4 SAFETY

4.1 Purpose and Overview

The purpose of this document is to provide guidance on safety analysis procedures for specific transportation planning and project development applications with a safety component. All planning and project development efforts need to be individually scoped as there are a number of different tools and techniques that can be applied. APM Section 4.1.2 identifies the recommended safety analysis procedures for common planning and project development applications.

The primary goal of any safety analysis presented in this chapter is to promote a proactive approach to reducing the frequency of fatal and serious injury (Injury-A) crashes. This is consistent with the Oregon Transportation Plan (OTP) that states "it is the policy of the State of Oregon to continually improve the safety and security of all modes and transportation facilities for system users including operators, passengers, pedestrians, recipients of goods and services, and property owners." The Oregon Transportation Safety Action Plan implements the OTP policy.

The first edition of the Highway Safety Manual (HSM) provides the technical foundation for many of the procedures discussed in this chapter. However, this chapter does not replicate the entire guidance of the HSM, and the reader is encouraged to consult the HSM directly where appropriate. The HSM is published by the American Association of State Highway and Transportation Officials (AASHTO) with support from the Federal Highway Administration (FHWA), the Institute of Transportation Engineers (ITE), and the Transportation Research Board (TRB) Highway Safety Performance Committee (ANB25).

The HSM is a national guide—and the first of its kind—providing science-based methods, procedures, and measures that integrate quantitative estimates of crash frequency and severity into roadway planning, evaluation, and project development. Prior to the HSM, crash analysis for planning and project development was typically limited to simple evaluations of crash data and somewhat subjective analysis. Evaluations of future safety performance were primarily limited to meeting design standards, with few options for comparing alternatives. In contrast, the tools in the HSM allow safety to become a meaningful performance measure that can be implemented at any stage of the transportation decision-making process.

HSM methodologies are provided to assist agencies in their effort to integrate safety into their decision-making processes, but are not intended to be a substitute for the exercise of sound engineering judgment. No standard of conduct or any duty toward the public or any person shall be created or imposed by the publication and use or nonuse of the HSM. The HSM does not supersede publications such as the MUTCD, the AASHTO Green Book, or other AASHTO and agency guidelines, manuals and policies.

As stated in the HSM, it is neither intended to be, nor does it establish, a legal standard of care for users or professionals.

HSM screening tools provide a robust methodology for objectively evaluating historical crash data based on frequency, severity, collision type, and other crash characteristics. The screening tools identify locations with the highest potential for reducing the frequency and severity of crashes and, by identifying factors contributing to the crashes, help choose effective potential countermeasures. Screening tools are discussed in APM Section 4.3.

The HSM Predictive Method is the first comprehensive model for estimating the frequency and severity of crashes based on traffic, roadway, and roadside characteristics. Predictive analysis can be applied to quantify the safety impact of design alternatives and forecast scenarios, using the understandable language of crash frequency and severity. Predictive analysis can also be applied in conjunction with historical data analysis to overcome statistical limitations inherent in historical data analysis. Predictive tools are discussed in APM Section 4.4.

The HSM framework also provides local agencies a methodology to expand on the foundation of the HSM by calibrating to local conditions and developing custom safety performance functions (SPFs). ODOT's webpage on the HSM includes information on completed and future research projects.

The APM does not address ODOT highway safety program procedures or traffic operations-level safety analysis. This includes road safety audits, collision diagrams, detailed safety investigations, and benefit-cost analyses. Contact the Traffic-Roadway Section for procedures related to those programs.

4.1.1 Statewide Crash Rate References

Statewide average crash rates are used in the critical crash rate analysis method and are useful resources for informal discussions of crash frequency.

The Oregon State Highway Crash Rate Tables are published annually by the ODOT CAR Unit. Crash Rate Table II shows statewide average crash rates for each of the last five years, by urban and rural area and by roadway classifications for state highways. These crash rates are based on overall crash frequency and total vehicle miles traveled on mainline state highways. Federal functional classifications can be found on the ODOT Federal Functional Classification (FC) webpage.

Exhibit 4-1 shows intersection crash rates by land type and traffic control, based on a 2011 assessment of data from 2003-2007. The crash rates here are based only on crashes that occurred at an intersection or because of an intersection and are given as a rate per million vehicles entering the intersection [million entering vehicles (MEV)].

Intersection crash rates also need to be compared to the published statewide 90th percentile intersection crash rates in Exhibit 4-1. Any rates close to or over the 90th percentile rates need to be flagged for further analysis. The intersection crash rate is calculated by the following formula:

$$Intersection\ Crash\ Rate\ per\ MEV = \frac{Annual\ Number\ of\ Crashes\ x\ 10^6}{(AADT)x\ (365\ days/year)}$$

The values shown in Exhibit 4-1 represent the 90th percentile crash rates from a study of 500 intersections in Oregon. The crash rates are grouped by rural/urban, signalized/unsignalized, and three-leg/four-leg intersections. Intersections with crash rates that exceed the 90th percentile values shown in the table should be flagged for further analysis. For more information on crash rates and using this table, see Section 4.3.4 Critical Crash Rate.

Exhibit 4-1: Intersection Crash Rates per MEV by Land Type and Traffic Control

	Rural				Urban			
	3SG	**3ST**	**4SG**	**4ST**	**3SG**	**3ST**	**4SG**	**4ST**
No. of Intersections	7	115	20	60	55	77	106	60
Mean Crash Rate	**0.226**	**0.196**	**0.324**	**0.434**	**0.275**	**0.131**	**0.477**	**0.198**
Median Crash Rate	0.163	0.092	0.320	0.267	0.252	0.105	0.420	0.145
Standard Deviation	0.185	0.314	0.223	0.534	0.155	0.121	0.273	0.176
Coefficient of Variation	0.819	1.602	0.688	1.230	0.564	0.924	0.572	0.889
90th Percentile Rate	**0.464**	**0.475**	**0.579**	**1.080**	**0.509**	**0.293**	**0.860**	**0.408**

Source: Assessment of Statewide Intersection Safety Performance, FHWA-OR-RD-18, Portland State University and Oregon State University, June 2011, Table 4.1, p. 47.

Note: Traffic control types include
3SG (three-leg signalized),
3ST (three-leg minor stop-control),
4SG (four-leg signalized),
4ST (four-leg minor stop-control).

For intersections other than the configurations shown in Exhibit 4-1, there are usually too few locations with that intersection configuration to provide statewide statistics. There are some stop controlled intersection configurations that could be approximated as indicated in Exhibit 4-2 and Exhibit 4-3 below. Any other intersection configurations not in Exhibit 4-1, Exhibit 4-2, or Exhibit 4-3 should by default be flagged for further analysis, since the unusual configuration is likely to warrant a closer look at the crashes.

Exhibit 4-2: 3 Legged Stop Control, with Driveway(s) into Intersection

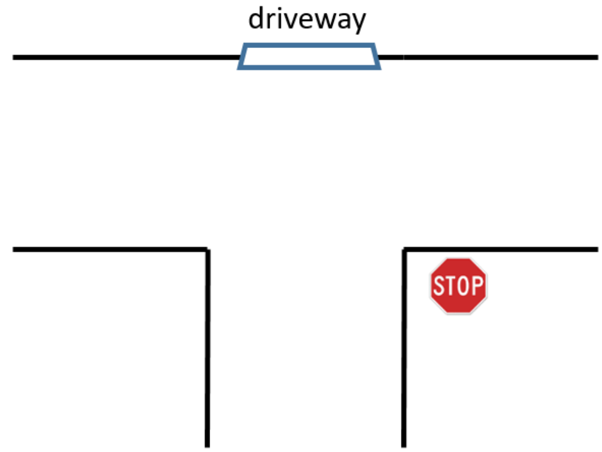
3 legged stop control, with driveway(s) into intersection

at what would be a fourth leg location.

Crash rate higher than the reference rate could indicate that the driveway volumes are affecting safe operation of the intersection.

If the driveway volume is low compared to the opposite minor leg, the 3ST reference crash rate could be applied.
Example:
Rogue River, E. Main at Broadway St.

If the driveway volume is high compared to the opposite minor leg, the 4ST reference crash rate could be applied.
Example:
Bend, Cooley Rd at NE Hennell Rd, Bend



Rogue River, E. Main at Broadway St.

Bend, Cooley Rd at NE Hennell Rd

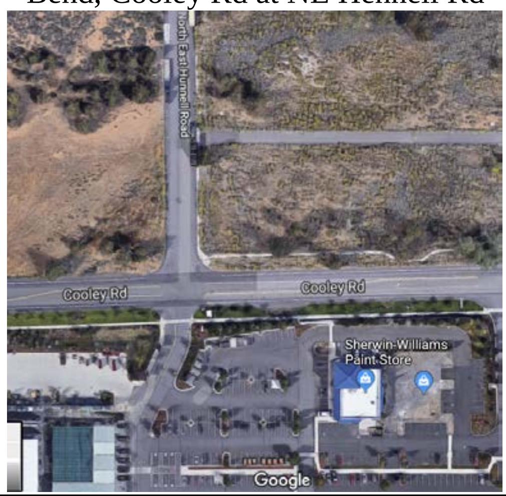
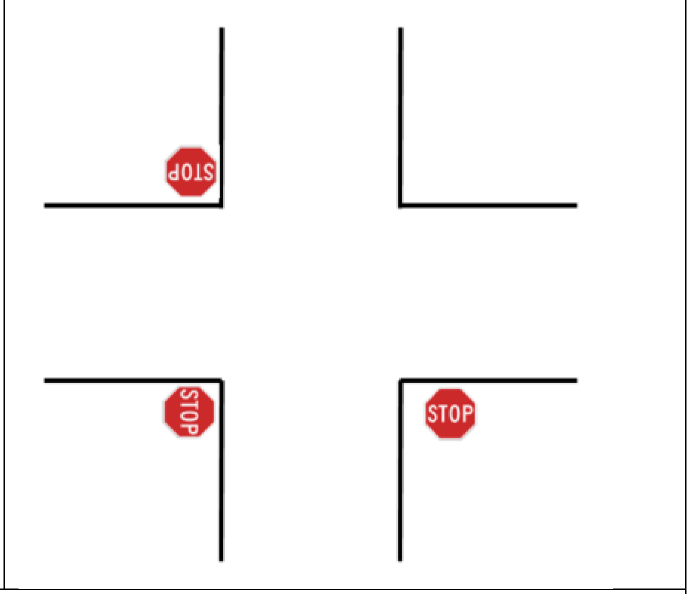


Exhibit 4-3: 4 Legged Intersection, 3 Way Stop

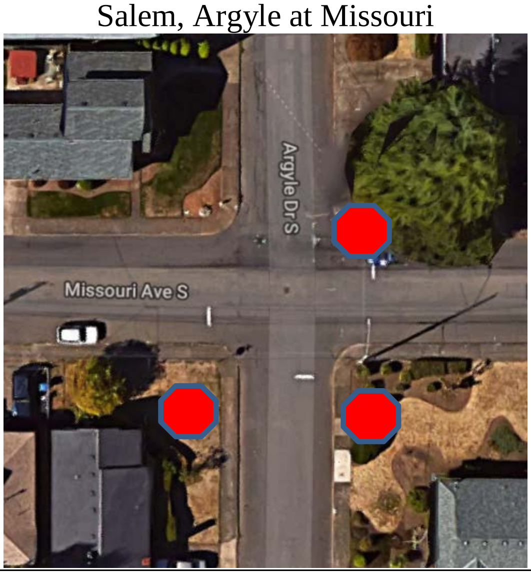
4 legged intersection 3 way stop

This configuration could apply the 4ST reference crash rate, since the minor legs have left turn conflicts similar to the 4ST.

Example:
Salem, Argyle at Missouri



Salem, Argyle at Missouri



Street view, looking west.

4.1.2 Tools and Procedures by Application Type

Safety analysis tools should be specified during the scoping process. Model scoping language is provided in APM Chapter 2. In order to facilitate scoping of tools, this section describes the recommended safety analysis tools and procedures for common application types as shown in Exhibit 4-4. Safety analysis tools are identified in order of increasing level of effort in the chart going from left to right. Plan or project level of detail is shown in increasing level of detail in the chart going from top to bottom. Best practice/recommended methods are shown with closed circles, while open circles identify optional or supplemental methods.

Exhibit 4-4: Applicability of Safety Analysis Tools by Plan or Project Type

Level of Effort +

Details +

Plan or Project Type	Other Methods			Highway Safety Manual (HSM) Methods					Other Tools
					Statistical Crash Data Screening		Predictive Methods		
	State Crash Rate	SPIS	Queue	CMFs	Critical Crash Rate	Excess Proportion of Specific Crash Types	Net Change in Predicted Crash Frequency or Predicted Crashes	Excess Expected Crash Frequency	PlanSafe
System Plans (TSP, RTP etc.)	○	●		●	●	●			○
MMA's	●	●	●	○	○	○			
Facility Plan	○	○	○	○	○	○	●	●	
Development Review	○	○	○	○	○	○	●	●	
NEPA / Project Development	○	○	○	○	○	○	●	●	

● Best practice or recommended method
○ Supplemental methods

The tools and procedures recommended here describe the crash analysis appropriate for the scope and scale of typical applications. A balanced approach to safety analysis should also consider queues, sight distances, safe and convenient crossing opportunities, and other safety-related techniques where appropriate for the application context.

- All Applications:
    - Safety Priority Index System (SPIS) – Identify top 5% or 10% locations from the most recent three (3) SPIS Site listings
- RTPs, Transportation System Plans (TSPs) and High-Level Corridor Plans:
    - Critical Crash Rate – required
    - Excess Proportion of Specific Crash Types – required
    - Crash rate comparison – minimum requirement when other methods can't be applied. Compare intersection crash rates to the 90th percentile crash rates (Exhibit 4-1) and segment crash rates to Table II in the CARS crash rates tables.
    - PLANSAFE – optional, system-wide predictive method. Recommended if there are regional transportation network changes proposed or if there is an expectation of significant demographic changes.
    - Crash Modification Factors (CMFs) – Optional. Use to estimate potential crash reduction of alternatives.

- Multimodal Mixed-Use Areas (MMAs)
    - MMAs are governed by OARs which require that public safety is not compromised. The primary safety analysis methods recommended for MMAs are the OAR requirements:
        - If the area has a crash rate above statewide averages. Crash rates are generally considered on the mainline and the crossroad.
        - If the area includes a top 10% SPIS site
        - If existing or future traffic queues will create a safety concern on the mainline highway exit
    - The new safety analysis options could provide additional value for MMA analysis.
    - The Critical Crash Rate could be a complement to crash rates as described in the OARs.
    - Excess Proportion of Specific Crash Types can be used to identify crash patterns and multimodal safety concerns.
    - The HSM Predictive Method can also be used to evaluate an MMA location and identify mitigation needs before an MMA is granted, or could be incorporated into guidelines for evaluating plan amendments within MMAs.
- Facility Plans/Refinement Plans:
    - HSM Predictive Method – required if valid model exists
        - Excess Expected Crash Frequency – use for existing conditions evaluation
        - Net Change in Predicted Crash Frequency – use for alternatives evaluation
    - If no valid model exists:
        - Use Critical Crash Rate, Excess Proportion of Specific Crash Types, and statewide crash rate comparisons for existing conditions
        - Use CMFs for alternatives evaluation
- Development Review:
    - HSM Predictive Method – recommended if valid model exists
        - Excess Expected Crash Frequency – use for existing conditions evaluation
        - Net Change in Predicted Crash Frequency – use for alternatives evaluation
    - If no valid model exists:
        - Use Critical Crash Rate, Excess Proportion of Specific Crash Types, and statewide crash rate comparisons for existing conditions
        - Use CMFs for alternatives evaluation
- Project Development / National Environmental Policy Act (NEPA) Work:
    - HSM Predictive Method – required if valid model exists
        - Excess Expected Crash Frequency – use for existing conditions evaluation
        - Net Change in Predicted Crash Frequency – use for alternatives evaluation
    - If no valid model exists:
        - Use Critical Crash Rate, Excess Proportion of Specific Crash Types, and statewide crash rate comparisons for existing conditions
        - Use CMFs for alternatives evaluation

- Countermeasure Development:
    - Using site characteristics and analysis results, identify contributing factors
    - Document Crash Modification Factor(s)
    - Perform additional geometric safety assessments, as applicable:
        - Intersection functional area
        - Sight distance
        - Conflict points
        - Access management

4.2 Crash Data

Crashes are used as the basis of safety analysis presented in this chapter. Crash frequency (number of crashes per year) and crash severity (rating based on most severe injury sustained in a crash) are fundamental indicators of the "safety" of a roadway.

Observed crash data provides information for describing and analyzing crash frequency and severity for historical time periods. Predictive methods proactively estimate crash frequency and severity for situations where observed crash data are not available, such as for future conditions. This chapter focuses on analysis of "objective" safety, which is based on quantitative measures that are independent of the observer. Objective safety is not directly experienced by a traveler, unless he or she is involved in a crash. In contrast, analysis of "subjective" safety involves the perception of how safe a person feels while using the transportation system. An assessment of subjective safety for the same location may vary between observers, and techniques for assessing the subjective safety of a location are not covered in this chapter. Subjective safety is an important component of many design and policy decisions. A person's choice of mode and route is strongly affected by how safe and comfortable the mode and route feels.

4.2.1 ODOT Crash Data Sources

The ODOT Crash Analysis and Reporting Unit (ODOT CAR) maintains a statewide crash record database that includes all reported crashes involving a motor vehicle on public roads. These data are collected by the Department of Motor Vehicles from police and driver reports then provided to ODOT CAR for quality assurance, standardization, and distribution. ODOT CAR produces a variety of publications annually that summarize crashes throughout the state of Oregon.

Crash data only include reported crashes to the Department of Motor Vehicles (DMV). Many crashes are not reported because they fall under the $2,500 reporting threshold or are just not reported (i.e., single vehicle incident, or on tribal lands). Errors can still occur in the coded crash records so it is important to carefully review and note any anomalies. Reporting errors on officer reports and DMV forms and officer reports such as crash location are common and while the crash reporting technicians attempt to reconcile them, sometimes data are not available or is incomplete. This is why sometimes perceived crash issues from local residents differ from available crash data. See Chapter 3 for more information.

The Crash Data System provides analysts access to detailed crash reports for a custom study area and time period. The Crash Data System can be accessed online on the Internet through ODOT's Unified Access Gateway and ODOT's Intranet site.

The Crash Data System provides tools for querying crash data by jurisdiction, location, and time. Crash data formatting and querying is different for state highways, city streets (non-state roads within city limits), and county roads (non-state roads outside city limits). Crash data can be downloaded in print-formatted or spreadsheet-formatted reports. Report download options include:

- **Summary by Year CDS150:** A general summary of crashes for the queried location, displayed by year, collision type, and generalized severity (fatal, nonfatal injury, property damage only).
- **Crash Location CDS390:** A detail report with a single line of data for each crash, including location, date, collision type, injury severity, and contributing factors.
- **Comprehensive (PRC) CDS380:** A detail report with at least three lines of data for each crash, including a row for every vehicle and participant in the crash. Summary includes location, date, collision type, injury severity, contributing factors, and more.

Data extracts are also available, providing unformatted full access to records for every crash, vehicle, and participant individually. Data extracts are available as a comma-delineated text document or as an Access database. The Access database includes code definitions and pre-defined report queries, making it a valuable resource for analysts familiar with database software.

The Comprehensive (PRC) CDS380 report or data extracts are recommended for use with the analysis procedures listed here, as these are the only formats that include the full injury severity scale (KABCO) and identify crashes involving pedestrians or bicyclists. The summary reports identify crashes involving pedestrians, but not bicyclists, and only include severity as fatal, nonfatal injury, or property damage. Summary reports may not include sufficient information for all analysis methods described in this chapter.

The crash data reports are heavily code-based and use of the Statewide Crash Data System Motor Vehicle Traffic Crash Analysis and Code Manual is required for a full understanding of the crash data. This manual and the online help documents provide additional important information about the crash data and reports and are available through the ODOT CAR Publications page or from within the Crash Data System.

Crash data are geocoded with latitude and longitude coordinate values. This allows for easy display on a map using a Geographic Information System (GIS) such as ArcMap, QGIS, or other online tools. If crash data are mapped using coordinate values, care should be taken to identify any records with the "Unlocatable_Flag" indicating that the coordinates are nonspecific default values.

Caution should be exercised when identifying actual crash locations from reported data. Crashes may be reported at the nearest integer milepoint or intersection even if they occurred hundreds of feet away. Crash data should be checked for discrepancies, such as where a crash occurred on a curve but where the reported location is a straightaway section.

4.2.2 Crash Characteristics, Trends, and Patterns

Crash analysis involves identifying trends and patterns on facilities. Analyzed crash types or severities may be all crashes or a more specific subset of crashes, such as fatal and serious injury crashes. These trends can then be used to identify applicable countermeasures for future mitigation. For guidance on performing a detailed on-site investigation and diagnosis of a safety trend, refer to the ODOT Safety Investigations Manual.

ODOT crash data includes many characteristics that can be used to identify trends and patterns. The analysis methods in this chapter primarily use the following characteristics:

- **Crash Location:** Geographical crash location is described by milepoint, distance to nearest intersection, and latitude and longitude coordinates.
- **Intersection-Related:** Crashes are identified as located at an intersection or related to the functioning of an intersection.
- **Driveway-Related:** Crashes are identified that are related to the use of a driveway.
- **Severity**: Crash severity is equal to the most serious injury sustained by anyone involved in the crash, based on the on-scene assessment (but which may not align with final medical determination of injuries). Severity is ranked on the KABCO scale:
    - K – Fatal injury, an injury that results in death
    - A – Incapacitating injury, a nonfatal injury that prevents the person from walking, driving, or doing activities they were capable of before the injury
    - B – Non-incapacitating evident injury, an injury that is evident to observers at the scene of the crash
    - C – Possible Injury, an injury or claim of an injury that is not evident to observers at the scene of the crash
    - O – No injury, also described as Property Damage Only (PDO)
- **Collision Type:** This field describes the intended movements of the vehicle(s) at the time of collision. Crashes are coded as one of the following collision types:
    - Angle – Vehicles collided while traveling on crossing or perpendicular paths, such as would occur if a vehicle ran a red light and crashed into a vehicle traveling on the crossing roadway
    - Head-On – Vehicles collided while traveling in opposite directions, their forward movement impeded while attempting to occupy a location simultaneously
    - Rear-End –Vehicles collided while traveling in the same direction, with one vehicle hitting the rear end of the second vehicle
    - Sideswipe-Meeting –Vehicles collided while traveling in opposite directions, with the side of at least one vehicle involved
    - Sideswipe-Overtaking – Vehicles collided while traveling in the same direction, with the side of at least one vehicle involved
    - Turning Movement – Collision involved one or more vehicles turning, originally traveling on parallel paths

- Parking Maneuver – Collision involved one or more vehicles entering or leaving a parked position. Parking begins when a vehicle first exits the traffic lane and ends when a vehicle resumes travel in the traffic lane.
  - Backing – Collision involving one vehicle backing in a traffic lane that struck another vehicle also in a traffic lane, does not include parking maneuvers
  - Fixed-Object or Other-Object – Collision where one vehicle struck a fixed object or other object (identified in the event field) on or off the roadway
  - Pedestrian – A collision where the first harmful event was an impact between a vehicle in traffic and a pedestrian. Does not include crashes where pedestrians are injured subsequent to the first impact, in which case pedestrians are coded as supplemental events to the crash.
  - Miscellaneous Collision – Any crash that does not fall into the other collision type categories, including collisions with animals
  - Non-Collision – Crash involved only one vehicle and is not classifiable as any other collision, for example, a roll-over
- **Bicyclist Involvement:** This information is contained in "Crash Type" field, separate from the "Collision Type" field described above. Bicyclist involvement is designated with the "Pedalcyclist" description.

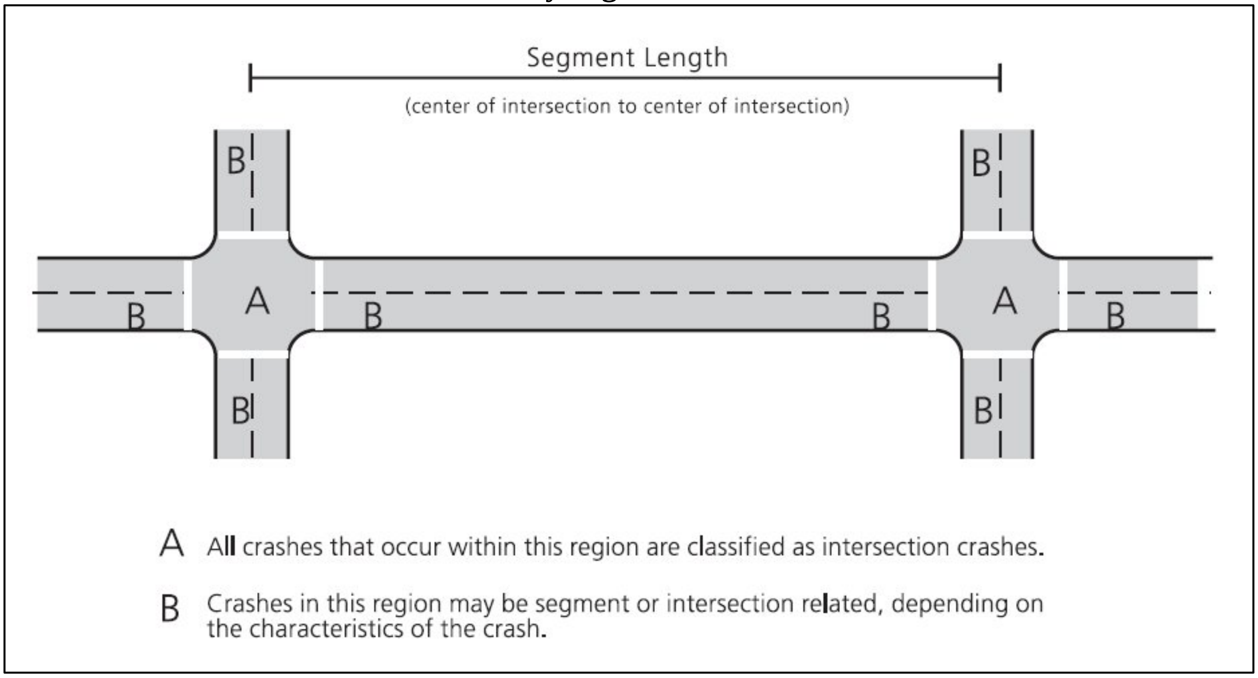
The crash data includes a wealth of other characteristics that may be of interest to the analyst, including direction of travel, lighting, weather and road conditions, work zones, vehicle and occupant details, use of alcohol and other drugs, use of safety restraints, cell phone use, speeding, and other contributing causes and events prior to the crash.

4.2.3 Assigning Crashes to Intersections and Segments

The safety analysis methods in this chapter require that each crash be uniquely assigned to an analysis site. Often this requires determining if the crash was intersection-related or roadway segment-related. The location and characteristics of the crash can be used to help determine the proper assignment for the crash.

Crashes that occur within an intersection are assigned to that intersection, as are crashes that occur on the intersection legs and are intersection-related in character. All crashes that are not assigned to an intersection are assigned to a segment. Exhibit 4-5 illustrates this concept. All crashes that occur in the "A" regions are intersection crashes. Crashes that occur in the "B" sections may be assigned to an intersection or the roadway segment on which they occur, depending on their characteristics.

Exhibit 4-5: HSM Definition of Roadway Segments and Intersections



Source: HSM Part C, Appendix A, Figure A-1

ODOT crash records include a field called "Intersection Related" that indicates a crash was related to an intersection, even though the crash was not coded as occurring at the intersection. (Note this field is not used for crashes coded as occurring at the intersection.) However, it may be that not all intersection-related crashes are identified with this field. The analyst should examine crashes near an intersection to determine if they have characteristics consistent with an intersection-related crash. For instance, rear-end collisions on an intersection approach are likely intersection-related. Conversely, run-off-the-road crashes or turning crashes near a driveway are likely segment-related. An understanding of the intersection's functional area (see APM Section 4.8.1) is also useful for assigning crashes to intersections and segments. The analyst also needs to observe operations in the field as part of the assessment, for example extent of queuing in determining intersection related crashes (see Chapter 3 for data collection procedures).

When performing both segment-based and intersection-based analyses, care should be taken to not double-count crashes. It is good practice to add a field identifying the analysis site to which each crash was assigned when including crash records in a project report.

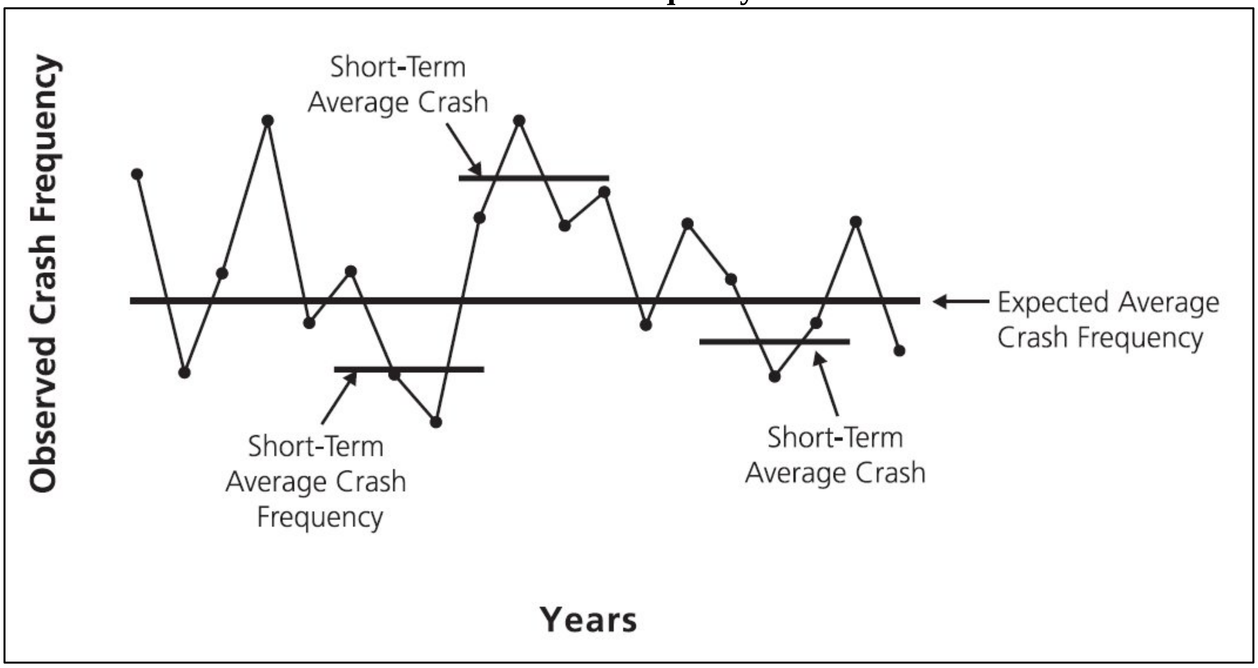
It should be noted that there may be more than one roadway segment analysis site between adjacent intersections, depending on roadway conditions. Segmenting, the process of dividing the study area into homogeneous analysis sites, is discussed in APM Sections 4.3.3 and 0.

Further information on assigning crashes to intersections and segments can be found in the HSM Part C, Appendix A, Section A.2.3.

4.2.4 Regression-to-the-Mean

Crashes are rare and random events, in that they represent a very small proportion of all events occurring on the transportation system and are partially influenced by factors that are unpredictable. As such, there is a natural variability in crash frequency at any specific location that should be considered when doing a crash analysis. This natural variation means that short-term crash frequencies using samples of one to five years of data may vary significantly from the long-term average crash frequency. Exhibit 4-6 illustrates this phenomenon. It is difficult to tell if the short-term sample represents a high, average, or low point in the natural variation of the crash frequency.

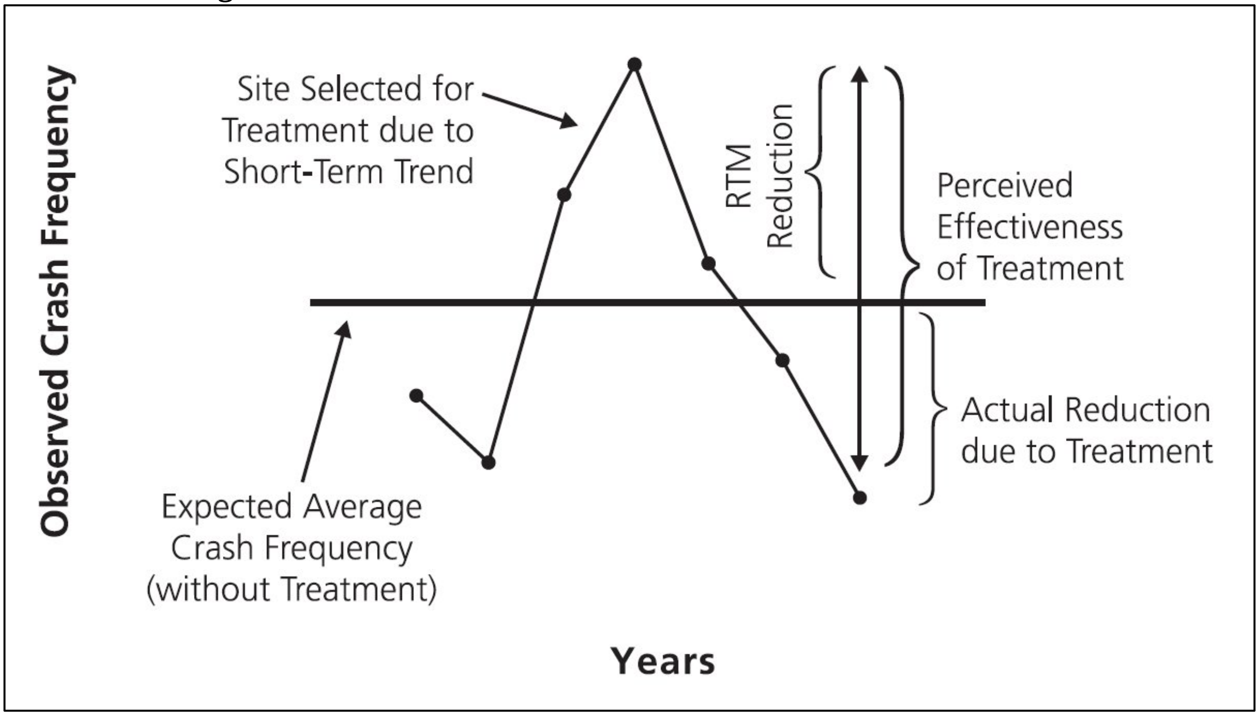
Exhibit 4-6: Variation of Short-Term Crash Frequency



Source: HSM Part A, Chapter 3, Figure 3-4

When a relatively high crash frequency is observed using a short-term sample, it is statistically probable that the next observation of that location will have a lower crash frequency. Similarly, when a low crash frequency is observed, it is likely that subsequent observations will be higher. This phenomenon is known as regression-to-the-mean (RTM), and is illustrated in Exhibit 4-7.

Exhibit 4-7: Regression-to-the-Mean Bias



Source: HSM Part A, Chapter 3, Figure 3-5

In a safety analysis, the effects of RTM can lead to a selection bias that prioritizes and evaluates countermeasures based on short-term trends. This may obscure locations with a higher expected average crash frequency or make it difficult to determine the actual reduction in expected average crash frequency due to a countermeasure.

Using a long-term sample is a way to account for RTM, and it is recommended that five years of crash data be used whenever possible. The predictive method described in this chapter uses statistical models to estimate the expected average crash frequency for a location with specific characteristics. Another way to account for RTM is to combine the predictive method with crash data [known as the Empirical-Bayes (EB) Method].

The analyst should be mindful of variations in conditions that may need to be accounted for when using multiple years of crash data—such as traffic volume changes, geometric and control changes, or disruptions due to construction. The predictive method is performed on a year-by-year basis, reflecting variations in conditions. When using screening methods, care should be taken to not include data from times with fundamentally different conditions.

4.2.5 Tools for Summarizing Crash Data

Crash Decoder Tool

The Crash Decoder Tool is an Excel-based spreadsheet with macros that uses the Comprehensive (PRC) CDS380 crash report (in Excel format) and the Excel look-up tables to translate the information. Once the sheet has decoded the information, filters can be applied to the dataset to investigate specific locations or issues. This tool also allows the analyst to create crash graphs that are helpful in both analysis and reporting. This tool can be used on all roadways. It is available on the ODOT Highway Safety Webpage. For more information refer to Appendix 4A.

Crash Graphing Tool (ODOT Employees Only)

The Crash Graphing Tool summarizes crash information of the "Direction" listing (in an Excel format) report from the State Highway Crash Reports and presents the information in standard graphs and charts. This report only analyzes state highways. Only ODOT employees can access this internal tool by contacting Information Services. For more information refer to Appendix 4A.

Crash Summary Database (ODOT Employees Only)

The Crash Summary Database, produced annually since 1990, is useful to generate quick summary reports that are often sufficient to answer questions when there is not time to do a detailed analysis. This software must be installed by an Information Services field technician. The crash summary database is a product of the most current Safety Priority Index System (SPIS) run so it uses the same three years of data. The crash summary gives an estimated crash rate based on the number of crashes, the average of the AADTs at the beginning and ending mile points of the segment and the numeric difference in the same mile points. This summary does not account for interruptions in the mile point distance (equations) or variation in the volumes when crossing multiple segments. The output reports only an estimated value along with the highest and number of SPIS sites within the section. It should not be used to report a formal crash rate unless all of the above items have been accounted for. Details on pulling crashes from the crash summary database, including use of ArcGIS, are found in Appendix 4A.

4.2.6 What Data to Report

When reporting the results of a crash analysis the narrative should describe the data and assumptions used, trends observed in the data, and the results of any crash analysis performed. Special consideration should be given to characterizing fatal and injury-A crashes and crashes involving transit, pedestrians, and bicyclists. The appendix should include data sufficient to reproduce the analysis, including the complete crash records used.

Try to use words like "more crashes than expected," "over-representation of crashes," "requires more investigation," or "will likely reduce crashes" when speaking about safety review locations.

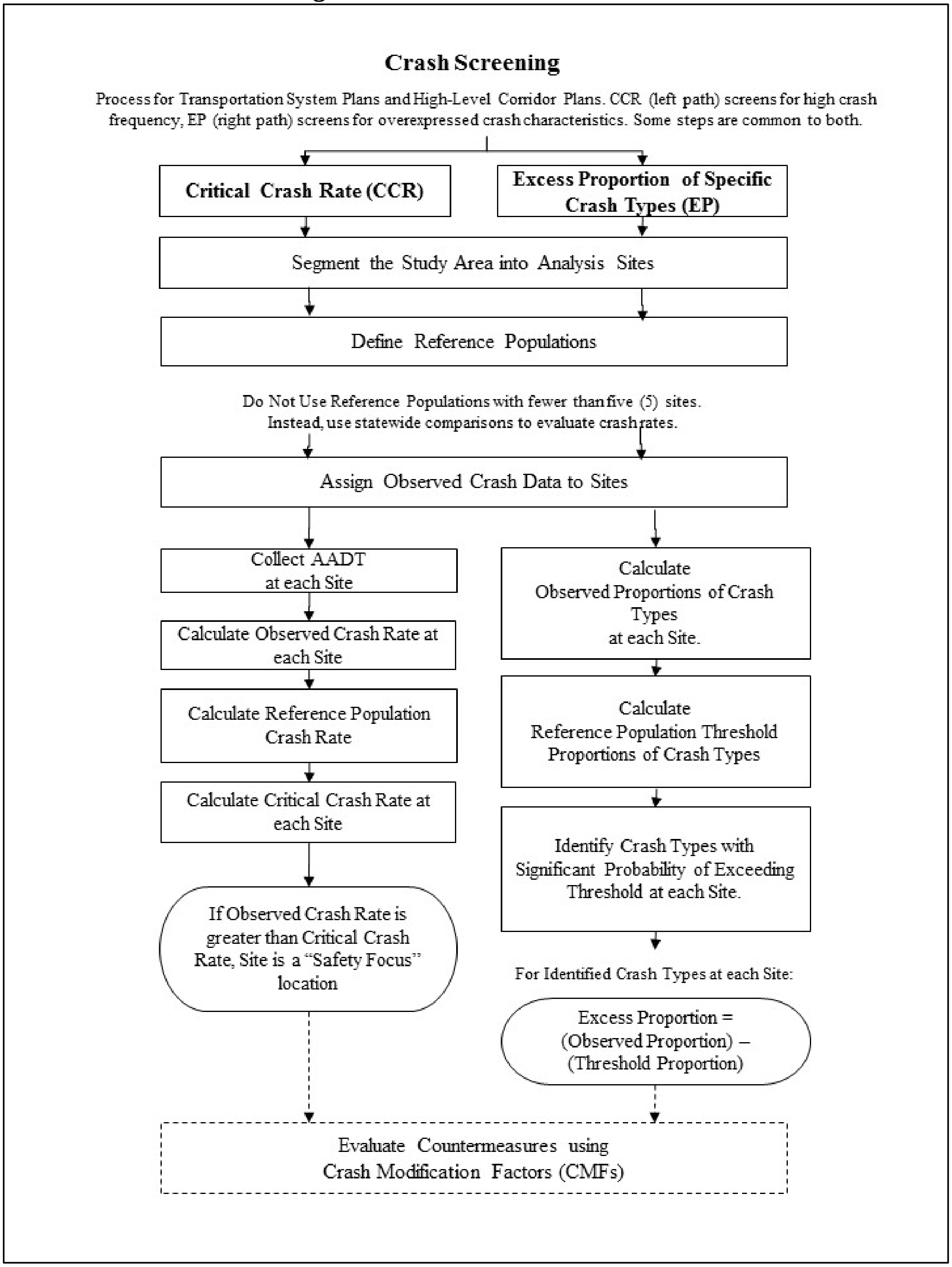
These words are more defensible because they are based on quantitative data and analysis. Avoid using subjective or qualitative words like “problem,” “hazard,” “unsafe,” etc.

- Crash Analysis Narrative
  - Data sources
  - Years of analysis
  - Assumptions used, including reference population descriptions
  - General crash trends and traffic conditions
  - Description of fatal, injury-A, transit, pedestrian, and bicycle crashes
- Crash Analysis Results Summary (as applicable)
  - Crash frequency per year at each study location by severity and by collision type
  - Crash rates and critical crash rates, including comparisons to statewide averages
  - Locations exceeding critical crash rates
  - Locations with an excess proportion of specific crash types
  - Excess expected average crash frequency
  - Predicted average crash frequency
  - PLANSAFE results
- Appendix (as applicable)
  - Crash records, including the corresponding study location assigned to each
  - Reference population statistics and descriptions
  - AADT values used for each study location
  - Unabridged critical crash rate results
  - Unabridged excess proportion of specific crash type results
  - Predictive method characteristics and results

4.3 Screening Methods

Screening methods are used to quickly characterize observed crash data from a large study area using a minimum of extra data. The results are used to identify a smaller set of locations that can then be analyzed in more detail. The HSM discusses network screening in more detail in Part B, Chapter 4. Screening methods are recommended for use with large-scale planning efforts such as Transportation System Plans (TSPs) and refinement plans. The flow chart in Exhibit 4-8 gives an overview of the process for crash data screening.

Exhibit 4-8: Crash Screening



4.3.1 Safety Priority Index System (SPIS)

Recommended Uses	All project types
Data Required	None
More Information	Safety Priority Index System website

The Safety Priority Index System (SPIS) is a statewide network screen for crash hotspots, using a methodology developed by ODOT in 1986 to flag potential safety issues on state highways. Major revisions have occurred from the original process. SPIS All-Roads covers all local roadways that have traffic volume data available in addition to state highways (typically these include all functionally classed public roads in Oregon).

The SPIS score is based on three years of crash data, and has three components: crash frequency, crash rate, and crash severity. ODOT bases SPIS analysis on 0.10-mile segments to account for variances in how crash locations are reported. To get a SPIS score, a segment must meet the segment qualifier of one of the following criteria:

- Three or more crashes have occurred at the same location over the previous three years.
- One or more fatal crashes have occurred at the same location over the previous three years.

