Oregon Department of Transportation

SAFETY INVESTIGATION MANUAL

Traffic-Roadway Section | Delivery & Operations Division

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Oregon Department of Transportation

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Preface

The purpose of this document is to provide a resource to ODOT traffic investigators with highway safety project investigation, analysis, evaluation, and documentation. This manual includes checklists and analysis procedures suitable for a variety of field and office safety investigations and assessments. This manual also includes information about the ODOT highway safety programs and tools, linkage to current standards and resources where design and operations methods are stipulated, a comprehensive procedure for safety investigation at both intersection and highway segments, and countermeasure definition and guidance.

Although the content of this manual is targeted for use within ODOT, the procedures outlined could be easily adapted by local jurisdictions for highway safety assessments. This manual does not contain roadway design policies or practices.

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Acronyms Glossary

AASHTO	American Association of State Highway and Transportation Officials
AADT	Annual Average Daily Traffic
ADA	American with disabilities Act
ADT	Average Daily Traffic
AMU	Access Management Unit
ARTS	All Roads Transportation Safety
BUD	Blueprint for Urban Design
CAR	Crash Analysis and Reporting Unit
CDS	Crash Data System
CMF	Crash Modification Factor
CRF	Crash Reduction Factor
DMV	Department of Motor Vehicles
DSD	Decision Sight Distance
DVL	Digital Video Log
FHWA	Federal Highway Administration
FUAB	Federal Urban Aid Boundary
FYA	Flashing Yellow Arrow
GIS	Geographic Information System
HDM	Highway Design Manual
HSEC	Highway Safety Engineering Committee
HSM	Highway Safety Manual
HSIP	Highway Safety Improvement Program
ITE	Institute of Transportation Engineers
LIDAR	Light Detection and Ranging
MEV	Million Entering Vehicles
MUTCD	Manual on Uniform Traffic Control Devices
MVMT	Million Vehicle Miles Travelled/

NCHRP	National Cooperative Highway Research Program
ODOT	Oregon Department of Transportation///
OTSDE	Oregon Transportation Safety Data Explorer
PDO	Property Damage Only
PRC	Product Representation Compact
PRT	Perception Reaction Time
PSD	Passing Sight Distance
RICS	Road Inventory and Classification Services Unit
RITIS	Regional Integrated Transportation Information System
TDS	Transportation Data Section
TPAU	Transportation Planning Analysis Unit
TSAP	Transportation Safety Action Plan/
TSM	Transportation Systems Motoring
SIM	Safety Investigation Manual
SPIS	Safety Priority Index System/
SSD	Stopping Sight Distance
STIP	Statewide Transportation Improvement Program
STM	Signal Timing Manual
UPRR	Union Pacific Railroad
VHC	Virtual Highway Corridor
vpd	vehicle per day

Chapter 1 Manual Overview and Purpose

Across the state, region, and nation highway safety investigators have developed a wide variety of tools and techniques for highway safety investigation procedures. Analysis techniques can range from network screening analysis, such as the Safety Priority Index System (SPIS) developed by Oregon Department of Transportation (ODOT), to specific localized safety assessment strategies.

ODOT's Transportation Safety Action Plan (TSAP) aims to eliminate fatalities and serious injuries on Oregon's transportation system by 2035 (*1*). Oregon can benefit from significant crash reductions by increasing safety awareness, promoting infrastructure and behavioral safety, and focusing on reducing fatal and serious injury crashes on all Oregon roadways. Safety investigations play a crucial role in achieving these goals set by every level of jurisdiction by identifying locations where additional investment would increase safety.

This manual assumes that a particular location (a segment of roadway or an intersection) has already been identified for investigation by any of the following:

- An investigation of a particular location (a segment of roadway or an intersection) identified by the SPIS program, the All Roads Transportation Safety (ARTS) program or as part of a proposed project;
- An investigation motivated by a citizen complaint or inquiry; or
- An investigation initiated due to a fatal crash or crashes.

This manual is primarily directed at the first type of investigations (the first bulletin).

