTO). *Highway Safety Manual*, 2010.

Carter, D. L., W. W. Hunter, C. V. Zegeer, S. J. Richard, and H. F. Huang. *Pedestrian and Bicyclist Intersection Safety Indices: Final Report*, Report No. FHWA-HRT-06-125, Federal Highway Administration, 2006.

National Highway Traffic Safety Administration (NHTSA). Fatality Analysis Reporting System (FARS). http://www.nhtsa.gov/FARS. Accessed 2018.

Transportation Research Board (TRB). *Highway Capacity Manual*, 2016.