> *Starting with the SPIS for crash years 2015-2017, it is planned to not include PDO (property damage only) crashes in the SPIS calculation, and for the segment qualifier to include one or more serious injury (Injury A) crashes.*

Locations with the top 5% and 10% are determined for each year of data and reported as locations for further investigation. Detailed documentation on SPIS can be found on the Safety Priority Index System website.

As part of a complete safety analysis, the analyst needs to identify and report any top 5% sites in the study area along with a summary of crash trend information that may contribute to the SPIS score. Overlapping segments should be reported as one group using only the highest SPIS score. The analyst should identify relevant improvements and/or countermeasures and whether any interim roadway or operational changes have taken place since the data were collected. Identified SPIS sites may differ from those highlighted using the previously identified in HSM screening methods due to differences in methodology.

The top 5% SPIS ranking requires the Region Traffic offices to conduct a safety investigation each year to determine if there is an appropriate safety improvement fix to the problem. Contact the Region Traffic office to obtain any applicable safety investigations performed in the study area. The SPIS ranking can be determined by contacting the appropriate Region Traffic office for assistance or on the SPIS webpage.

4.3.2 Oregon Adjustable Safety Index System (OASIS) (ODOT Employees Only)

OASIS was developed as an online safety analysis tool that does the same calculations as SPIS, but provides the opportunity for the user to change some parameters and filters that can be modified in OASIS include:

- Crash Years (whether to use three of five years of crash data)
- Segment Length
- Segment Qualifier (minimum crash history required for inclusion in analysis)
- Road Jurisdiction
- Collision Type
- Weather condition
- Light Condition
- Road Surface Condition
- Special Conditions:
    - Work Zone Involved
    - Speed Involved
    - Alcohol or Drugs Involved
    - Pedestrian or Bike Involved
    - Truck Involved
    - Deer or Elk Involved
    - Cell Phone Involved
    - Intersection Involved
    - Roadway Departure Involved
    - Curved Involved
    - Signalized Involved
- Scoring Formula and Weighting

The OASIS tool allows the user to quickly create a statewide custom safety screening analysis, for example, examining only crashes involving pedestrians or bicyclists. This program is available only to Traffic Roadway staff and ODOT Region Staff.

Since parameters can be changed, OASIS data should be carefully reported to indicate parameters used, and only compared to results of the same input parameter set. Users should also be cautioned that OASIS top 5%, top 10% are only for the particular OASIS run. If data from more than one run are combined, the percentile cutoffs need to be checked and reset appropriately, such as if doing OASIS for the entire state, both local roads and state highways.

4.3.3 Reference Populations

Recommended Uses	Critical Crash Rate and Excess Proportions of Specific Crash Types
Data Required	Crash frequency for target crash types of interest Site characteristics such as: Land Use (Rural/Urban) Geometry (Number of through lanes, intersection legs, etc.) Traffic Control (Signalized, two-way stop control, etc.) AADT Traffic Volumes
More Information	HSM Part B, Chapter 4, Section 4.2.2

Reference populations are central to the HSM screening methods presented in this chapter. Reference populations are groups of study sites (such as intersections or roadway segments) that have similar characteristics and serve as a comparison for evaluating safety performance.

Reference populations represent the typical safety performance for a specific type of study site. The safety performance of an individual study site is compared to the average safety performance of a reference population, using either the Critical Crash Rate method or the Excess Proportion of Specific Crash Types method to establish a performance standard specific to the study site and reference population.

Potential characteristics that can be used to define reference populations include:

- Traffic control (e.g., signalized, two-way or four-way stop control, yield control, roundabout)
- Number of approaches (e.g., three-leg or four-leg intersections)
- Cross-section (e.g., number of through lanes and/or turning lanes)
- Functional classification (e.g., arterial, collector, local)
- Adjacent land use (e.g., urban, suburban, rural)
- Traffic volume ranges [e.g., total entering volume (TEV), peak hour volume, average annual daily traffic (AADT)]
- Terrain (e.g., flat, rolling, mountainous)
- Access density (e.g., driveway and intersection spacing)
- Median type and/or width
- Operating or posted speed

Defining characteristics for a reference population will vary depending on the amount of detail known about each study site, the size of the network to be screened, and the focus of the safety analysis. Each reference population must contain at least five sites to be statistically valid.

Reference populations may be composed of “internal” or “external” sites, or a combination of both. Internal sites are locations being studied for the safety analysis; external sites are locations not being studied for the safety analysis.

For example, a city TSP may be screening the safety performance of a variety of intersections within the city. An internal reference population might be composed of four-way stop-controlled intersections being screened in the city. An external reference population might be composed of four-way stop-controlled intersections from similar adjacent cities.

Internal reference populations are the minimum requirement for network screening. Since all data are being collected for the project, there is no need to gather extra data. Internal reference populations are best for prioritizing locations within a study area or for identifying outliers within a study area.

External reference populations may be used when it is desired to assess statewide safety performance conditions to assess statewide safety performance, use the mean crash rate from Exhibit 4-1.

When reporting screening results, clearly identify the reference populations used.

4.3.4 Critical Crash Rate

Recommended Uses	Transportation System Plans and Corridor Plans May be used for existing conditions assessment in development review or project development when predictive methods are unavailable
Data Required	Crash frequency by severity AADT traffic volumes Reference populations
More Information	HSM Part B, Chapter 4, Section 4.4.2.5

Crash rates describe crash frequency in relation to traffic volume. Crash rates at intersections are typically given in units of crashes per million entering vehicles (crashes/MEV). Crash rates for segments are typically given in units of crashes per million vehicle miles traveled [crashes/million vehicle miles traveled (MVMT)]. It is recommended that Annual Average Daily Traffic (AADT) values be used in calculating crash rates. APM Section 5.7 contains procedures for calculating AADT. If AADT data are not available, Average Daily Traffic (ADT) can be substituted.

The Critical Crash Rate analysis method evaluates each study site's crash rate compared to the average crash rate of that site's reference population. Study sites with significantly higher crash rates (exceeding the Critical Crash Rate) are identified for further analysis.

The Critical Crash Rate method evaluates the overall magnitude of the observed crash rate for one target crash type at a time. Two variations on Critical Crash Rate are commonly used, one evaluating total crash rate and one evaluating the crash rate considering only fatal and injury-A severity crashes.

The Critical Crash Rate method does not allow for estimates of future safety performance and cannot be used for evaluating alternatives. This method does not address RTM, so short time periods (less than three years) should not be used. Crash rates also do not account for the non-linearity of crash frequency with respect to traffic volumes. Analysts should be aware that crash rates may be reduced simply by an increase in traffic volumes alone. A reduction in crash rate at higher traffic volumes is often the expected roadway behavior and does not indicate a fundamental change in underlying safety performance. The predictive methods discussed in APM Section 4.4 can address all three of these limitations.

A spreadsheet is available from the safety analysis tools section of the ODOT Transportation Development Planning Technical Tools website that automates much of the Critical Crash Rate calculations. A planning level method for calculating critical crash rates using the ODOT Visum Safety Add-In tool is found in Appendix 4A.

The general procedure for network screening using the Critical Crash Rate method is as follows:

1. Identify analysis sites and assign observed crashes (see APM Section 4.2.3)
2. For each analysis site, using the target crash frequency and AADT traffic volume calculate the crash rate (or observed crash rate) on a MEV basis
3. Establish reference populations and calculate the average crash rate for each reference population
4. Choose the desired statistical significance level (95% is recommended)
5. For each analysis site, calculate the reference population critical crash rate. This value is unique for each analysis site and is a function of the reference population average crash rate, traffic volume at the site, and the desired statistical significance.
6. For each analysis site, calculate the statewide comparison critical crash rate. This value is unique for each analysis site and is a function of the mean crash rate from Exhibit 4-1, traffic volume at the site, and the desired statistical significance.
7. Identify any sites where the observed crash rate is greater than the calculated reference population critical crash rates
8. Identify any sites where the observed crash rate is greater than the calculated statewide comparison critical crash rates
9. Identify any sites where the observed crash rate is greater than the published statewide comparison rates. Intersections should also be compared with the 90th percentile rates in Exhibit 4-1. Segments should also be compared with the average rates in Crash Rate Table II.

This process is repeated for each area of interest. The analysis should be done using a critical crash rate based on total crashes. An additional suggested analysis is to use a critical crash rate based on only fatal and injury-A severity crashes. If multiple sets of reference populations are being used (e.g., internal and external), the process is repeated for each set of reference populations.

The process is generally the same for intersections and for segments. Intersection critical crash rate analysis should use only crashes associated with intersections and segment critical crash rate analysis should use only crashes associated with segments (see APM Section 4.2.3).

For intersections and segments, the crash rate is derived using different measures of traffic exposure. For intersections, crash rates are derived using Million Entering Vehicles (MEV), while segments are derived using Million Vehicle Miles Traveled (MVMT).

$$MEV = \frac{AADT \times 365 \times n}{1{,}000{,}000}$$

$$MEV = Million\ \ Entering\ \ Vehicles$$

$$n = Number\ of\ \ Years$$

$$MVMT = \frac{AADT \times L \times 365 \times n}{1{,}000{,}000}$$

$$MVMT = Million\,Vehicle - Miles\ of\ \ Travel$$

$$L = Segment\ Length$$

$$n = Number\ of\ \ Years$$

Segments also must be divided into sites that are similar in character, as described in APM Section 4.3.3 on reference populations. Segment boundaries should be placed where the reference population changes, at intersections that have observed crashes, and at other logical breakpoints in order for segments not to exceed two or three miles in length. For some very long corridors such as in rural eastern Oregon, segments could be up to five miles in length. Segments should ideally be close to one mile in length. For urban areas, obtaining one mile segments is difficult, however the majority of urban crashes are intersection related. Short sections less than a half mile in length typically skew the crash rates and should be avoided.

However, it may not be possible to avoid short segments in which case the length should be normalized to a mile and the rate recalculated. This recalculated rate would be compared to Table II to see if it still exceeds. For example, if a 0.25 mi segment had a crash rate of 8.0 crashes per MVMT, then the normalized rate would be 8.0 crashes per MVMT x 0.25 mile = 2.0 crashes per MVMT.

For segments on milepointed highways, length may be calculated based on Begin and End Milepoint. All crashes (both intersection and non-intersection) are included in a Table II-based segment crash analysis. Segment lengths need to be adjusted if they contain a milepoint equation. Milepoint equations can be found from the Equations and Milepoint Range Report.

When reporting the results of this method, include the following for each target crash type:

- Crash frequency for each analysis site
- AADT (or ADT) traffic volume for each analysis site
- Reference population characteristics and summary statistics
- Observed crash rate for each analysis site
- Critical crash rate for each analysis site
- Sites identified as exceeding their critical crash rate

For this method to be statistically valid, there needs to be at least five to ten sites in each reference population. If there are fewer than five sites available to create a reference population, these methods do not apply (since there are not enough sites to screen). This method may also produce small crash rate variances that may overlook sites with a significant crash problem. Also, the sites within the study area reference populations may have different variances when compared to similar sites statewide. To minimize these issues, crash rates should also be compared to published statewide crash rates as described below. The Critical Crash Rate method can also be used for a statewide comparison by replacing the reference population average crash rate with the appropriate mean crash rate from Exhibit 4-1.

Segment crash rates should be compared to the appropriate average crash rate from the Oregon State Highway Crash Rate Tables, annually published by the ODOT CAR Unit. In this document, crash rates for given segments of all state highways are calculated and listed for each of the last five years.

Crash Rate Table II is the primary table used in segment crash rate analysis. It shows statewide average crash rates for each of the last five years, by urban and rural area, and by roadway classification. Federal functional classifications can be found on the ODOT Federal Functional Classification (FC) webpage.

The following examples illustrate the calculation of MEV, segment crash rates, and the calculation of Critical Crash Rates for intersections and segments.

Example 4-1: Segment Crash Rate Calculation and Comparison

A 1.6-mile principal highway segment in a rural area has experienced 22 reported crashes over the last three years. The segment AADT from the State Highway Vehicle Classification Data Report is 23,000.

$$\text{Rate} = \frac{\text{Number of Crashes X 1,000,000}}{\text{Length (in miles) X AADT X (Yrs X 365)}}$$

$$= \frac{22 \text{ X } 1,000,000}{1.6 \text{ X } 23,000 \text{ X } 3\text{Yrs X } 365}$$

$$= 0.55 \text{ Crashes per Million Vehicle Miles (MVM)}$$

As shown in the table below, the statewide average crash rates are:

2005	0.67
2006	0.69
2007	0.68
Average	0.68

The segment crash rate of 0.55 is less than the average statewide rate of 0.68.

Statewide Crash Rate Table

TABLE II: FIVE-YEAR COMPARISON OF STATE HIGHWAY CRASH RATES

Table II presents a comparison of state highway crash rates for the past five years, for urban and rural areas, by functional classification. Mileage is shown for the current data year only.

See Table IV for information on official highway mileage and VMT data.

JURISDICTION AND FUNCTIONAL CLASSIFICATION	MILES*	2007 Rate	2006 Rate	2005 Rate	2004 Rate	2003 Rate
TOTAL STATE HWY SYSTEM	**7,455.23**	**0.85**	**0.85**	**0.87**	**0.79**	**0.98**
Interstate Freeways	729.57	0.38	0.39	0.41	0.38	0.42
Other Fwys/Expressways	52.26	0.73	0.78	0.80	0.78	0.87
Non-Freeways (combined)	6,673.40	1.27	1.26	1.25	1.13	1.45
Other Principal Arterials	3,281.04	1.28	1.29	1.28	1.16	1.52
Minor Arterials	1,964.61	1.20	1.14	1.14	1.02	1.20
Urban Collectors	8.69	1.10	0.68	1.19	1.23	2.08
Rural Major Collectors	1,382.20	1.25	1.11	1.14	0.93	1.25
Rural Minor Collectors	36.86	0.64	0.66	1.30	0.32	1.30
Rural Local	0.00	0.00	16.52	4.23	2.68	8.06
Rural Areas	**6,414.01**	**0.58**	**0.58**	**0.59**	**0.51**	**0.59**
Interstate Freeways	539.37	0.28	0.29	0.31	0.25	0.26
Non-Freeways (combined)	5,874.64	0.79	0.77	0.77	0.68	0.80
Other Principal Arterials	2,658.39	0.68	0.69	0.67	0.61	0.71
Minor Arterials	1,839.04	0.99	0.93	0.98	0.83	0.97
Rural Major Collectors	1,340.60	1.24	1.08	1.10	0.92	1.20
Rural Minor Collectors	36.61	0.69	0.36	1.40	0.35	1.40
Rural Local	0.00	0.00	16.52	4.23	2.68	8.06

* Couplet and Roadway 3 data are included. Frontage road and connection data are excluded.

A segment crash rate that exceeds the statewide average crash rate may be an indication that further investigation is necessary, although it is possible that upon further investigation it may be determined that no improvements are necessary. Likewise, cost-effective improvements to reduce crashes could still be identified even with a segment crash rate lower than the statewide average.

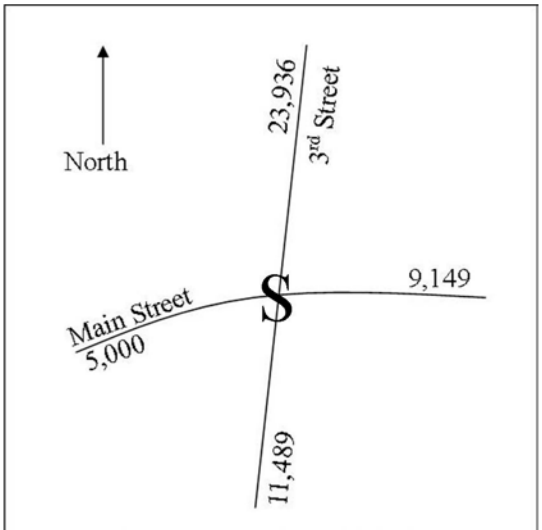
Example 4-2: Million Entering Vehicles (MEV)

As a part of an urban street modernization project, a safety analysis needs to be done for Main St. This street is a congested urban corridor with a mixture of unsignalized and signalized intersections with varying numbers of lanes.

Traffic counts were taken at each intersection and crashes for the previous five years have been compiled. In order to calculate the HSM Critical Crash Rate the total MEV is needed for each intersection.

Data Needs

Directional count data are needed for each leg of each intersection. If ADT-capable counts are not available and the best data available are the Traffic Volume Tables (TVT) or a non-directional tubular count, a 50/50 directional split can be assumed. For the intersection of Main St. and 3rd St., ADTs entering the intersection from each leg were developed and are shown in the diagram below. See Chapter 5 for the process to develop directional ADTs.



Entering ADTs at Main St and 3rd St

Step 1: Adjustment of ADTs to AADTs

The ADTs entering the intersection need to be converted to AADTs. See Chapter 5 for the process to develop the appropriate adjustment factors. Note: If using the TVT for volumes, this step does not apply. The volumes in the TVT have already been adjusted to AADT. In this case move directly to Step 2.

$$AADT = ADT \times Adjustment\ \ Factor\,*$$
$$Entering\ \ AADTs\ at\ \ Main\ \ Street\ \ and\ \ 3rd\ \ Street$$
$$AADT_{North} = 23936 \times 0.94 = 22500$$
$$AADT_{South} = 11489 \times 0.94 = 10800$$
$$AADT_{East} = 9149 \times 0.94 = 8600$$
$$AADT_{West} = 5000 \times 0.94 = 4700$$

* See Chapter 5 for steps to calculate the adjustment factor.

Step 2: Million Entering Vehicles (MEV)

$$Total\ Entering\ AADT = \sum Entering\ \ AADTs$$
$$Total\ Entering\ AADT_{Main\ Street\ at\ 3rd\ Street} = 22500 + 10800 + 8600 + 4700 = 46{,}600$$

$$MEV = \frac{Total\ Entering\ AADT \times 365 \times n}{1{,}000{,}000}$$
$$AADT = Annual\,Average\,Daily\,Traffic$$
$$n = Number\ \ of\ \ Years$$
$$MEV_{Main\ Street\ at\ 3rd\ Street} = \frac{46{,}600 \times 365 \times 5}{1{,}000{,}000} = 85.0\,MEV$$

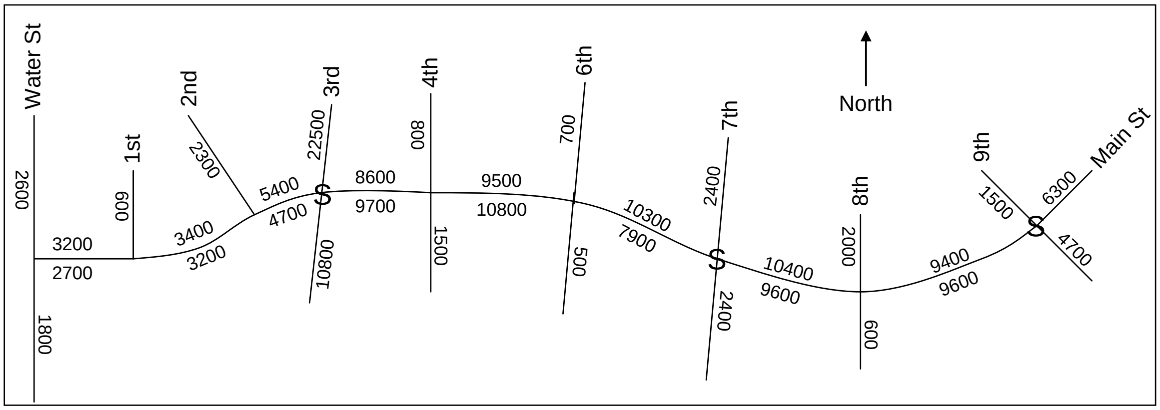
Example 4-3: HSM Critical Rate for Intersections with Internal Reference Population

As part of an urban street modernization project corridor plan, a safety analysis needs to be done for Main St. This street is a congested urban corridor with a mixture of unsignalized and signalized intersections with varying numbers of lanes.

The project engineer has created existing year average daily traffic (ADT) volumes from available intersection counts. The ADT counts were converted into AADT (an average value for 2005-2009 using appropriate seasonal factors and annual growth factors), which are shown as daily total entering volumes in the figure below. In addition, intersection crash data for the past five years are shown in the table below. Crash data are summarized by year and by severity.
A critical crash rate analysis will be performed considering all crashes and considering Fatal plus Injury-A crashes as the target crash type.

Data Needs

Existing Year Annual Average Daily Entering Traffic Volumes



Intersection Crashes per Year

Intersection	Type	Year					Total
		2005	2006	2007	2008	2009	
Water St.	Unsignalized	2	1	0	1	2	6
1st St.	Unsignalized	0	0	0	0	0	0
2nd St.	Unsignalized	0	0	0	0	1	1
3rd St.	Signalized	6	8	5	6	4	29
4th St.	Unsignalized	0	0	0	1	1	2
6th St.	Unsignalized	6	2	3	2	1	14
7th St.	Signalized	3	1	2	6	3	15
8th St.	Unsignalized	0	0	2	3	0	5
9th St.	Signalized	3	6	2	0	1	12
Total		**20**	**18**	**14**	**19**	**13**	**84**

Intersection Crashes by Severity

Intersection	Type	Severity					Total
		Fatal	**Inj. A**	**Inj. B**	**Inj. C**	**PDO**	
Water St.	Unsignalized	0	2	0	1	3	6
1st St.	Unsignalized	0	0	0	0	0	0
2nd St.	Unsignalized	0	0	0	0	1	1
3rd St.	Signalized	0	3	5	9	12	29
4th St.	Unsignalized	0	0	0	0	2	2
6th St.	Unsignalized	0	5	1	3	5	14
7th St.	Signalized	0	1	1	4	9	15
8th St.	Unsignalized	0	0	1	1	3	5
9th St.	Signalized	0	1	3	3	5	12
Total		**0**	**12**	**11**	**21**	**40**	**84**

The HSM Critical Rate screening method will be used to determine the intersections with the greatest need.

Note: All sample calculations given at the intersection of Water St. and Main St.

Step 1: At each intersection, calculate the volume on a Million Entering Vehicle (MEV) basis

$$(1) \quad MEV = \frac{AADT \times 365 \times n}{1{,}000{,}000}$$

$$MEV = Million \;\; Entering \;\; Vehicles$$

$$n = Number \; of \;\; Years$$

$$MEV = \frac{7{,}600 \times 365 \times 5}{1{,}000{,}000} = 13.9 \; MEV$$

Step 2: Calculate the crash rate at each intersection

$$(2) \quad R = \frac{Crash\ Total}{MEV_n}$$

$$R = Observed \;\; Crash \;\; Rate$$

Crash rate for all crashes

$$R = \frac{6}{13.9} = 0.43 \frac{Crashes}{MEV}$$

Crash rate for Fatal and Injury-A target crash type

$$R_{FA} \frac{2}{13.9} = 0.14 \frac{Fatal + A\ Crashes}{MEV}$$

Intersection	Daily Volume	MEV (1)	Crash Total	F+A Crash Total	Crash Rate (2)	F+A Crash Rate (2)
Water St.	7,600	13.9	6	2	0.43	0.14
1st St.	6,700	12.2	0	0	0.00	0.00
2nd St.	10,900	19.9	1	0	0.05	0.00
3rd St.	46,600	85.0	29	3	0.34	0.04
4th St.	21,500	39.2	2	0	0.05	0.00
6th St.	22,300	40.7	14	5	0.34	0.12
7th St.	23,100	42.2	15	1	0.36	0.02
8th St.	19,800	36.1	5	0	0.14	0.00
9th St.	22,100	40.3	12	1	0.30	0.02

Step 3: Calculate the average crash per population

(3a) Divide the intersections into varying populations (groups) based on operational (i.e., unsignalized/signalized/roundabouts) or geometric (i.e., three-leg/four-leg) differences. Only one reference population of sufficient size exists for this example. Six intersections fall under the unsignalized type (Type 1) reference population. There are not enough three-leg or four-leg unsignalized intersections to further subdivide the reference populations. The critical rate method cannot be used for the signalized intersections (Type 2) since there are only three in the reference population. TPAU will be contacted to propose adding external reference sites to the signalized reference population (not included in this example).

$$(3b)\ R_a = \frac{\sum_{i=1}(N_{obs,i})}{\sum_{i=1}(MEV_i)}$$

$R_a = Average\ crash\ rate\ for\ reference\ population\ a$

$R_{FA(a)} = Average\ Fatal + A\ crash\ rate\ for\ reference\ population\ a$

Average Crash Rate for Unsignalized Intersections reference population:

$$R_1 = \frac{6+0+1+2+14+5}{13.9+12.2+19.9+39.2+40.7+36.1}$$

$$= 0.17\ \frac{Crashes}{MEV}$$

Average Fatal + Injury-a Crash rate for Unsignalized Intersections reference population:

$$R_{FA(1)} = \frac{2+0+0+0+5+0}{13.9+12.2+19.9+39.2+40.7+36.1}$$

$$= 0.04\ \frac{Crashes}{MEV}$$

Equation (3b) is a reduced version of Equation 4-10 found in the 1st edition Highway Safety Manual, Volume 1, Chapter 4.

Step 4: Calculate a critical crash rate for each intersection

$$(4) \quad R_c = R_a + Confidence\ Level \times \sqrt{\frac{R_a}{MEV_n} + \frac{1}{2 \times MEV_n}}$$

$$R_c = Critical\ crash\ rate$$

$$R_a = Weighted\ average\ crash\ rate\ \ for\ reference\ population$$

Critical crash rate for all crashes

$$R_C = 0.17 + 1.645 \times \sqrt{\frac{0.17}{13.9} + \frac{1}{2 \times 13.9}} = 0.39\ \frac{Crashes}{MEV}$$

Critical crash rate for Fatal + Injury-A crashes

$$R_{FA(C)} = 0.04 + 1.645 \times \sqrt{\frac{0.04}{13.9} + \frac{1}{2 \times 13.9}} = 0.17\ \frac{F + A\ \ Crashes}{MEV}$$

Table 4-9 in the HSM (page 4-36) gives P-levels to correspond to differing confidence levels. Typical use would be 95% confidence (P=1.645).

Intersection	Intersection Population Type (3a)	Crash Rate (2)	Critical Crash Rate (4)	Over Critical (5)
Water St.	1	0.43	0.39	Over
1st St.	1	0.00	0.41	Under
2nd St.	1	0.05	0.35	Under
4th St.	1	0.05	0.29	Under
6th St.	1	0.34	0.29	Over
8th St.	1	0.14	0.30	Under

Intersection	Intersection Population Type (3a)	F+A Crash Rate (2)	F+A Critical Crash Rate (4)	Over F+A Critical (5)
Water St.	1	0.14	0.17	Under
1st St.	1	0.00	0.18	Under
2nd St.	1	0.00	0.14	Under
4th St.	1	0.00	0.11	Under
6th St.	1	0.12	0.11	Over
8th St.	1	0.00	0.11	Under

Step 5: Compare observed crash rate with critical crash rate

Compare the critical crash rate with the crash rate for each intersection. Any intersection with a crash rate that exceeds its critical rate should be flagged for further review.
In the above example, the following intersections were flagged for further analysis:

- Water St. and Main St.
- 6^{th} St. and Main St.

Step 6: Compare observed crash rate with statewide 90^{th} percentile rates (Exhibit 4-1)

The crash rates at all study intersections (including those without a reference population) are compared to the statewide 90^{th} percentile crash rates for urban three-leg minor stop-controlled (U3ST), urban four-leg minor stop-controlled (U4ST), and urban four-leg signalized (U4SG) intersections.

Intersection	Intersection Population Type	Observed Crash Rate	Statewide 90^{th} Percentile Crash Rate
Water St.	U3ST	0.43	0.293
1^{st} St.	U3ST	0.00	0.293
2^{nd} St.	U3ST	0.05	0.293
3^{rd} St.	U4SG	0.34	0.860
4^{th} St.	U4ST	0.05	0.408
6^{th} St.	U4ST	0.34	0.408
7^{th} St.	U4SG	0.36	0.860
8^{th} St.	U4ST	0.14	0.408
9^{th} St.	U4SG	0.30	0.860

In the above example, the following intersection was flagged for further analysis:

- Water St. and Main St.

Step 7: Conclusions

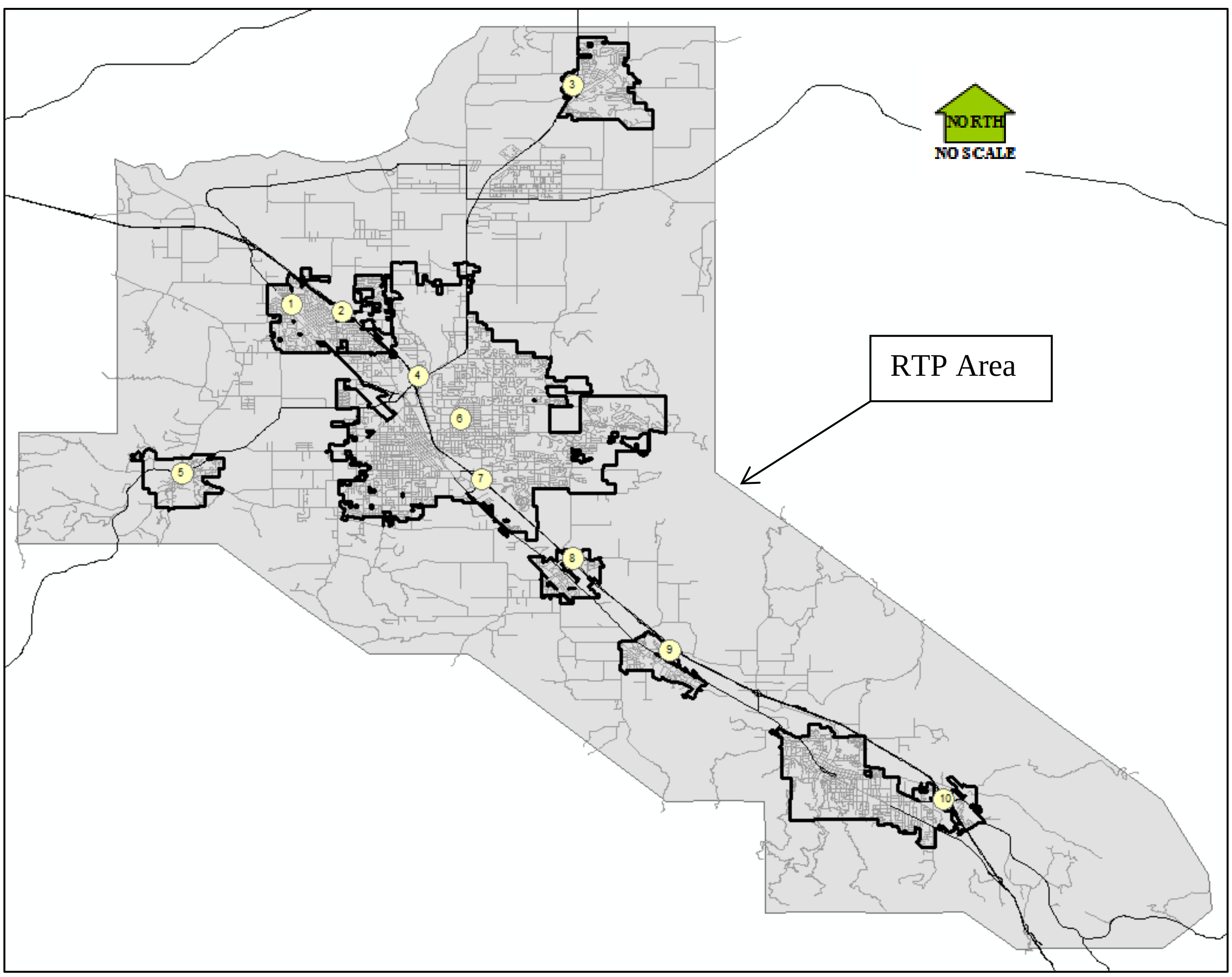
From the analysis, the intersections of Main St. and Water St. and Main St. and 6^{th} St. exceed the critical rate. Main St. and 6^{th} St. also exceeds the Fatal plus Injury-A critical rate, and the statewide 90^{th} percentile crash rate. These intersections are “safety focus” locations that need to be reviewed in more depth. At a minimum, crashes and patterns need to be identified and potential countermeasures indicated. More in-depth HSM predictive analysis could be done for the existing conditions and any later future conditions, which could also include finding the most cost-effective countermeasures.

Example 4-4: HSM Critical Rate for Intersections with Statewide Reference Population

As part of an RTP update, screening level statewide comparative safety analysis is to be performed on ten urban four-leg signalized intersections within the RTP area. The goal of this analysis is to identify intersections that have crash rates above other similar intersection types statewide. This analysis will consider all crash types and severities.
The project engineer has created existing year average daily traffic (ADT) volumes from available intersection counts and converted into AADT (total entering volumes). In addition, intersection crash data for the past five years are shown in the table below. Crash data are summarized by year and by severity.

Data Needs

<u>Existing Year Annual Average Daily Entering Traffic Volumes</u>



Intersection Crashes per Year

Intersection	Type	Year					Total
		2010	2011	2012	2013	2014	
1	Signalized	5	5	3	4	2	19
2	Signalized	4	3	5	4	2	18
3	Signalized	1	1	2	1	1	6
4	Signalized	4	1	1	5	5	16
5	Signalized	4	1	1	4	2	12
6	Signalized	3	3	4	3	3	16
7	Signalized	1	1	1	1	5	9
8	Signalized	4	1	4	5	4	18
9	Signalized	3	1	2	5	1	12
10	Signalized	1	4	1	2	1	9
Total		30	21	24	34	26	135

The HSM Critical Rate screening method will be used to determine the intersections with the greatest need.

Note: All sample calculations given for Intersection #1

Step 1: At each intersection, calculate the volume on a Million Entering Vehicle (MEV) basis

(1) $$MEV = \frac{AADT \times 365 \times n}{1{,}000{,}000}$$

$$MEV = Million\ \ Entering\ \ Vehicles$$

$$n = Number\ of\ \ Years$$

$$MEV = \frac{9{,}700 \times 365 \times 5}{1{,}000{,}000} = 17.7\ MEV$$

Step 2: Calculate the crash rate at each intersection

(2) $$R = \frac{Crash\ Total}{MEV_n}$$

$$R = Observed\ Crash\ Rate$$

Crash rate for all crashes

$$R = \frac{19}{17.7} = 1.07\ \frac{Crashes}{MEV}$$

Intersection	Daily Volume	MEV (1)	Crash Total	Crash Rate (2)
1	9,700	17.7	19	1.07
2	19,700	36.0	18	0.50
3	12,400	22.6	6	0.27
4	12,300	22.4	16	0.71
5	11,000	20.1	12	0.60
6	16,600	30.3	16	0.53
7	11,500	21.0	9	0.43
8	8,000	14.6	18	1.23
9	8,600	15.7	12	0.76
10	11,500	21.0	9	0.43

Step 3: Calculate the average crash per population

(3a) Because this is a statewide comparison, use the mean crash rate for Urban 4SG intersections from Exhibit 4-1.

Exhibit 4-1: Intersection Crash Rates per MEV by Land Type and Traffic Control

	Rural				Urban			
	3SG	3ST	4SG	4ST	3SG	3ST	4SG	4ST
No. of Intersections	7	115	20	60	55	77	106	60
Mean Crash Rate	**0.226**	**0.196**	**0.324**	**0.434**	**0.275**	**0.131**	**0.477**	**0.198**
Median Crash Rate	0.163	0.092	0.320	0.267	0.252	0.105	0.420	0.145
Standard Deviation	0.185	0.314	0.223	0.534	0.155	0.121	0.273	0.176
Coefficient of Variation	0.819	1.602	0.688	1.230	0.564	0.924	0.572	0.889
90th Percentile Rate	**0.464**	**0.475**	**0.579**	**1.080**	**0.509**	**0.293**	**0.860**	**0.408**

Source: Assessment Of Statewide Intersection Safety Performance, FHWA-OR-RD-18, Portland State University and Oregon State University, June 2011, Table 4.1, p. 47.

Note: Traffic control types include 3SG (three-leg signalized), 3ST (three-leg minor stop-control), 4SG (four-leg signalized), 4ST (four-leg minor stop-control).

Step 4: Calculate a critical crash rate for each intersection

$$(4) \quad R_c = R_a + Confidence\ Level \times \sqrt{\frac{R_a}{MEV_n}} + \frac{1}{2 \times MEV_n}$$

$R_c = Critical\ crash\ rate$

$R_a = Weighted\ average\ crash\ rate\ \ for\ reference\ population$

Critical crash rate for all crashes

$$R_C = 0.477 + 1.645 \times \sqrt{\frac{0.477}{17.7} + \frac{1}{2 \times 17.7}} = 0.78 \frac{Crashes}{MEV}$$

Table 4-9 in the HSM (page 4-36) gives P-levels to correspond to differing confidence levels. Typical use would be 95% confidence (P=1.645).

Intersection	Intersection Population Type (3a)	Crash Rate (2)	Critical Crash Rate (4)	Over Critical (5)
1	Signalized	**1.07**	**0.78**	**Over**
2	Signalized	0.50	0.68	Under
3	Signalized	0.27	0.74	Under
4	Signalized	0.71	0.74	Under
5	Signalized	0.60	0.76	Under
6	Signalized	0.53	0.70	Under
7	Signalized	0.43	0.75	Under
8	Signalized	**1.23**	**0.81**	**Over**
9	Signalized	0.76	0.80	Under
10	Signalized	0.43	0.75	Under

Step 5: Compare observed crash rate with critical crash rate

Compare the critical crash rate with the crash rate for each intersection. Any intersection with a crash rate that exceeds its critical rate should be flagged for further review. In the above example, intersections #1 and #8 were flagged for further analysis.

Step 6: Compare observed crash rate with statewide 90th percentile rates (Exhibit 4-1)

The crash rates at all study intersections (including those without a reference population) are compared to the statewide 90th percentile crash rates for urban three-leg minor stop-controlled (U3ST), urban four-leg minor stop-controlled (U4ST), and urban four-leg signalized (U4SG) intersections.

Intersection	Intersection Population Type	Observed Crash Rate	Statewide 90th Percentile Crash Rate
1	U4SG	**1.07**	**0.860**
2	U4SG	0.50	0.860
3	U4SG	0.27	0.860
4	U4SG	0.71	0.860
5	U4SG	0.60	0.860
6	U4SG	0.53	0.860
7	U4SG	0.43	0.860
8	U4SG	**1.23**	**0.860**
9	U4SG	0.76	0.860
10	U4SG	0.43	0.860

In the above example, intersections #1 and #8 are flagged for further analysis.

Step 7: Conclusions

From the analysis, intersections #1 and #8 exceed the critical rate based on a statewide comparison as well as the statewide 90th percentile crash rate. These intersections are "safety focus" locations that need to be reviewed in more depth. At a minimum, crashes and patterns need to be identified and potential countermeasures indicated. More in-depth HSM predictive analysis could be done for the existing conditions and any later future conditions, which could also include finding the most cost-effective countermeasures.

Example 4-5: Critical Crash Rate for Segments

A screening level safety analysis is to be performed on North Santiam Highway, a rural state highway corridor. The route is approximately 80 miles in length and has both level and rolling terrain . It contains multilane, two-lane, passing and climbing lane sections. It is desired to identify segments for further safety analysis. The Critical Crash Rate method will be applied to segments within the corridor. The study area is shown below.

Study Area

> *All sample calculations given are for the reference population 4-lane highway, and for Segment 5.*

Step 1: Obtain comprehensive (PRC) crash report in Excel format for corridor

Five years of crash data should be obtained using the PRC crash report, available for both state highways and local roads on the ODOT Internal Crash Reports website or the External Crash Reports website. The PRC report contains multiple records per crash. Only the crash level record (first record) is needed. The vehicle and participant level records should be filtered out so that only the crash level record remains for each crash.

Step 2: Filter out urban areas and rural intersections

The PRC report identifies intersection crashes using the RD_CHAR_SHORT_DESC field. Filter out these crashes. Intersection crashes can generally be assumed to be any that are at an intersection with at least one crash, plus 0.01 miles on either side of the intersection milepoint, as well as any coded as intersection-related. Segments are subdivided at intersections with at least one crash. Intersections with no crashes can be included within segments. The intersections with crashes can be analyzed separately using the Intersection Critical Rate method described previously.

Step 3: Obtain AADTs from the State Highway Vehicle Classification Report

For state highways, AADTs are obtained from the State Highway Vehicle Classification Report. For non-state highways, AADTs will need to be calculated following procedures in Chapter 5.

Step 4: Segmenting

Segments are developed based on reference populations. Segment boundaries should be placed where the reference population changes, at intersections that have crashes, and at other logical breakpoints in order for segments not to exceed two or three miles in length. For some very long corridors such as in rural eastern Oregon, segments could be up to five miles in length.

A variety of potential reference populations could be considered, including:

- Urban/rural
- Freeways/arterials
- Number of travel lanes (2, 3, 4, 5, etc.)
- Divided/undivided
- Presence of auxiliary lanes (passing lanes, climbing lanes)
- Terrain (level, rolling and mountainous)
- Geographic area or elevation
- AADT level

Data sources for determining reference population boundaries include TransGIS, Transviewer, the digital video log, and the State Highway Vehicle Classification Report.
At least five segments are needed for each reference population. If there are enough segments, it may be possible to have subgroupings, such as initially by number of lanes and then by terrain. It may also be desirable to separately analyze more than one reference population. This may help to further identify crash trends. Specific types of crashes could be examined as well, such as those involving snow and ice or fatal and injury crashes.

Freeway reference populations could include basic freeway lane sections, weave sections, and ramp merge or diverge sections.

Each segment is assigned a Begin and End Milepoint. Segment lengths need to be adjusted if they contain a milepoint equation. Milepoint equations can be found from the Equations and Milepoint Range Report.

Step 5: Identify the number of crashes in each segment

Each segment is assigned the total number of crashes within that segment. This process can be automated using the PRC crash data from Step 1 as a lookup table to sum the number of crashes in each segment between begin and end milepoints.

In this example, five segments were identified within the reference population of four-lane divided highway segments, as show in the following table.

Segment	Reference Population Type	Begin Milepoint	End Milepoint	5-Year Crash Total	AADT	Crash Rate
1	4 Lane Divided	4.10	6.84	21	24400	0.17
2	4 Lane Divided	6.88	8.89	7	19100	0.10
3	4 Lane Divided	8.93	11.53	8	19100	0.09
4	4 Lane Divided	11.54	13.23	8	13100	0.20
5	4 Lane Divided	13.24	13.80	5	8900	0.55

Step 6: Calculate the crash rate for each segment

The remaining steps can be automated using the Critical Rate Calculator. It is convenient if the data previously developed is formatted to paste directly into the calculator input cells.

$$(1) \quad MVMT = \frac{AADT \times L \times 365 \times n}{1{,}000{,}000}$$

$$MVMT = Million\ Vehicle - Miles\ of\ Travel$$

$$L = Segment\ Length$$

$$n = Number\ of\ Years$$

$$R = Crash\ Rate = \frac{Number\ of\ Crashes}{MVMT}$$

The MVMT for Segment 5 is calculated as follows:

$$MVMT = \frac{8900 \times (13.80 - 13.24) \times 365 \times 5}{1{,}000{,}000} = 9.10$$

The crash rate for Segment 5 is calculated as follows:

$$R = \frac{5}{9.10} = 0.55$$

Step 7: Calculate the average crash rate for each reference population

$$(2)\ R_a = \frac{\sum_{i=1} (N_{obs,i})}{\sum_{i=1} (MVMT_i)}$$

$$R_a = Average\ segment\ crash\ rate\ for\ reference\ population\ a$$

For the reference population of four-lane divided highway segments, the average crash rate is calculated as follows:

$$R_1 = \frac{21+7+8+8+5}{122.01+70.06+90.63+40.40+9.10}$$

$$= 0.15\ Crashes/MVMT$$

Step 8: Calculate a critical crash rate for each segment

$$(3)\quad R_c = R_a + Confidence\ Level \times \sqrt{\frac{R_a}{MVMT_n}} + \frac{1}{2 \times MVMT_n}$$

$$R_c = Critical\ crash\ rate$$

$$R_a = Weighted\ average\ crash\ rate\ for\ reference\ population$$

The segment 5 critical crash rate is calculated as follows:

$$R_C = 0.15 + 1.645 \times \sqrt{\frac{0.15}{9.10}} + \frac{1}{2 \times 9.10} = 0.41\ Crashes/MVMT$$

Step 9: Compare observed crash rate with critical crash rate

Segments can be ranked and prioritized by the amount the segment crash rate exceeds its critical rate. Mapping the safety priority locations may be desirable for visualization.