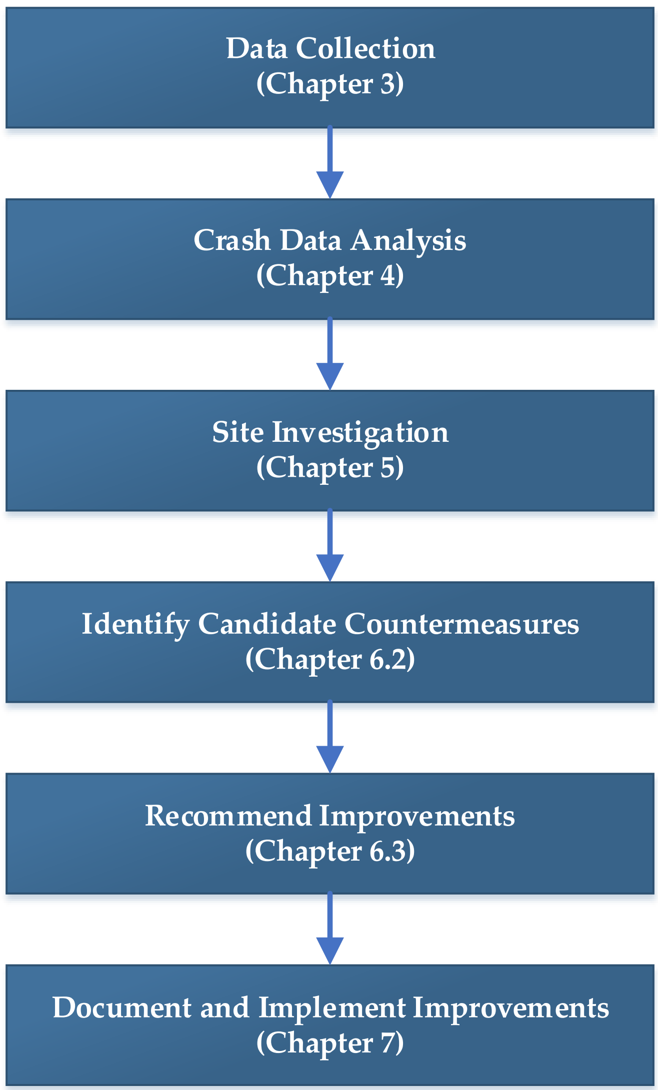
Table 1-1 below summarizes the basic tasks in the safety investigation process and the location in the *Safety Investigation Manual* (SIM).

Table 1-1: Basic Tasks in Safety Investigation Process

Task	***Objective of Task***	***Location in SIM***
In office analysis of data sources	To develop a preliminary understanding of the most common crash types and location of these crashes, the problem area, and items to look for in a field review	Chapter's 2, 3 & 4
Field or desktop review of location	To confirm problems identified during in-office analysis, to uncover potentially new understandings of crash mechanisms, to inspect physical features of the site for documentation.	Chapter 5
In-office selection of solutions	To recommend cost-effective solutions that will improve the safety performance of the studied facility	Chapter 6
Producing the necessary documentation	To provide a documentation of the investigation	Chapter 7

The basic analysis procedures identified in this manual include the six steps demonstrated in **Figure 1-1**.

Figure 1-1: Overview of Analysis Approach



Chapter 2 Safety Investigation Basics

This chapter provides a brief overview about basic principles of safety investigations. The safety investigations process is a combination of scientific evaluation, the investigator's knowledge and experience, and good judgment. Many tools are available to support the countermeasure selection using a data-driven approach. The investigator, however, still needs to stitch together many clues as to why crashes occurred without having the benefit of any actual first-hand knowledge of the crash. The investigator must glean clues from a detailed analysis of crash data and a thorough investigation of field data. These clues can then be evaluated by the investigator to identify preventable crashes.

The ODOT ARTS program identifies two approaches for identifying preventable crashes and countermeasures: Hotspot and Systemic. The Hotspot approach identifies countermeasures at locations with disproportionately high crash rates. Projects proposed through this approach are often higher cost, location specific countermeasures. The systemic approach applies low-cost countermeasures proven to reduce fatal and serious-injury crashes that are commonly implemented throughout the roadway network. The focus of this manual is on the hotspot approach to help the investigator identify feasible and effective countermeasures, make recommendations, and document the entire process.

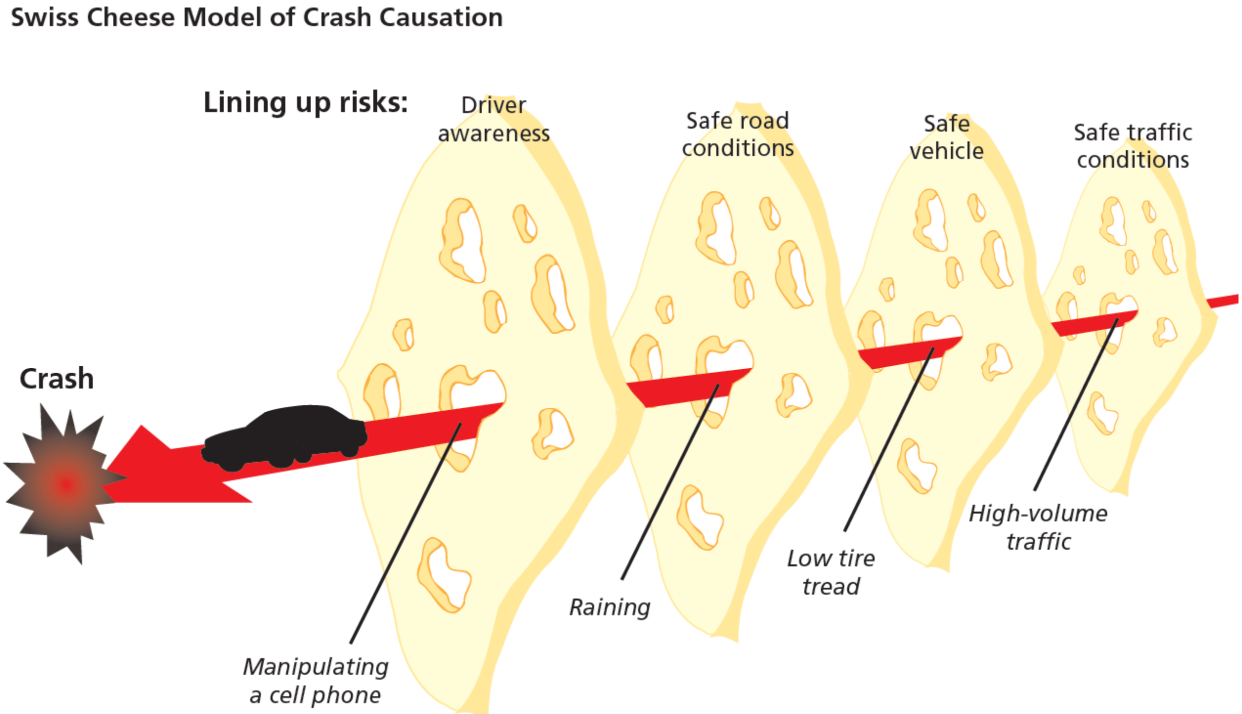
2.1 Principles of Safety Investigations

There are two principles that are useful to keep in mind when attempting to diagnose a crash problem. First, crashes should be considered rare events. Even though there are about 50,000 reported crashes in Oregon per year, the vast majority of interactions between vehicles, users, and the infrastructure do not result in crashes. For a crash to occur, a number of failures or errors (events) have to occur simultaneously. For example, if a rear-end crash occurs at a signalized intersection, one or more of the following events must have transpired:

- Two vehicles approach traffic signal as the indication turns red.
- The driver in the lead vehicle stops.
- Driver in following vehicle following too closely, too fast, or is inattentive.
- Braking (if any) is not sufficient to stop the trailing vehicle in time.

If any one of these sequential events leading up to a crash was altered in some way, the crash may have been avoided. Clearly, a crash can happen even with a well-engineered, appropriately signed, and enforced facility. This concept is illustrated in **Figure 2-1** that shows the multiple failures in various systems that must occur for a crash to happen.

Figure 2-1: Crash Causation Visualization



If we take a longer view (years), some number of crashes per year can be expected. This long view can be thought of the "expected crashes" or the "average over the long run." These expected crashes per year vary for different environments (a rural interstate or urban minor arterial) because driver expectations, potential conflicts, traffic volumes, or design standards are different. It should be pointed out that the "expected crashes" concept does not mean that this number of crashes is acceptable. This concept only reflects the recent safety performance (which can be improved). The goal is to eliminate crashes, particularly fatal and severe injury crashes.

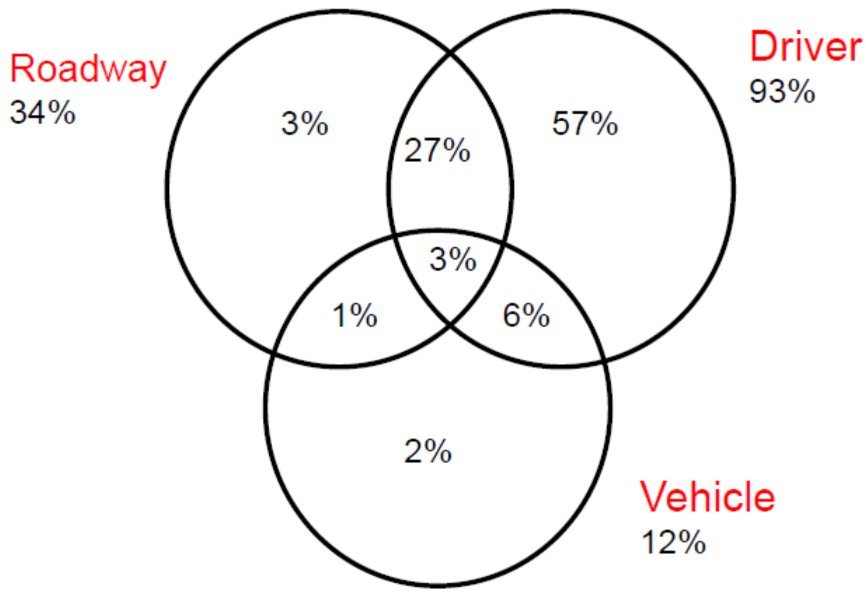
Second, we assume that most drivers, cyclists, and pedestrians would prefer to avoid a crash and will do so in most situations; however, we know that humans will make errors. While we might expect some crashes to happen, if crashes exceed what we expect then something is most likely correctable at our location under investigation. Therefore, our investigative efforts are searching for a pattern of crashes that is out the ordinary. If these patterns can be detected, they are the most reliable guide to the remedial action. How to do this is described in **Chapter 4**.