Segments identified for further analysis can then be analyzed in more detail by identifying specific crash types, causes, and locations within the segment. For example, for a climbing lane segment, each portion of the climbing lane can be examined—the uphill, crest, and downhill sides.

For Segment 5, the observed crash rate is 0.55, which exceeds Segment 5's critical crash rate of 0.41.

Step 10: Conclusions

From the analysis, Segment 5 exceeds the critical rate and is a "safety focus" location that needs to be reviewed in more detail. At a minimum, crashes and patterns need to be identified and potential countermeasures indicated. More in-depth HSM predictive analysis could be done for the existing conditions and any later future conditions, which could also include finding the most cost-effective countermeasures. A variation of this method could be to calculate fatal and injury-only crash rates. This could help to identify segments with potential crash severity issues.

4.3.5 Excess Proportion of Specific Crash Types

Recommended Uses	Transportation System Plans and Corridor Plans May be used for existing conditions assessment in development review or project development when predictive methods are unavailable
Data Required	Crash frequency by collision type, and pedestrian and bicyclist involvement Reference populations
More Information	HSM Part B, Chapter 4, Section 4.4.2.10.

The example in HSM Section 4.4.2.9 has a number of errors and the APM spreadsheet should be followed instead.

The Excess Proportion of Specific Crash Types method quantifies the extent to which a specific crash type (the target crash type) is overrepresented at an analysis site, compared to the average representation within a reference population. Sites with significant overrepresentation are "safety focus" locations identified for further analysis. Since it does not require traffic volumes, it is well suited to large-scale regional analysis.

This analysis method can be used to assess any number of target crash types simultaneously. Analysis of collision type, pedestrian involvement, and bicyclist involvement are required. The analyst is encouraged to additionally include other crash characteristics that may be relevant to the project.

The Excess Proportion of Specific Crash Types analysis does not consider the overall frequency or rate of crashes, instead it considers only the types of crashes observed. It is useful for identifying locations that may benefit from targeted countermeasures. This method is best used in conjunction with Critical Crash Rate, as the two methods have complementary strengths and weaknesses.

This method does not allow for estimates of future safety performance and cannot be used for evaluating alternatives.

This method is generally unaffected by RTM. However, the analysis may be of limited usefulness for small study areas having low crash frequencies of the target crash type. For this method to be statistically valid, there needs to be at least five sites in each reference population. In addition, a minimum of two of those sites must have two or more observed crashes of the target crash type. It is preferred to have more than the minimum number of sites.

While the methodology will work with only two sites, caution should be exercised where there are fewer than 5 sites meeting the criteria. If this is an issue and the study area is a portion of an urban area, expanding the study area for this methodology to include the entire urban area should be considered. Also, expanding the number of years of crash records should be considered as long as no significant changes occurred within that timeframe that may have affected crash history.

A spreadsheet is available under safety analysis tools on the ODOT Transportation Development Planning Technical Tools webpage that automates much of the Excess Proportion of Specific Crash Types analysis. The analyst can provide input data in a summary table manually or can use automated extraction macros to analyze a PRC comprehensive crash summary report directly from ODOT. If the automated method is used, the results should be reviewed to ensure that all intersection-related crashes have been included, even those not identified as such in the records. The analyst must clean and format the results as described in the instructions tab before use. A planning level method for calculating critical crash rates using the ODOT Visum Safety Add-In tool is found in Appendix 4A.

Using the automated process still requires cleaning of the data as described in the instructions for the spreadsheet. The cleaning becomes more time consuming when using local roadways.

The general procedure for network screening using the Excess Proportion of Specific Crash Types method is as follows:

1. Identify analysis sites and assign observed crashes (see APM Section 4.2.3)
2. For each analysis site, determine the total crash frequency and the crash frequency for the target crash type
3. For each analysis site, calculate the proportion of total crashes for the target crash type. This is the number of target crashes divided by the number of total crashes (the observed proportion)
4. Establish reference populations and calculate the proportion of total crashes for the target crash type for each reference population (the threshold proportion)
5. Calculate the sample variance and “alpha” and “beta” parameters for the target crash type for each reference population
6. Using these results, at each site calculate the probability of the observed proportion exceeding the threshold proportion
7. Select the limiting probability for the analysis. Only sites with a probability over this limiting probability will be further evaluated. The recommended minimum value is 60%, but higher values can be used to limit the number of sites to a reasonable study size. The limiting probability can be interpreted as the likelihood that the expected long-term observed proportion actually exceeds the expected long-term threshold proportion.

8. For all sites that exceed the limiting probability, calculate the excess proportion of the target crash type by subtracting the threshold proportion from the observed proportion.

This process is repeated for each target crash type. If multiple sets of reference populations are being used (e.g., internal and external), the process is repeated for each set of reference populations.

Results can be used to help diagnose crash trends at each analysis site. For each target crash type, the greater the excess proportion, the greater the likelihood that the site will benefit from a countermeasure that addresses that crash type.

When reporting the results of this method, the following should be included:

- Crash frequency of each target crash type at each analysis site
- Reference population characteristics and summary statistics
- Limiting probability used
- Excess proportion of each target crash type at each analysis site

Example 4-6: HSM Excess Proportions at Intersections

As a part of a corridor safety project, a safety analysis needs to be completed for 25 intersections along Salem Highway (#072). The focus of this study is to increase safety by reducing angle crashes. The project is to reduce crashes at five intersections along the corridor. There are no ADT-capable counts along the corridor and the budget does not allow for taking any new counts. Crashes occurring along the corridor are examined, and those that are determined to be intersection crashes (see APM Section 4.2.3) are summarized by intersection and crash characteristics. The analyst also has the option of importing the length of the highway in question using the spreadsheet to summarize the data. Using the PRC data requires a cleaning process to take place after the data are pulled.

General & Site Information	
Analyst:	LJP
Agency/Company:	ODOT
Date:	1/7/16
Project Name:	APM Example 4-6
Highway Number and Name:	072 Salem Hwy
Mile Points:	All
Crash Years Pulled:	2008-2011

Calculate Probability

Intersection Crash Data Type of Crash						
MP	Reference Pop	Street 1	Street 2	Angle	Rear	Total
1.54	4SG	Salem Parkway	Verda Ln NE	5	14	22
3.16	4SG	Broadway St NE	Salem Parkway	13	17	36
3.55	3ST	Hickory St NE	Liberty St NE	1	0	2
3.56	3ST	Commercial St NE	Hickory St NE	4	0	5
3.57	3SG	Commercial St NE	Pine St NE	3	3	8
3.62	3SG	Liberty St NE	Pine St NE	18	2	20
3.73	3ST	Grove St NE	Liberty St NE	2	1	5
4.24	3ST	Commercial St NE	Hood St NE	7	3	13
4.30	3ST	Commercial St NE	Gaines St NE	2	8	10
4.36	3SG	Commercial St NE	Market St NE	5	13	24
4.79	3SG	Commercial St NE	Union St NE	14	3	22
4.84	3ST	Front St Parkway NE	Union St NE	5	3	13
4.85	3SG	Commercial St NE	Marion St NE	3	8	42
5.39	3SG	Commercial St NE	Ferry St SE	20	7	33
5.43	3SG	Commercial St NE	Trade St SE	8	6	31
5.47	3SG	Ferry St SE	Liberty St SE	8	3	19
5.52	3SG	Liberty St SE	Trade St SE	10	3	18
5.65	3SG	Church St SE	Ferry St SE	5	8	18
5.69	3SG	Church St SE	Trade St SE	3	1	7
5.93	4SG	Pringle Creek Parkwa	Winter St NE	3	6	13
6.20	4SG	Pringle Creek Parkwa	12th St SE	4	10	18
6.77	3SG	Mission St SE	17th St SE	1	23	33
7.52	4SG	Mission St SE	25th St SE	2	50	60
7.92	4SG	Mission St SE	Turner Rd SE	3	36	51
8.26	3SG	Hawthorne Ave SE	Mission St SE	3	68	84

Step 1: Organize Sites into Reference Populations

Intersections are divided into reference populations by traffic control and number of intersection legs (see APM Section 4.3.3). Reference populations are identified by the analyst during the initial steps of the spreadsheet. Each intersection is then placed into a reference population. Use of the digital video log, aerial photos and other electronic sources is suggested for placing intersections into reference population.

The next 6 steps are all done within the spreadsheet. Once the sites have been organized, the spreadsheet can calculate the following steps.

Step 2: Calculate Observed Proportions

$$p_i = \frac{N_{observed,i}}{N_{observed,i(total)}}$$

Where: P_i= Observed proportion at site i

$N_{observed,i}$= number of observed target crashes at i

$N_{observed,i(total)}$= Total number of crashes at i

Step 3: Calculate a Threshold Proportion

$$p*_i = \frac{\sum N_{observed,i}}{\sum N_{observed,i(total)}}$$

Where: P_i= Threshold proportion

$\Sigma\ N_{observed,i}$= Sum of observed target crash frequency within the population

$\Sigma\ N_{observed,i(total)}$= Sum of total observed crash frequency within population

Step 4: Calculate Sample Variance[1]

$$Var(X/Y) = \frac{E^2(x)}{E^2(y)}\left[\frac{Var(X)}{E^2\,(X)} + \frac{Var(Y)}{E^2(Y)} - 2\frac{Cov(X,Y)}{E(X)E(Y)}\right]$$

Where:

$E(X) =$ Mean number of target crashes.

$E(Y) =$ Mean number of total crashes

$Cov(X,Y) =$ using the Excel Covariance function (COVARIANCE.S)

$Var(x) =$ using the Excel Variance function (VAR.S)

$Var(Y) =$ use the Excel Variance function (VAR.S)

If the number of sites with more than two type 'i' crashes is not greater than one, the variance is zero. There are also rare instances where the variance is calculated to be zero. If the variance is zero, the probability cannot be calculated because there is nothing to compare.

Step 5: Calculate the Alpha and Beta Parameters

$$\alpha = \frac{\overline{p*_i}^2 - \overline{p*_i}^3 - s^2\left(\overline{p*_i}^2\right)}{Var(N)}$$

$$\beta = \frac{\alpha}{\overline{p_i^*}} - \alpha$$

Where:

$n_{sites} =$ Total number of sites being analyzed

$p*_i =$ Threshold proportion

$p_i =$ Observed proportion

$Var(N) = s^2$

[1] This replaces Equation 4-20 in HSM 1st Edition 2010, which was found to have a number of errors.

Step 6: Use the Excel Function to Calculate the Beta Distribution

$$p\left(\frac{p_i > p_i^*}{N_{observed,i}, N_{observed,i(total)}}\right) = 1 - betadist(p_i^*, \alpha + N_{observed,i}, \beta + N_{observed,i\ (total)} - N_{observed,i}$$

$Where:$

$p*_i =$ Threshold proportion

$p_i =$ Observed proportion

$N_{observed(total)} =$ Total number of crashes for site i

$N_{observed,i} =$ Observed target crashes for site i

The resulting number is the probability of a specific crash type being greater than the long-term expected proportion of that crash type at the specified intersection type.

Steps 7 and 8: Choose Limiting Probability and Calculate the Excess Proportion

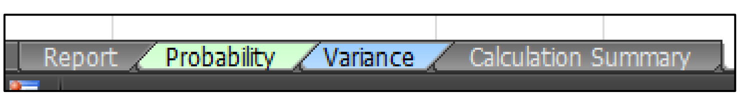
$$p_{diff} = p_i - p*_i$$

$Where:$

$p*_i = Threshold \quad proportion$

$p_i = Observed \quad proportion$

The spreadsheet first calculates the probability of each crash type exceeding a threshold proportion. . The calculated probability can be interpreted as the likelihood that the long-term expected proportion of a crash type at the intersection is greater than the threshold proportion. In order to calculate the excess proportion the analyst must use engineering judgement to set the limiting probability. According to the HSM "the selection of a limiting probability can vary depending on the probabilities of each specific crash type exceeding a threshold proportion. If many sites have a high probability the limiting probability can be set higher." The default limiting probability of the spreadsheet is 90% but is adjustable. The excess proportion that is calculated is simply the difference in the observed crash proportion and the threshold proportion for the reference population. The data output and a short explanation of the output for this example is shown here. The spreadsheet places the output onto the Probability tab. If the analyst chooses, they can use the "Create Report" button to create a printer friendly summary of the intersections with an excess proportion.



Step 9: Interpreting Results

The Report Tab summarizes those intersections with a probability greater than the set limiting probability. It separates out each crash type and sorts each crash type by descending Excess Proportion. According to the HSM, the greater the excess proportion, "the greater the likelihood that the site will benefit from a countermeasure targeted at the collision type under consideration.”

General & Site Informaiton	
Analyst:	LJP
Agency/Company:	ODOT
Date:	1/26/2016
Project Name:	APM Example 4-6

Highway Number and Name:	072, Old Salem Hwy
Mile Points:	All
Crash Years Pulled:	2008-2011
Limiting Probability:	0.9

Notes

Angle Crashes					
					Excess
MP	RefPop	Street 1	Street 2	Probability	Proportion
3.62	3SG	Liberty St NE	Pine St NE	1.00	0.62
4.79	3SG	Commercial St NE	Union St NE	1.00	0.36
5.39	3SG	Commercial St NE	Ferry St SE	1.00	0.32
5.52	3SG	Liberty St SE	Trade St SE	0.99	0.27
3.16	4SG	Broadway St NE	Salem Parkway	1.00	0.21
5.47	3SG	Ferry St SE	Liberty St SE	0.90	0.14

Rear Crashes					
					Excess
MP	RefPop	Street 1	Street 2	Probability	Proportion
4.3	3ST	Commercial St NE	Gaines St NE	1.00	0.49
8.26	3SG	Hawthorne Ave SE	Mission St SE	1.00	0.40
6.77	3SG	Mission St SE	17th St SE	1.00	0.28
7.52	4SG	Mission St SE	25th St SE	1.00	0.17

					Excess
MP	RefPop	Street 1	Street 2	Probabilit	Proportion

Fix Crashes					
					Excess
MP	RefPop	Street1	Street2	Probability	Proportion
6.2	4SG	Pringle Creek Park	12th St SE	0.97	0.08
5.43	3SG	Commercial St NE	Trade St SE	0.95	0.06
4.85	3SG	Commercial St NE	Marion St NE	0.92	0.04
3.16	4SG	Broadway St NE	Salem Parkway	0.93	0.02

Page 1

Head Crashes					
					Excess
MP	RefPop	Street1	Street2	Probability	Proportion
5.43	3SG	Commercial St NE	Trade St SE	1.00	0.04
4.85	3SG	Commercial St NE	Marion St NE	1.00	0.02

NonCol Crashes					
					Excess
MP	RefPop	Street1	Street2	Probability	Proportion
5.43	3SG	Commercial St NE	Trade St SE	0.93	0.06
4.85	3SG	Commercial St NE	Marion St NE	0.95	0.06

SS-M Crashes					
					Excess
MP	RefPop	Street1	Street2	Probability	Proportion
4.85	3SG	Commercial St NE	Marion St NE	1.00	0.07
5.47	3SG	Ferry St SE	Liberty St SE	1.00	0.06
5.43	3SG	Commercial St NE	Trade St SE	1.00	0.05
4.79	3SG	Commercial St NE	Union St NE	1.00	0.04
6.77	3SG	Mission St SE	17th St SE	1.00	0.04
4.36	3SG	Commercial St NE	Market St NE	1.00	0.03

Turn Crashes					
					Excess
MP	RefPop	Street1	Street2	Probability	Proportion
3.57	3SG	Commercial St NE	Pine St NE	0.92	0.17
5.93	4SG	Pringle Creek Park	Winter St NE	0.94	0.11
4.85	3SG	Commercial St NE	Marion St NE	0.91	0.04

Using the Liberty Street and Trade Street intersection, the 0.274 means that there are 27% more observed angle crashes than the calculated threshold for three-leg stop-controlled intersections in this population.

Angle Crashes					
					Excess
MP	RefPop	Street 1	Street 2	Probability	Proportion
3.62	3SG	Liberty St NE	Pine St NE	1.000	0.619
4.79	3SG	Commercial St NE	Union St NE	1.000	0.355
5.39	3SG	Commercial St NE	Ferry St SE	1.000	0.325
5.52	3SG	Liberty St SE	Trade St SE	0.992	0.274
3.16	4SG	Broadway St NE	Salem Parkway	0.998	0.211
5.47	3SG	Ferry St SE	Liberty St SE	0.901	0.140

For this population of intersections, a total of 6 intersections have a greater than 90% chance of having a greater proportion of angle crashes than expected. Intersections with a probability greater than the limiting probability (default of 90%) and an excess proportion of at least 0.10 or a probability greater than the limiting probability and flagged by either the Critical Rate or the SPIS top 10% need to be further investigated.

In looking at the probability of 0.992, this means that there's a 99.2% chance that the long term expected proportion of angle crashes at Liberty St SE and Trade St SE will be greater than the long term expected proportion of angle crashes at 3-legged Signal-Controlled intersections when compared to the rest of this population of intersections. Then the 0.274 in the excess proportion column implies the "the likelihood that the site will benefit from a countermeasure targeted at the collision type under consideration." (HSM 4-58) The greater the excess proportion the greater the likelihood.

Turn Crashes					
MP	RefPop	Street1	Street2	Probability	Excess Proportion
3.57	3SG	Commercial St NE	Pine St NE	0.92	0.17
5.93	4SG	Pringle Creek Parkw	Winter St NE	0.94	0.11
4.85	3SG	Commercial St NE	Marion St NE	0.91	0.04

The spreadsheet will automatically grey out intersections with an excess proportion of less than 0.10. Unless these intersections are flagged by either the Critical Rate calculation or the SPIS 10% they may dropped from further investigation. Use engineering judgement to determine if there are other factors at the greyed out intersections to determine if they need to be further investigated.

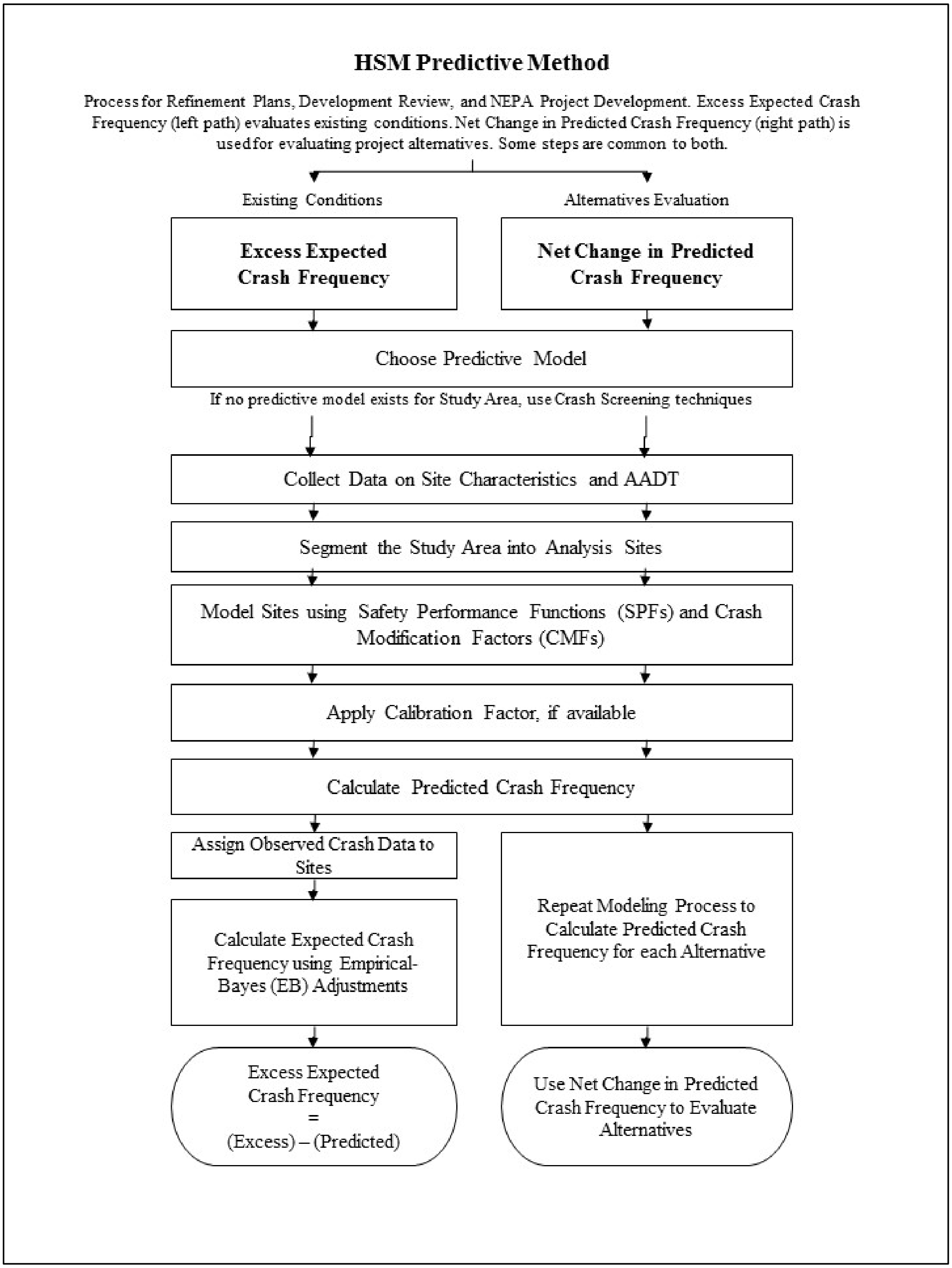
4.4 Predictive Methods

Predictive methods are used for detailed assessment of safety performance at the segment or intersection level. These methods are based on models developed for predicting crash frequency based on geometric and operational characteristics. The results are used to evaluate existing, future and alternative conditions. The HSM discusses predictive methods in more detail in Part C. Predictive methods are recommended for use with more detailed efforts such as Facility Plans, Development Review and Project Development.

Recommended Uses	Facility Plans, Development Review, and Project Development
Data Required	Crash frequency by severity, collision type, and pedestrian and bicyclist involvement [if using the Empirical Bayes (EB) Method] AADT traffic volumes for major and minor roads Pedestrian and bicyclist volumes or estimates Traffic control information Geometric design and roadway details Data requirements vary by predictive model and are discussed in APM Section 4.4.6. Complete HSM Part C data requirements can be found in HSM Part C, Sections 10.4, 11.4, and 12.4
More Information	HSM Part C, Chapters 10-12 ISATe User Manual PLANSAFE User Manual

The flow chart in Exhibit 4-9 gives an overview of the process for HSM Predictive Method.

Exhibit 4-9: HSM Predictive Method



The HSM has introduced a new way of evaluating safety performance of a roadway segment and/or intersections using substantive safety. This new predictive method, detailed in Part C of the HSM, was created from extensive research and analysis rather than relying on design standards (also known as nominal safety). The overall method estimates crashes per year and severity, depending on specific local conditions.

Predictive methods do not require observed crash data to derive quantitative safety evaluations, and therefore can be used with future scenarios or design alternatives that do not yet exist. This allows for a rigorous quantitative safety analysis in circumstances where it was previously impossible, such as development review or National Environmental Policy Act (NEPA) project development. Predictive methods also allow for a fine-grained safety analysis of locations without need of a reference population, which is beneficial for detailed corridor studies where an established safety concern exists.

The HSM predictive equation is located in HSM Section C.4 but is generalized to:
Predicted Crashes =

Safety Performance Function x Crash Modification Factor(s) x Calibration Factor

The HSM makes a distinction between the crashes based only on characteristics (Predicted Crashes) versus characteristics plus local crash history (Expected Crashes). Predicted Crash Frequency is based on the geometric design, traffic control and traffic volumes of the local conditions. The Expected Crash Frequency is the combination of the predicted crash frequency with the historical crash frequency (using the Empirical-Bayes methods).

Expected Crashes =
(EB Weighting Factor x Predicted Crashes) + [(1- EB Weighting Factor) x Observed Crashes]

The generalized process for the predictive method is as follows:

1. Divide the study area into homogenous analysis sites, called "segmentation," for intersections and roadway segments
2. Choose an appropriate predictive model for each site
3. Gather AADT or ADT traffic volumes, roadway characteristics, and traffic control features for each site
4. Characterize each site using SPFs and CMFs from Part C of the HSM
5. Apply calibration coefficients, if available
6. Calculate predicted crashes
7. If using Empirical Bayes (EB) method, assign crashes to sites and calculate expected crashes

This process is then repeated for each alternative to be evaluated. APM Section 0 describes the HSM Predictive Method process in more detail.
Because predictive methods have very specific methodology requirements and are under frequent revision, it is recommended that the analyst consult the appropriate source documentation (including published updates and errata) before beginning a predictive analysis.

The SPFs, CMFs, and calibration coefficients used for a predictive analysis are collectively referred to as the predictive model. Predictive models are specific to a particular type of roadway and require substantial research effort to produce. The HSM provides a methodology for jurisdictions interested in developing local predictive models.

4.4.1 Available Predictive Models and Current Limitations

Predictive models are available to analyze the following types of roadways:

- Rural two-way, two-lane roads (HSM Part C Chapter 10)
- Rural multilane highways (HSM Part C Chapter 11)
- Urban and suburban arterials (HSM Part C Chapter 12)
- Freeways, interchanges, and ramp terminals (ISATe / HSM Supplemental Chapters 18 and 19)

However, the predictive models mentioned above cannot be used in the following situations:

- Highways or arterials with six or more through lanes
- Rural freeways with eight or more through lanes
- Urban freeways with ten or more through lanes
- Interchange designs other than diagonal or partial clover (Parclo)
- Single-point urban, crossing/diverging diamond, or continuous flow interchanges
- Freeway ramp terminals on a one-way street, metered entrance, or roundabout
- All-way stop intersections
- Yield-control intersections
- Rural three-leg signalized intersections

ODOT is in the process of developing additional predictive models for:

- Access management (SPR 720)
- Roundabouts (SPR 733)
- Improved SPFs for signalized intersections (SPR 756)

When predictive models are not available or cannot be used for a location, the analyst should use the screening methods described in APM Section 4.3 and other techniques described in APM Section 4.8 to describe the existing conditions. The effect of potential countermeasures can be estimated using CMFs as described in APM Section 4.6.

If the predictive method can be applied to all but a small portion of the study area, it is acceptable to implement the predictive method where available. In this case, the narrative should explain the reasoning and expected impact of the omission and omitted locations should be clearly identified.

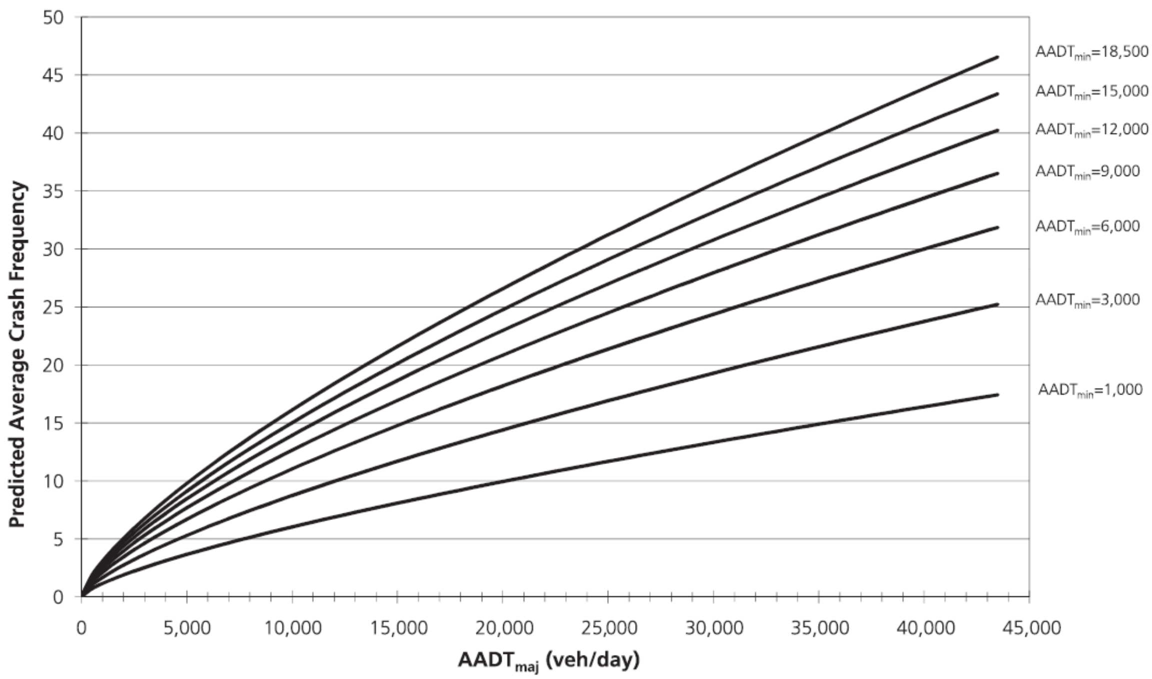
4.4.2 Safety Performance Functions (SPFs)

SPFs are developed using empirical research and regression models. SPFs predict crash frequency for a "base condition" roadway as a function of traffic volume. A unique SPF is developed for significant base condition variations, such as rural multilane highway segments or urban four-leg signalized intersections. CMFs adjust these predictions to account for differences from the SPF base conditions.

SPFs account for the fundamental non-linearity of crash frequency with respect to traffic volumes. An example of a non-linear SPF plot is shown in Exhibit 4-10. Crash rates alone do not capture the non-linearity of crash frequency with respect to traffic volumes. Analysts should be aware that crash rates may be reduced simply by an increase in traffic volumes alone. A reduction in crash rate at higher traffic volumes is often the expected roadway behavior, and does not indicate a fundamental change in underlying safety performance.

For example, consider the function in Exhibit 4-10 for a minor AADT of 1,000 vehicles/day (the bottom curve). At a major AADT of 8,000 vehicles/day, the predicted average crash frequency is approximately five crashes per year. This is a crash rate of 1.52 crashes per MEV. At a major AADT of 35,000 vehicles/day, the predicted average crash frequency is approximately 15 crashes per year. This is a crash rate of 1.14 crashes per MEV. Although the crash rate is lower in the second case, it is due to expected roadway behavior and not a change in underlying safety performance.

Exhibit 4-10: Rural Multilane SPF Four-leg Signalized Intersections (4SG)*



**Source: Fig 11-7 on p 11-23 in Ch. 11 of Volume 2, Part C, 1st Edition HSM*

4.4.3 Crash Modification Factors (CMFs)

CMFs describe the effect of specific treatments on the estimated crash frequency. In the HSM predictive method, CMFs adjust the "base condition" prediction of an SPF to account for additional characteristics of the local site. HSM predictive models require specific CMFs (from HSM Part C) that must be included in the model and developed in conjunction with the SPF. The required CMFs are further described in the HSM chapters for each predictive model and are included in the model spreadsheets or other computational tools.

In general, a CMF is multiplied with the crash frequency predicted by the SPF to account for any change in predicted crashes from the base condition. A CMF greater than 1.0 implies an increase in crashes, while a CMF less than 1.0 would have a decrease in crashes. A CMF equal to 1.0 means no change is expected.

For example a base model SPF may have four-foot shoulders but the actual site has eight-foot shoulders. In this example, one would expect a crash reduction because the roadway has a wider shoulder, so the CMF should be less than one. The actual value of the CMF will vary depending on facility type.

CMFs can also be used to estimate the effects of countermeasures or changes in conditions on observed crash frequency, independent from predictive models. CMFs for general use are included in the HSM Part D and CMF Clearinghouse, among other sources. These CMFs are based on independent research and are reviewed and approved by the HSM Task Force. There is a considerably wider selection of CMFs that can be used this way.

CMFs are an active area of research, and the best available CMF for a situation may change frequently. See APM Section 4.6 Countermeasure Selection and Evaluation for further information on selecting and applying CMFs to evaluate countermeasure effectiveness.

Part C CMFs were developed in conjunction with the model development and are unique to the HSM Predictive Method.

CMFs in Part C should only be used with Part C SPFs and the HSM Predictive Method.

The term crash reduction factor (CRF) was part of the early discussions of predictive crash methods (and is still frequently used in other literature) but was dropped in preference to the modification factors. CRFs relate to CMFs in the following way (see Section 4.6 for more information on CRFs):

CMF = 1- (CRF/100), so a CMF of 0.2 is a CRF of 80%.

4.4.4 Local Calibration Coefficients

Calibration coefficients are developed locally by comparing predictive results to locally observed results. These adjust the prediction to account for differences in geography, crash reporting, enforcement policy, and driver behavior between the general models provided in the HSM and the location of application. Oregon calibration coefficients are not yet available for all predictive models. In cases where a state- or region-specific SPF has been produced, calibration coefficients are not applied.

In Oregon, crash reporting is a driver responsibility with some enhancement for enforcement. This means that it is more likely to have a police report if there was a serious injury than for a crash involving property damage only. Oregon's required reporting threshold is typically higher than many other states (at $1,500) so many minor crashes are not reported and do not show up in the crash data. Because of these reporting requirements, Oregon conditions data should not be directly related to national averages or adjacent states (i.e., Washington), which have different reporting thresholds.

ODOT has created Oregon calibration factors for some of the HSM Part C models in the report, *Calibrating The Future Highway Safety Manual Predictive Methods For Oregon State Highways*. This report covers the Rural Two-Lane models, Rural Multilane models, and Urban/Suburban Arterial models for both segments and intersections. The ODOT Driveway Safety models do not require calibration, because they were developed using local Oregon data. PLANSAFE does not require calibration by the analyst, because the program self-calibrates using provided data. An attempt was made to calibrate the freeway and interchange Part C models but was unsuccessful. Results from the Enhanced Interchange Safety Analysis Tool (ISATe) must be reported uncalibrated, as described below.

The locally-derived calibration factors listed in Exhibit 4-11 adjust total predicted crash frequencies to a value that is representative of Oregon conditions. Predicted crashes are multiplied by the calibration factor to determine the calibrated predicted crashes. For example, if an uncalibrated model estimated 10 predicted crashes per year and had a local calibration factor of 0.50, the locally-calibrated result would be five predicted crashes per year.

Exhibit 4-11: Locally-Derived Oregon HSM Calibration Factors

Facility Type		Calibration Factor
Segments		
Rural Two-Lane		
R2	2-lane undivided	0.74
Rural Multilane		
MRU	Undivided	0.37
MRD	Divided	0.77
Urban/Suburban Arterials		
U2U	2-lane undivided	0.62
U3T	3-lane with TWLTL	0.81
U4D	4-lane divided	1.41 / 0.64 *
U4U	4-lane undivided	0.63
U5T	5-lane with TWLTL	0.64
Intersections		
Rural Two-Lane		
R3ST	3-leg, minor stop	0.31
R4ST	4-leg, minor stop	0.31
R4SG	4-leg, signalized	0.45
Rural Multilane		
MR3ST	3-leg, minor stop	0.15
MR4ST	4-leg, minor stop	0.39
MR4SG	4-leg, signalized	0.15
Urban and Suburban Arterials		
U3ST	3-leg, minor stop	0.35
U4ST	4-leg, signalized	0.45
U3SG	3-leg, signalized	0.73
U4SG	4-leg, signalized	1.05

* Value of 1.41 based on small sample size and geometric designs no longer used. Value of 0.64 should be used for all future new designs.

Source: Calibrating The Future Highway Safety Manual Predictive Methods For Oregon State Highways

Additional locally derived severity and crash type distributions are included in the calibration report linked to the above table. The best way to ensure that all appropriate Oregon calibration factors are accounted for is to use or refer to the HSM Spreadsheets that are pre-filled with Oregon calibration factors. These spreadsheets include tables with all recommended locally derived calibration factors and distributions, and are described in APM Section 4.4.13 below.

Where an Oregon calibration factor does not exist, the results of the predictive analysis should only be used for relative comparisons such as net difference in predicted crashes or percent change in predicted crashes. Uncalibrated predicted crashes should be identified as such and reported separately from calibrated predicted crashes or expected crashes.

4.4.5 Excess Expected Crash Frequency using Empirical Bayes (EB) Adjustments to Include Historical Crash Data

The HSM makes a distinction between the crashes based only on characteristics (predicted crashes) versus characteristics plus local crash history (expected crashes). Predicted crash frequency is based on the geometric design, traffic control and traffic volumes of the local conditions. The expected crash frequency is the combination of the predicted crash frequency with the historical crash frequency (using the EB Method). The benefit of the EB method is that it accounts for the RTM error, which is the natural fluctuation of crashes that occurs over the years independent of the contributing factors the analysis is trying to review. The EB method results in a more reliable estimate of crash frequency, while still accounting for unique site characteristics that influence safety but are not included in the predictive models.

The EB method requires a calibrated prediction model (with overdispersion factor) and substantial similarity between the analysis period for which crash data exist and the analysis period being used for the predictive method.

EB Method Can Be Used	EB Method Cannot Be Used
• Existing Conditions • Future conditions with traffic volume changes only • Future conditions with minor geometric changes (i.e., wider shoulders) or addition of turn or passing lanes.	• Uncalibrated predictive models, such as ISATe • Where no crash data from any time period are available • Future conditions with entirely new roadways where none existed before • Future conditions modifying existing roadways that include major alignment changes, the addition of through lanes, or a change in traffic control devices

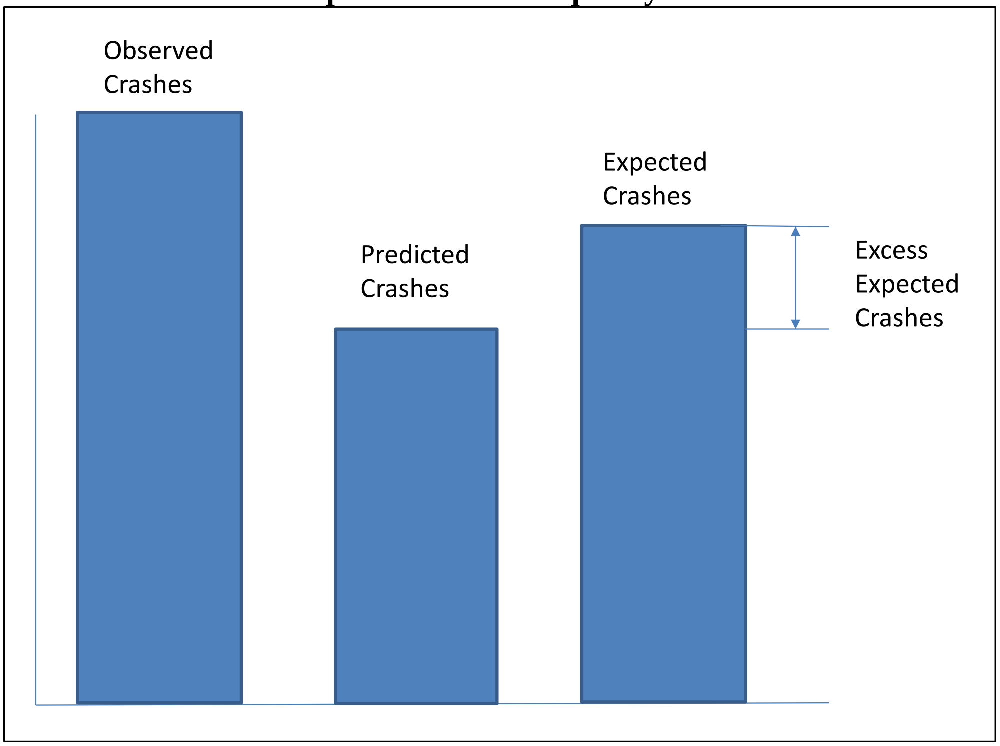
The EB method can be performed at a site-specific level or a project level. Site-specific EB adjustments are done for each analysis site and require the analyst to associate each crash with a specific site. Project EB corrections are done using crash data aggregated over all analysis sites and do not require crashes to be associated with a specific site. The site-specific EB method is preferred and should be used in most situations, since crash data available through ODOT are geocoded and can be associated with specific analysis sites.

When the EB method is performed, the result is an expected crashes value. This value is reported using the "Excess Expected Average Crash Frequency," defined as:

Excess Expected Average Crash Frequency = Expected Crashes – Predicted Crashes

An example of Excess Expected Average Crash Frequency is illustrated in Exhibit 4-12. In this example, Excess Expected Crash Frequency is a positive number, meaning the long term average crash frequency at this site is greater than for comparable sites. The site should be investigated further for potential safety countermeasures. In other cases, Excess Expected Crash Frequency may be a negative value, meaning the long term average crash frequency at the site is less than for comparable sites.

Exhibit 4-12: Excess Expected Crash Frequency



APM Section 4.2.3 contains guidance for assigning observed crashes to an analysis site and determining if they are intersection-related or roadway segment-related.

Instructions and examples for using the EB method are provided in the HSM Part C, Appendix A, Section A.2.

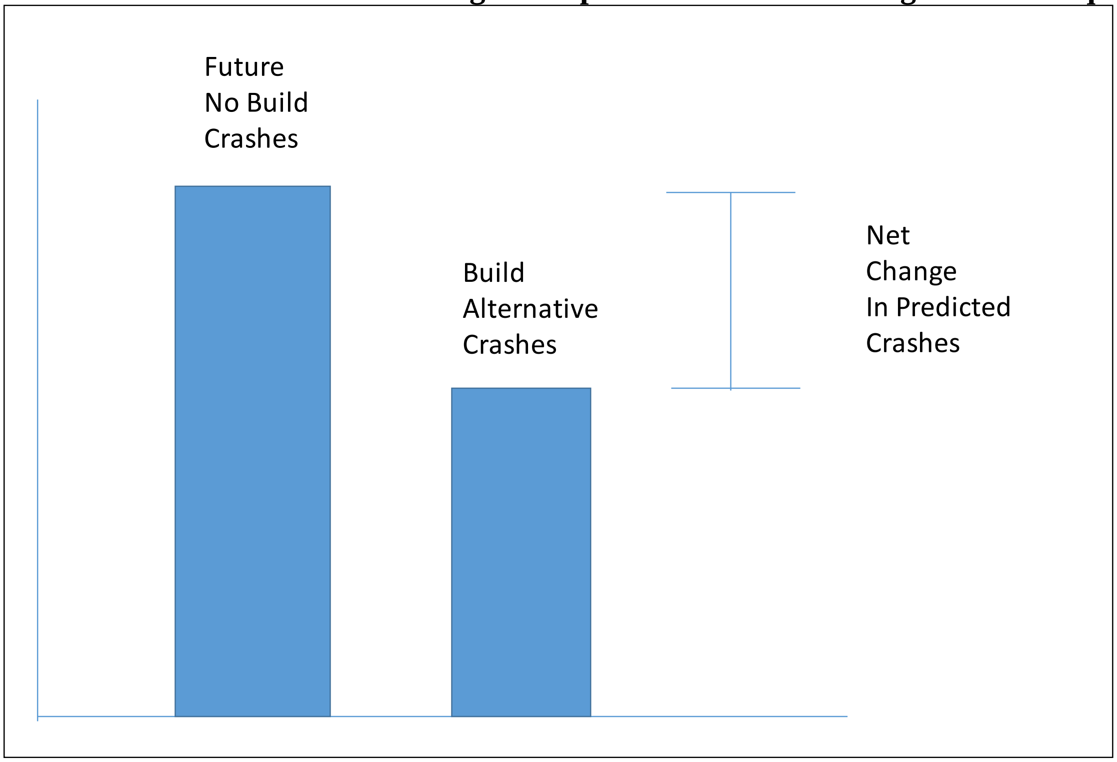
4.4.6 Net Change in Expected or Predicted Crashes

Alternatives should be compared using the net change in expected or predicted crashes, by severity, if possible. Expected crashes can be determined for alternatives if the only changes are in AADT (see APM Section 4.4.5 for more information). If expected crashes can be calculated for all alternatives under consideration, use net change in expected crashes. Otherwise, use net change in predicted crashes. Calculate expected or predicted crashes for each alternative, including the no-build alternative. Subtract the expected or predicted crash frequency of the no-build alternative from each build alternative to determine the net change in expected or predicted crashes for the build alternative. Any alternative with a negative net change in expected or predicted crashes indicates a modeled decrease in crashes. Alternatives with positive net change in expected or predicted crashes indicate a modeled increase in crashes.