Once the pattern is found, the next step in the diagnostic effort is to try to determine what might be causing these crashes to occur. Interpreting the crash pattern data, conducting a field or desktop investigation, and gathering and reviewing other data to identify likely contributing causes and countermeasure selection is discussed in **Chapters 5** and **6**.

2.2 What Factors Contribute to Crashes?

In a landmark study, Treat et al. (*2*) performed an in-depth study of crashes that happened in Indiana. A team of experts defined the one event leading up to the crash that, had it not happened, the crash would have been avoided. They assigned that one event to three categories: driver, roadway, and vehicle. The results of this analysis are summarized in the diagram in **Figure 2-2**. As one might expect, the study found that in almost all crashes, there is likely a driver-related component. There is also a strong overlap with the other elements, particularly the roadway. Roadway defects or vehicle defects are only a small percentage of the total. The results of this study have been closely replicated by more recent studies with updated methods.

Figure 2-2: Crash Causes Venn Diagram from Treat Et Al. Study



This does not imply that roadway user errors are not preventable. On the contrary, the strong overlap with the roadway causes means that our investigative efforts should focus on these driver elements, also called human factors. By considering human factors in safety investigations, the relationship between the system, control devices, and the users is enhanced (*3*). If we recognize that driver abilities, behaviors, attitude, speed, risk taking (e.g., alcohol use, excessive speed, phone distractions), fatigue, physical abilities (e.g., vision, ability to turn head), and cognitive decisions or reactions, we can better identify engineering solutions that might improve the situation.

While some driver elements can only be changed through education or enforcement, there are driver related errors that can be linked to the roadway (including operations) environment. Probably the most important concept to consider when investigating crash locations is called "driver expectancy." This concept means that drivers are conditioned to expect certain events to happen. For example, drivers know that the yellow signal indication means that a red signal indication is to follow and they should be prepared to stop. This "expectancy" decreases reaction time and improves operations. If there is an unusual situation, driver confusion or overload is more likely to occur and this can result in crashes. From an engineering standpoint these considerations are accounted for in the form of driver expectancy, information transfer (i.e., spreading and redundancy), sight distance, reflectivity, and geometric design (*4*).

Other human factors often need to be considered such as visual clutter or competing stimuli, experience and age of the drivers, and driver comfort or satisfaction. For example, drivers are more likely to take risks when turning left if they have become impatient due to a long delay. In this situation, a solution to turning crashes may be an operational one. Additional material on human factors can be found in *National Cooperative Highway Research Program (NCHRP) Report 600: Human Factors Guidelines for Road Systems. Human Factors Guidelines for Road Systems: Second Edition* (*3*).

2.3 RELATIONSHIP OF CRASHES AND SEVERITY TO SPEED

Speed influences several factors in driving and crash severity. Higher speeds correlate with longer braking distances, which can cause issues with crash avoidance and vehicle control. This is particularly true in single-vehicle crashes where the driver is exceeding the speed limit, among other driving errors. It is well known that speed significantly effects crash outcomes. Upon impact, vehicle occupants continue to move in the direction of motion until striking another object (inside the vehicle or outside). At higher speeds, individuals are more likely to face more severe injuries due to this collision. This is particularly true with older drivers with increased vulnerability to injury (*5*). While seat belts and airbags work to decrease severity, higher speeds often overcome their usefulness and increase the likelihood of serious injuries or fatalities.

Speed is critical for vulnerable road user safety. High vehicle speeds correspond with more severe injuries in pedestrians and bicyclists upon impact. Risk of severe injuries and death increases slowly until 30 mph, after which risk increases rapidly (*6*). At 60 mph (100 km/h), pedestrian survival rate is less than 10% (*7*). Management of speed can play a key role in improving safety.