Net Change In Expected/Predicted Average Crash Frequency = Expected/Predicted No Build Crash Frequency - Expected/Predicted No Build Crash Frequency

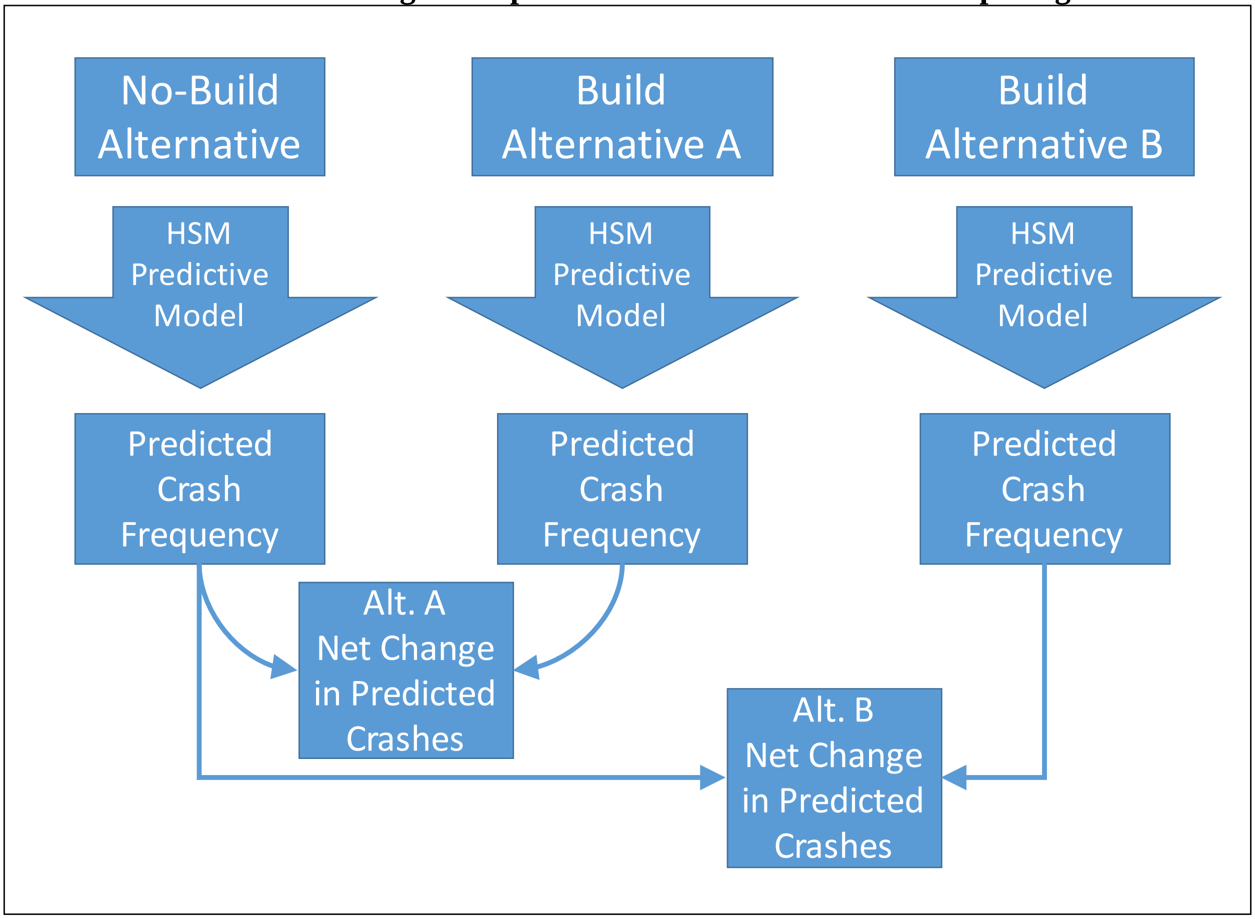
An example of Net Change in Expected/Predicted Average Crash Frequency is illustrated in Exhibit 4-13. In this example, the Net Change in Predicted Crashes represents a reduction in crash frequency, meaning that in comparison to the No Build, the Build Alternative will reduce the long term average crash frequency at this site by the amount of the Net Change.

Exhibit 4-13: Net Change in Expected/Predicted Average Crash Frequency



The Net Change in Crash Frequency can also be used to compare alternatives with each other, as shown in Exhibit 4-14.

Exhibit 4-14: Net Change in Expected/Predicted Crashes for Comparing Alternatives



4.4.7 Data Needs and Sources

HSM predictive methods require a substantial amount of roadway, geometric design, and traffic control data. Primary data are routinely collected during a project or are available in the ODOT TransGIS Database or the ODOT State Highway Inventory Reports. The ODOT Transportation Development Trans Data Portal provides a quick guide to many ODOT data sources. Other data will need to be collected through a desk survey using satellite imagery and street-level imagery (such as the ODOT Digital Video Log or Google StreetView) or through field visits. Some information may be infeasible to collect and can be estimated using the resources in this section.

Each HSM predictive model requires different data to estimate crashes, depending on the SPF base condition and available model CMFs. The analyst should consult the appropriate model methodology reference text before beginning an analysis to determine the data needed for each model and for the required data collection procedures.

- Rural two-lane roads (HSM Part C Chapter 10, Section 10.4)
- Rural multilane roads (HSM Part C Chapter 11, Section 11.4)
- Urban and suburban arterials (HSM Part C Chapter 12, Section 12.4)
- Freeways and interchanges (ISATe User Manual, Chapter 2, Page 19)

Based on sensitivity tests performed with the HSM models, accurate information on AADT volume data are the most important input. This includes minor street AADT for all models and pedestrian volumes for urban intersection models.

If minor street AADT is not available from the local jurisdiction, the analyst should provide a best estimate. If AADTs will be estimated, consult with TPAU to determine the appropriate methodology before beginning an analysis. In some situations, minor AADT may be inferred from nearby volumes or travel demand models may help provide an estimate. The major road AADT to minor road AADT ratio of similar intersections is another possible starting point for estimation. ITE trip generation rates may be appropriate for isolated minor roads.

If daily pedestrian volumes are not available, HSM Table 12-15 provides guidance on estimating daily pedestrian volumes based on general level of pedestrian activity.

Exhibit 4-15 is meant to give a general sense of the site characteristic data required for the HSM predictive method, but it is not intended to be exhaustive.

Exhibit 4-15: Data Needed for HSM Predictive Methods

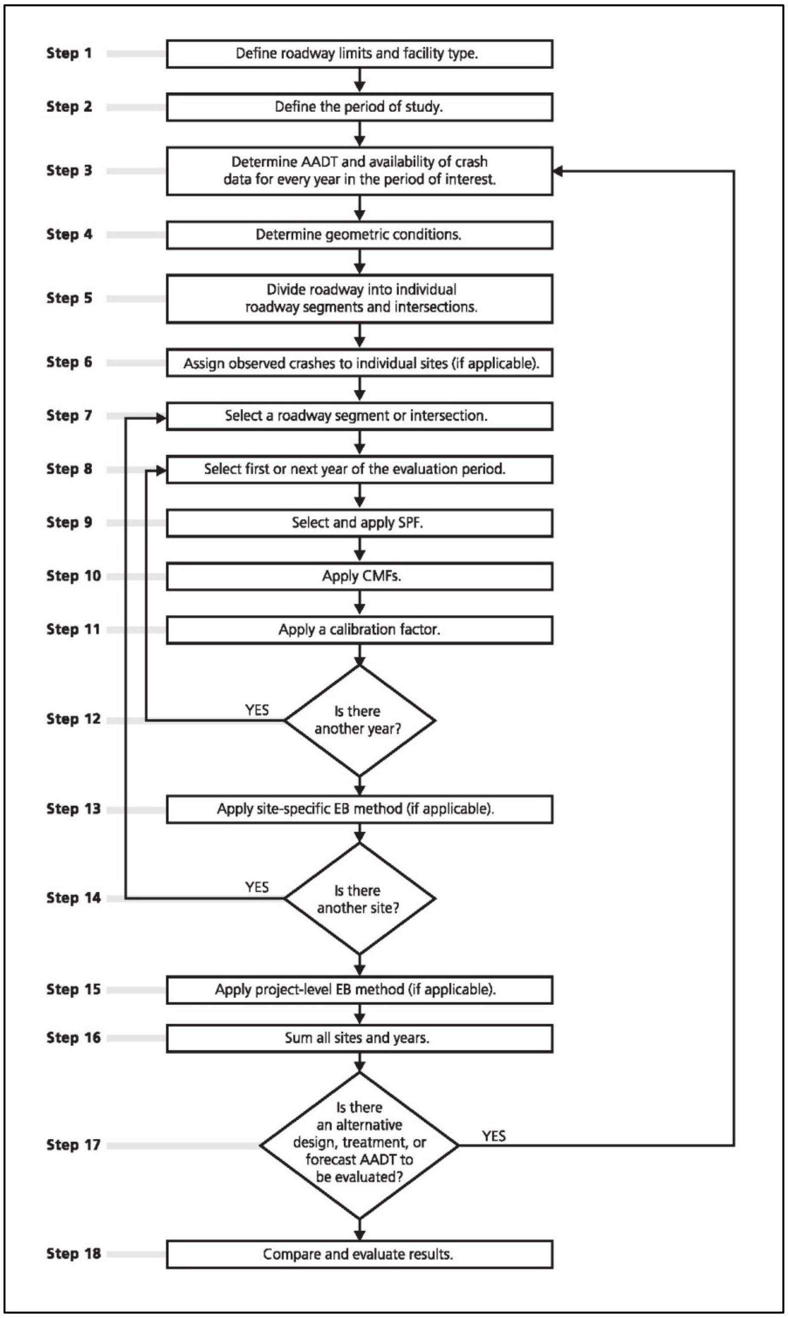
Information Needed	Data Source
Roadway Segments	
Length of Segment	TransGIS or Imagery
AADT	TransGIS or Inventory Report or Project
Lane Width	TransGIS or Inventory Report or Imagery
Shoulder Width and Type	TransGIS or Inventory Report or Imagery
Horizontal Curve Dimensions	TransGIS or Inventory Report or Imagery
Grade	Imagery or Inventory Report or Elevation Maps
Driveway Density and Type	TransGIS Imagery
Centerline and Edgeline Rumble Strips	Imagery
Passing Lanes	TransGIS or Inventory Report or Imagery
Two-Way Left-Turn Lanes	TransGIS or Inventory Report or Imagery
Roadside Hazard Rating	Imagery
Segment Lighting	Imagery
Automated Speed Enforcement	Imagery
Median Type and Median Width	Imagery or Inventory Report
Sideslope	Imagery
Type of On-street Parking	Imagery
Roadside Fixed Object Density and Offset	Imagery
Actual or Posted Speed	TransGIS or Imagery
Intersections	
Number of Intersection Legs	TransGIS or Imagery
Type of Traffic Control	Imagery
Intersection Skew Angle	TransGIS or Imagery
Approaches with Right-Turn Lanes	Imagery
Approaches with No Right-Turn on Red	Imagery
Approaches with Left-Turn Lanes	Imagery
Approaches with Left-Turn Signal Phasing	Imagery or Signal Timings
Intersection Lighting	Imagery
Most Traffic Lanes Crossed by Pedestrians	Imagery
Number of Bus Stops within 1,000 feet	TransGIS or Imagery
Presence of Schools within 1,000 feet	Imagery or Other Point-of-Interest Reference
Number of Alcohol Sales Locations within 1,000 feet	Imagery or Other Point-of-Interest Reference
Presence of Red Light Camera	Site Visit

4.4.8 Predictive Method Process

The HSM Predictive Method process consists of 18 steps that result in an estimation of crash frequency for a project area. Each analysis site is considered individually for each year of analysis. These individual results are summed to determine the study area total. This process is repeated for each alternative to be evaluated. Exhibit 4-16 illustrates this process graphically. HSM Section C.5 describes these steps:

- **Step 1:** Define the limits of the roadway and facility types in the study network, facility, or site for which the expected average crash frequency, severity, and collision types are to be estimated
- **Step 2:** Define the time period of interest
- **Step 3:** For the study period, determine availability of AADT and (if using the EB Method) observed crash data
- **Step 4:** Determine geometric design features, traffic control features, and site characteristics for all sites in the study network
- **Step 5:** Divide the roadway network or facility under consideration into individual roadway segments and intersections, which are referred to as sites
- **Step 6:** Assign observed crashes to the individual sites (if using the EB Method)
- **Step 7:** Select the first or next individual site in the study network. If there are no more sites to be evaluated, go to Step 15.
- **Step 8:** For the selected site, select the first or next year in the period of interest. If there are no more years to be evaluated for that site, proceed to Step 15.
- **Step 9:** For the selected site, determine and apply the appropriate SPFs for the site's facility type and traffic control features
- **Step 10:** Multiply the result obtained in Step 9 by the appropriate CMFs to adjust the predicted average crash frequency to site-specific geometric design and traffic control features
- **Step 11:** Multiply the result obtained in Step 10 by the appropriate calibration factor
- **Step 12:** If there is another year to be evaluated in the study period for the selected site, return to Step 8. Otherwise, proceed to Step 13.
- **Step 13:** Apply site-specific EB Method (if using the EB Method)
- **Step 14:** If there is another site to be evaluated, return to Step 7, otherwise, proceed to Step 15
- **Step 15:** Apply the project level EB Method (if the site-specific EB Method is not applicable)
- **Step 16:** Sum all sites and years in the study to estimate total crashes or average crash frequency for the network
- **Step 17:** Determine if there is an alternative design, treatment, or forecast AADT to be evaluated. Steps 3 through 16 of the predictive method are repeated for each alternative.
- **Step 18:** Evaluate and compare results

Exhibit 4-16: HSM Predictive Method Process



Source: HSM Section C.5, Figure C-2

4.4.9 Study Area Segmentation

Segmentation, step 5 in the predictive method, is the process of dividing the study area into smaller analysis sites that are each relatively uniform in character. Sites should be comprehensive, collectively covering all of the study area. When a segment ends or begins at an intersection, the segment lengths are measured from the center of the intersection.

Each intersection with a public road should be an individual site, even if it is a minor local road. Roadway segments, such as highways, streets, freeways, and ramps, should be divided into individual sites at a minimum at every intersection. Segments between intersections may need to be split into multiple sites, so that each site is uniform in character for the predictive model. Segments do not need to be split at driveways. Limiting the minimum segment length to 0.10 miles is appropriate to keep the analysis manageable.

Segments should always be split into distinct sites where any of the following change:

- Number of through lanes
- AADT
- Land use (rural/urban)
- Presence or type of median
- Posted speed limit

Continuous values such as lane width, shoulder width, or grade are generally rounded to some extent for the purposes of segmenting. The unrounded values are then averaged (weighting by length) for the predictive analysis. Some characteristics, such as the presence of curves and rumble strips, may not require the creation of a new site in some models and can instead be expressed as a percent of the site with that characteristic.

Segmenting requirements vary by predictive model, and the analyst is referred to the appropriate predictive model methodology reference text for further details before starting an analysis.

- Rural two-lane roads (HSM Part C Chapter 10, Section 10.5)
- Rural multilane roads (HSM Part C Chapter 11, Section 11.5)
- Urban and suburban arterials (HSM Part C Chapter 12, Section 12.5)
- Freeways and interchanges (ISATe User Manual, Chapter 2, Page 34)

4.4.10 Multiple-Year Analysis

The predictive method requires each year of the analysis period to be modeled individually. For future alternatives, a single year of analysis is adequate. For historical analysis, three to five years of crash data and matching site characteristics should be used. Often, most site characteristics do not change over the analysis period aside from the AADT.

When AADT is not available for every year in the analysis period, the following rules can be used for estimating AADT:

- For years between two known AADT values, use a linear interpolation
- For years after the latest known AADT value, use the latest known AADT value
- For years before the first known AADT value, use the first known AADT value

---

Example 4-7: HSM Predictive Analysis

<u>Predictive Method for Urban and Suburban Arterial Intersections</u>

The predictive method for urban and suburban arterials is described in the 1st edition HSM, Volume 2, Chapter 12, Section 12.4. The HSM lists an 18-step process for the urban/suburban arterial predictive method.

Note: The predictive method example is based on Adams St. and 128th St., which is a four-leg signalized intersection. The example is done only for the year 2010. A full analysis would analyze each year in the study period, from 2006-2010.

Step 1: Determine the limits of the roadway and facility types that will be included in the study network, facility, or site

Step 2: Define the time period of interest

Step 3: Determine AADT and availability of crash data for each year in the period of interest

Step 4: Determine geometric design features, traffic control features, and site characteristics for all sites in the study network

Data for the case study of the Adams St. and 128th St. intersection are shown in the following table for use in this example problem. The figure below shows these data in the HSM spreadsheet tool.

Data Requirement	Intersection of Adams St. and 128^{th} St.
AADT (vehicles/day)	AADTs were found through the local agency's traffic counts information page. Major street AADT is 23,150 vpd, and minor street AADT is 12,300 vpd.
Pedestrian volumes	The pedestrian volume was estimated as 50 pedestrians per day. Table 12-15 of the 1^{st} edition HSM, Volume 2, Chapter 12 gives estimates of pedestrian crossing volumes based on the general level of pedestrian activity.
Number of intersection legs	The intersection has four legs.
Type of traffic control	The intersection is signalized.
Number of approaches with a left-turn lane	All four of the approaches to the intersection have left-turn lanes.
Number of approaches with left-turn signal phasing and type of left-turn signal phasing for each movement	All four of the left-turn lanes have protected/permissive phasing.
Number of approaches with a right-turn lane	None of the approaches to the intersection have right-turn lanes.
Number of approaches with right-turn-on-red operation prohibited	None of the approaches have prohibited right-turn-on-red movements.
Presence/absence of intersection lighting	There is intersection lighting.
Presence/absence of Red Light Cameras	No red light cameras.
Maximum number of traffic lanes to be crossed by a pedestrian in any crossing maneuver at the intersection considering the presence of refuge islands	The maximum number of lanes to be crossed by a pedestrian is five lanes.
Number of bus stops within 1,000 feet of the intersection	There are four bus stops located within 1,000 feet of the intersection.
Presence of schools within 1,000 feet of the intersection	There are no schools located within 1,000 feet of the intersection.
Number of alcohol sales establishments that sell alcohol within 1,000 feet if the intersection	There are four different establishments that sell alcohol within 1,000 feet of the intersection.

HSM Spreadsheet Data Input

Worksheet 2A -- General Information and Input Data for Urban and Suburban Arterial Intersections			
General Information		**Location Information**	
Analyst	TPAU	Roadway	Adams Street
Agency or Company	ODOT	Intersection	128th Street
Date Performed	01/01/11	Jurisdiction	
		Analysis Year	2010

Input Data		**Base Conditions**	**Site Conditions**
Intersection type (3ST, 3SG, 4ST, 4SG)		--	4SG
AADT $_{major}$ (veh/day)	$AADT_{MAX}$ = 67,700 (veh/day)	--	23,150
AADT $_{minor}$ (veh/day)	$AADT_{MAX}$ = 33,400 (veh/day)	--	12,300
Intersection lighting (present/not present)		Not Present	Present
Calibration factor, C_i		1.00	1.05
Data for unsignalized intersections only:		--	
Number of major-road approaches with left-turn lanes (0,1,2)		0	
Number of major-road approaches with right-turn lanes (0,1,2)		0	
Data for signalized intersections only:		--	
Number of approaches with left-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	4
Number of approaches with right-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	0
Number of approaches with left-turn signal phasing [for 3SG, use maximum value of 3]		--	4
Type of left-turn signal phasing for Leg #1		Permissive	Protected / Permissive
Type of left-turn signal phasing for Leg #2		--	Protected / Permissive
Type of left-turn signal phasing for Leg #3		--	Protected / Permissive
Type of left-turn signal phasing for Leg #4 (if applicable)		--	Protected / Permissive
Number of approaches with right-turn-on-red prohibited [for 3SG, use maximum value of 3]		0	0
Intersection red light cameras (present/not present)		Not Present	Not Present
Sum of all pedestrian crossing volumes (PedVol) -- Signalized intersections only			50
Maximum number of lanes crossed by a pedestrian (n_{lanesx})		--	5
Number of bus stops within 300 m (1,000 ft) of the intersection		0	4
Schools within 300 m (1,000 ft) of the intersection (present/not present)		Not Present	Not Present
Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection		0	4

Step 5: Divide roadway into individual roadway segments and intersections

- Since there is only one site to be analyzed, this step is unnecessary.

Step 6: Assign observed crashes to individual sites

- It is useful to summarize the observed crashes to match with the crash prediction categories used by the predictive model. The Urban/Suburban Intersection model predicts multiple vehicle crashes and single vehicle crashes separately using different SPFs. It also provides predicted crash breakdowns by severity, fatal and injury (FI) or property damage only (PDO). Vehicle-bicycle crashes and vehicle-pedestrian crashes are independently identified.
- A total of nine observed crashes in 2010 were assigned to this site:
    - 4 FI crashes
    - 5 PDO crashes
    - 8 multiple-vehicle crashes
    - 1 single-vehicle crash
    - 1 vehicle-bicycle crash (also considered a single-vehicle crash)

Step 7: Select a roadway segment or intersection

- The intersection of Adams St. and 128th St. has been selected for further study.

Step 8: Select first or next year of the evaluation period

- Year 2010 is being considered in this example.

Step 9: Select and apply SPF

- SPFs relevant to Urban and Suburban Arterial Intersections are found in Section 12.6.2 of the 1st edition, HSM, Volume 2.
- Multiple-vehicle collisions: 6.884 total, 2.284 FI, 4.601 PDO
- Single-vehicle collisions: 0.435 total, 0.113 FI, 0.322 PDO
- Vehicle-bicycle collisions (predicted as a fixed portion of all vehicle collisions): 0.070 total, 0.070 FI, 0 PDO
- Vehicle-pedestrian collisions: 0.029 total, 0.029 FI, 0 PDO

Step 10: Apply CMFs

- Intersection left-turn lanes: CMF_{1i} (Table 12-24 in the 1st edition, HSM, Volume 2, Chapter 12)
    - For the intersection of Adams St. and 128th St., CMF_{1i} = 0.66
- Intersection left-turn signal phasing: CMF_{2i} (Table 12-25 in the 1st edition, HSM, Volume 2, Chapter 12)
    - For the intersection of Adams St. and 128th St., CMF_{2i} = 0.96
- Intersection right-turn lanes: CMF_{3i} (Table 12-26 in the 1st edition, HSM, Volume 2, Chapter 12)
    - For the intersection of Adams St. and 128th St., CMF_{3i} = 1.00
- Right-turn-on-red: CMF_{4i}
    - $CMF_{4i} = 0.98^{n_{prohib}}$

    Where:

    CMF_{4i} = crash modification factor for the effect of prohibiting right turns on red on total crashes

    n_{prohib} = number of signalized intersection approaches for which right-turn-on-red is prohibited

    - For the intersection of Adams St. and 128th St., CMF_{4i} =1.00
- Lighting: CMF_{5i}
    - $CMF_{5i} = 1 - 0.38 \times p_{ni}$

    Where:

    CMF_{5i} = crash modification factor for the effect of intersection lighting on total crashes

p_{ni} = proportion of total crashes for unlighted intersections that occur at night Default values for p_{ni} can be found in Table 12-27 in the 1st edition HSM, Volume 2, Chapter 12. It is recommended to replace the default values with locally derived values.

- For the intersection of Adams St. and 128th St., CMF_{5i} =0.95 using a locally-derived value (p_{ni} =0.154)

- Red-light cameras: CMF_{6i}
  - CMF_{6i} is based on the presence of red-light cameras. The base condition is their absence. There are no red-light cameras at the intersection of Adams St. and 128th St., so for the example CMF_{6i} =1.00. The formula for CMF_{6i} is (12-37) found in the 1st edition HSM, Volume 2, Chapter 12.

CMF_{1i}	CMF_{2i}	CMF_{3i}	CMF_{4i}	CMF_{5i}	CMF_{6i}	CMF_i
0.66	0.96	1.00	1.00	0.95	1.00	0.60

The CMFs above apply to vehicle crashes and have a combined value of 0.60.
The CMFs below apply only to vehicle-pedestrian crashes and have a combined value of 4.65.

- Bus stops: CMF_{1p} (Table 12-28 in the 1st edition, HSM, Volume 2, Chapter 12)
  - There are more than three (two bus stops at 128th and Adams St., one a block north on 128th and one half a block west on Adams St.) bus stops within 1,000 feet of Adams St. and 128th St., so CMF_{1p} =4.15.

- Schools: CMF_{2p} (Table 12-29 in the 1st edition, HSM, Volume 2, Chapter 12)
  - There are no schools within 1,000 feet of Adams St. and 128th St., so CMF_{2p} =1.00.

- Alcohol sales establishments: CMF_{3p} (Table 12-30 in the 1st edition, HSM, Volume 2, Chapter 12)
  - There are four (two stores, one restaurant, and one gas station) alcohol sales establishments within 1,000 feet of Adams St. and 128th St., so CMF_{3p} =1.12.

CMF_{1p}	CMF_{2p}	CMF_{3p}	CMF_p
4.15	1.00	1.12	4.65

Step 11: Apply a calibration factor

- The recommended Oregon Highway Safety Manual Calibration factor for urban and suburban four-way signalized intersections is 1.05.
- The resulting predicted crash values are:
    - 4.4 predicted multiple-vehicle crashes
    - 0.3 predicted single-vehicle crashes
    - 0.14 predicted pedestrian crashes
    - 0.07 predicted bicycle crashes

Step 12: Is there another year? If yes, return to step 8. (Only one year is included in this example.)

Step 13: Apply site-specific EB Method (This step is not included in this example.)

- Observed crashes are matched with the output of each SPF, and the EB Method is performed using the overdispersion parameter of the SPF.
- The following graphic shows the results of the site-specific EB Method calculation for vehicle crashes using the HSM Spreadsheets.

HSM Spreadsheet Results with Site-Specific EB Method

Worksheet 3A -- Predicted Crashes by Severity and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Collision type / Site type	Predicted average crash frequency (crashes/year)			Observed crashes, $N_{observed}$ (crashes/year)	Overdispersion Parameter, k	Weighted adjustment, w	Expected average crash frequency,
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix
INTERSECTIONS							
Multiple-vehicle							
Intersection 1	4.367	1.450	2.918	8	0.390	0.370	6.656
Single-vehicle							
Intersection 1	0.276	0.071	0.204	1	0.360	0.910	0.341
COMBINED (sum of column)	4.643	1.521	3.122	9	--	--	6.997

Worksheet 3B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1)	(2)	(3)
Site Type	N_{ped}	N_{bike}
INTERSECTIONS		
Intersection 1	0.141	0.073
COMBINED (sum of column)	0.141	0.073

Worksheet 3C -- Site-Specific EB Method Summary Results for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	$N_{predicted}$	N_{ped}	N_{bike}	$N_{expected (VEHICLE)}$	$N_{expected}$
Total	$(2)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(8)_{COMB}$ Worksheet 3A	(3)+(4)+(5)
	4.6	0.1	0.1	7.0	7.2
Fatal and injury (FI)	$(3)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(5)_{TOTAL} * (2)_{FI} / (2)_{TOTAL}$	(3)+(4)+(5)
	1.5	0.1	0.1	2.3	2.5
Property damage only (PDO)	$(4)_{COMB}$ from Worksheet 3A	--	--	$(5)_{TOTAL} * (2)_{PDO} / (2)_{TOTAL}$	(3)+(4)+(5)
	3.1	0.0	0.0	4.7	4.7

Step 14: Is there another site? If yes, return to step 7. (This step is not included in this example.)

Step 15: Apply project-level EB Method (This step is not included in this example.)

Step 16: Sum all sites and years

- Results from all sites and all years would be summed together for the study area total.
- For this intersection, the calibrated predictive method results for 2010 are:
  - 7.2 expected crashes
  - 2.5 expected fatal and injury crashes
  - 4.7 expected property damage only crashes
  - 0.14 predicted pedestrian crashes (assumed fatal or injury)
  - 0.07 predicted bicycle crashes (assumed fatal or injury)
- Results should ultimately be reported as excess expected, which is the expected crash value minus the predicted crash value.
  - 2.6 excess expected crashes
  - 1.0 excess expected fatal and injury crash
  - 1.6 excess expected property damage only crashes

Step 17: Repeat for alternative designs, treatments, or forecast AADT to be evaluated

- The predictive method is repeated for each alternative to be evaluated; however, no alternatives are included in this example.
- Countermeasures that are included in the predictive model can be evaluated by changing the CMFs used in the predictive method. This includes the addition of dedicated turn lanes, left-turn signal phasing, lighting, etc. This can be quickly achieved by duplicating and modifying the HSM spreadsheet used for the original analysis.
- Countermeasures that are not included in the predictive model can be evaluated by using CMFs from other sources. No more than three CMFs should be evaluated simultaneously in this fashion.
- See APM Section 4.6 for further information on countermeasures.
- See APM Section 4.4.5 to determine if the EB Method can be applied to alternative designs, treatments, or forecast AADT.

Step 18: Evaluate and compare results

- The evaluation and reporting of predictive method results is discussed below, in APM Section 0.

Note: Although the steps seem quite lengthy, the calculations can be expedited through the use of spreadsheets or other tools, discussed below in APM Section 4.4.13.

4.4.11 Reporting Predictive Method Results

When reporting predictive results, include the predictive models used along with a table of sites and characteristics. Depending on the availability of calibration factors and the use of the EB Method, the predictive method will result in one of these types of estimates for each site:

- Uncalibrated predicted crash frequency
- Calibrated predicted crash frequency
- Expected crash frequency
- Excess expected crash frequency

Depending on the predictive model used, these results may be reported by crash severity and/or collision type. Within a study area, this may result in a mix of these estimate types. When summing the predictive results for a project area total, each estimate type (uncalibrated predicted, calibrated predicted, expected, and excess expected) should be summed individually by severity and identified in the reporting. Any sites that are analyzed uncalibrated should be denoted.

Existing conditions evaluations should be reported using excess expected crash frequency, by severity, if possible. A positive excess expected crash frequency indicates that the site is performing more poorly than the HSM models suggest is normal for that site. Higher values of excess expected crash frequency indicate more potential for improvement.

Alternatives should be compared using the net change in expected or predicted crashes, by severity, if possible. Expected crashes can be determined for alternatives in limited situations (see APM Section 4.4.5 for more information).

Predicted or expected crashes should be reported over the study period as the total number of crashes in the study period, rounded to the nearest integer (for example, 15 crashes over five years). Alternatively a long-term yearly average frequency could be reported, for example 3.4 crashes per year.

4.4.12 Project-Induced Volume Changes

A project build alternative will often create new capacity and relieve congestion in the study area. As a result, the new roadway can attract previously latent demand. The project build alternative will thus have higher forecast traffic volumes than the no-build alternative. For large projects with regional impact, the difference in forecast volumes can be substantial.

It may be valuable to report and discuss the safety impacts of a project's design, independent of the effects of increased vehicle exposure. If there are significant (more than 10%) volume changes due to project build alternatives, the analyst has the option of reporting predictive results using both the actual build volumes and the future no-build volumes on the build alternative. The use of future no-build volumes must be clearly identified as such, and the report should acknowledge that the results are not the actual forecast estimates and are for discussion purposes only.

4.4.13 Tools for Implementing Predictive Methods

Computational tools are available to help in implementing the HSM Predictive Method. These tools are recommended to ensure uniform and transparent application of analysis techniques.

HSM Spreadsheets

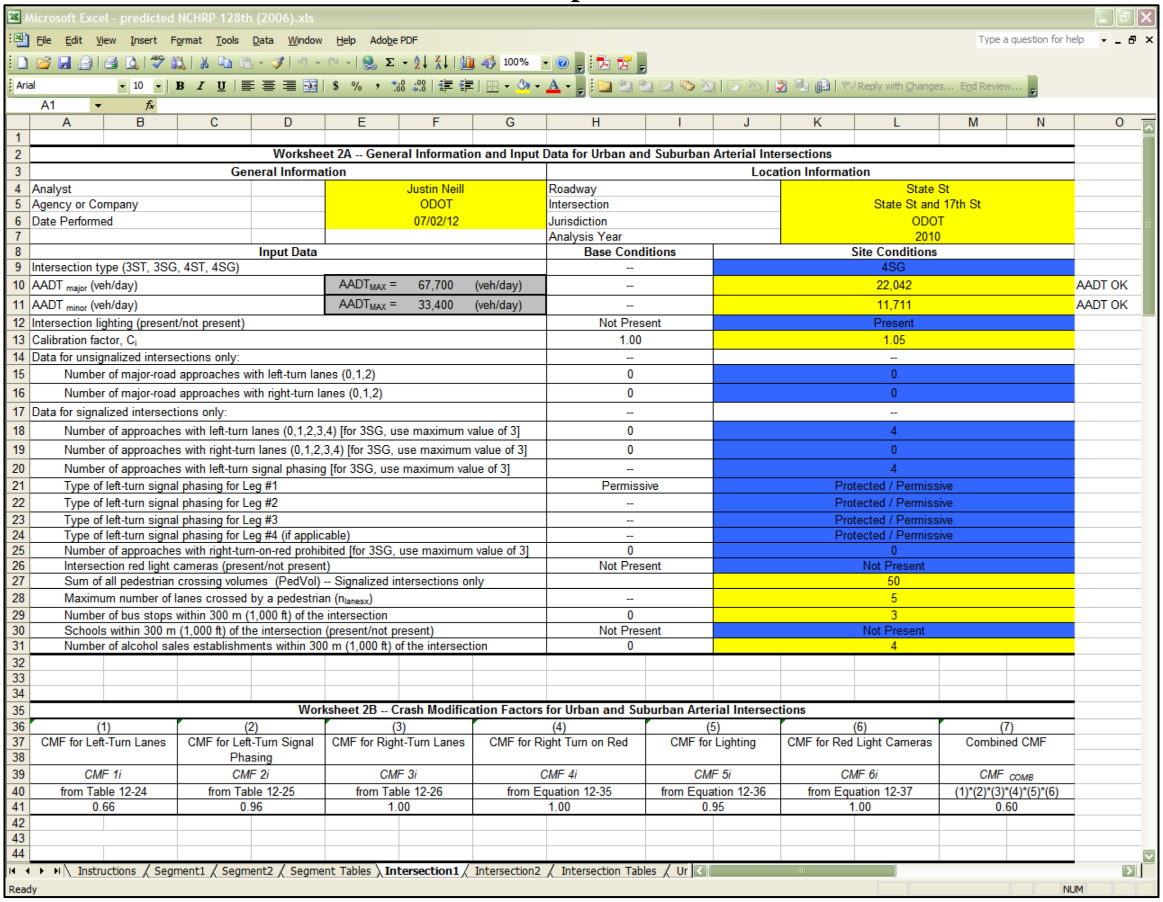
The HSM spreadsheets were developed as part of National Cooperative Highway Research Program (NCHRP) Project 17-38, Highway Safety Manual Implementation and Training Materials, to aid in training the HSM Part C predictive method (see Exhibit 4-17). These spreadsheets are designed for only two segments and two intersections for one year, but can be modified to include additional segment and intersection capacity. However, adding worksheets to increase the number of segments and intersections in an analysis can be moderately time consuming.

The spreadsheet displays results by segments and intersections and also separates the results into crashes by single-vehicle, multiple-vehicle non-driveway, and multiple-vehicle driveway-related. The worksheets are free to download, but do not have any technical support, at this time, for any changes or updates to the HSM. Data needs are consistent with the normal HSM Part C requirements.

The basic NCHRP spreadsheets allow the user to apply the EB Method for the current analysis period, but post-processing is required to apply the EB Method to alternatives where no observed crash data are available. See the discussion in APM Section 4.4.5 for more information on applying the EB Method.

The spreadsheets containing Oregon-specific calibration factors and crash proportions can be downloaded from the ODOT HSM Webpage. The general, non-calibrated, spreadsheets can be downloaded from the HSM Website.

Exhibit 4-17: HSM Spreadsheet Screenshot



Microsoft Excel - predicted NCHRP 128th (2006).xls

Worksheet 2A -- General Information and Input Data for Urban and Suburban Arterial Intersections			
General Information		**Location Information**	
Analyst	Justin Neill	Roadway	State St
Agency or Company	ODOT	Intersection	State St and 17th St
Date Performed	07/02/12	Jurisdiction	ODOT
		Analysis Year	2010

Input Data		Base Conditions	Site Conditions	
Intersection type (3ST, 3SG, 4ST, 4SG)		--	4SG	
AADT $_{major}$ (veh/day)	AADT$_{MAX}$ = 67,700 (veh/day)	--	22,042	AADT OK
AADT $_{minor}$ (veh/day)	AADT$_{MAX}$ = 33,400 (veh/day)	--	11,711	AADT OK
Intersection lighting (present/not present)		Not Present	Present	
Calibration factor, C_i		1.00	1.05	
Data for unsignalized intersections only:		--	--	
Number of major-road approaches with left-turn lanes (0,1,2)		0	0	
Number of major-road approaches with right-turn lanes (0,1,2)		0	0	
Data for signalized intersections only:		--	--	
Number of approaches with left-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	4	
Number of approaches with right-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	0	
Number of approaches with left-turn signal phasing [for 3SG, use maximum value of 3]		--	4	
Type of left-turn signal phasing for Leg #1		Permissive	Protected / Permissive	
Type of left-turn signal phasing for Leg #2		--	Protected / Permissive	
Type of left-turn signal phasing for Leg #3		--	Protected / Permissive	
Type of left-turn signal phasing for Leg #4 (if applicable)		--	Protected / Permissive	
Number of approaches with right-turn-on-red prohibited [for 3SG, use maximum value of 3]		0	0	
Intersection red light cameras (present/not present)		Not Present	Not Present	
Sum of all pedestrian crossing volumes (PedVol) -- Signalized intersections only			50	
Maximum number of lanes crossed by a pedestrian (n_{lanesx})		--	5	
Number of bus stops within 300 m (1,000 ft) of the intersection		0	3	
Schools within 300 m (1,000 ft) of the intersection (present/not present)		Not Present	Not Present	
Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection		0	4	

Worksheet 2B -- Crash Modification Factors for Urban and Suburban Arterial Intersections						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CMF for Left-Turn Lanes	CMF for Left-Turn Signal Phasing	CMF for Right-Turn Lanes	CMF for Right Turn on Red	CMF for Lighting	CMF for Red Light Cameras	Combined CMF
CMF 1i	*CMF 2i*	*CMF 3i*	*CMF 4i*	*CMF 5i*	*CMF 6i*	*CMF $_{COMB}$*
from Table 12-24	from Table 12-25	from Table 12-26	from Equation 12-35	from Equation 12-36	from Equation 12-37	(1)*(2)*(3)*(4)*(5)*(6)
0.66	0.96	1.00	1.00	0.95	1.00	0.60

Instructions / Segment1 / Segment2 / Segment Tables / Intersection1 / Intersection2 / Intersection Tables / Ur

Cost-Effectiveness Index Analysis spreadsheet

The Cost-Effectiveness Index Analysis spreadsheet is an adaption of the HSM spreadsheets to analyze countermeasures for bicycle and pedestrian crashes on urban and suburban arterials. This spreadsheet allows up to 9 segments and 8 intersections to be analyzed. If countermeasure costs are known a cost effectiveness index can be calculated.

ISATe

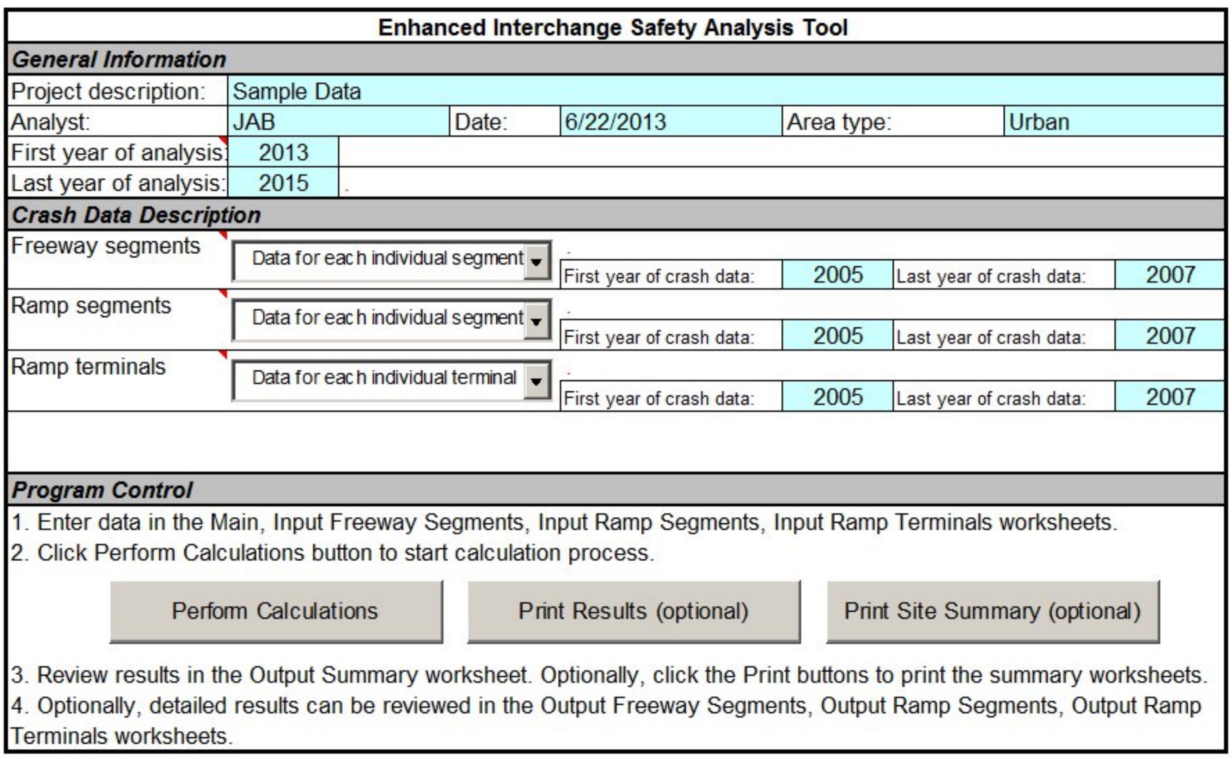
The Enhanced Interchange Safety Analysis Tool (ISATe) is a predictive model for freeway mainline segments and common interchange elements in both urban/suburban and rural contexts, implemented as a macro-enabled spreadsheet. The methodology used is consistent with the HSM Part C Predictive Method. ISATe has been incorporated in the HSM 2014 Supplement as Chapters 18 and 19. The ISATe spreadsheets and users guide are available for download from the HSM website as one of the spreadsheet tools.

ISATe can be used to analyze a single type of site, such as an extended length of freeway mainline. It can also be used to analyze a collection of interconnected sites of different types, such as a complex interchange. If the study area includes sites that are not covered by ISATe, other HSM Part C predictive methods can be used to complete the study area analysis. For example, the urban arterial predictive model may be used to evaluate the freeway overpass or neighboring intersections as applicable.

Predicted crashes are reported by each of the KABCO severity levels and by crash type. Expected crashes can be reported using the site-specific or project-level EB Method if crash data are available. The spreadsheet automates applying the EB Method with crash data from any time period, not only the analysis time period. The EB Method should be used only when study conditions are similar to those during the crash period, as described in APM Section 4.4.5.

As with other HSM predictive methods, ISATe requires the analyst to segment the facility into homogenous sites. Segmentation requirements for ISATe are somewhat more specific than other HSM models. Additional details are available in the “Segmentation Criteria” section of the ISATe User Manual on page 34. ISATe screen captures are shown Exhibit 4-18 through Exhibit 4-20.

Exhibit 4-18: ISATe Main Screen



Enhanced Interchange Safety Analysis Tool

General Information

Project description:	Sample Data				
Analyst:	JAB	Date:	6/22/2013	Area type:	Urban
First year of analysis:	2013				
Last year of analysis:	2015				

Crash Data Description

Freeway segments	Data for each individual segment	First year of crash data:	2005	Last year of crash data:	2007
Ramp segments	Data for each individual segment	First year of crash data:	2005	Last year of crash data:	2007
Ramp terminals	Data for each individual terminal	First year of crash data:	2005	Last year of crash data:	2007

Program Control

1. Enter data in the Main, Input Freeway Segments, Input Ramp Segments, Input Ramp Terminals worksheets.
2. Click Perform Calculations button to start calculation process.

Perform Calculations | Print Results (optional) | Print Site Summary (optional)

3. Review results in the Output Summary worksheet. Optionally, click the Print buttons to print the summary worksheets.
4. Optionally, detailed results can be reviewed in the Output Freeway Segments, Output Ramp Segments, Output Ramp Terminals worksheets.

Exhibit 4-19: ISATe Input Worksheet (Partial)

Input Worksheet for Freeway Segments	Segment 1 Crash Period	Segment 1 Study Period	Segment 2 Crash Period	Segment 2 Study Period	Segment 3 Crash Period	Segment 3 Study Period	Segment 4 Crash Period	Segment 4 Study Period
Clear / Echo Input Values (View results in Column AV) / Check Input Values (View results in Advisory Messages)								
Basic Roadway Data								
Number of through lanes (n):	5	5	5	5	4	4	4	4
Freeway segment description:	Station 0+00.00		Station 4+75.20			Alt seg		
Segment length (L), mi:	0.09	0.09	0.05	0.05	0.08	0.08	0.25	0.25
Alignment Data								
Horizontal Curve Data See note								
1 Horizontal curve in segment?:	No	No	No	No	No	No	Both Dir.	Both Dir.
Curve radius (R_1), ft:							2800	2800
Length of curve (L_{c1}), mi:							0.23	0.23
Length of curve in segment ($L_{c1,seg}$), mi:							0.15	0.15
2 Horizontal curve in segment?:							No	No
Curve radius (R_2), ft:								
Length of curve (L_{c2}), mi:								
Length of curve in segment ($L_{c2,seg}$), mi:								
3 Horizontal curve in segment?:								
Curve radius (R_3), ft:								
Length of curve (L_{c3}), mi:								
Length of curve in segment ($L_{c3,seg}$), mi:								
Cross Section Data								
Lane width (W_l), ft:	10.8	12	10.8	10.8	12	12	12	12
Outside shoulder width (W_s), ft:	4	4	5	5	9	9	10	10
Inside shoulder width (W_{is}), ft:	2.5	2.5	2.5	2.5	9	9	9	9
Median width (W_m), ft:	7	7	7	7	21	21	22	22
Rumble strips on outside shoulders?:	No	No	No	No	Yes	Yes	Yes	Yes
Length of rumble strips for travel in increasing milepost direction, mi:					0.08	0.08	0.25	0.25
Length of rumble strips for travel in decreasing milepost direction, mi:					0.08	0.08	0.25	0.25
Rumble strips on inside shoulders?:	No	No	No	No	Yes	Yes	Yes	Yes
Length of rumble strips for travel in increasing milepost direction, mi:					0.08	0.08	0.175	0.175
Length of rumble strips for travel in decreasing milepost direction, mi:					0.08	0.08	0.175	0.175
Presence of barrier in median:	Center	Center	Center	Center	Center	Center	Center	Center

Exhibit 4-20: ISATe Output Summary (Partial)

Output Summary								
General Information								
Project description:	Sample Data							
Analyst:	JAB	Date:	12/16/2014		Area type:		Urban	
First year of analysis:	2013							
Last year of analysis:	2015							
Crash Data Description								
Freeway segments	Segment crash data available?			Yes	First year of crash data:			2005
	Project-level crash data available?			No	Last year of crash data:			2007
Ramp segments	Segment crash data available?			Yes	First year of crash data:			2005
	Project-level crash data available?			No	Last year of crash data:			2007
Ramp terminals	Segment crash data available?			Yes	First year of crash data:			2005
	Project-level crash data available?			No	Last year of crash data:			2007
Estimated Crash Statistics								
Crashes for Entire Facility			**Total**	**K**	**A**	**B**	**C**	**PDO**
Estimated number of crashes during Study Period, crashes:			120.5	0.3	1.7	10.9	40.3	67.4
Estimated average crash freq. during Study Period, crashes/yr:			40.2	0.1	0.6	3.6	13.4	22.5
Crashes by Facility Component		**Nbr. Sites**	**Total**	**K**	**A**	**B**	**C**	**PDO**
Freeway segments, crashes:		4	24.5	0.1	0.4	2.2	4.3	17.5
Ramp segments, crashes:		6	4.9	0.0	0.1	0.7	1.1	3.0
Crossroad ramp terminals, crashes:		6	91.1	0.1	1.2	8.0	34.9	46.9
Crashes for Entire Facility by Year		**Year**	**Total**	**K**	**A**	**B**	**C**	**PDO**
Estimated number of crashes during the Study Period, crashes:		2013	40.1	0.1	0.6	3.6	13.4	22.4
		2014	40.2	0.1	0.6	3.6	13.4	22.5
		2015	40.2	0.1	0.6	3.6	13.4	22.5

PLANSAFE

PLANSAFE is a free GIS-based tool that estimates the anticipated safety impact of changes in traffic flow, demographics, and safety policy at a regional scale. PLANSAFE is not an HSM-based tool, although it is based on a similar methodology that has been modified for macroscopic implementation. The PLANSAFE SPFs were designed for use with the limited data typically available for a long-range regional analysis.

The tool uses outputs from a travel demand model and historic crash data with macro-level predictive analysis to determine the predicted future safety performance at a census block group or Transportation Analysis Zone (TAZ) unit of resolution. The results can be used to evaluate relative safety across an entire study area, neighborhoods/districts, a city, or a region.

PLANSAFE is available for download on the PLANSAFE TRB webpage. An updated version is in development but is not yet publically available.

PLANSAFE is an option for use on TSPs that involve major transportation network modifications or significant demographic changes. It provides a system-wide safety assessment for future scenario analysis that is unavailable with any other tool.

Minimum data requirements for PLANSAFE are the following GIS layers (geocoded) for baseline and alternative conditions:

- Road network (arterials and higher) with traffic volumes
- Intersection locations
- Baseline safety performance measure, such as total observed crash frequency
- At least one measure of demographic information, such as number of housing units

Safety performance predictions can be reported using various target crash types including all crashes, fatal and serious injury crashes, bicyclist crashes, pedestrian crashes, and others. Results are reported for each census block group or TAZ and can be exported in tabular or map form. PLANSAFE includes a variety of SPFs for each target crash type. These SPFs are dynamically evaluated and self-calibrated using observed crash data to provide the best performance with the data available. The analyst should always choose to use the SPF with the highest “Goodness of Fit” value. Additional data can be included to improve the accuracy of predictions.

What data are recommended varies based on the target crash type being predicted. Recommended datasets for each target crash type are shown in Exhibit 4-21.

Exhibit 4-21: PLANSAFE Recommended Data

Variable	TC	Int	NInt	KA	KAB	Ped	Bike	Deer
Target Crashes/Polygon	X	X	X	X	X	X	X	X
Total Number of Intersections/Polygon		X		X	X	X		
Total Roadway Length/Polygon (mile)		X						
VMT/Polygon	X	X	X	X	X	X	X	
Number of Intersections/Mile	X					X		X
Population between 16 and 64/Polygon	X	X	X					
Proportion Urban Population/Polygon	X			X	X	X	X	
Proportion Minority Population/Polygon	X			X	X	X		
Housing Units/Polygon				X	X	X	X	X
Density of Children in K12/Polygon				X	X	X		
Number of Schools/Polygon							X	
Average Household Income/Polygon				X				
Proportion Population in Urban Areas/Polygon								X
Rural Minor Arterial/Polygon (mile)								X
Rural Major Collector/Polygon (mile)								X
Sum of Combined Freeways, Principal Arterial, Rural Minor Arterial/Polygon (mile)	X							

TC = Total Crashes, Int = Intersection Crashes, NInt = Non-Intersection Crashes, KA = Injury Level K and A, KAB = Injury Levels K, A, and B. Ped = Pedestrian Crashes, Bike = Bike Crashes, Deer = Large Animal Crashes

What data are recommended varies based on the target crash type being predicted.

Using all recommended data, PLANSAFE SPF predictions are of a similar accuracy to HSM models, though the results are not as geographically specific as the HSM Predictive Method. Baseline and future roadway and traffic data are typically derived from a travel demand model. Baseline demographic data are available from the U.S. Census or American Community Survey. The analyst will need to provide future demographic conditions forecast through a travel demand model or by other methods. Data GIS layers are summarized by TAZ or census block group polygons using the PLANSAFE GIS tools or manually following the methodology in the PLANSAFE documentation.

PLANSAFE prediction sensitivity to demographic conditions vary based on the underlying SPF. Variables in the SPFs used in PLANSAFE generally have elasticities between 0 and 2, which describe how responsive the SPF prediction is to change in that variable. At an elasticity of 1, an X% increase in the variable will result in an X% increase in the predicted crashes. For example, consider an SPF predicting fatal and serious injury crashes that includes a variable for the percentage of population in urban areas at an elasticity of 1. An increase in urban population from 25% to 35% would increase the prediction from 100 to 110 fatal and serious injury crashes per year.

CMFs for countermeasures can be manually added to the future predictions to specific geographic regions or as systemic actions to the study area as a whole. Although a table of CMFs is provided in the PLANSAFE software, it is the responsibility of the analyst to ensure that any CMF is used appropriately and of sufficient quality (see APM Section 4.6). For example, a CMF that is intended for use with intersection crashes should not be applied to all crashes throughout the region.

At the time of this writing, some of the GIS toolbox components for PLANSAFE do not function with recent versions of ArcGIS. Without these tools, PLANSAFE can be very time-intensive and is best performed by analysts familiar with the software model. Consult the PLANSAFE manual for required GIS methodology.

Exhibit 4-22 gives an overview of the data flow within PLANSAFE and Exhibit 4-23 summarizes the analysis steps.

Exhibit 4-22: PLANSAFE Data Flow

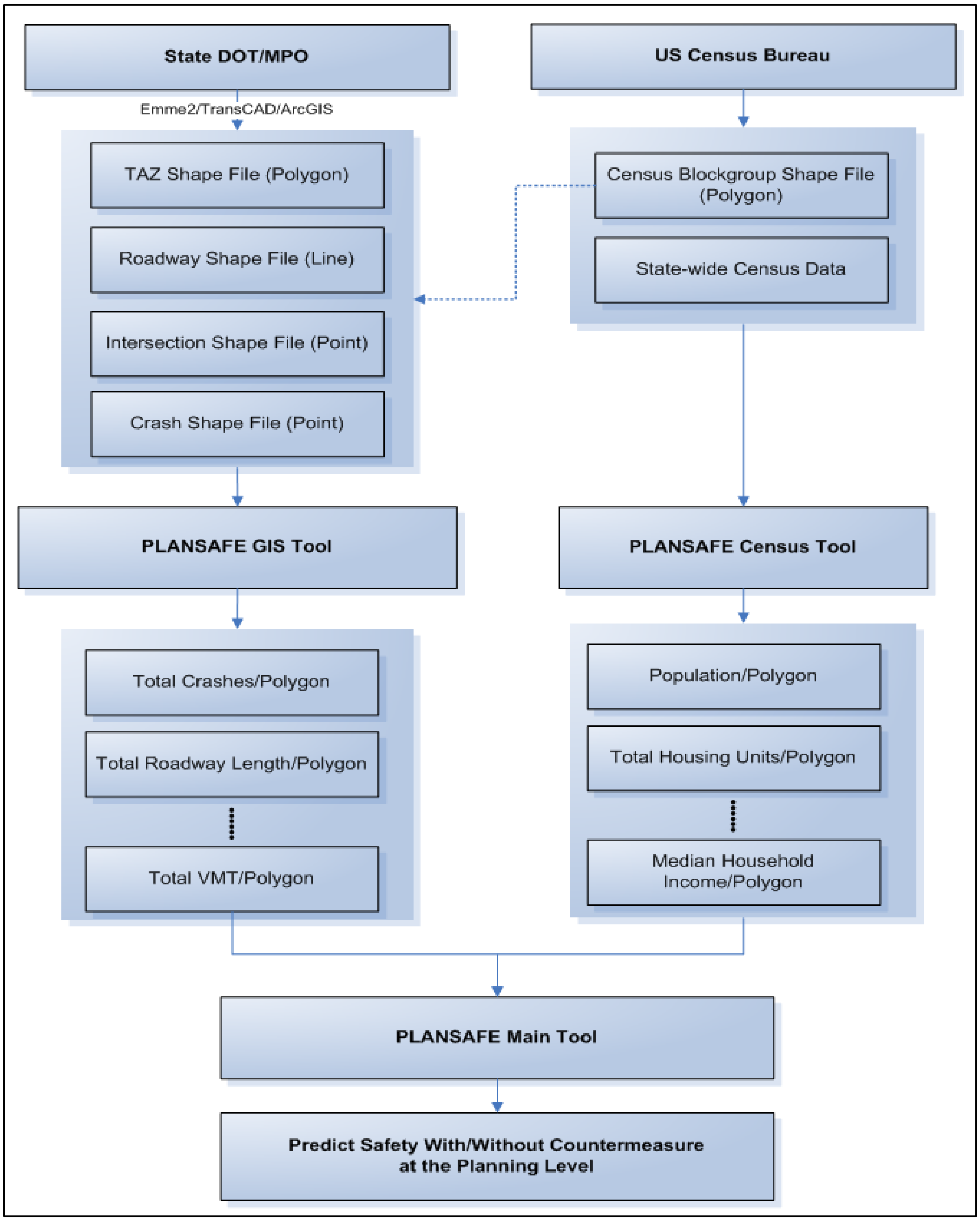
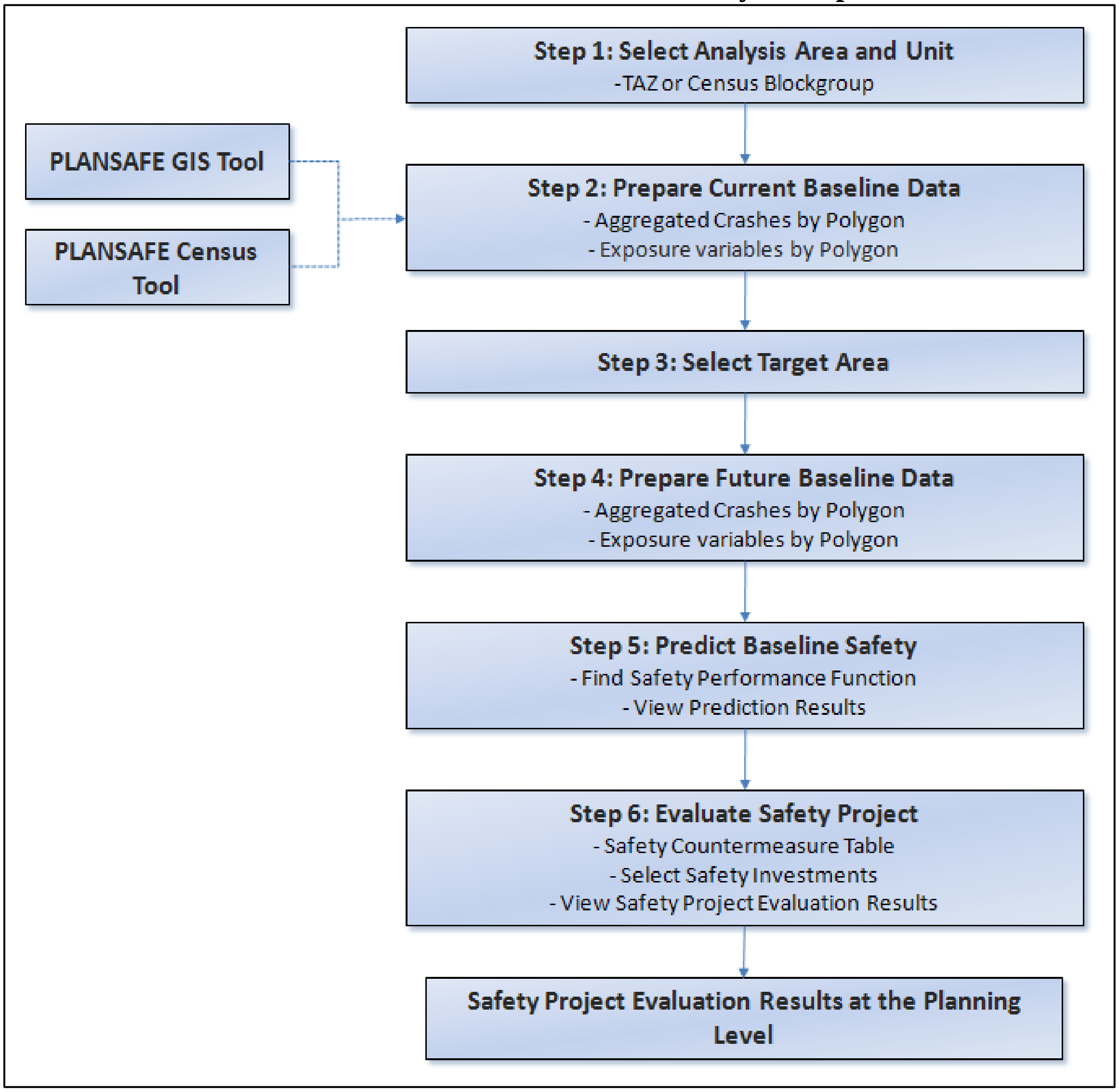


Exhibit 4-23: PLANSAFE Analysis Steps



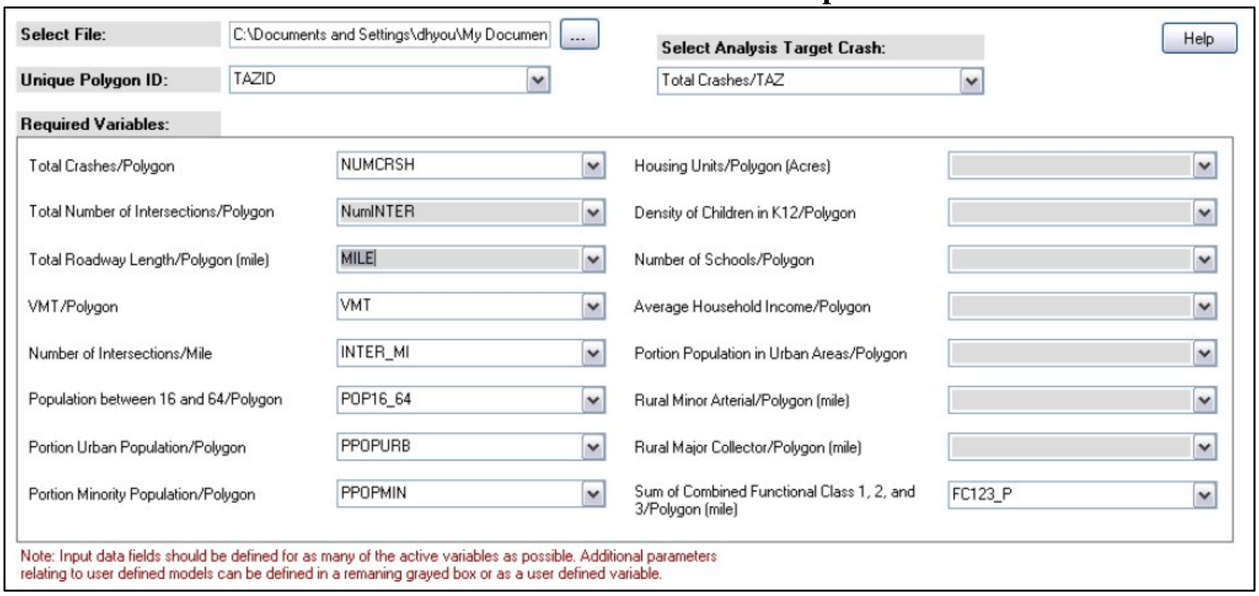
Example 4-8: PLANSAFE Regional Safety Analysis

The City of Klamath Falls is preparing an update to its TSP that includes plans for considerable new residential development. In addition to an intersection-based safety analysis, it would like to perform a PLANSAFE predictive analysis to assess the overall impact of residential growth, set citywide safety performance goals, and help direct its systematic safety countermeasures.

The results of a travel demand model were exported by TAZ for the current year and for the horizon analysis year. A desktop GIS client was used with the PLANSAFE GIS tool and the PLANSAFE Census tool to post-process crash data, census data, and roadway data into the format needed for analysis in PLANSAFE.

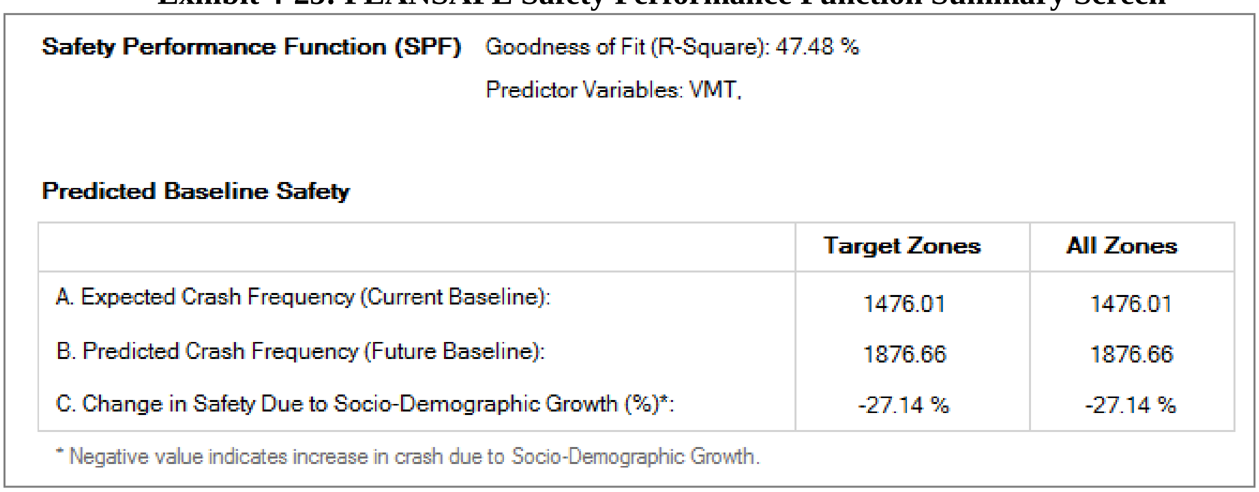
The City's TSP safety policy is focused on reducing the total number of crashes, so this was chosen as the target crash type for the PLANSAFE analysis. Exhibit 4-24 shows the data input screen where field names from the GIS shapefile are matched with the required variables, shown with white input boxes. Grey boxes are optional, but including them increases model performance.

Exhibit 4-24: PLANSAFE Data Input Screen



After the variables in the GIS file have been identified for the current baseline data, the analysis zone is selected and the process is repeated for the future baseline data. PLANSAFE recommends the best available SPF based on the data available, which is chosen by the City analysts. Exhibit 4-25 shows the SPF performance summary screen.

Exhibit 4-25: PLANSAFE Safety Performance Function Summary Screen



Using the selected SPF, PLANSAFE predicts the current expected crash frequency (current baseline) and future predicted crash frequency (future baseline). The results can be viewed in tabular form and with a map. Exhibit 4-26 displays the results by TAZ in table form, while Exhibit 4-27 shows the results on a map, with red indicating high predicted crash growth.

Exhibit 4-26: PLANSAFE Tabular Results

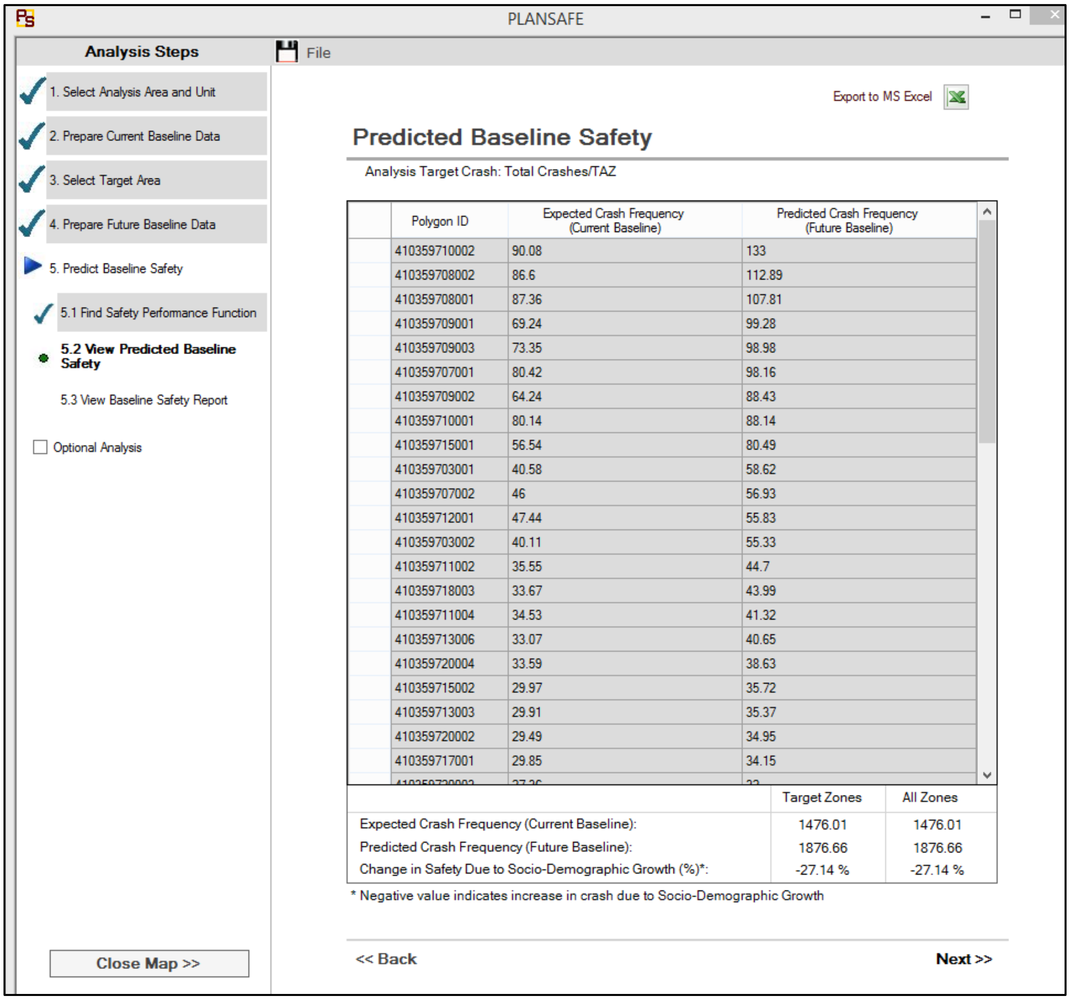
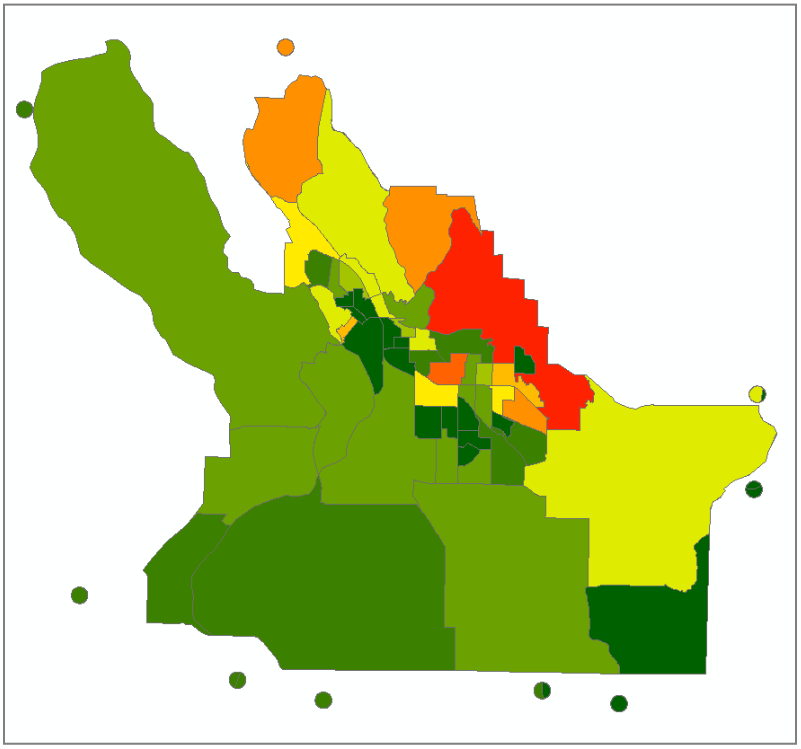


Exhibit 4-27: PLANSAFE Results Map



Based on the analysis, it is anticipated that the 24% growth in vehicle miles traveled (VMT), 15% growth in population and 18% growth in housing units in the region will, on average, result in a predicted increase in crashes by 27%, to 626 per year by the year 2025.

The analysis results estimate that without additional systemic countermeasures, there will be a 27% growth in the total number of crashes in the city due to demographic growth. Based on this, the City implements a safety program in its TSP with the goal of keeping the city's total crash growth below 15% through the forecast horizion.

Later in the TSP process, the City will evaluate systemic countermeasure options using PLANSAFE to quantify the expected results.

4.5 Multimodal Safety Analysis

Pedestrians and bicyclists are considered to be vulnerable road users, and identifying and improving conditions for these road users is an important part of many transportation plans and projects. Safety analysis for these modes is more difficult than for typical motor vehicle crashes because of practical limitations such as:

- Compared to motor vehicle crashes, fewer pedestrian and bicycle crashes occur and only a portion are reported. With fewer reported crashes to study, identifying statistically significant crash patterns is more difficult than for other types of vehicular crashes.

- Exposure data, such as pedestrian and bicycle volumes, are not widely available and travel patterns vary by user.
- Few systematic countermeasures for reducing pedestrian and bicycle crashes have been studied.

Although most frequently discussed in the context of pedestrian and bicycle safety, these limitations apply to other modes with limited data—such as motorcycles, freight, and transit—that may also be of interest in a safety analysis.

These practical limitations may limit the multimodal utility of the screening and predictive analysis methods included in this chapter. Additionally, subjective safety (the perceived safety by the traveling public) is an important component of multimodal planning and design. A person's choice of mode and route is strongly affected by how safe and comfortable the person feels about them.

4.5.1 Using Screening and Predictive Methods with Multimodal Crashes

When an analysis has few records of crashes involving pedestrians and bicyclists, reporting the details of those crashes with a narrative may be the only option available. In instances where sufficient crash data and/or exposure data exist, the screening and predictive analysis methods described in this chapter may be used.

4.5.2 Screening

SPIS does not include explicit consideration of multimodal crashes, but OASIS can be used to quickly identify hot-spots of crashes involving pedestrians or bicyclists across a large geographic region. This is done by adjusting the OASIS crash conditions criteria to include only pedestrian- or bike-involved crashes. The same can also be done for truck-involved crashes.

The critical crash rate method can be applied with a multimodal focus in two ways. One way is to use the traditional critical crash rate methodology with multimodal crashes as the target crash type. This would evaluate the pedestrian and bicycle crash frequency while controlling for vehicular exposure. Since vehicles are involved in all recorded multimodal crashes and vehicular exposure is usually at least an order of magnitude higher than multimodal exposure, this is generally sufficient.

Another potential way is to use pedestrian or bicycle volumes in the analysis. This should be limited to situations where multimodal traffic is generally high and varies in the project area, with available good historic data. An example is a popular mixed-use path with many street crossings. This analysis uses the same critical crash rate methodology described in APM Section 4.3.4, but with a crash rate calculated for a specific target mode, such as vehicle-bicycle crashes per million entering bicycles. Considerations would need to be given for historically and seasonally adjusting the pedestrian and bicycle volumes. This alternative analysis should be in addition to a traditional critical crash rate.

The excess proportions of specific crash types method is well suited for multimodal crash analysis, as this method does not require exposure data. As long as the target mode is included as a crash type to be considered, the analysis will flag locations where crashes of that mode are overrepresented. However, the analyst should be aware that this method may overlook crash types that are not well represented in the overall sample, which may hinder multimodal analysis particularly for small study areas.

4.5.3 Predictive

Most HSM Part C predictive analysis methods report pedestrian and bicycle crashes separately from other crash types and thus can be used for multimodal analysis. In general, the pedestrian and bicycle HSM predictive methods are less well developed than the motor vehicle predictive methods. Pedestrian crashes at urban and suburban signalized intersections are characterized by a unique SPF, considering vehicle and pedestrian volumes and pedestrian crossing distance. However, all other pedestrian and bicycle crashes are predicted using a locally derived crash adjustment factor. This factor is developed for each basic road configuration, considering vehicle speed, and predicts pedestrian or bicycle crashes as a simple fixed percentage of motor vehicle crashes.

ISATe does not predict pedestrian or bicycle crashes. Although freeways are generally not designed for pedestrians or bicyclists, interchange terminals may have high amounts of multimodal activity. Safety for these users is not evaluated through ISATe.

PLANSAFE does allow for pedestrian or bicycle crash prediction, though results are reported aggregated by census block group or TAZ.

4.5.4 Risk-based Multimodal Safety Analysis

The recent ODOT Pedestrian and Bicycle Safety Implementation Plan includes an effort to address the limitations inherent in multimodal safety analysis through a risk-based screening methodology. The risk-based process identifies roadway characteristics that have contributed to pedestrian and bicycle crashes in the historical crash data then evaluates the road network based on the presence of high-risk characteristics. This allows for a prioritization of safety projects that is proactive, addresses perceived safety by users, and is applicable where no or few pedestrian or bicycle crashes have been recorded.

Identified high-risk screening characteristics include:

- Posted speed
- Number of lanes
- Presence of bicycle facilities
- Number of driveways
- Presence of transit stops
- Occurrence of pedestrian or bicycle crashes
- Annual average daily traffic
- The presence of signalized intersections or pedestrian activated systems

The risk-based method of the plan is limited by the availability of data for the roadway network. Although the risk of serious pedestrian crashes is probably related to factors such as pedestrian volume, pedestrian age, and volume of turning vehicles, these factors were not included in the method because the data were not available across the roadway network.

This risk-based screening method is distinct from the HSM screening and predictive methods. Unlike the HSM screening methods, it is not based on crashes and does not require any crashes to have been recorded in the study area. Unlike the HSM predictive methods, the aim is not to quantify the effects of any particular treatment or roadway design. Risk-based screening is a complement to HSM analysis methods.

Although risk-based safety analysis methods can be useful in many planning contexts, the results cannot be used to apply for funding from the FHWA's Highway Safety Improvement Program (HSIP). Risk-based analysis results can be used to support an application to the "Enhance" portion of ODOT's State Transportation Improvement Program (STIP) but not to the "Fix-It" portion of the STIP.

The analyst is encouraged to contact TPAU if a risk-based multimodal safety analysis is being considered for a project or system plan.

4.6 Countermeasure Selection and Evaluation

Most crash analysis projects will specify general or potential ranges of countermeasures. The results of the analysis methods in this chapter can be used as a starting point for identifying countermeasures. Sites that demonstrate an excess of a specific crash type are more likely to benefit from countermeasures targeted at that crash type.

There are many resources that provide potential countermeasures for a given crash pattern.

- The initial source for countermeasures should be the ODOT approved set of proven countermeasures and associated CRFs that are used for the All Roads Transportation Safety (ARTS) Program. Use of these CRFs allow for all countermeasures to be evaluated consistently and fairly. If the desired countermeasure is not in the ARTS CRF list, a CMF from Part D or from the CMF Clearinghouse (studies with 3 star rating or better) may be used.
- Information on countermeasure selection is included in the ODOT Safety Investigations Manual and Chapter 6 of the HSM.
- Part D of the HSM is also an extensive resource of countermeasure treatments and includes quantitative CMFs that estimate the expected change in crash frequency resulting from implementation.
- The CMF Clearinghouse (http://www.cmfclearinghouse.org) is an active online database maintained by the FHWA providing CMFs and supporting research. The FHWA has developed a list of proven systemic countermeasures that are widely applicable to common situations.
- PedBikeSafe.org is an interactive FHWA guide to pedestrian and bicycle safety countermeasures. The website guides users to targeted countermeasures based on crash trends, patterns, and the road context.

Some CMFs are applicable only for specific facility types, AADT ranges, or base conditions. Engineering judgment is critical in selecting the appropriate CMF for a project. CMFs are an active area of research, and the best available CMF for a situation may change frequently.

> *If CMFs are being used that are not derived from the ARTS CRF list, the ODOT CMF standard is to use CMFs with quality ratings of three stars or better (star rating is a rating of the type of research and more stars indicate better, more reliable results). For many countermeasures, there may be multiple CMFs available with different levels of crash reduction.*

Care should be taken not to just pick the CMF with the highest reduction because a particular CMF may apply to all crashes, or just severe crashes, or for a particular crash type. The CMF study parameters may limit applicability to a particular roadway configuration or to a specific volume range. The CMF AADT range should be no more than +/- 10% away from the countermeasure location AADT. Values greater than this indicate that the subject roadway likely does not have the same characteristics as the one in the CMF study.

Certain countermeasures may require coordination, review, or approval by the Region or State Traffic Engineer (see list of ODOT Traffic Engineering Authorities). Region Traffic will likely perform a detailed safety investigation of the crash patterns later during project delivery/design phase. When selecting countermeasures, the analyst should coordinate with Region Traffic and/or ODOT TRS.

Countermeasures can generally be grouped into four categories: education, enforcement, emergency medical services and engineering.

- **Education** is a variety of public information campaigns using a broad range of media to reach a target audience. These campaigns can be effective in reducing driver error or problematic behaviors by making motorists aware of the risks and consequences of certain driving behaviors and environments encountered. These can be handled by the Region Public Information office (for a specific area) or by the Traffic Safety Division (for programmatic issues).
- **Enforcement** involves increased policing activity to encourage compliance with existing traffic controls and regulations. Increased enforcement is often implemented due to frequent driver violations. The application of enforcement countermeasures is typically coordinated by Region Traffic Sections.
- **Emergency Medical Services (EMS)** involves working with EMS providers to improve response time to incidents, which plays a role in the severity of the crash.
- **Engineering** is a broad range of improvements to the transportation system to improve roadway safety. These may include geometric improvements, ITS applications, changes to traffic controls (signing, striping, signals, etc.), changes to roadway surfacing, or operational enhancements.

Specific investigation into countermeasures should be at the appropriate level for the analysis being conducted.

Countermeasure options in a system plan or alternative design concepts should be screened based on the relative safety improvement expected, which may be reported as a range of feasible values. This reduction can be determined using CMFs applied to historic crash values. Reporting should indicate the source and quality of CMFs used. Reporting should also identify what types of crashes the CMFs are expected to reduce. When possible, report crash reductions by severity level with an emphasis on fatal and serious injury crashes.

4.7 Multimodal Mixed-Use Areas (MMAs)

A recent amendment to Oregon Administrative Rule (OAR) 660-012-0060 (Plan and Land Use Regulation Amendments) introduced the Multimodal Mixed-Use Area (MMA) designation that local governments can use to gain new flexibility in applying transportation performance standards in specific locations. An MMA allows a local government to amend a functional plan, comprehensive plan, or land use regulation without consideration of motor vehicle congestion, delay, or travel time.

Amendments within an MMA must still comply with transportation standards and policies promoting safety for all modes.

In evaluating a local request for ODOT concurrence with a proposed MMA designation near an interchange, ODOT must consider the following safety factors per OAR 660-012-0060(10)(a):

- Whether the interchange area has a crash rate that is higher than the statewide crash rate for similar facilities. The statewide crash rate tables are available on the ODOT Crash Analysis and Reporting Unit Publications webpage.
- Whether the interchange area is in the top 10% of locations identified by the SPIS. SPIS locations can be found on the SPIS webpage or through TransGIS.
- Whether existing or potential future traffic queues on the interchange exit ramps extend onto the mainline highway or the portion of the ramp needed to safely accommodate deceleration. Procedures for estimating queue lengths are found in Section 7.5 of the APM Version 1. Intersection functional areas are discussed in APM Section 4.8.1.

It is strongly encouraged that these considerations be taken into account during ODOT review of all proposed MMA designations, including those that are not near an interchange. In addition, a predictive analysis is encouraged for roadways within the proposed MMA to determine the excess expected average crash frequency. This crash frequency can be used in addition to crash rates to characterize the prevailing safety conditions of the MMA area.

Additionally, for local governments, it is suggested that safety performance standards using one of the predictive methods described in this chapter be established for considering land use amendments within designated MMAs. Standards could be based on reducing or maintaining within a predetermined range the predicted or expected crash frequency. Increases in estimated crashes caused by exposure would be offset by proposed safety countermeasures or payment into a safety fund.

4.8 Other Safety-related Techniques

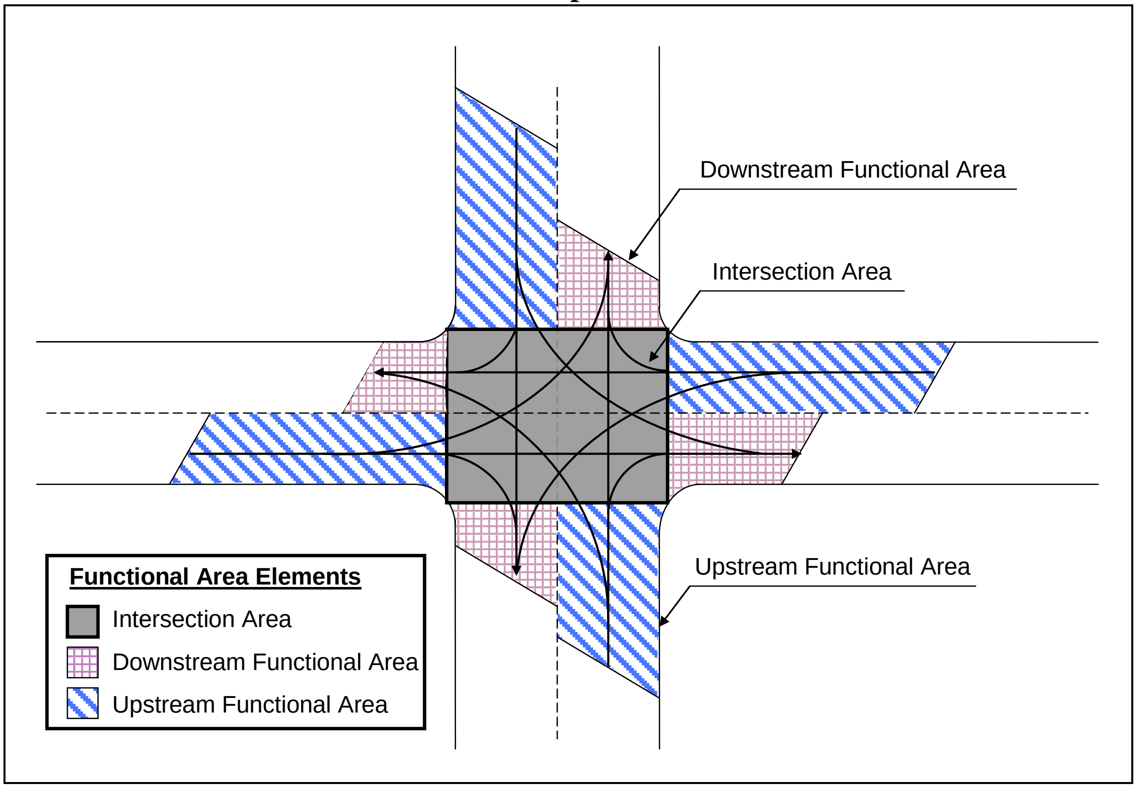
The techniques listed in this section provide a detailed review of the safety impact associated with intersection functional areas, sight distance, intersection conflict points, and segment access management. These techniques can be used in addition to the screening and predictive tools identified in this APM chapter to assist in evaluating a proposed build alternative or safety mitigation. The application of these techniques incorporates necessary human factors into the analysis. Functional area, sight distance, conflict points and other techniques focus on the need to spread apart the necessary driver information processing points. Drivers can be confused or miss obstacles if information about driveways, intersections, and other elements are too closely spaced. In addition, as the driving population ages, the importance of analyzing the human factor cannot be overstated. The analyst is strongly encouraged to be familiar with Chapter 2 of the HSM.