2.4 CRASH RATES

2.4.1 CRASH RATE CALCULATION

In most cases, as traffic volumes increase, if nothing else changes to the transportation facility, the number of crashes is also likely to increase. This is the reason crash rates are calculated - to normalize for exposures. The crash rate is expressed as crashes per million vehicle miles-traveled (MVMT) for segments and per million entering vehicles (MEV) for intersections. For fatal and A-injury crashes, the crash rate is typically calculated as crashes per 100 MVMT.

For segments the rate calculation is:

$$Rate = \frac{C * 1{,}000{,}000}{V(D)(L)}$$

Where

C = number of crashes in study period
V = volume, in Average Daily Traffic (vehicles per day (vpd)) in directions of travel
D = number of days in study period (assume 365 days in a year)
L = length of segment (miles).

For intersections, the rate is calculated

$$Rate = \frac{C * 1{,}000{,}000}{V(D)}$$

Where

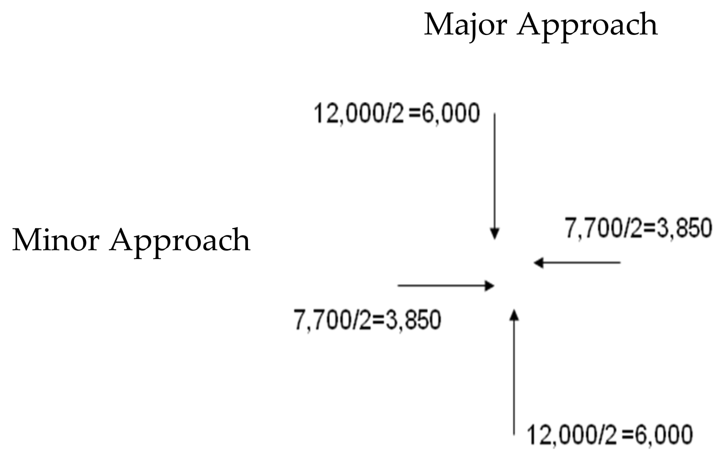
C = number of crashes in study period
V = the sum of volumes entering from all approaches, (vpd)
D = number of days in study period, (assume 365 days in a year)

Example 2.1:

- Observed <u>40</u> crashes on a <u>17.5</u> mile segment in <u>one</u> year. The average daily traffic (ADT) was <u>5,000</u> vpd.
- $Rate = \frac{40*1{,}000{,}000}{5{,}000(1*365)(17.5)} =$ 1.25 crashes per MVMT

Example 2.2:

- Observed <u>25</u> crashes in <u>6</u> years at a 4-Leg intersection. The ADT for the minor approach was <u>7,700</u> vpd and the major approach was <u>12,000</u> vpd.
- ADT volumes are always expressed for both directions of travel. To get **entering** volumes the ADTs can just be summed since the volume of traffic that enters from each direction is assumed to be approximately one-half the ADT. If the intersection were a 3-Leg intersection, only one-half of the ADT from the T-leg would be used. It may be helpful to do a quick sketch such as:



– $Rate = \frac{25*1,000,000}{(12,000+7,700)(6*365)}$ = 0.579 crashes per MEV

Example 2.3:

– Observed 20 crashes in 6 years at a 3-Leg intersection. The ADT for the minor approach was 5,100 vpd and the major approach was 10,500 vpd. Recall that a typical year should have 365 days.

– ADT volumes are always expressed for both directions of travel. To get **entering** volumes the ADTs can just be summed since the volume of traffic that enters from each directions is approximately one-half the ADT. Since the intersection is a 3-Leg intersection, **only one-half of the ADT from the T-leg is used in the exposure**.

– $Rate = \frac{20*1,000,000}{(10,500+[5,100/2])(6*365)}$ = 0.6998 crashes per MEV

– (say 0.70 crashes per MEV)

To make comparisons, critical rate is often used. The critical crash rate is a method that studies the crash rate at a specific site in comparison of an average crash rate of that intersection or segment's "reference population" (*8*). This rate calculated as:

$$R_C = R_A + K\sqrt{\frac{R_A}{M}} + \frac{1}{2M}$$

Where

R_C = critical rate
R_A = the average rate for similar facility (peer rate)
K = probability constant based on desired level of significance (1.645 for 90%)
M = millions of VMT or entering vehicles

If the crash rate at the study location exceeds the critical rate, it is flagged. The investigator can use this as an indication to whether the location is exceeding average crash patterns as compared to other facilities. Peer rates can be found in the Crash Rate Summary book published annually by the ODOT Crash Analysis and Reporting Unit (CAR) and they are included in the worksheet as a look-up function.