4.8.1 Functional Area of an Intersection

A functional area analysis should be done to evaluate the impact of closely-spaced intersections, access points, or any combination of both. This can be for either existing or proposed (alternative) conditions. Areas with long queues should also be reviewed for functional area impacts. The analysis should also be done when adding new connections to a roadway to verify that functional area overlap does not occur and vehicle maneuvers can be performed lawfully. The functional area of an intersection is the area in which an intersection affects vehicle paths. The intersection functional area—defined as the physical area where two roads overlap—influences driver decisions, vehicle movements, and vehicle queues. The sections beyond the intersection area are composed of upstream and downstream functional areas. The upstream functional area for vehicles moving toward the intersection has four maneuvering elements. The downstream functional area for vehicles traveling away from the intersection has one. These maneuvering elements are listed in the next section. Each element is unique in its contribution to the functional area. Exhibit 4-28 shows the functional area of an intersection.

The upstream functional area described in this section is defined similarly to the "influence area" used in the Highway Safety Manual (HSM). The HSM does not use the downstream functional area definition. In addition, the functional area in this section is not the same as the weaving distance calculation used in the approach permitting (development review) process

Exhibit 4-28: Components of the Functional Area[2]



Both upstream and downstream functional areas may need to be studied for an intersection improvement or any project with access in the immediate intersection area. However, only the upstream functional area needs to be studied if an access is opened upstream of an intersection and only the downstream functional area needs to be studied if an access is opened downstream of an intersection. Functional area analysis may determine the placement of an access, the provision of turn movements, or the number of travel lanes.

Upstream Functional Area

Four elements make up the distance a vehicle travels as it approaches an intersection:

- **Distance traveled during the perception-reaction time (d_1):** The perception-reaction time has four phases—perception, intellection, emotion, and volition (PIEV). This distance involves the driver seeing the intersection, thinking about their options, making a decision, and initiating their response. The perception-reaction time is 2.0 seconds for desirable conditions and 1.0 seconds for limiting conditions as set by the Transportation Research Institute (TRI) of Oregon State University in Discussion Paper No. 7, Functional Intersection Area (January 1996) (1), which was prepared for ODOT to

[2] Data referenced through exhibits in this section were obtained from the Discussion Papers presented to the Oregon Department of Transportation by the Transportation Research Institute (TRI) of Oregon State University.

support its policies, practices, and procedures. A table of perception-reaction distances for varying time intervals is shown in Exhibit 4-30.

- **Distance traveled while the driver decelerates or brakes and moves laterally into a turn bay (d_2):** The limiting condition for a vehicle traveling laterally over a 12-foot lane is three seconds in urban areas with an assumed lateral movement at four feet per second (fps). For each 12-foot lane, three seconds of travel time should be added. Four seconds of travel time per 12-foot lane should be assumed for rural conditions, with an assumed lateral movement at three fps.
- **Distance traveled during full deceleration (d_3):** These maneuver distances are based on a 6.7 fps^2 deceleration rate accommodating 85% of drivers. The limiting condition accommodates 50% of drivers with a deceleration rate of 9.2 fps^2 or higher. The distances of d_1, d_2, and d_3 are dependent on vehicle speed. Maneuver distances ($d_2 + d_3$) and PIEV plus maneuver distance ($d_1 + d_2 + d_3$) are based on the intersection functional area approaches from the ODOT's Access Management Manual. Values for just the maneuver distance and PIEV plus maneuver distance are developed from the uniform acceleration formulas and are listed in the table in Exhibit 4-31. Note that storage length, d_4, is not included in the values of Exhibit 4-31. Perception-reaction time may not always be included in an upstream functional area analysis if decisions are made prior to the driver's approach to the intersection.
- **Storage length (d_4):** Calculated by the 95th percentile queue for turning or through traffic, whichever is greater.

Exhibit 4-29 depicts the succession of these movements.

Exhibit 4-29: Upstream Functional Area; d_1, d_2, d_3, and d_4

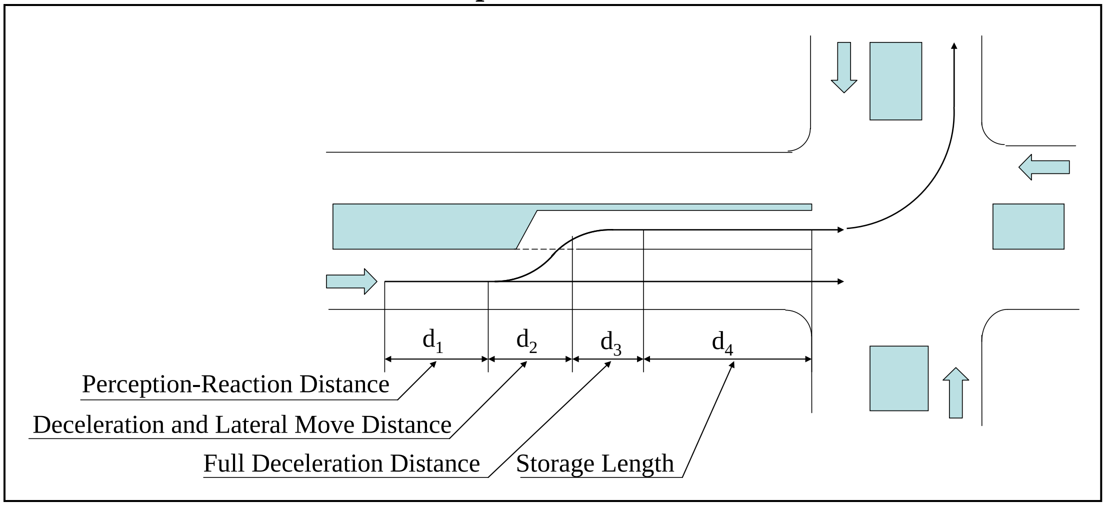


Exhibit 4-30: Perception-Reaction Time, d_1

Distance Traveled During Perception-Reaction					
US Customary Units (Feet)(1)(2)					
Speed (mph)	Perception-Reaction Time (Seconds)(3)				
	1.0	2.0	3.0	4.0	5.0
30	45	90	130	175	220
40	60	115	175	235	295
45	65	130	200	265	330
50	75	145	220	295	370
60	90	175	265	355	440
70	105	205	310	410	515

(1) Rounded to 5 feet

(2) US Customary: distance (feet) = 1.47*(speed in mph)*t

(3) Distance traveled in t-seconds

A functional area analysis has four possible values:

- The unfamiliar path under desirable conditions
- The unfamiliar path under limiting conditions
- The familiar path under desirable conditions
- The familiar path under limiting conditions

Limiting conditions are used for projects that have design constraints. A project using limiting conditions must justify this reasoning and provide appropriate documentation. From one to all of these scenarios may need to be checked depending on driver types and roadway conditions.

The familiar vehicle path would be used by drivers who would anticipate the intersection and know the lane to be in to complete the turn. This is more likely near grocery stores or residential areas. The unfamiliar vehicle path would be used by drivers who may not know anything about the intersection before approaching. This is more likely near developments such as tourist areas and regional stores.

Exhibit 4-31 demonstrates the difference between desirable conditions and limiting conditions. Desirable conditions allow for a longer perception-reaction time and a lesser rate of deceleration. Area demographics may affect these values because older, younger, and unfamiliar drivers may have longer perception-reaction times.

Exhibit 4-31: Upstream Functional Intersection Area, $d_1 + d_2 + d_3$

Upstream Functional Intersection Area Excluding Storage, in Feet[1]				
Speed (mph)	Desirable Conditions		Limiting Conditions	
	Maneuver Distance[2] [6] (ft)	PIEV[3] Plus Maneuver Distance (ft)	Maneuver Distance[4] [6] (ft)	PIEV[5] Plus Maneuver Distance (ft)
	$d_2 + d_3$	$d_1 + d_2 + d_3$	$d_2 + d_3$	$d_1 + d_2 + d_3$
20	70	130	70	100
25	110	185	105	140
30	160	250	145	190
35	215	320	190	240
40	275	395	245	305
45	345	475	300	365
50	425	570	365	440
55	510	670	435	515
60	605	780	510	600
65	710	900	590	685

(1) Rounded to 5 feet

(2) 10 mph speed differentials, 5.8 fps^2 deceleration while moving from the through lane into the turn lane; 6.7 fps^2 average deceleration after completing lateral shift into the turn lane

(3) 2.0 second perception-reaction-time

(4) 10 mph speed differential; 5.8 fps^2 deceleration while moving from through lane into the turn lane; 9.2 fps^2 average deceleration after completing lateral shift into the turn lane

(5) 1.0 second perception-reaction time

(6) Assumes turning vehicle has “cleared the through lane” (a following through vehicle can pass without physically encroaching on the adjacent through lane when the turning vehicle has moved laterally 10 ft. Also assumes a 12 ft. lateral movement will be completed in 3.0 seconds

Turn lanes may be installed at unsignalized intersections to improve safety and at signalized intersections to expand the roadway capacity. The minimum length for a turn bay (including the taper) is the deceleration and lateral move distance and the full deceleration distance, plus the storage length ($d_2 + d_3 + d_4$). The upstream functional area increases/decreases with the number of lanes (related to d_2), the rate of deceleration (related to d_3), and the queue (d_4). Vehicles that change lanes at an intersection expand the influence area of the intersection and the intersection functional area.

Turn lanes remove turning vehicles from the general flow of traffic allowing through vehicles to proceed without significant slowing or stopping. Research indicates that the crash potential between turning vehicles and through traffic increases exponentially as the speed differential increases. It is desirable to have no more than a 10 mph speed differential between vehicles in the through lanes and vehicles entering turn bays. Providing a turn lane with adequate deceleration distance significantly lowers the speed differential between turning vehicles and through traffic.

Turn lanes at a signalized intersection serve as capacity expanders and are constructed where demand approaches or exceeds capacity. The typical urban turn bay is 100 feet unless capacity or speeds require it to be longer, while the typical rural turn bay is 150 feet. The 95th percentile queue is generally calculated by traffic analysis software for signalized intersections. Chapter 13 contains the procedures to consider turn bays for intersections and estimating the length for right-turn and left-turn vehicle queues.

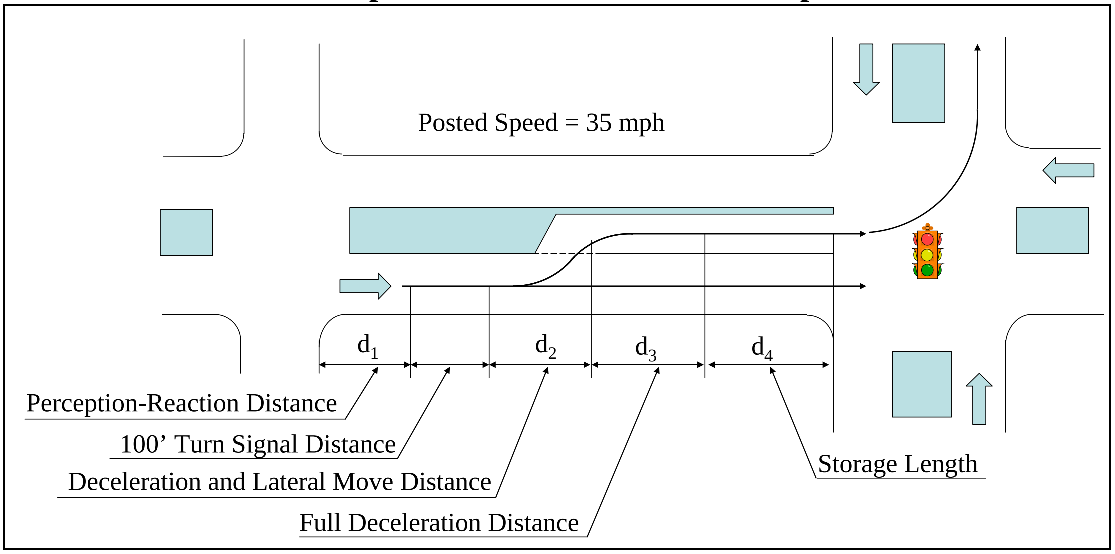
Example 4-9: Upstream Functional Area Distance Calculation

A development proposes to access the roadway upstream of a signalized intersection. The intersection shown has a volume of 100 vph using the left-turn lane.

The road has a posted speed of 35 mph. How close to the intersection can a proposed driveway be placed?

Assume the signal has a 120-second cycle length.

Upstream Functional Area Example



Solution

<u>PIEV Plus Maneuver Distance ($d_1 + d_2 + d_3$)</u>

Check values from Exhibit 4-31:

Limiting Condition

$d_{L1} = d_1 + d_2 + d_3 = 240$ feet

Desirable Condition

$d_{D1} = d_1 + d_2 + d_3 = 320$ feet

<u>Storage Length (d_4)</u>

For this signalized intersection, the Left-Turn Movement Queue Estimate Technique from Chapter 14 was used.

Assume each cycle is 120 seconds (30 per hour)

Assume the constant, t, is 1.85 to find the 95th percentile queue. (See Chapter 7 for background information)

$$\text{Length} = \frac{\text{volume}}{\#\text{ of cycles/hour}} * t * 25\text{feet}$$

$$\frac{100\text{ vph}}{30\text{ cycles/hr}} * 1.85 * 25\text{ feet} = 154.17\text{ feet} = 154\text{ feet (rounded)}$$

<u>Turn Signal Length</u>

Another 100 feet must be added to provide distance for the turn signal to be used.

<u>Total Functional Area Length</u>

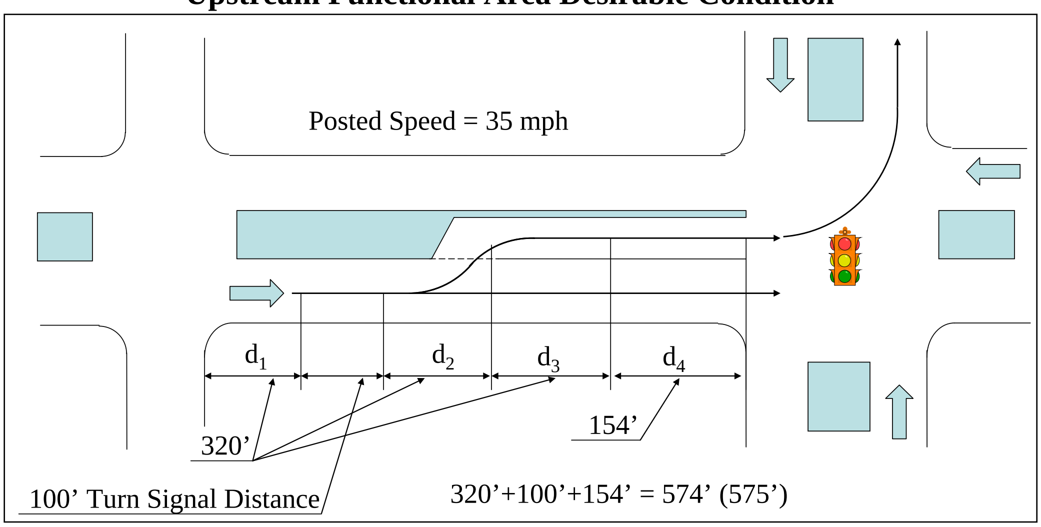
Limiting Condition

$d_{LTotal} = d_1 + d_2 + d_3 + d_4 +$ Signal Distance = 240' + 154' + 100' = 494 feet

Desirable Condition

$d_{DTotal} = d_1 + d_2 + d_3 + d_4 +$ Signal Distance = 320' + 154' + 100' = 574 feet

Upstream Functional Area Desirable Condition



Using the values for a 35-mph speed in Exhibit 4-31, the desirable conditions path is 575 feet long and the limiting conditions path is 495 feet long. The desirable condition calculated using the value from Exhibit 4-31 is the greatest distance and is the closest location to access the highway with respect to the intersection. The driveway should be no less than 575 feet from the intersection.

Downstream Functional Area

As a vehicle travels away from an intersection the driver needs a minimum stopping sight distance (d_5) before approaching another intersection or driveway. The stopping sight distance is the distance traveled while braking to avoid an unexpected obstacle. Stopping sight distance is determined by AASHTO by the speed, brake reaction time, and the deceleration rate. A table developed from the following AASHTO equation is shown in Exhibit 4-32:

$$d = 1.47 * V * t + 1.075 * \left(\frac{V^2}{a} \right)$$

Where: V – speed, mph
t – brake reaction time, 2.5s
a – deceleration, ft/s^2

If an acceleration lane is present, the stopping sight distance is measured from the end of the taper. The downstream intersection functional area includes the distance traveled during acceleration before merging into the general traffic flow. Acceleration lanes are rarely provided for at-grade arterials. Lane drops that have an auxiliary lane longer than the distance traveled during acceleration before merging will not be included in the functional area analysis.

Exhibit 4-32: Downstream Functional Area

Downstream Intersection Functional Area	
Speed (mph)	**AASHTO Stopping Sight Distance (Feet)**
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570

Note that the downstream functional area analysis is a check for adequacy in safety and legality. Further analysis will be necessary to ensure the adequacy of the design.

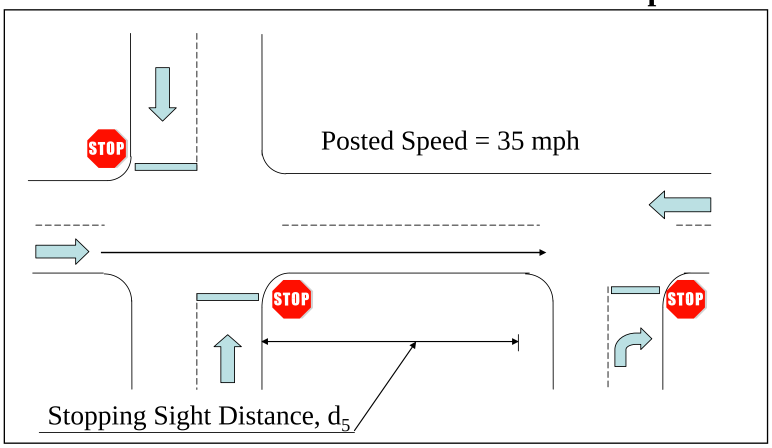
Functional Intersection area is detailed in the ODOT Access Management Manual and further information is contained in Discussion Paper No. 7, Functional Intersection Area (1), Transportation Research Institute (TRI) of Oregon State University (January 1996).

Example 4-10: Downstream Functional Area Distance Calculation

A driveway is located 350 feet downstream of the intersection shown. The main street has no traffic control and a speed of 35 mph.

Is there adequate spacing between the intersection and the driveway? What is the stopping sight distance (d_5) for this intersection? The following figure shows a general diagram of the intersection area.

Downstream Functional Area Example



Solution

Stopping Sight Distance, d_5

Check values from Exhibit 4-32: AASHTO Stopping Sight Distance at 35 mph

d_5 = 250 feet

The driveway must be at least 250 feet from the next downstream intersection to avoid a stopping sight distance conflict. Keep in mind that the downstream functional area analysis is a check for adequacy in safety and legality. Further analysis will be necessary to ensure the adequacy of the design.

Functional Area Application

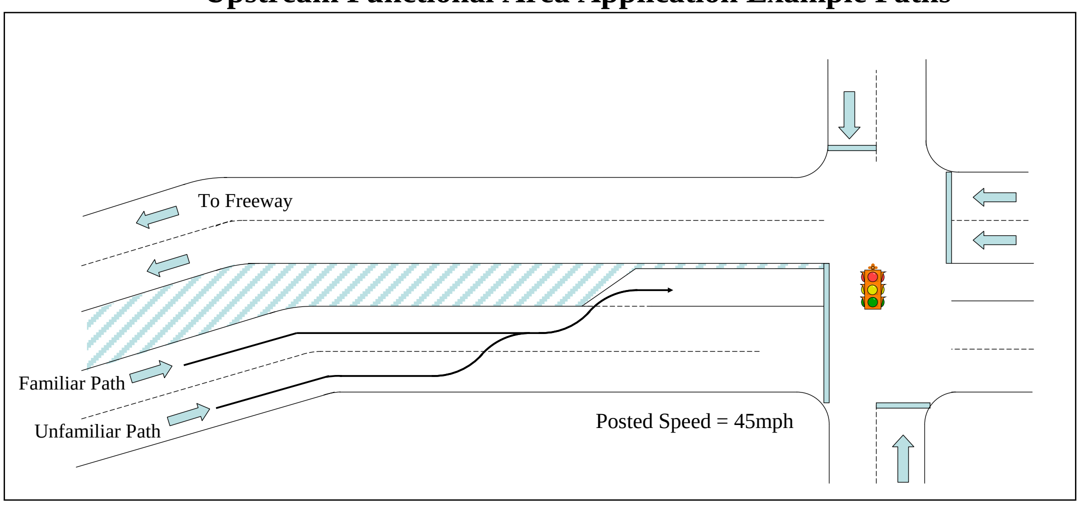
The principles of functional area can be used to test geometric and operational adequacy before detailed analysis starts. The primary objective is to check vehicle paths for adequate length to perform safe and legal maneuvers. For example, a path that connects a right turn onto a roadway to a turn left at the next intersection, or two paths come from two roadways merging together and terminating at a signal, may require lane changes that have safety and legal constraints. Although a functional area analysis may reveal potential conflicts, simulation is used to ensure the adequacy of design in the detailed analysis. Generally, functional area overlaps will appear in simulation results as slowdowns or bottlenecks.

Example 4-4: Functional Area Application – Geometric Adequacy

There is a two-lane ramp transitioning from a freeway to an arterial and has geometry similar to an interchange. An intersection is proposed on the arterial near this ramp as shown in the following figure. The queue at a speed limit of 45 mph is estimated at 400 feet.

Test the adequacy of the design for a driver in either lane of the exit ramp to turn left into the driveway. Can movements from the off-ramp to northbound intersection leg occur safely in this design? Check both the familiar path and the unfamiliar path.

Upstream Functional Area Application Example Paths



Solution

Familiar drivers will generally use the familiar path, the lane closest to the turn bay, in anticipation of the left turn. Unfamiliar drivers may take the unfamiliar path, which starts from the furthest lane or the “wrong lane” and must change lanes into the turn bay. The maneuver distance over one lane is 198 feet when a three-second maneuver time is assumed.

<u>At Speed Maneuver Distance</u>

$$\left(\frac{45\text{miles}}{\text{hr}}\right)*\left(\frac{1\,\text{hr}}{3600\,\text{s}}\right)*\left(\frac{5280\text{ft}}{1\,\text{mile}}\right)*3\text{s}=198\text{ft}\ \ (200\text{ feet})$$

Perception-reaction (PIEV) distances are found in Exhibit 4-30. Assume a two-second PIEV (130 feet) for desirable conditions and a one-second PIEV (65 feet) for limiting conditions as set by the TRI.

The maneuver distances for the turn bay include the deceleration and lateral move distance along with the full deceleration distance. The maneuver distances are found in Exhibit 4-31. For a speed of 45 mph, there should be 300 feet of distance to meet the limiting conditions and 345 feet is desirable.

Lane changes and turn movements should be signaled for 100 feet prior to the action. If an unfamiliar driver follows the unfamiliar path, a lane change must be signaled to move laterally into the near lane and the turn bay separately. The following figures show the components of the unfamiliar path and familiar path for desirable and limiting conditions.

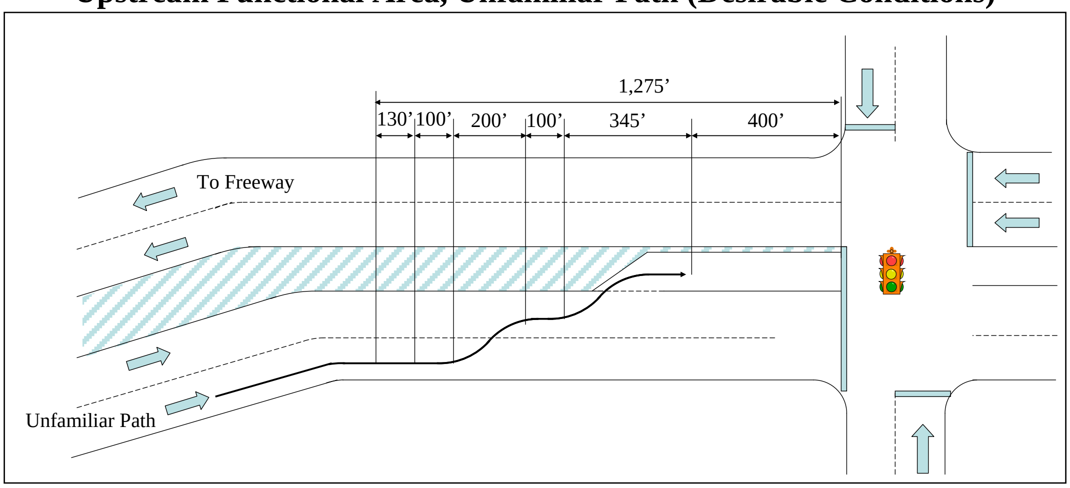
<u>Unfamiliar path (desirable conditions)</u>

d_{UD} = 130’ (PIEV) + 100’ (turn signal) + 200’ (at speed maneuver) + 100’ (turn signal) + 345’ (desirable distance into the turn bay) + 400’ (queue)
d_{UD} = 1,275’

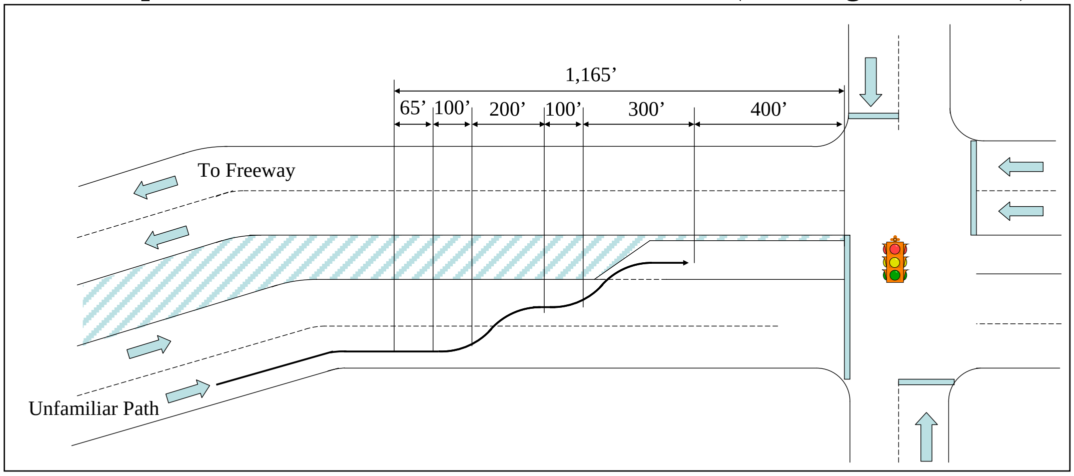
<u>Unfamiliar path (limiting conditions)</u>

d_{UL} = 65’ (PIEV) + 100’ (turn signal) + 200’ (at speed maneuver) + 100’ (turn signal) + 300’ (limiting distance into the turn bay) + 400’ (queue)
d_{UL} = 1,165’

Upstream Functional Area, Unfamiliar Path (Desirable Conditions)



Upstream Functional Area, Unfamiliar Path (Limiting Conditions)



<u>Familiar path (desirable conditions)</u>

d_{FD} = 130’ (PIEV) + 100’ (turn signal) + 345’ (desirable distance into the turn bay) + 400’ (queue)

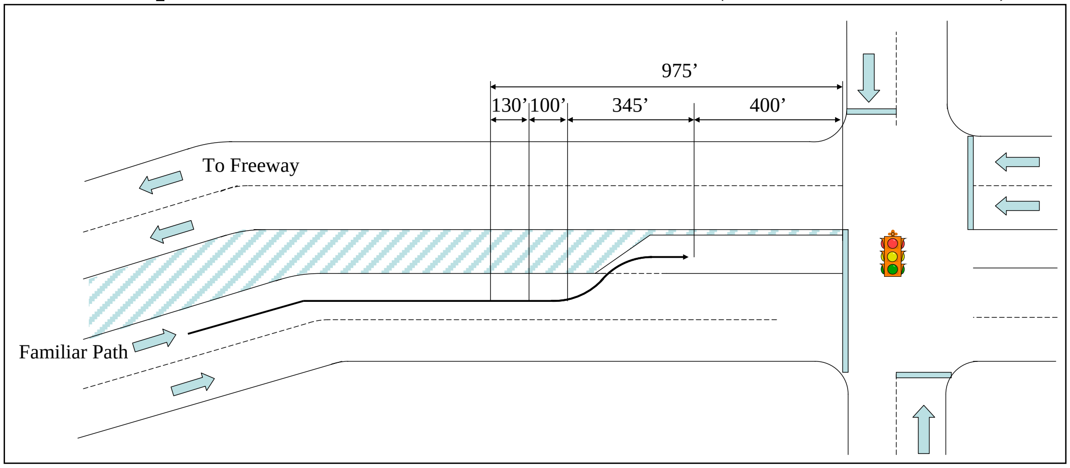
d_{FD} = 975’

<u>Familiar path (limiting conditions)</u>

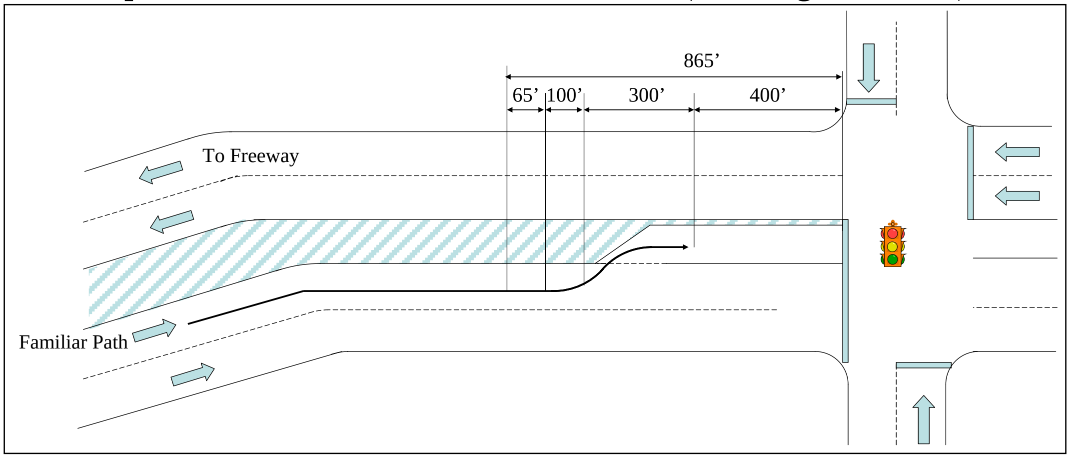
d_{FL} = 65’ (PIEV) + 100’ (turn signal) + 300’ (limiting distance into the turn bay) + 400’ (queue)

d_{FL} = 865’

Upstream Functional Area, Familiar Path (Desirable Condition)



Upstream Functional Area, Familiar Path (Limiting Condition)



Unfamiliar path (desirable conditions): d_{UD} = 1,275’
Unfamiliar path (limiting conditions): d_{UL} = 1,165’
Familiar path (desirable condition): d_{FD} = 975’
Familiar path (limiting condition): d_{FL} = 865’

Ideally, the design would need to allow 1,275 feet between the stop bar at the intersection back to the gore point. If the distance available was between 865 feet and 1,165 feet, then drivers using the unfamiliar path would be subject to high speed differentials.

4.8.2 Sight Distance

The length of roadway visible to a driver is referred to as "sight distance." The amount of visible roadway needed by a driver at any given time depends on the maneuvers or decisions that must be made at that moment. The four basic categories of sight distance are:

- Intersection sight distance
- Stopping sight distance
- Decision sight distance
- Passing sight distance

Note: Some portions of the access management process use different sight distance methods than what would be normally used for operations and project development. See OAR 734-051 for more information.

Although each of these is briefly described below, intersection and stopping sight distance are most frequently examined in traffic analysis. For additional information on sight distance refer to ODOT's Highway Design Manual or Section 3.2 of the AASHTO Green Book.[3]

- **Intersection sight distance** is considered adequate when drivers at or approaching an intersection have an unobstructed view of the entire intersection and of sufficient approach lengths of the intersecting roadways to see oncoming vehicles and select appropriate turning gaps. Sight distance must be unobstructed along both approaches at an intersection and across the corners to allow the vehicles simultaneously approaching to see each other and react in time to prevent a collision. Intersection sight distance should be obtained at every road approach, whether it is a signalized intersection or private driveway. In no case should the sight distance be less than safe stopping sight distance (minimum).
- **Stopping sight distance** is the minimum distance required for a vehicle traveling at a particular design speed to come to a complete stop after an obstacle on the road becomes visible. This distance is used frequently for fatal-flaw screening in project analysis.
- **Decision sight distance** should be provided at locations where multiple information processing, decision making, and corrective actions are needed. Sample locations where decision sight distance is needed include unusual intersection or interchange configuration and lane drops.
- **Passing sight distance** is the minimum distance required for a vehicle to safely and comfortably pass another vehicle. If adequate passing sight distance opportunities cannot be accommodated in the project design, passing lanes or climbing lanes should be considered.

[3] AASHTO A Policy on Geometric Design of Highways and Streets, 6th Edition, 2011.

4.8.3 Conflict Points

Introduction

It is good practice to determine the conflict points at intersections and major accesses in the study area for most analysis work other than TSPs. Bicycle and pedestrian conflicts especially should be determined in areas of high multimodal demand such as transit-oriented developments (TODs) and MMAs. Areas with functional area overlaps or overrepresentation of crashes should have the conflict points quantified. The number of conflict points can also be a good alternative screening evaluation criteria.

Every roadway access creates conflict points for drivers, pedestrians, and bicyclists. Conflict points are locations where one vehicle path impacts another. Each conflict point is a possible crash location. Crashes occur at conflict points when one roadway user fails to yield to another. The crash potential associated with each conflict point varies depending on the complexity, volume of the movements, and speed. Multilane highways have more conflict points and a higher crash potential because of the increased exposure area, exposure time, and potential for obstructed sight distance by vehicles in adjacent lanes. Reducing the number of conflict points decreases crash potential.

Conflict points are classified as diverging, merging, weaving, turning, and crossing. Crossing paths are major conflicts. Diverging, merging, and weaving paths are minor conflict points. Diverging conflicts occur where one path separates into two. Merging conflicts occur where two paths come together. Weaving conflicts involve vehicles changing paths. Both major and minor conflict points may occur at high speeds, but minor conflicts typically involve vehicles traveling in the same direction. Vehicles crossing paths at high speeds may not have the sight distance or ability to minimize the severity of the crash.

Turning and crossing conflicts can also involve pedestrians and bicyclists. A crossing conflict point, which involves pedestrians and bicyclists, occurs where a vehicle path passes through a crosswalk or bike path; a turning conflict point occurs where the turning vehicle path passes through a crosswalk or bike path. Pedestrian crashes are not limited by locations. The pedestrian-vehicle conflicts are counted separately from vehicle-vehicle conflict points.

This section is a reference only. Every intersection is unique and must be analyzed appropriately. The analysis should consider geometry, permitted turn movements, the level of control of non-permitted movements, and the number of lanes for each movement. Reducing conflict points allows drivers to move through an area with less distraction so that traffic flows smoothly at constant speeds. With fewer conflict points, drivers can better maintain their attention on roadway conditions.

Conflict points can be reduced through three measures:

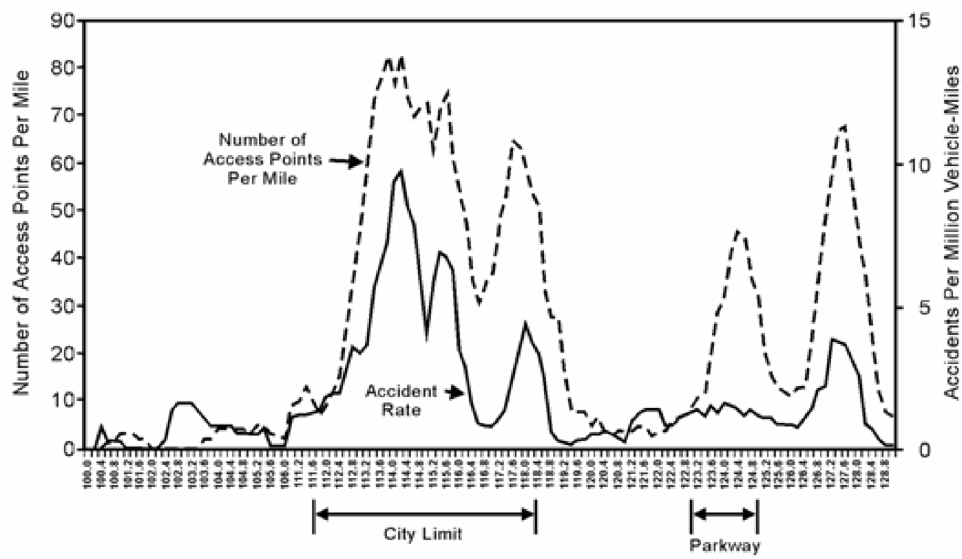
- Limit the number and/or type of access points
- Install medians, channelization, and other control devices (e.g., roundabouts) to restrict or control turning movements
- Grade separate traffic flows

Limit the Number and/or Type of Access Points

Limiting driveways or access points should be considered at locations with limited sight distance, high crash frequency, high volume-to-capacity ratios, or poor access to facilities. Combining driveways reduces access and conflict points. Accommodating entering traffic at one location simplifies driver tasks. Combining multiple driveways into one joint-use driveway directs traffic more safely, clearly, and efficiently.

Exhibit 4-33 shows the relationship between access density and crash rates in Lincoln City and Lincoln Beach. The crash rates increase as the density of access points increases. The area labeled City Limit in Exhibit 4-33 is Lincoln City on US101, which has a high density of access points. The area labeled Parkway is in Lincoln Beach where a non-traversable landscaped median limits access to driveways and side streets. Crash rates in the Parkway section are greatly reduced.

Exhibit 4-33: Access Points Per Mile vs. Crashes Per Mile



Comparison of Access Connections Per Mile with
Crashes Per Mile on a Segment of US 101 in Oregon

From Analysis of Traffic Accidents Within the Functional Area of Intersections and Driveways
Technical Report Trans 1-95 1995

Locating driveways on lower classification roadways or backage/frontage roads also reduces the number of conflict points along the main roadway. Removing driveways from an arterial or a collector decreases delay caused by turning vehicles. Diverting traffic to local roads directs traffic to one access point and simplifies conditions.

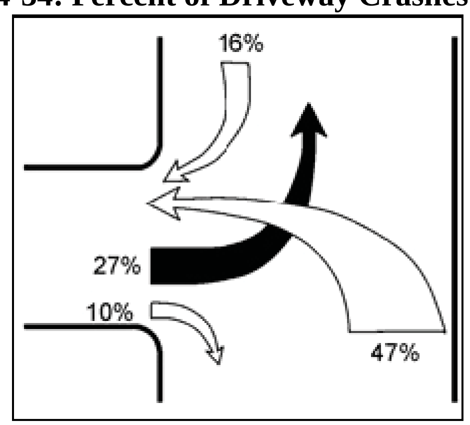
Refer to OAR 734, Division 51 for information concerning signal spacing, backage/frontage roads, or access rights. Sometimes access rights to individual parcels are obtained. Rules regarding obtaining property access rights to state highways, signal spacing, and backage/frontage roads are found in OAR 734, Division 51 and on the ODOT Access Management website.

Non-Traversable Median or Traffic Control Devices to Restrict Turning Movements

Medians are a roadway element intended to separate traffic traveling in opposite directions. A median can be traversable or non-traversable. A traversable median may be a painted or concrete mountable median that allows emergency traffic to cross over it. A non-traversable median is a physical barrier (examples include the Jersey barrier, landscaped, or grassy median) that separates opposing traffic and prohibits movement across the median. Installing a non-traversable median restricts turning and crossing movements at roadway accesses. Non-traversable medians reduce conflict points by eliminating turn movements that impact the general traffic flow. More information about median types can be found in Chapter 5.5 of the Oregon Highway Design Manual (HDM).

A median that impacts the State Highway Freight System must comply with the ORS 366.215 which states that the Oregon Transportation Commission (OTC) may not permanently reduce the vehicle-carrying capacity of an identified freight route when altering, relocating, changing, or realigning a state highway unless safety or access considerations require the reduction. According to the Transportation Research Board, Access Management Manual 2003, 47% of crashes involve left-turn ingress movements and 27% of crashes involve left-turn egress movements, shown in Exhibit 4-34. Controlling turn movements can allow one turn direction and divert others elsewhere.

Exhibit 4-34: Percent of Driveway Crashes by Movement



Non-traversable medians reduce overall crash frequency, improve pedestrian safety, and enhance visuals. They restrict traffic from making complex left turns and provide median openings at designated locations. They may also provide a pedestrian refuge between directions of traffic and decrease pedestrian clearance intervals. Including a raised median can significantly reduce pedestrian collisions at uncontrolled locations, with CMFs of 0.61 when used with an unmarked crosswalk and 0.54 when used with marked crosswalks.[4] Replacing a two-way left-turn lane with

[4] Zegeer, C. V., Stewart, R., Huang, H., and Lagerwey, P., "Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines." FHWA-RD-01-075, McLean, Va.,

a raised median in urban environments has demonstrated a CMF of 0.77 for all crashes.[5] Landscaping large medians improves the aesthetics of the roadway. Although medians improve the roadway, they are costly and may require the acquisition of right-of-way.

Grade-Separated Roadways

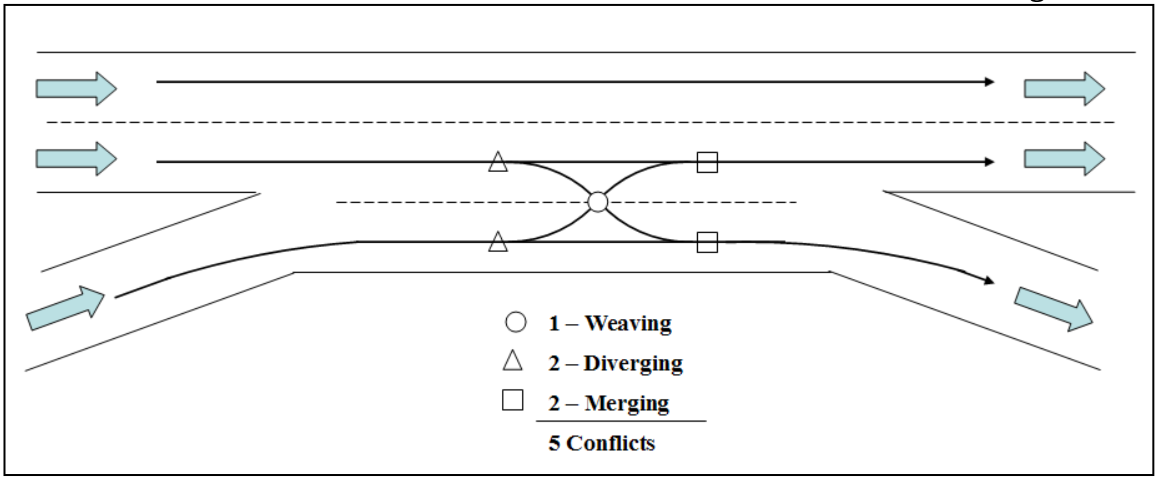
Grade-separated roadways are locations where one roadway crosses over the other. Grade separation should be considered where an at-grade signal cannot accommodate traffic capacity or where crash history indicates a need for grade separation. Conflict points are decreased by removing major flow grade crossings and by rerouting turning traffic. Interchanges are grade-separated connections of two or more roads. Interchanges reduce conflict points and the severity of crashes. Although interchanges occupy a large amount of space and require costly structural work, they reduce delay, reduce crashes, and improve efficiency of a corridor.

It can be difficult to accommodate pedestrians at interchanges because of the separation of paths. For more information about accommodating pedestrians or bicyclists, refer to the Oregon Bicycle and Pedestrian Plan and the related Bicycle & Pedestrian Design Guide.

Weaving Segments

Weaving segments, where vehicles traveling in the same direction cross paths, create several conflict points. Exhibit 4-35 and Exhibit 4-36 show two examples of weaving vehicle paths entering and exiting the roadway. A single-lane change weaving segment has five minor conflict points. A lane-balanced two-lane change weaving segment has seven minor conflict points. More information about weaving segments can be found in Chapter 12.

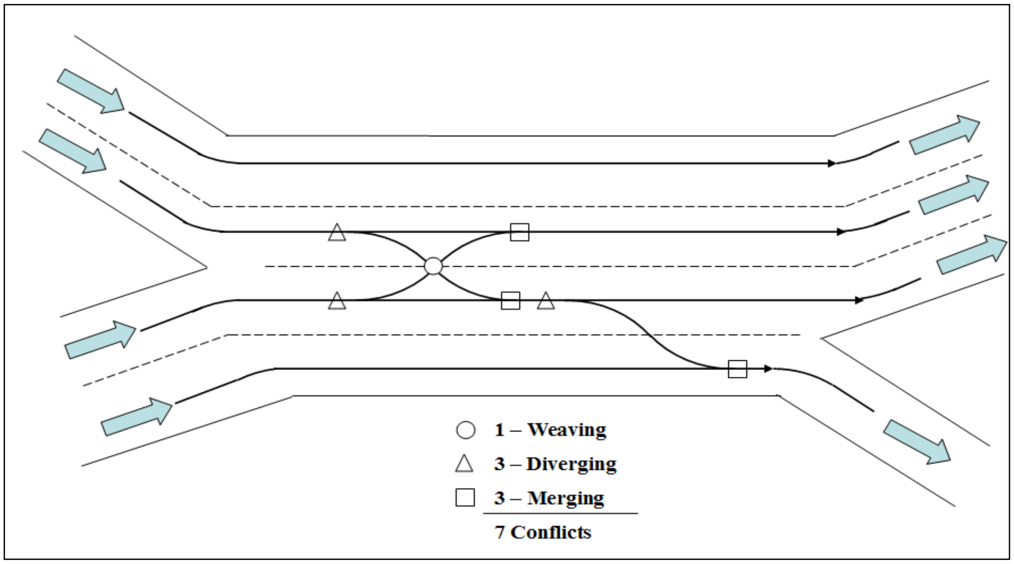
Exhibit 4-35: Conflict Points for a Weave with One Lane Change



Federal Highway Administration, (2002)

[5] Mauga, T. and Kaseko, M., "Modeling and Evaluating the Safety Impacts of Access Management (AM) Features in the Las Vegas Valley." Transportation Research Record: Journal of the Transportation Research Board 2171, pp. 57-65, 2010

Exhibit 4-36: Conflict Points for a Weave with Two Lane Changes



Unchannelized Intersections

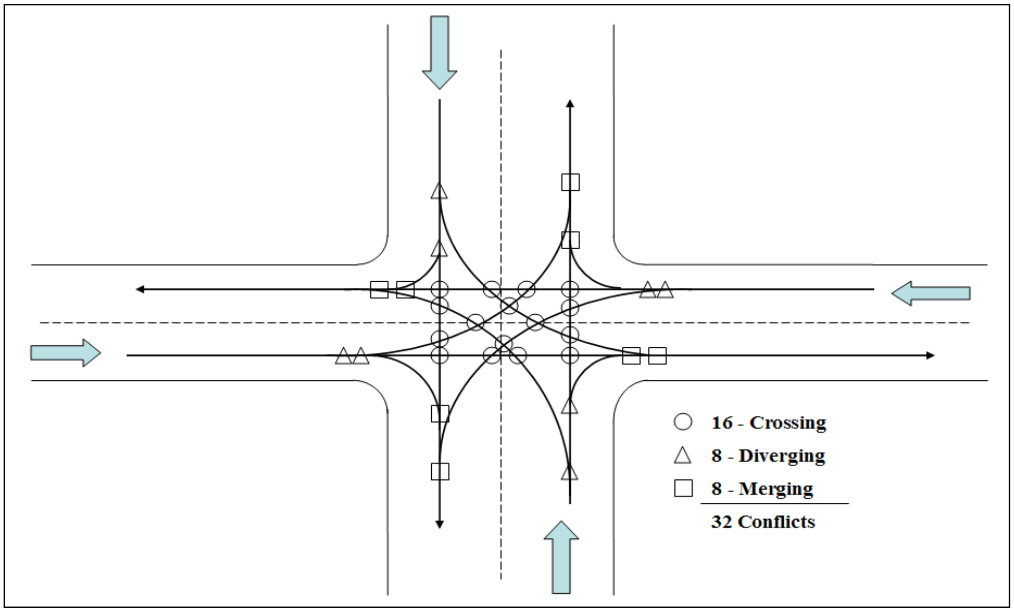
Unchannelized intersections are where two roadways without medians and/or turn restrictions intersect and that allow full access to traffic. Every such intersection should be analyzed as a unique situation. Unchannelized intersections may have other forms of traffic control such as a traffic signal. Although a traffic signal does not reduce the number of conflict points, it increases driver communication and awareness. For movements that operate with separate signal phases, the exposure to conflicts is significantly reduced compared to movements that operate with unsignalized control or permissive signal phasing.

Note: The intersections analyzed and illustrated in the figures are typical configurations; however, for clarity, turn lanes are not included. The addition of single turn lanes should not increase the number of conflict points. Any additional through or dual turn lanes must be included in the analysis.

Four-Leg Intersection

The four-leg intersection with no medians, shown in Exhibit 4-37, has the most conflict points of all intersections. The four-leg intersection allows movement in all directions and is the most familiar to drivers.

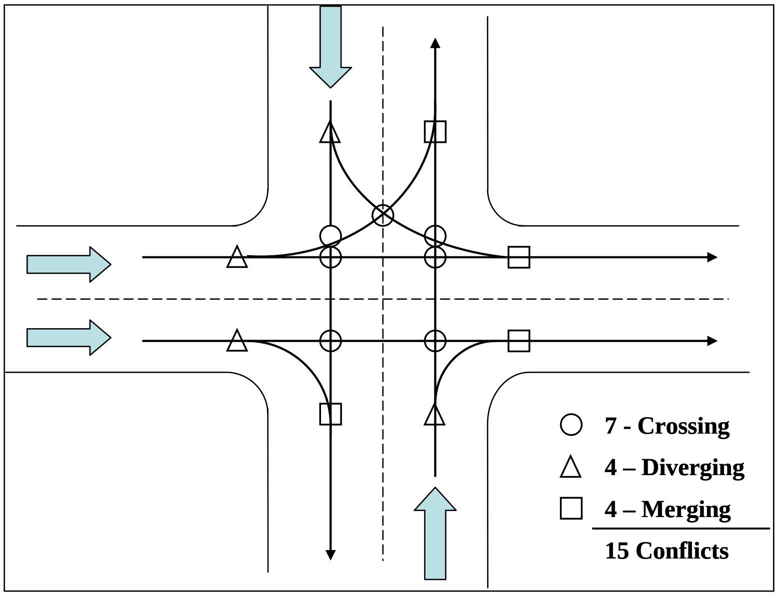
Exhibit 4-37: Conflict Points for a Four-Leg (Both Two-Way Roads) Intersection



Four-Leg Intersection of a Two-Way Road and a One-Way Road

A four-leg intersection of a two-way road and a one-way road is shown in Exhibit 4-38. The one-way road may be part of a couplet. The one-way road limits turns and reduces conflict points.

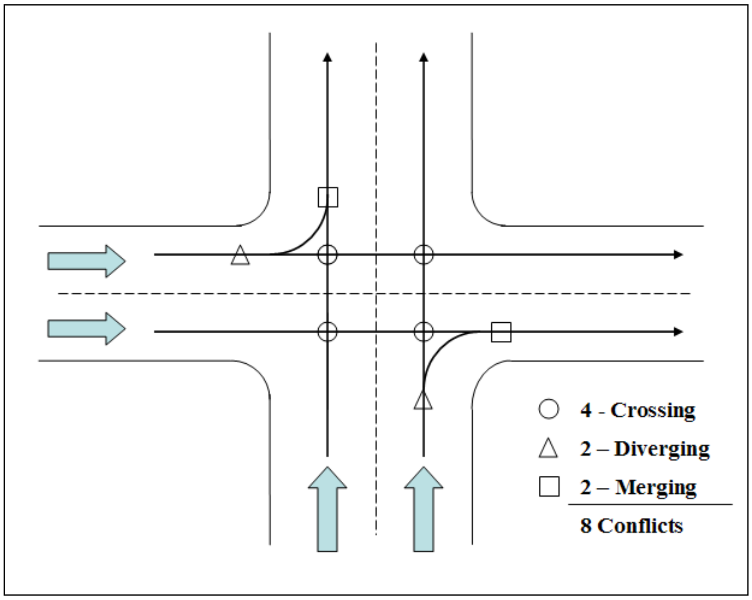
Exhibit 4-38: Conflict Points for a Four-Leg Intersection of a Two-Way Road and a One-Way Road



Four-Leg Intersection of Two One-Way Roads

A four-leg intersection of two one-way roads is shown in Exhibit 4-39. The one-way roads may be part of a couplet. The one-way roads limits turns and reduce conflict points.

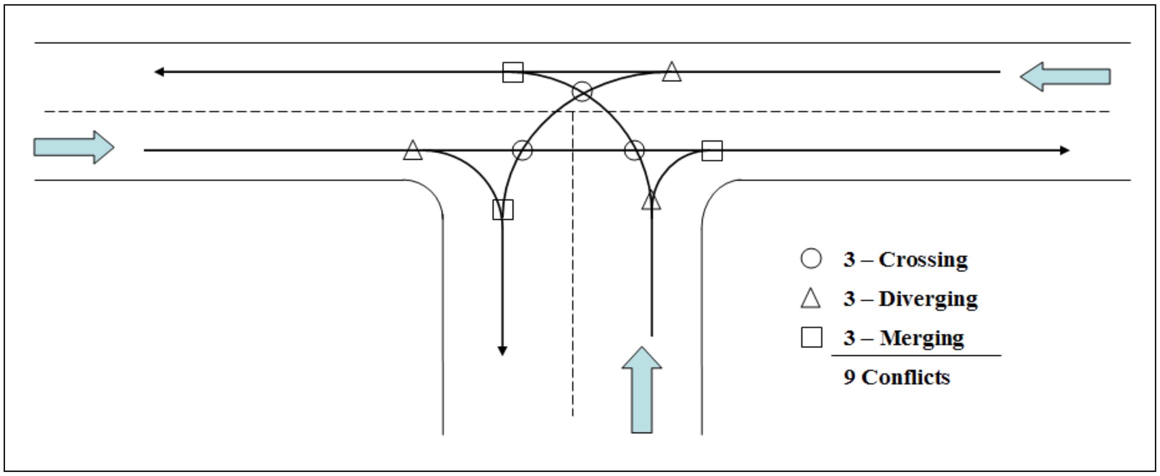
Exhibit 4-39: Conflict Points by Lane for a Four-Leg Intersection of Two One-Way Roads



T-Intersection

A T-intersection is a location where one roadway ends at its intersection with another roadway. The T-intersection shown in Exhibit 4-40 permits turns in all directions. The intersection in the figure has nine conflict points, three of which are major.

Exhibit 4-40: Conflict Points for the T-Intersection



Channelized Intersections

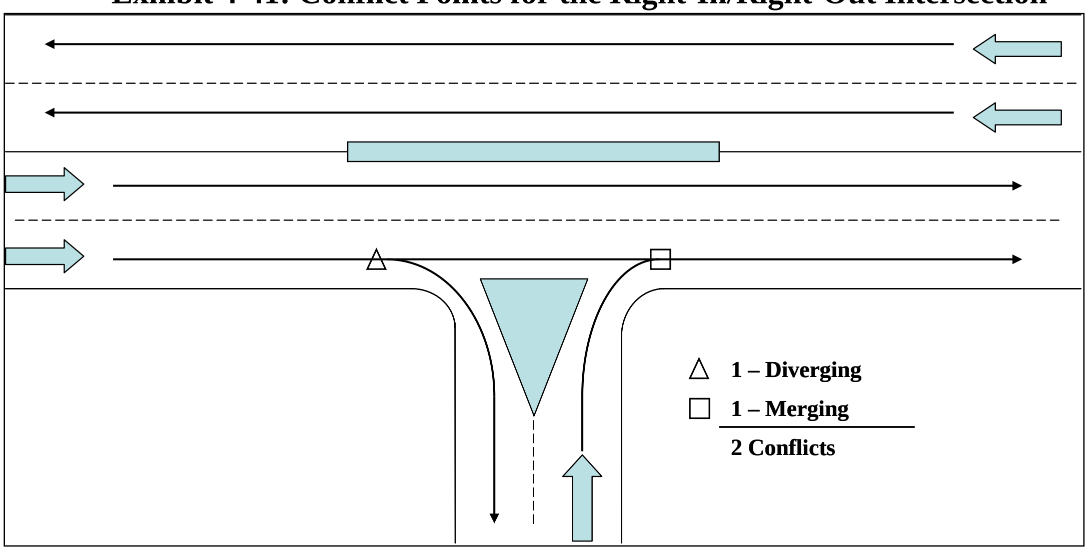
A channelized intersection restricts turn movements by signs, pavement markings, medians, or some other type of traffic control. Channelized intersections include, but are not exclusive to, right-in/right-out intersection, non-traversable median separated four leg intersection, left-turn ingress intersection, left-turn egress intersection, and roundabout. Both ends of the non-traversable median should be analyzed for the required traffic control in order to meet traffic needs safely.

Intersections and driveways that are restricted to right-in/right-out have two conflict points, but complex channelized intersections may have up to eleven conflict points.

Right-In/Right-Out (RIRO) Intersection

The right-in/right-out (RIRO) geometry shown in Exhibit 4-41 restricts traffic to right-turn movements only and forces roadway users to complete a left turn at another location either in a permitted U-turn or at a completely different intersection or roadway. Additional lane changing/weaving may also be necessary. This reduces crashes at the location of the right-in/right-out intersection, but requires left-turning vehicles to travel farther to get to their destination. The analyst needs to address where the left-turning vehicles will end up so potential safety issues are not created elsewhere.

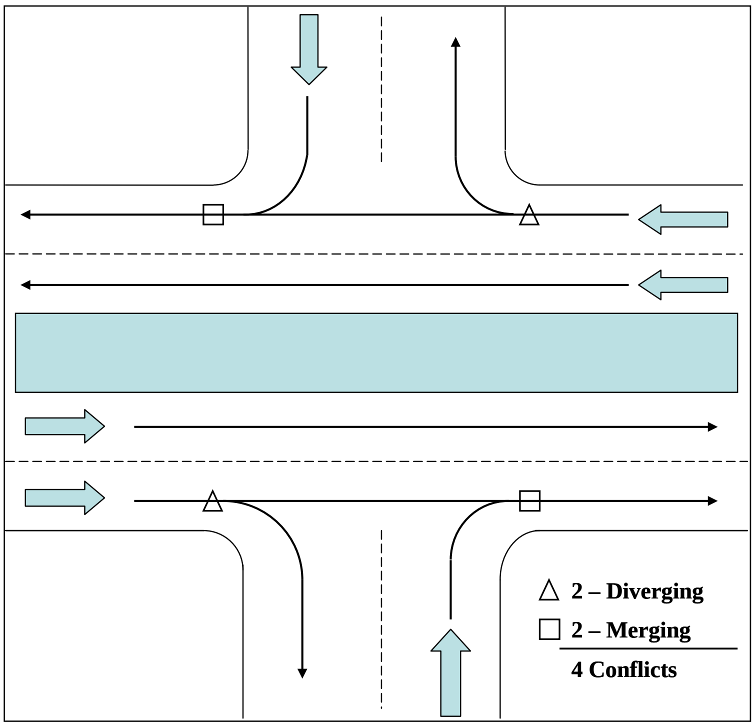
Exhibit 4-41: Conflict Points for the Right-In/Right-Out Intersection



Non-Traversable Median Separated Four-Leg Intersection

Installing a non-traversable median changes the traffic flows of the typical four-leg intersection by effectively creating two right-in/right-out intersections as shown in Exhibit 4-42. Left-turning or crossing vehicles must complete those maneuvers at another location, eliminating the major conflict points. This reduces the conflict points from the typical 32 to just four. The intersection is restricted to right turns, which improves safety and operations but also adds out-of-direction travel.

Exhibit 4-42: Conflict Points for a Median Separated Four-Leg Intersection



Roundabout

Roundabouts are considered at locations where speeds and volumes may not require a traffic signal for smooth operations. The roundabout, shown in Exhibit 4-43, directs all traffic to move in a counter-clockwise direction that allows movements in all directions. This limits conflict points to merging and diverging movements. It also reduces vehicular travel speed, which reduces the severity of any associated crashes. Bypass lanes would produce additional conflict points at their respective merge and diverge locations. A multilane roundabout, shown in Exhibit 4-44, has more conflict points and increased capacity. Chapter 13 contains capacity analysis procedures for roundabouts and bypass lanes.

Exhibit 4-43: Conflict Points for a Single Lane Roundabout

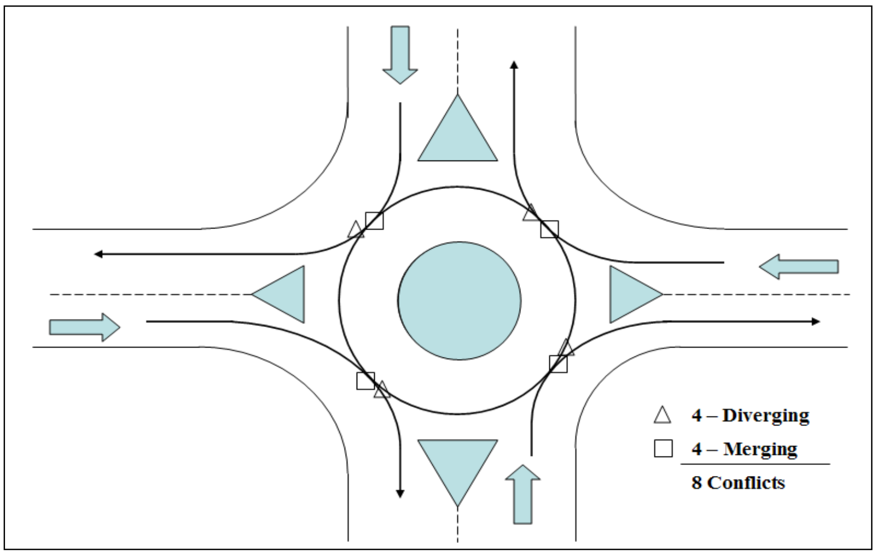
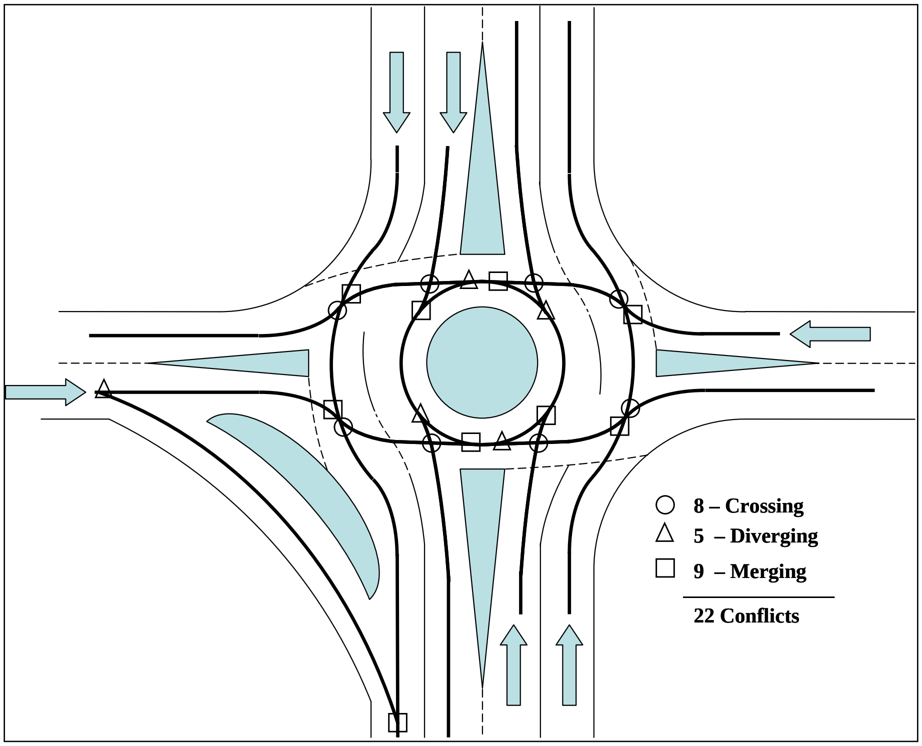


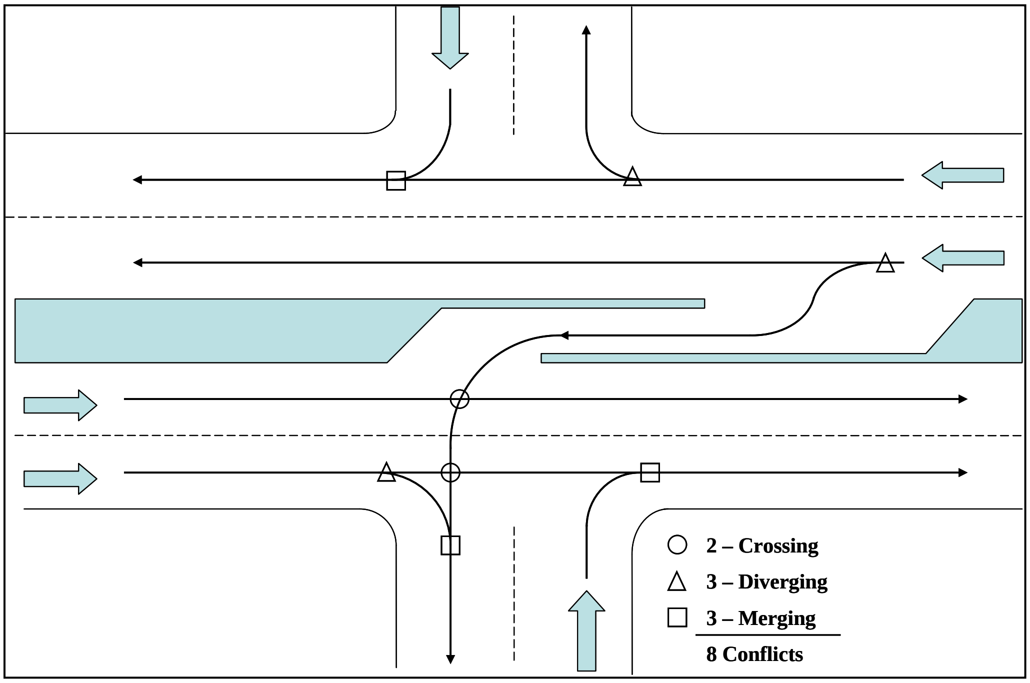
Exhibit 4-44: Conflict Points for a Multilane Roundabout



Left-Turn Ingress Intersection

The left-turn ingress intersection shown in Exhibit 4-45 permits one direction of traffic to turn left, from a turn bay, while the opposing left and crossing movements are prohibited. The permitted left turn may have significantly higher volumes or may service a critical access.

Exhibit 4-45: Conflict Points for a Median with One Left-Turn Ingress Intersection



Two Left-Turn Ingresses Intersection

Exhibit 4-46 shows the geometry for two left-turn ingresses. Only the traffic turning left into the access street is permitted through the median. Vehicles can remain in the median until there is a sufficient gap to complete the turn. More left-turn egress and left-turn ingress examples are shown in Exhibit 4-47 through Exhibit 4-49. Locations that provide a median restricting egress or ingress turns require median openings for vehicles to make U-turns. The median openings add a merge and a diverge point to the segment or intersection. Any intersection along a median that permits U-turns must be analyzed for conflict points, with the inclusion of the merge and diverge conflict points caused by the U-turn.

Exhibit 4-46: Conflict Points for a Median with Two Left Turn Ingresses Intersection

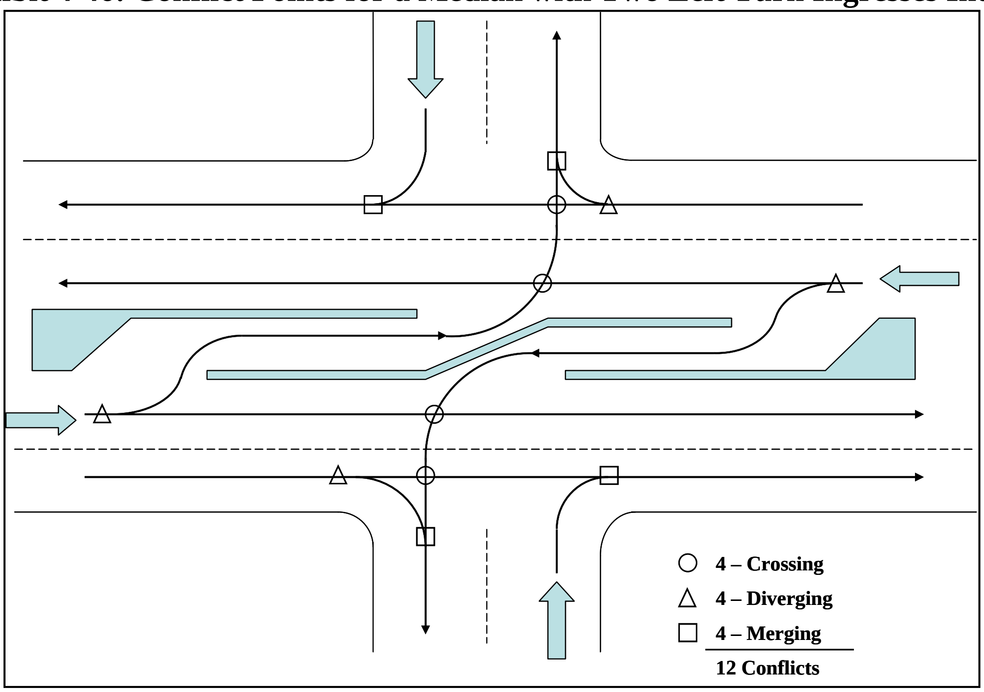


Exhibit 4-47: Conflict Points for a Median with a Left-Turn Ingress and Egress Intersection

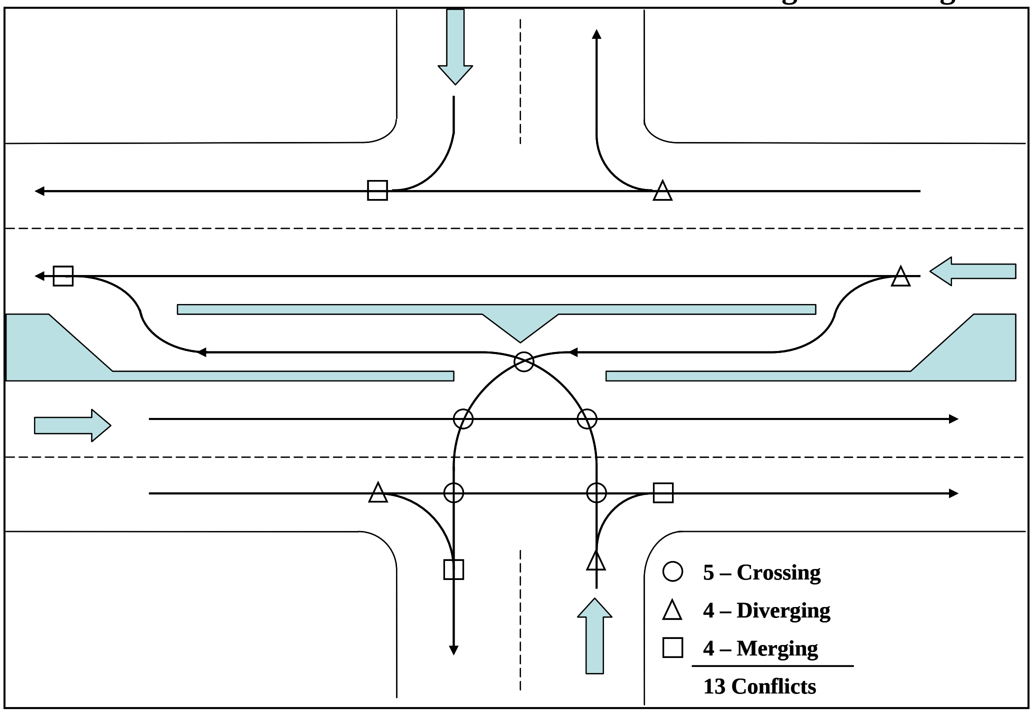


Exhibit 4-48: Conflict Points for a Median with One Left-Turn Egress Intersection

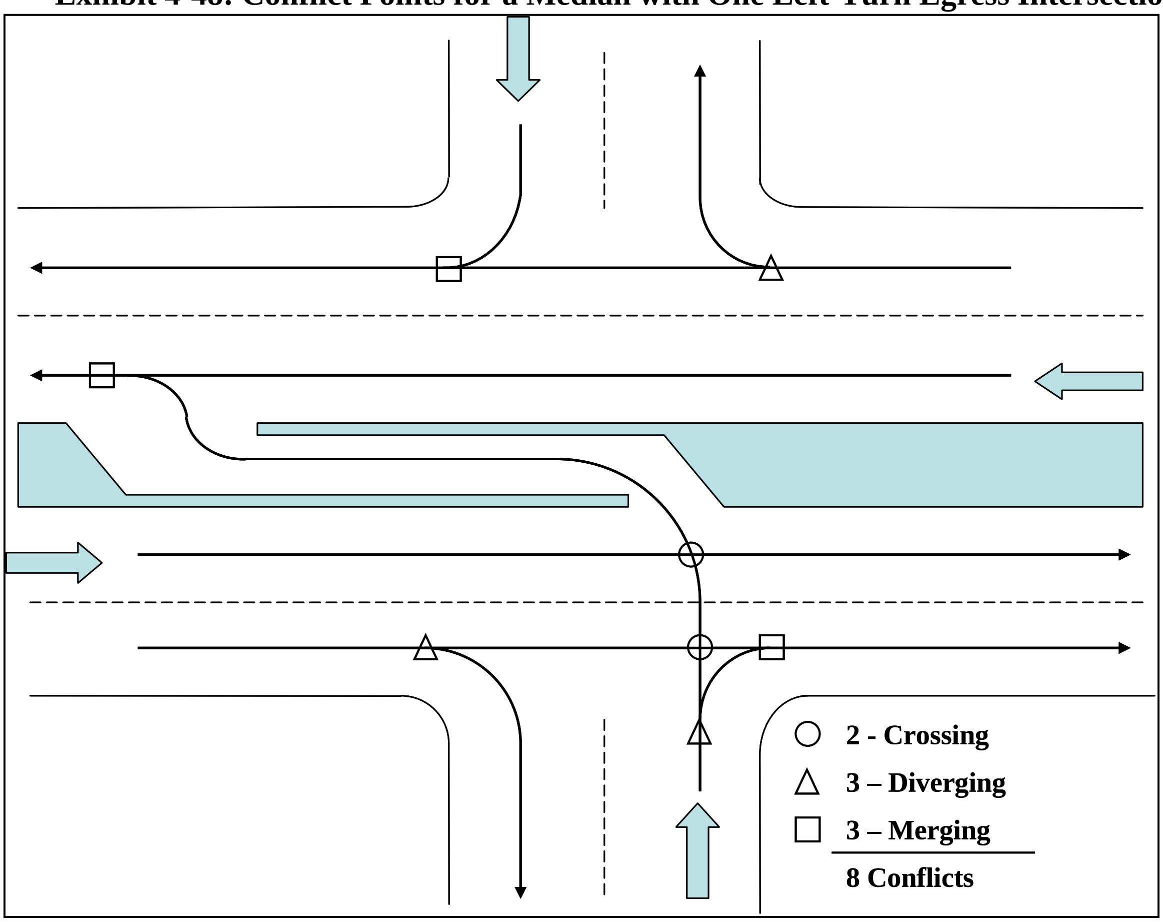
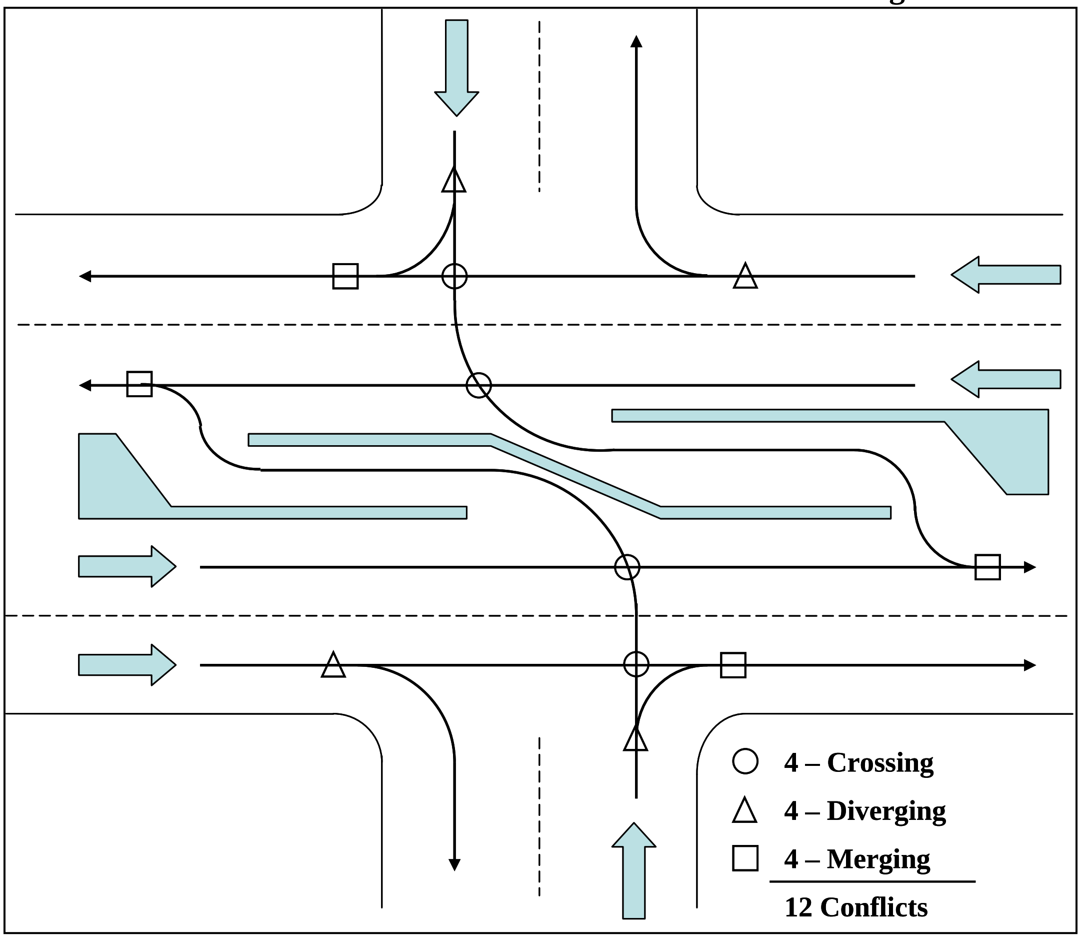


Exhibit 4-49: Conflict Points for a Median with Two Left-Turn Egresses Intersection



Indirect Left Turns

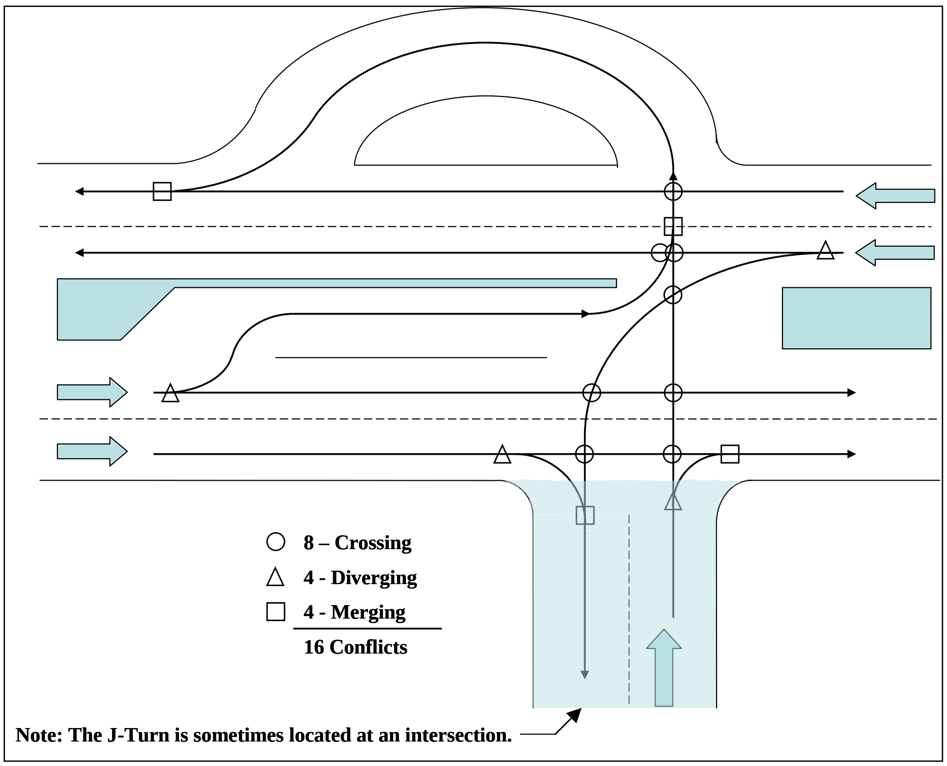
Some intersections require creative accommodations for left turning vehicles. The treatment of left turns must be considered at intersections with restricted turns, high volumes or high speeds to achieve the greatest capacity and safety for traffic.

J-Turn

The J-turn is an opportunity for larger vehicles to turn left on either side of a non-traversable median. The median restricts intersections and driveways to right-in/right-out, which reduces the conflict points. Vehicles can turn left at median openings which may be accompanied by a stand-alone J-turn, a J-turn intersection, or a signalized J-turn intersection. The J-turn intersection shown in Exhibit 4-50 has sixteen conflict points. Locations where the J-turn does not meet a crossing roadway or driveway have three conflict points: one diverge, one crossing, and one merge conflict point.

The J-turn intersection also allow turning vehicles to join traffic moving in its desired direction. An add-lane at the J-turn will eliminate the merge conflict point, shown in Exhibit 4-50, and increase the capacity of the segment. The J-turn reduces the congestion and improves the safety of median openings. A J-turn intersection may or may not have pedestrian crossings.

Exhibit 4-50: Conflict Points for a J-Turn Intersection

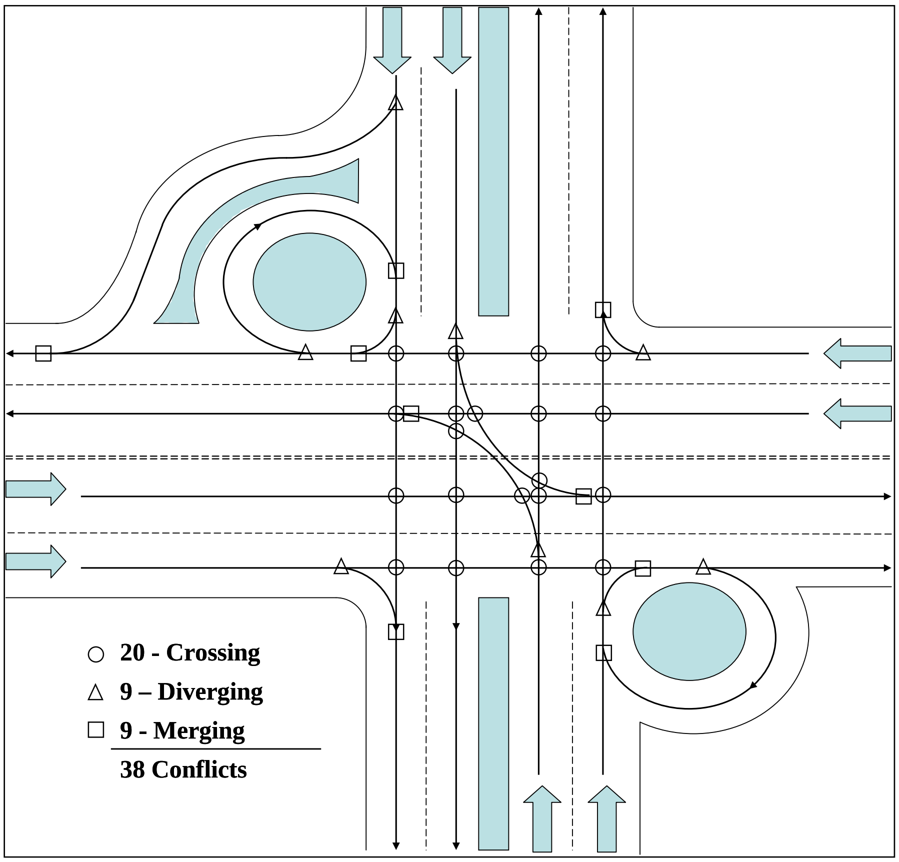


Jug Handle Intersection

The jug handle intersection, shown in Exhibit 4-51, is commonly used when there are high left-turn volumes which cannot be accommodated by a signalized intersection. The left-turning traffic passes through the intersection as a through movement both before and after diverging onto a loop ramp to complete the left turn. This reduces the congestion by removing phases from the traffic signal and improves the safety of the intersection by reducing the number of conflict points. The jug handle can be located in various quadrants of the intersection depending on the restricted turn movements.

Note: Jug handle configurations are not always installed as pairs and are not always accompanied with right turn bypass lanes.

Exhibit 4-51: Conflict Points for a Jug Handle Intersection



Pedestrian Conflict Points

Pedestrian conflict points are counted separately from vehicle-vehicle conflict points. Pedestrian conflict points are located at the intersection crosswalks or midblock crossings. Turning vehicles and crossing vehicles are counted separately. Intersections with wide cross-sections, such as a median separated four-way intersection, are more attractive to pedestrians when a curb-protected pedestrian refuge is provided between directions of travel. Exhibit 4-52 through Exhibit 4-54 show examples of pedestrian conflict points for intersections of two-way roads with and without a median and a four-way intersection with restricted left-turn ingresses.