Example 2.4:

If we observed 40 crashes on a 17.5 mile segment in one year with an ADT of 5,000, does the observed rate exceed the critical rate at 90th % confidence if the average rate for similar segments is 1.02 crashes per MVMT?

- $\text{Observed}_{\text{Rate}} = \frac{40*1{,}000{,}000}{5{,}000(1*365)(17.5)} = 1.25 \text{ crashes per MVMT}$
- $\text{M} = \frac{5{,}000(1*365)(17.5)}{1{,}000{,}000} = 31.94$
- $\text{R}_\text{A} = 1.02 \text{ crashes per MVMT}$
- $\text{R}_\text{C} = 1.02 + 1.645\sqrt{\frac{1.02}{31.94}} + \frac{1}{2*(31.94)} = 1.33 \text{ crashes per MVMT}$
- Answer: No, the observed rate, 1.25 crashes per MVMT is less than the critical rate 1.33 crashes per MVMT.

2.4.2 *Cautions With Rates*

Rates can be a useful calculation as they attempt to control for differences in volume. They are most appropriate when comparing same functional classification, volume range, intersection type, or other distinguishing features or "apples to apples." The use of rates can lead to incorrect conclusions if comparisons are made across very different facilities. For example, one should not compare a rural interstate crash rate to a rural principal arterial rate for the purposes of assessing safety performance. To obtain average rates for a particular facility type, see the ODOT CAR publication, *Crash Rate Book* which is published annually.

https://www.oregon.gov/odot/Data/Pages/Crash.aspx

When comparing rates over time, it is important to remember that rates can change by modifying the number of crashes (numerator) or the volume, duration, or segment length (denominator). For example, a facility could be made "safer" if volumes increase but crash counts do not (the rate would be lower). If no actual improvements have been made to the facility, the road is not any safer in the physical sense, only the risk has changed.

Segment length is another important consideration in crash rate calculations. Ideally, segments should be near one mile in length. This is often difficult to achieve in urban areas with intersections closely spaced and short segment lengths (less than half a mile) may be unavoidable and give skewed crash rates (*8*).

There is some evidence that bicyclists and pedestrians have lower risk with increased bicycle and pedestrian volumes. This is generally attributed to the "safety in numbers" concept. One interpretation is that motor vehicle operators are more likely to expect these users (and drive accordingly) if they routinely see more cyclists and pedestrians. This may apply when more cyclists or pedestrians are present at a location, such as an intersection, even if drivers do not regularly interact with more vulnerable road users (*9*). A review of many studies examining the effect of safety in numbers concluded that the safety in numbers concept can be shown empirically (*10*).

2.5 Duration of Crash Data to Study

A common question in the investigation process is: How many years of crash data to use? If too long a period is chosen, there is more likelihood that there will have been changes to site conditions (e.g., volumes, drivers, reporting thresholds, periodic maintenance, etc.). If too short a period is selected, there is likely not enough data to analyze and the crash patterns may not be representative of the long-term performance of the facility.

A general recommendation is to use 3 years of crash data for analysis. In some situations, 5 years may be appropriate if there is limited crash data to evaluate. The 5-year period may also be appropriate if there are unique site conditions.

2.6 Crash Severity

The investigator should consider more than just total crashes in an investigation. There are a number of good reasons to do this. First, collision patterns may differ when looking at severity levels. By considering severity separately a significant problem may be uncovered. Second, severe crashes represent a greater cost to society (both those directly impacted by the crash) and more effort and funding should be directed at mitigating these crashes.

It is suggested to consider crashes in three severity groupings:

- Fatal and A-injury crashes are a better representation of high-energy collisions than just fatal crashes. The difference in outcomes (between fatal and A-injury) can be a result of minor differences in the crash circumstances (e.g. difference of inches in the point of collision impact, difference in driver age, or seat belt use). Considering fatal and A-injury crashes together increases the likelihood that unusual severe crashes are detected.
- B-injury and C-injury crashes are representative of lower-level crashes and have moderate societal cost.
- Property Damage Only (PDO) crashes are the least reliable in terms of data quality. They are affected by changes in reporting threshold and are less likely to have a police report. However, they are useful as an indicator of the total crash problem, and underreporting makes it difficult to quantify countermeasure

effectiveness. It is estimated that more than 50% of the property damage only crashes in Oregon are reported each year. In addition, a recent coding change to the ODOT crash data limits the amount of information recorded in the database for PDO crashes.

The investigator should also consider that it is possible for some safety countermeasures to decrease the severity of some crashes while increasing the frequency of less severe crashes. For example, installing a median barrier will increase property damage crashes (vehicles will hit an object that was not there before) but head-on crashes will be virtually eliminated. This trade-off in severity can be analyzed using a benefit-cost methodology.

2.7 Risk-Based Approach to Safety

In a transportation context, risk is defined as a probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through preemptive action. The amount of risk can be interpreted by the probability of the outcome and potential severity of the outcome if the event occurs. When considering most projects to improve motor vehicle safety, there is usually sufficient reported crashes to identify safety issues. Crash rates are a measure of risk.

Risk can also be considered in the absence of crash data. A simple example can be found in the decision to shield a non-traversable embankment with guardrail. This decision is usually made in the absence of historical crash data. If the embankment is steep and there is sufficient traffic volume, the guardrail may be installed because the risk is high. For most pedestrian and bicycles projects under consideration, there will not be many reported crashes to consider for analysis. An alternative to crash analysis is to use a risk-based lens. For vulnerable road users, the probability is a function of exposure and consequence is a function of operating conditions (e.g., vehicle speeds and size). A risk scoring includes elements of exposure and expectations of the severity of the outcome. This approach is evolving and the most recent guidance can be obtained by contacting ODOT's State Traffic Safety Engineer identified in **Chapter 1**.

Chapter 3 Overview of Data Types and Sources

There will be different data elements needed for segments and intersections. The basic data collection procedure is identified in **Figure 3-1**. For a safety investigation, the basic information that will need to be collected includes:

- Crash data (typically 3 years);
- Route numbers, ODOT internal highway number(s), highway name, local roadway names, and mileposts;
- Functional classification of the roadways;
- Rural, urban, or (suburban) character;
- Current and past traffic volumes;
- Current configuration and design of the roadway (number of lanes, type of pavement, shoulder types and width, roadside features, pavement marking, presence of traffic signal, etc.).

3.1 In-Office Data

3.1.1 Crash Data

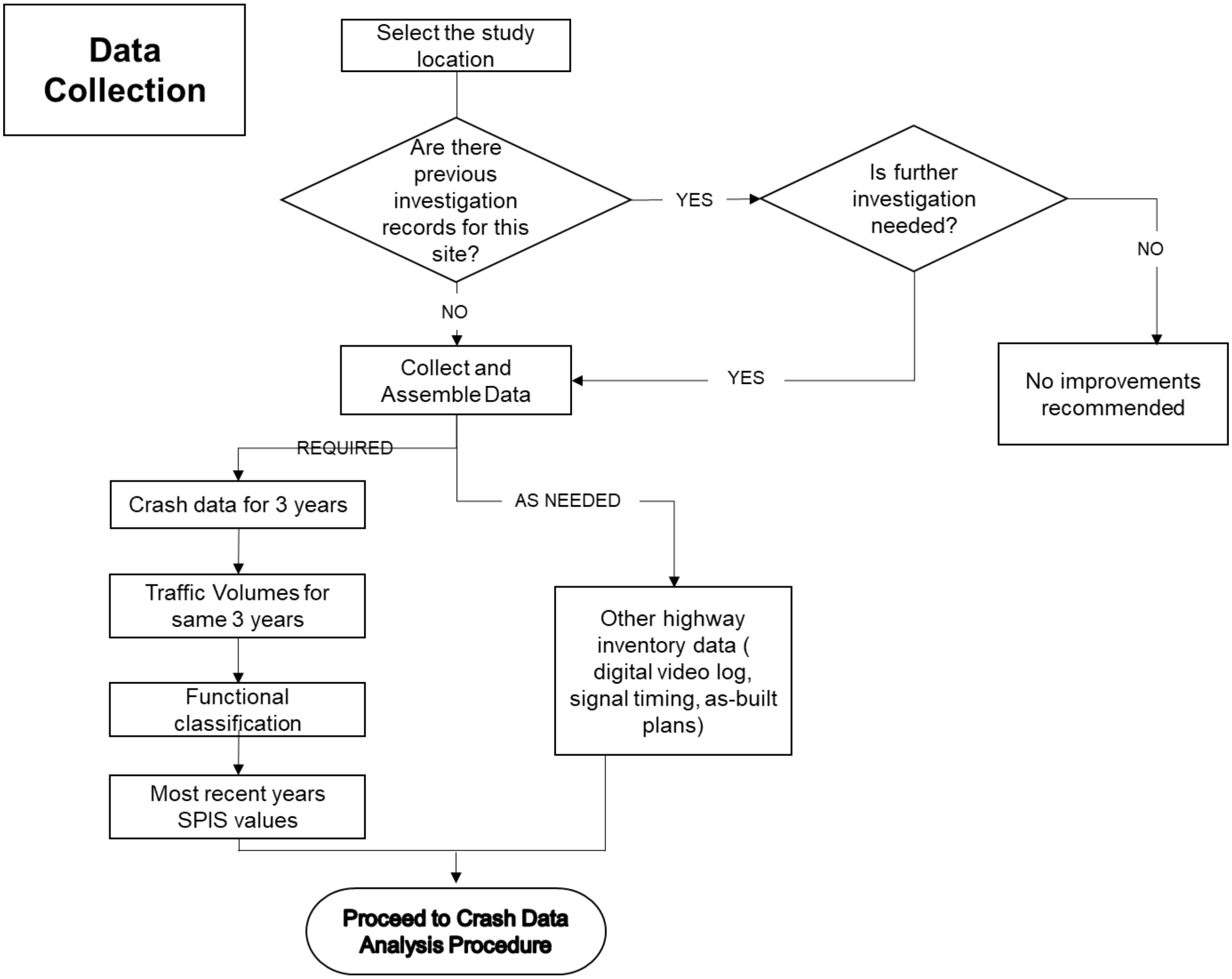
The crash data collected and complied by ODOT CAR will be a key input in the safety investigations process. The crash data are maintained for analysis and are easily accessible to the investigator.