Exhibit 4-52: Pedestrian Conflict Points for a Four-Leg Intersection

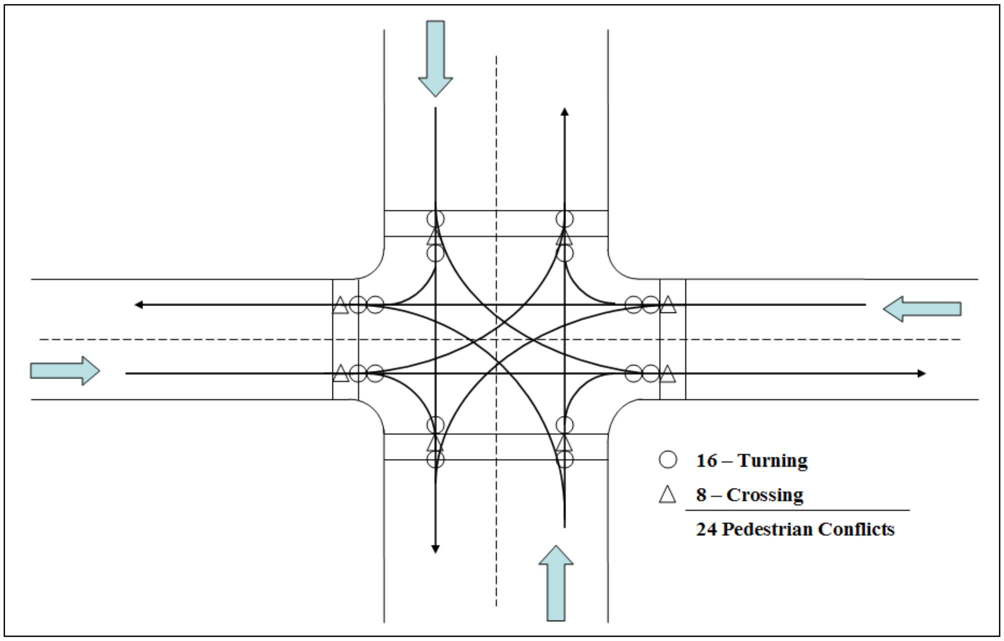


Exhibit 4-53: Pedestrian Conflict Points for a Median Separated Four-Leg Intersection

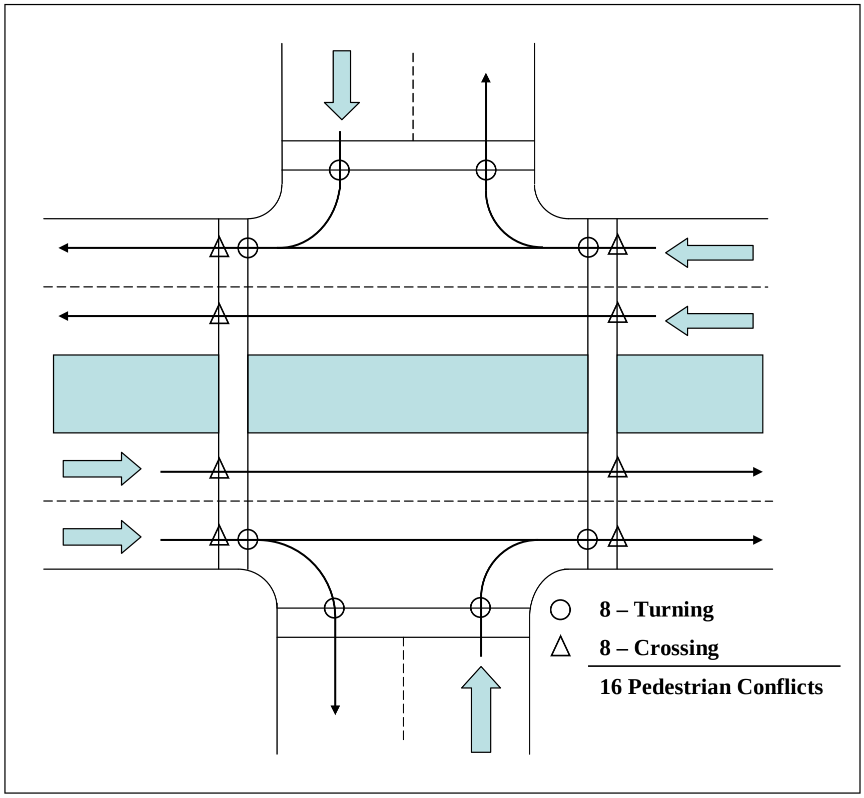
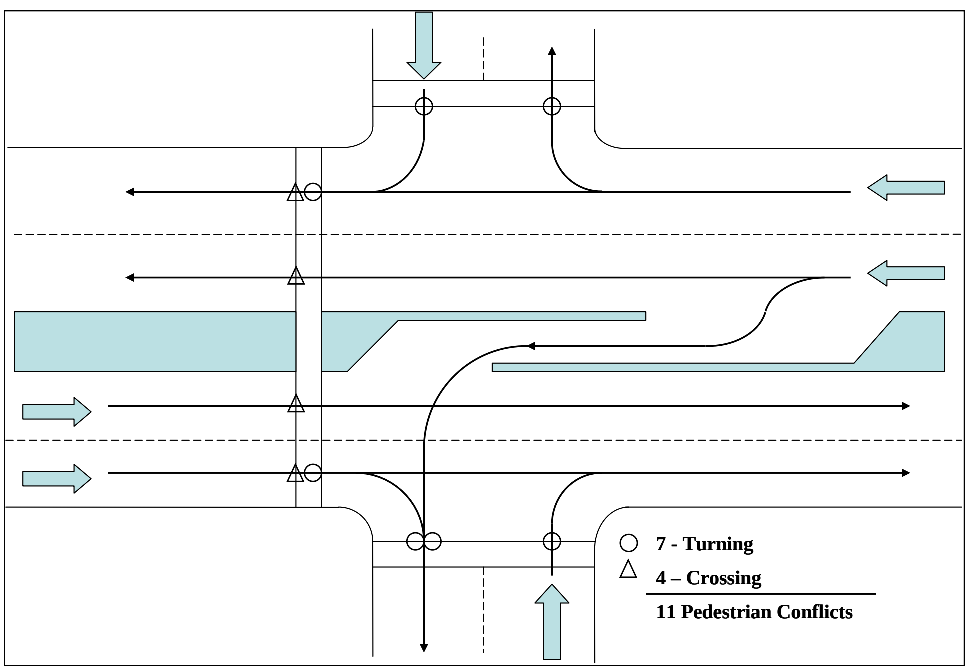


Exhibit 4-54: Pedestrian Conflict Points for a Median with One Left-Turn Ingress Intersection



Grade-Separated Access

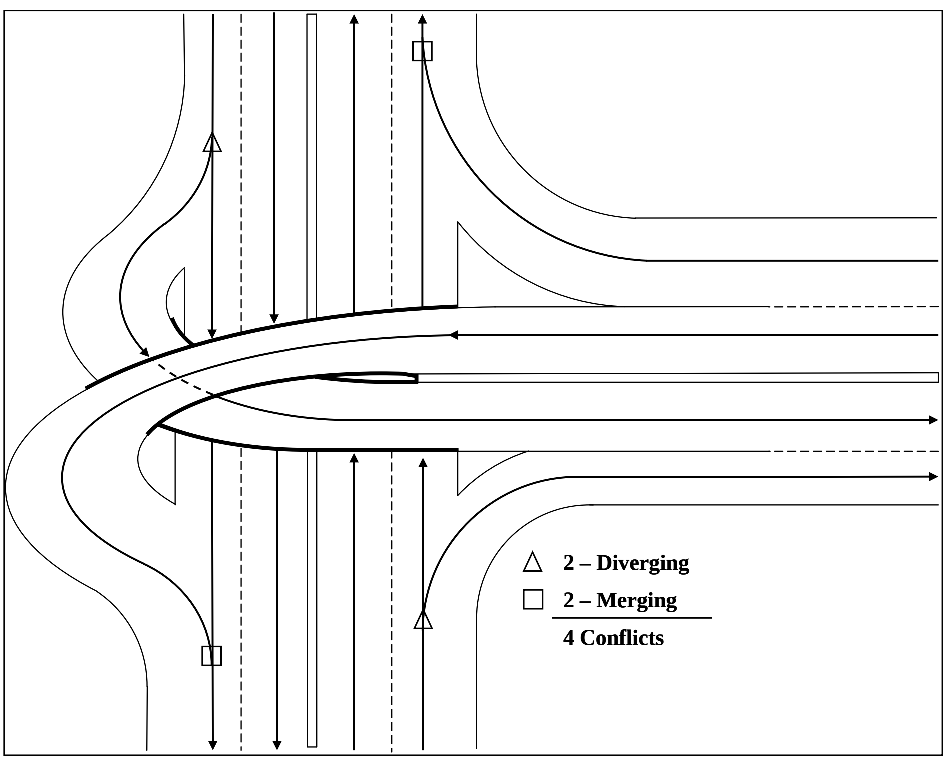
High-speed and high-volume junctions may need grade-separated access to meet traffic capacity while reducing crashes. Interchanges remove major flow grade crossings increasing capacity and reducing conflict points. Interchanges may have as few as six conflict points (directional interchange) or as many as 28 conflict points (left-turn flyover).

Directional Interchange

The directional interchange has all free flow ramps with only four (three diverging and three merging) minor conflict points in the system as seen in Exhibit 4-55. It is similar to a T-intersection with large volumes and high speeds. Traffic does not cross paths due to the grade separation. Each free-flow connection has a merge and diverge conflict point. Due to the high volumes and speed, pedestrian crossing does not occur at the street level.

The full-directional interchange, shown in Exhibit 4-55, has three levels of grade separation. A partial directional interchange is a junction where one leg has lower speeds and is accommodated by a loop ramp. A partial directional interchange has only two levels of grade separation. Since each free-flow ramp has one merge and one diverge conflict point, the partial directional interchange has the same conflict points as the full-directional interchange. Likewise, a four-way directional interchange would have eight conflict points, four merge and four diverge. Add itional conflict points could be introduced if ramps are closely spaced.

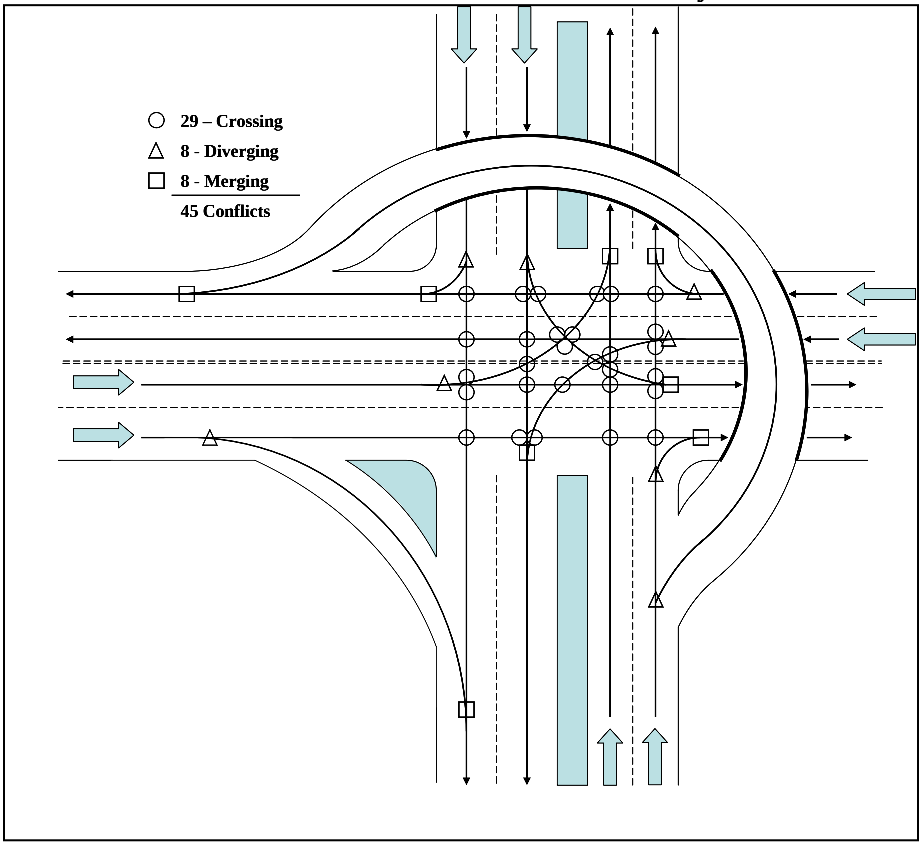
Exhibit 4-55: Conflict Points for a Directional Interchange



Left-Turn Flyover Intersection

The left-turn flyover intersection, shown in Exhibit 4-56, is commonly used when one direction has high left-turn volumes that cannot be accommodated by a signalized intersection. The left-turning traffic is grade-separated as it crosses over the opposing traffic, reducing conflict points and congestion. Pedestrian crossings may or may not be modified from the standard intersection.

Exhibit 4-56: Conflict Points for a Left-Turn Flyover Intersection

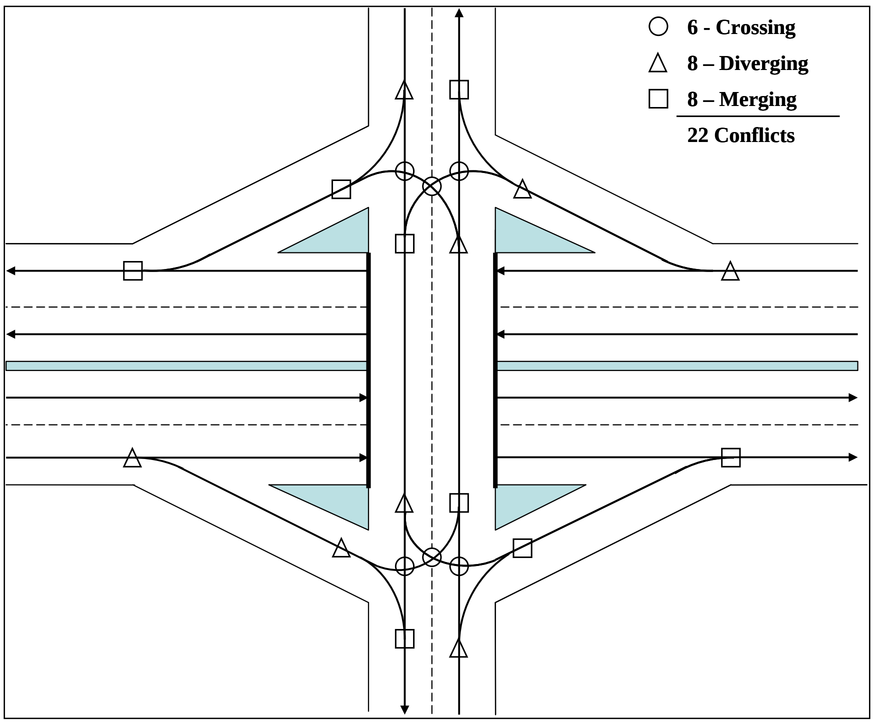


Diamond Interchange

The diamond interchange has four ramps and may have traffic control at the minor road. Traffic is directed to turn on or off each ramp, which creates conflict points. There is potential for weaving conflicts if this interchange has two or more lanes in each direction. Conventional, compressed, and tight diamond interchanges all travel the same paths and the conflict points are the same. Exhibit 4-57 shows the conflict point configuration for a conventional diamond interchange.

Pedestrian crossings are generally not provided at locations along the major, free-flowing movement.

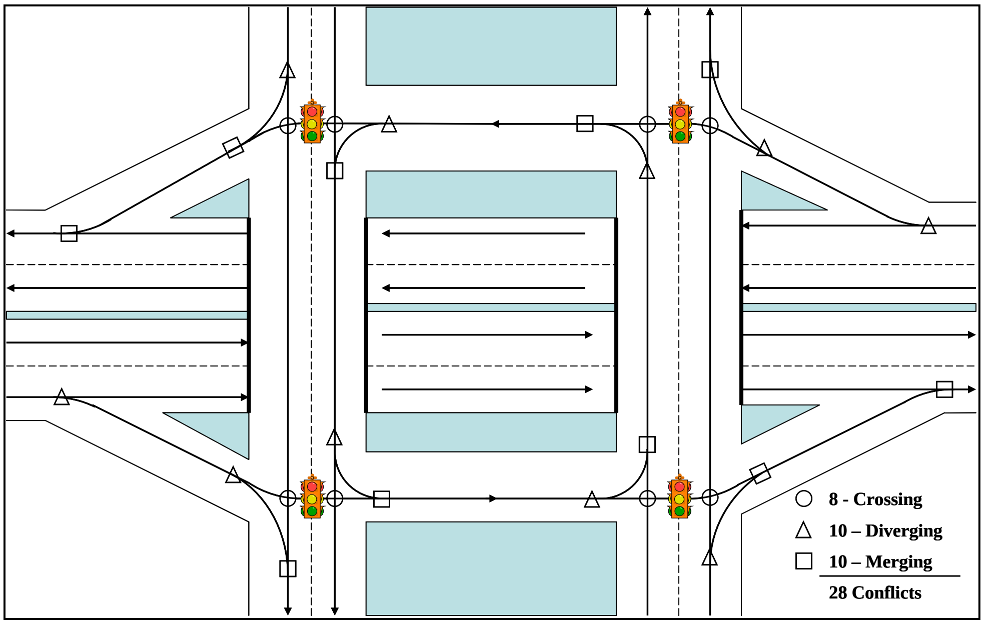
Exhibit 4-57: Conflict Points for a Diamond Interchange



Split Diamond Interchange

A split diamond interchange, shown in Exhibit 4-58, has only four ramps that connect to each other with segments that travel parallel to the major roadway. This type of interchange is appropriate where minor roads are one-way streets and will most likely be accompanied with traffic signals at the ramp terminals. It may be furnished on a regular grid system where the minor streets are two-way as well.

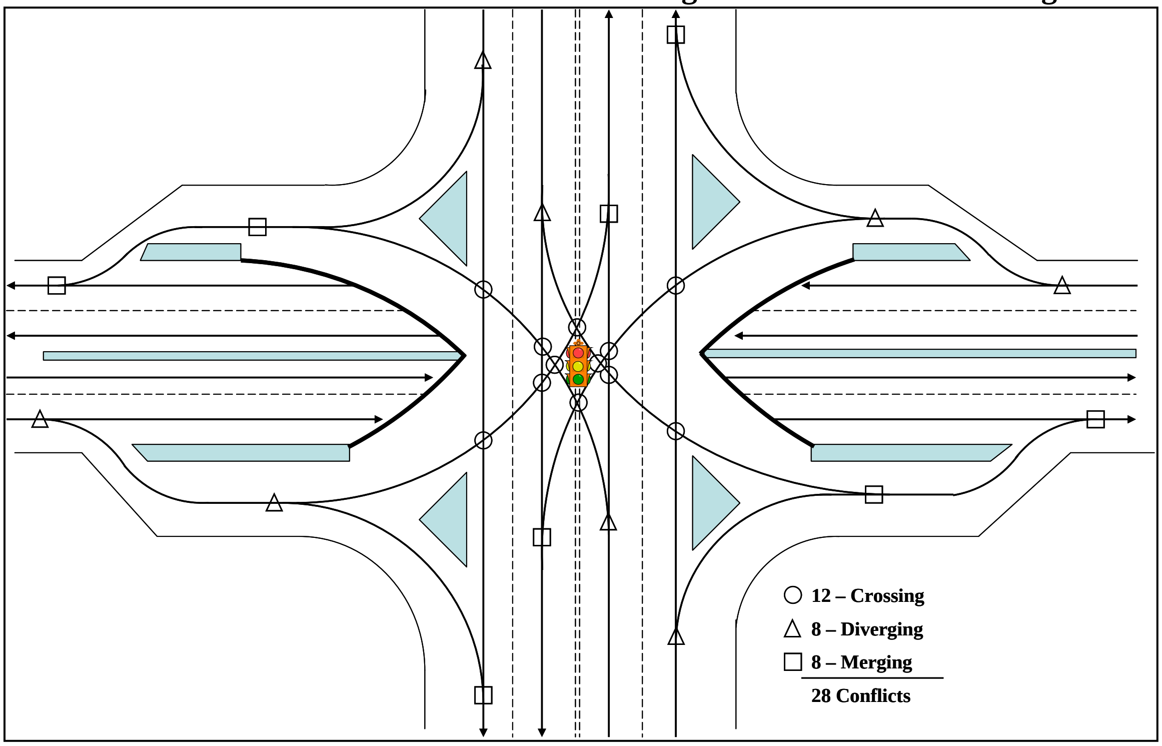
Exhibit 4-58: Conflict Points for a Split Diamond Interchange



Single Point Urban Interchange (SPUI)

The single point urban interchange has four ramps that converge to one point that is controlled by a traffic signal. All minor movement vehicles must travel through the same grade-separated intersection. This type of interchange conserves space and provides large capacity, since the signal operates with fewer phases. These conflict points are shown in Exhibit 4-59.

Exhibit 4-59: Conflict Points for a Single Point Urban Interchange

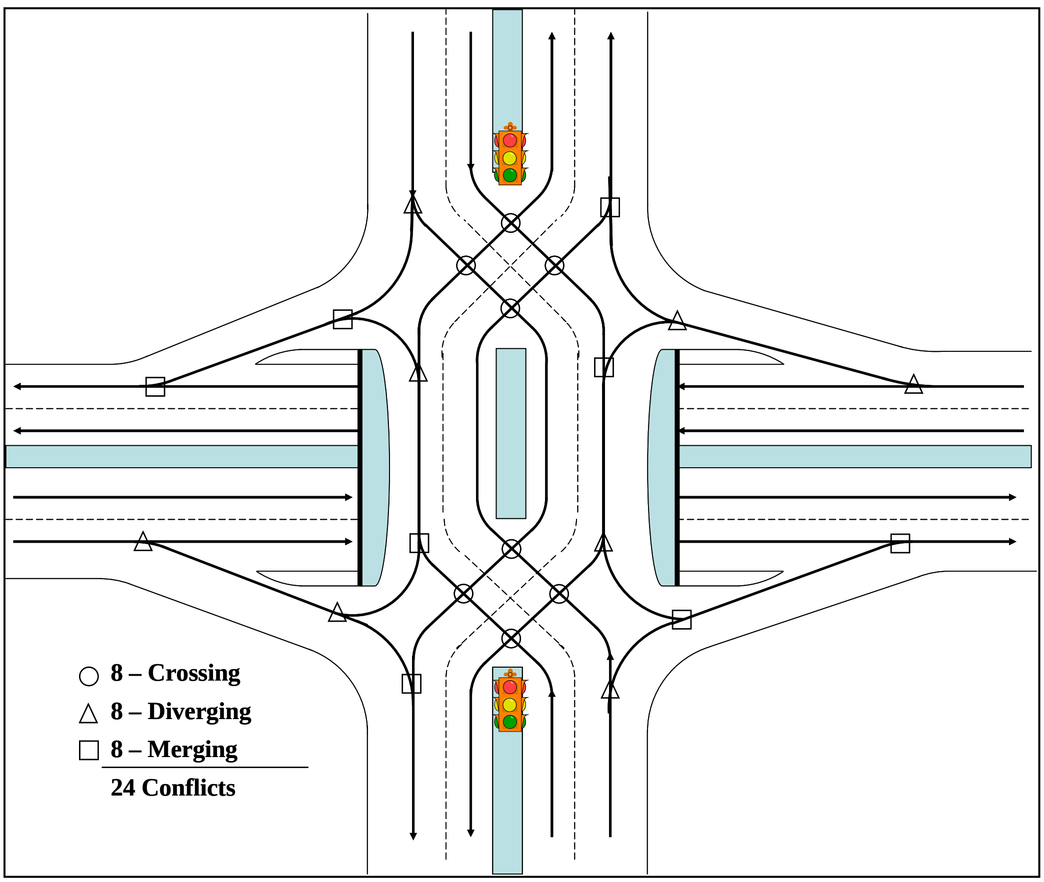


Divergent Diamond Interchange

The divergent diamond interchange has four ramps where vehicles that want to turn right may get on or off the roadway, as shown in Exhibit 4-60. The divergent diamond is designed so that as traffic on the minor roadway approaches the interchange intersections, the opposing lanes change the side of the road that is being used. This allows turn conflicts to be merge/diverge rather than crossing. Vehicles that want to turn left follow the appropriate traffic flow and merge into the receiving lane without interference of opposing traffic. The divergent diamond overlap allows vehicles to turn left at the designated signalized intersections reducing crossing paths and conflict points. This configuration also allows the use of fewer phases in the traffic signal operation.

Due to high speeds and high volumes, the divergent diamond must consider appropriate pedestrian crossings. There have been designs that show pedestrian crossings over the ramps and down the middle of the minor leg.

Exhibit 4-60: Conflict Points for a Divergent Diamond Interchange

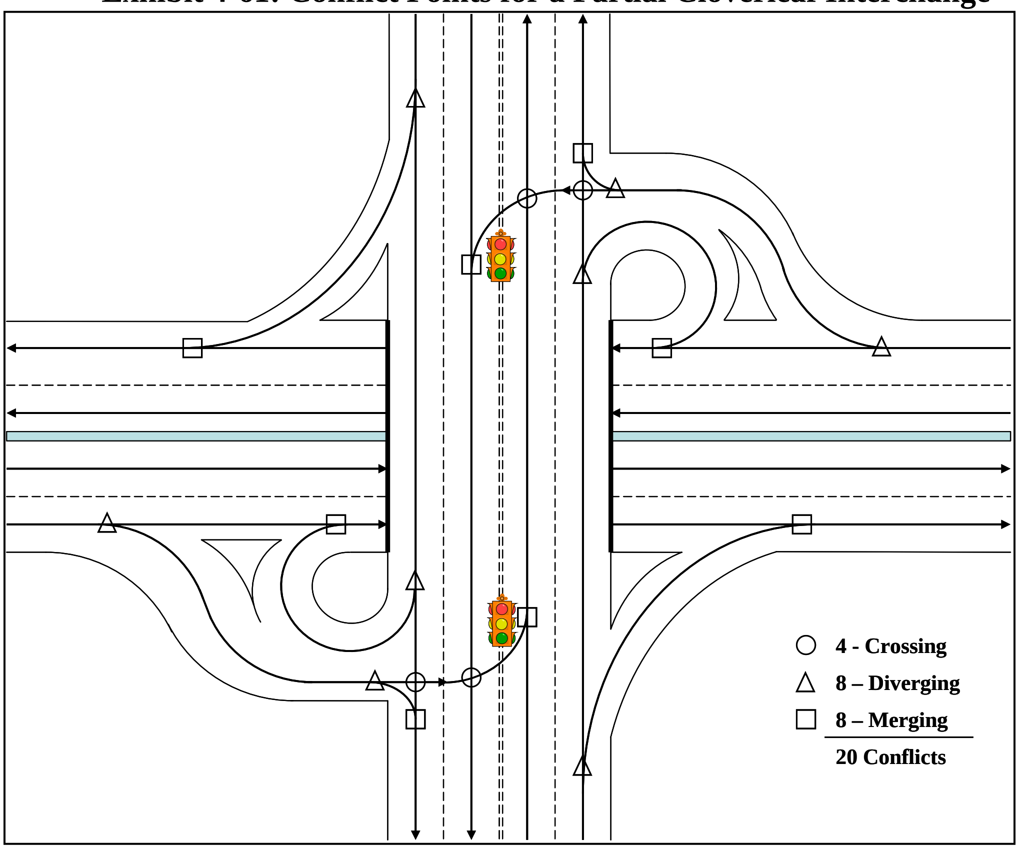


Partial Cloverleaf Interchange

The partial cloverleaf, shown in Exhibit 4-61, reduces conflict points by providing elevated ramps to maneuver on and off the roadway. The on ramps are free flow but the off-ramps are controlled by traffic signs or signals. Vehicle paths cross only for left-turning traffic from the ramps. There is potential for weaving conflicts if this interchange has two or more lanes in each direction.

Although a full cloverleaf configuration is a possible design, Oregon and many other states no longer use them because of the short distance between the merging/diverging paths of the ramps. If present, pedestrian crossings would direct people over the ramps where the speeds are lowest and drivers have adequate sight distance.

Exhibit 4-61: Conflict Points for a Partial Cloverleaf Interchange



4.8.4 Access Management

Access management is the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway. Appropriate access management promotes the safe and efficient use of the transportation network while providing access to adjacent land uses. Access management can often be a low-cost solution to congestion and reduce crashes.

In 1948, the Oregon State Highway Department was tasked with policing access to Oregon's state highways. The state highway approach permitting process was created to regulate the number of private driveways or public approaches onto a state highway. The Highway Division was also required to regulate the design of driveways, in order to ensure they complied with current design standards. When ODOT was established in 1973, access management remained a department duty with processes specified in the Oregon Administrative Rules (OARs). The goal of this policy was and is to protect viability of the state's highway infrastructure and to provide the motoring public with safe and reasonable access.

Note: Conflict points are discussed in detail in Section 4.8.3

4.8.5 Effects of Access Management Implementation

Good access management techniques improve both the roadway and adjacent land use. Details and research citations on the safety, operational, economic and other effects of access management as noted below are documented in the TRB's Access Management Manual[6].

Safety Effects

- Reduction of crashes involving vehicles as well as pedestrians and bicyclists[7]
- Limit number of traffic conflict points
- Separate conflict areas
- Preserve functional area of intersections
- Fewer conflicts for bicyclists
- Medians reduce crashes as well as provide pedestrian dwelling areas for two-stage crossings
- Reduced speed differentials resulting from through traffic meeting with turning traffic.
- Improved sight distance

Operational Effects

- Proper spacing of access points and intersections improves the flow of traffic. Poor spacing, design and location of driveways may reduce average travel speeds by up to 5 mph to 10 mph from desired speeds.[8]
- Reduced access density improves free-flow speed and reduces delay and congestion
- Up to 40% fewer vehicle hours of delay on access controlled roadways as compared to uncontrolled roadways
- Preserve integrity of the roadway system
- Extend functional life of the roadway

[6] Access Management Manual, Transportation Research Board, 2003.
[7] HSM Part D, Chapter 13, Section 13.14 includes CMFs for access management on rural two-lane roads and urban/suburban arterials. See also ODOT Driveway Safety Models.
[8] Access Management and the Relationship to Highway Capacity and Level of Service, Florida DOT, 1996

Economic Effects

- Access improvements on corridors have been shown to result in increased property values by decreasing travel time.
- Predictable travel times benefit service industries and manufacturing facilities operating under "just in time" delivery contracts
- Combining driveways creates more room for parking and landscaping and may result in lower maintenance. Providing cross-access between retail parking lots often encourages multistop business trips by customers who otherwise may not have stopped.
- Non traversable median projects generally have little or no overall adverse impact on business activity.

Other Effects

- Improved traffic flow resulting from access management reduces vehicle emissions and fuel consumption.

Driveway Safety Assessment Predictive Models

ODOT has produced a predictive model to assist with assessing driveway safety on rural and urban arterial roadways in Oregon. The Revised ODOT Driveway Safety Models are available as a spreadsheet tool with instructions, with background information available in the Validation Report and Original SPR 720 Report.

The Revised ODOT Driveway Safety Models spreadsheet can be used to quantify and predict the effect of access management changes on non-intersection crashes. It includes a model for urban arterials and for rural arterials. The model has the following data requirements:

- Segment length
- Annual average daily traffic
- Speed limit
- Total number of through travel lanes
- Presence of a two-way left-turn lane (urban only)
- Number of commercial plus industrial driveways (urban only)
- Total driveways in segment (rural only)
- Number of industrial driveways (rural only)
- Total number of driveway clusters (rural only, methodology included in spreadsheet)

The spreadsheet provide the number of predicted crashes in five years, split into a baseline exposure value and an additional roadside and driveway effect value.

Rules, Policies, and Guidance

Laws pertaining to the control of access to public highways in Oregon are found in Oregon Revised Statutes (ORS) Chapter 374.

Administrative rules for highway approaches, access control, spacing standards and medians are found in OAR Chapter 734, Division 51 (OAR 734-051). Division 51 establishes procedures, standards, and approval criteria used by ODOT to govern highway approaches, access control, spacing standards, medians and restriction of turning movements.

The Oregon Highway Plan (OHP) serves as the policy basis for implementing OAR 734-051 through three goals:

- **Goal 1: System Definition.** To maintain and improve the safe and efficient movement of people and goods and contribute to the health of Oregon's local, regional, and statewide economies and livability of its communities.
- **Goal 2: System Management.** To work with local jurisdictions and federal agencies to create an increasingly seamless transportation system with respect to the development, operation, and maintenance of the highway and road system that:
  - Safeguards the state highway system by maintaining functionality and integrity;
  - Ensures that local mobility and accessibility needs are met; and
  - Enhances system efficiency and safety.
- **Goal 3: Access Management.** To employ access management strategies to ensure safe and efficient highways consistent with their determined function, ensure the statewide movement of goods and services, enhance community livability and support planned development patterns, while recognizing the needs of motor vehicles, transit, pedestrians and bicyclists.

The ODOT Access Management program website provides guidance on access management.

Types of Access Management Efforts

Access management encompasses a variety of different activities. The following is a brief description of each area. Detailed guidance on these efforts can be found on the ODOT access management website. It is important to coordinate with the Region Access Management Engineer (RAME) and other access management staff early in planning and project development processes.

Standards

Section 4020 of Division 51 contains standards for approval of private approaches, including the access spacing tables for roadways and interchanges. The spacing standards are also contained in OHP Appendix C. In addition, Table 12 of OHP Appendix C contains standards for spacing between interchanges.

Planning

Access management is one of the principal goals of the OHP (Goals 1, 2 & 3). Plans involving public road connections to the highway should be coordinated with the RAME as they are not subject to the approach permitting process. A resource for more information on access management in planning is NCHRP Report 548, *A Guidebook for Including Access Management in Transportation Planning*.

ODOT encourages the development of access management plans and interchange area management plans to maintain and improve highway performance and safety by improving system efficiency and management before adding capacity.

An **Access Management Plan (AMP)** is a plan adopted by the OTC for managing access on a designated section of highway or the influence area of an interchange to maintain and improve highway performance and safety. Detailed guidance on AMPs can be found on the ODOT access management website.

An **Interchange Area Management Plan (IAMP)** is a plan to determine transportation solutions or land use/policy actions needed in an interchange area and how best to balance and manage transportation and land use issues over time. It is an important tool in protecting the function and operations of state highway interchanges and the supporting local street network. Assistance in the preparation of IAMPs is available in the ODOT Interchange Area Management (IAMP) Guidelines.

Project Development

Access management in project delivery in addressed in Division 51 Section 734-051-5120. ODOT encourages the development of access management strategies and access management plans during project delivery to maintain and improve highway performance and safety by improving system efficiency and management before adding capacity.

An **Access Management Strategy (AMStrat)** is a product developed by the project team that identifies the location and type of approaches and other necessary improvements that will occur as part of the project. The strategy may range from general statements on a preservation project to maps showing specific access closures in a modernization project. Division 51 requires access management strategies for modernization projects, projects within an influence area of an interchange where the project includes work along the crossroad, or projects on an expressway. Access management strategies may be developed for other highway projects.

The goal of an AMStrat is to improve safety and operations through measures taken during project delivery. These may include physical improvements to reduce conflicts such as medians and deceleration lanes, with treatments of existing approaches to mitigate, modify, relocate, consolidate, or close them as needed and as resources allow.

Operational notices provide requirements and guidance on access management in project development and delivery. PDLT Notice 03 addresses access management in project development. PDLT Notice 03 addresses access management specifically for pavement preservation projects.

A tabular evaluation of spacing standards should be conducted as part of existing conditions, future no-build, and alternative analyses and documented in the appropriate technical memorandums and narratives. This should cover all applicable roadway segments in the study area. Local jurisdiction’s spacing standards shall be used for non-state roadways.

Example 4-5 Access Spacing Standards Reporting

This is an example of a typical access spacing standards reporting at the project development level included in a technical report.

The spacing and location of intersections and driveways affect traffic safety and operations. These access points introduce conflicts and are frequently the cause of slowing or stopping vehicles that can significantly degrade the flow of traffic and reduce the efficiency of the transportation system. Appendix C in the OHP has spacing standards for public road approaches and private access to be used in the planning process.

The following spacing standards apply to this project:[9]

- **Interchange to interchange:** Two miles for freeway interchanges with two-lane crossroads in a rural area, measured between interchange lane tapers.
- **Next intersection adjacent to ramp terminal:** 1,320 feet for a two-lane crossroad in a rural area next to a full or right-in/right-out intersection.
- **Street spacing:** 1,320 feet for a rural statewide highway at 55 mph and 500 feet for a rural district highway at 45 mph. There is no standard for private accesses as they are discouraged on state highways.

The table below shows the comparison between roadway segments and their appropriate spacing standard. Existing street and ramp spacing is well below standards for all segments in the project area. In the example, on I84 the distance between the Biggs-Junction and Rufus interchange is approximately five miles, which is compliant with standards. Bargeway Lane directly accesses the I84 westbound on-ramp acceleration lane. The access point is less than 300 feet downstream of the I84 westbound ramp terminal intersection and approximately 600 feet upstream of the freeway entrance. Extending the length of the on-ramp, so that the acceleration lane begins west of the Bargeway Lane, will reduce the potential for accelerating vehicles to crash with slow moving and/or turning vehicles entering/exiting Bargeway Lane.

On US97, the distance between the I84 EB ramp terminal and the Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection is less than half the spacing standard. Queuing and blocking on this segment will become an issue as volumes grow; however, because of the topography and waterway constraints, meeting the spacing standards for this segment will not be possible even under the best conditions. On the segment south of the Celilo-Wasco/Biggs Rufus Frontage Rd. and US97 intersection, there are two driveways for the Shell Gas and Travel Stop; the first (for cars) is approximately 550 feet south of the intersection and the second (for trucks) is approximately 900 feet south of the intersection.

On the Celilo-Wasco Spur, there are multiple driveways on both sides of the highway. The first, for McDonalds and the Grand Central Travel stop on the opposite side of the road, is approximately 150 feet west of the Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection. The second, for both locations, is approximately 300 feet west of the intersection.

[9] OAR 734-051, Highway Approach Permitting, Access Control, and Access Management Standards. Effective June 30, 2014.

Spacing Standard Summary

Access Management Classification	Roadway	Segment	Spacing Standard*	Existing Conditions**
Interchange to Interchange	I84	Between Biggs Junction and Rufus Interchange	2 miles	5 miles
Next intersection adjacent to ramp terminal	US97	Between I84 EB ramp terminal and Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection	1320 feet	600 feet
Street Spacing: Statewide Highways	US97	Between Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection and entrance to Shell Gas and Travel Stop	1320 feet	550 feet
Street Spacing: District Highways	Celilo-Wasco Spur	Between Celilo-Wasco/Biggs Rufus Frontage Rd and US97 intersection and the entrance to McDonalds / Travel Stop	500 feet	150 feet

** OHP Spacing Standards*
***Approximate approach spacing*
Black-shaded cells indicate that the spacing standard is not met.

Permits

An Application for State Highway Approach is required for new approaches and in other circumstances. The outcome of the permitting process is issuance of a permit to construct the approach. Once construction is approved, a final Permit to Operate, Maintain and Use a State Highway Approach is issued. Details on the permitting process are found in Division 51 as well as Chapter 4 of ODOT's Access Management Manual.

Access Management Techniques

A variety of administrative and design techniques can be applied to preserve and enhance the safety and operational character of a roadway segment and to mitigate the traffic problems at many types of locations. The appropriate technique depends on the context of the roadway, traffic, land use, and environmental characteristics. There is no one-size-fits-all solution. The following is not an exhaustive list. HDM Section 8.2 contains additional information on the design of road approaches.

- **Minimize:** Relocate driveways to farthest edge of property, consolidate driveways to increase separation, close, acquire access rights, joint and cross access, provide secondary access
- **Administrative:** Access policies and codes, subdivision and partition review, vehicle use limitations, purchase of access control, Division 51, spacing tables
- **Alternate Access:** Backage or frontage roads

- **Restrictions:** Painted/Non Traversable medians, porkchops to preclude direct left turns. Raised medians remove major conflict points from direct left turns. Studies indicate significant crash reductions from installation of raised medians.[10] Raised medians also significantly benefit pedestrian safety.[11]
- **Location:** Sight distance, spacing, corner clearance, signal spacing
- **Design:** Width reduction, definition, throats vs. aprons, curb radius, directional median openings, shoulder bypass, jug handles, frontage roads, service roads, illumination, visual cues at driveways. Indirect turns such as U-turns and J-turns or roundabouts are safer than direct left turns.[12] Frontage and backage roads facilitate traffic circulation by separating local from through traffic.
- **Channelization:** Left- and right-turn lanes on adjacent roadway and on access. Providing space for left turns away from through traffic can significantly reduce crashes.[13]

4.8.6 Turn Lane Criteria and Traffic Control

Certain crash types and the overall crash frequency at a location may be addressed by mainline turn lanes or improved traffic control. Analysis of the existing or no-build conditions should identify these safety deficiencies that are addressed in the build alternative analysis. Left- and right-turn lanes at unsignalized locations can be installed to reduce high-speed rear-end collisions by removing slower turning vehicles from through traffic. The criteria for turn lanes are outlined in detail in Chapter 7.

High frequency of turning or angle crashes may indicate a need to investigate traffic control improvements. Traffic control improvements may remove simultaneous conflict points such as an all-way stop, roundabout, or a traffic signal. Conflict points could also be removed or minimized by using medians, channelization, or grade separation. Traffic control may also include bike or pedestrian islands and devices. Traffic control is discussed in detail in subsequent chapters.

4.9 Online Safety Resources

4.9.1 ODOT Safety Resources

Oregon Highway Safety Website

Overview webpage describing ODOT safety programs and resources. Includes links to many analysis tools and data resources, as well as information on funding sources and ODOT research.

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[10] Mauga, T. and Kaseko, M., "Modeling and Evaluating the Safety Impacts of Access Management (AM) Features in the Las Vegas Valley." Transportation Research Record: Journal of the Transportation Research Board 2171, pp. 57-65, 2010

[11] Zegeer, C. V., Stewart, R., Huang, H., and Lagerwey, P., "Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines." FHWA-RD-01-075, McLean, Va., Federal Highway Administration, (2002)

[12] Xu, L., "Right Turns Followed by U-Turns Versus Direct Left Turns: A Comparison of Safety Issues." ITE Journal, Vol. 71, No. 11, Washington, D.C., Institute of Transportation Engineers, (2001) pp. 36-43.

[13] Lyon, C., B. Persaud, N. Lefler, D. Carter, and K. Eccles. "Safety Evaluation of Installing Center Two-Way Left-Turn Lanes on Two-Lane Roads." TRB 87th Annual Meeting Compendium of Papers CD-ROM. Washington, D.C., 2008.

Oregon Highway Safety Manual Website
Oregon-specific HSM tools, research, and implementation information. Includes links to pre-calibrated HSM Predictive Method spreadsheets.

Highway Safety Investigations Manual
The Highway Safety Investigations Manual is a resource to assist ODOT traffic investigators and analysts with detailed highway safety project screening and evaluations. The manual includes checklists and analysis procedures suitable for a variety of field and office safety investigations and assessments. A set of worksheets is available containing tools and forms to facilitate the analysis.

Low-Cost Systemic Safety Countermeasures
Guidance and fact sheets on the use of research-proven low-cost safety countermeasures that can be deployed on a systematic basic. Through the collective efforts of ODOT's Traffic Operations Leadership Team (TOLT) and Highway Safety Engineering Committee (HSEC), many of these safety countermeasures are thoroughly integrated into the options the ODOT Regions must consider when addressing highway safety issues to reduce fatal and serious injury crashes throughout Oregon.

Transportation Development Trans Data Portal
Index page that lists many transportation data sources available through ODOT.

4.9.2 ODOT Safety Plans

Transportation Safety Action Plan (TSAP)
The TSAP is the guiding safety policy document for ODOT and includes the specific actions that are being taken to provide a safer travel environment. The document also serves as the federally mandated Strategic Highway Safety Plan (SHSP).

Roadway Departure Safety Implementation Plan
Roadway Departure crashes account for approximately 66% of all fatalities in Oregon. Data analysis of Oregon crashes was combined with cost-effective strategies to identify locations for the most effective use of funds to achieve an approximate 20% reduction in roadway departure fatalities. This systematic approach involves deploying large numbers of relatively low-cost, cost-effective countermeasures on targeted segments of road with a history of roadway departure crashes.

Intersection Safety Implementation Plan
This plan developed by Oregon and FHWA focuses on reducing fatal and major injury crashes at intersections. In Oregon, an average of 72 fatalities at intersections occurs each year. Although this number is declining, this plan is geared towards reducing this number even more. Using cost-effective strategies to apply both systemic improvements as well as hot spot improvements can be used to reach approximately a 13% reduction in intersection fatalities.

Bicycle and Pedestrian Safety Implementation Plan
Provides a systemic approach to reducing pedestrian and bicycle risks and crashes in Oregon. Includes two network screening methods, a traditional crash-based process and a risk-based systemic safety planning process using roadway characteristics that have contributed to pedestrian and bicycle crashes over the study period. The plan provides a list of candidate priority locations and a toolbox of relevant countermeasures.

4.9.3 National Safety Analysis Resources

Official AASHTO Highway Safety Manual Website
Includes purchasing information, case studies, implementation tools, and online training guides for the HSM. Also includes user forums for practitioners and published corrections to the HSM.

Crash Modification Factors Clearinghouse
Companion tool to HSM Part D Crash Modification Factors. Provides a searchable database of up-to-date CMFs with details on applicability and links to the original research. This is a free web site funded by FHWA and maintained by the University of North Carolina Highway Safety Research Center.

PEDBIKESAFE.org
FHWA website for the Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE) and Bicycle Safety Guide and Countermeasure Selection System (BIKESAFE). The site includes practitioner guidebooks, proven countermeasure information, and various case studies covering treatment implementation.

Appendix 4A – Crash Attribution and Automation

(1) Discussion Paper No. 7, Functional Intersection Area, Transportation Research Institute, Oregon State University, January, 1996