- Crash Coding Manual

  An invaluable resource for the investigator will be the ODOT *Motor Vehicle Traffic Crash Analysis and Code Manual*. This document helps the investigator interpret the various codes about a particular crash. A full description of this data source is outside the scope of this manual, but there are some key concepts that are highlighted in the following sections. The ODOT *Motor Vehicle Traffic Crash Analysis and Code Manual* descriptions are located at the following web site:

  https://www.oregon.gov/ODOT/Data/Documents/CDS_Code_Manual.pdf

Figure 3-1: Flowchart of Procedure to Collect Data



- Crash Reporting Process

  For a crash to be "reportable" and recorded in the ODOT crash database, the crash must occur on a public roadway and meet the minimum reporting thresholds. Current Oregon law requires a citizen to report the crash to the Department of Motor Vehicles (DMV) on an *Oregon Traffic Accident and Insurance Report* form within 72 hours if:
  - Damage to the vehicle a person was driving was over $2,500 or
  - Damage to any vehicle was over $2500 and any vehicle was towed from the scene as a result of damages from the crash; or
  - Injury or death resulted from the crash; or
  - Damage to any one person's property other than a vehicle involved in the crash exceeded $2,500.

These reporting thresholds change over time by legislative action and can affect the number of property damage crashes that are reported. The most recent change occurred in 2018.

If a police officer responds to the scene, he or she completes the *Oregon Police Traffic Crash Report*. Police officers are not required to file a report unless they have completed an investigation; however, they are more likely to prepare a report for the more severe crashes (this varies by police department).

A citizen must file a report even if a police officer completed his or her own report. Both police and citizens submit their forms to the DMV. After the crash reports are assembled and processed for insurance verification and other driving records information, they are sent to CAR for coding. Next, the crash coders in CAR weave together the citizen and any police reports (if submitted) into a composite picture of the crash, sorting out any discrepancies in the information.

Because Oregon relies so heavily on citizen reports, there will be data issues despite the best efforts of the CAR unit. First, it is important to note that not all crashes that occur will be reported in the Oregon statewide Crash Data System (CDS). There will be instances where an investigator has evidence of a crash but it is not in the CDS. Sometimes, particularly in rural areas where it is hard to accurately report locations, the location information will not be correct. It is also worth noting that the precision of the milepost of the crash (to the hundred of a mile) is not necessarily the precision of the actual crash location. This milepost is based on interpretation of the CAR coders while referencing the highway inventory data. For example, if a crash was reported to occur 200 feet north of Y Road which is at milepost 5.11, the crash would be coded to milepost 5.15 (i.e., the precision implied by 2-decimal milepost is only related to the precision of the intersection location or other roadway attribute).

If an investigator finds an error in the CDS, he or she should contact the CAR to see if a correction should be made to the database.

- Data Structure

The CDS contains information for each vehicle, driver, and (most) passengers involved in motor vehicle crashes. This information is stored in a relational database with three primary tables (crash, vehicle, and participant). The crash table is a summary of the event and includes crash-level information such as location, date, time, and weather and summaries of other elements. There is one record (row) of data per crash. The vehicle table will include 1 entry for each vehicle in the crash. The participant table also includes one entry for each person involved in the crash.

To illustrate the data structure, a two-vehicle crash involving two drivers and 3 passengers shown schematically in **Figure 3-2**. The crash table will have 1 record summarizing the event (C1000). The vehicle table will contain 2 records, 1 for each car involved, V500 and V700). The participant table will have 5 records for the people that were involved in the crash (P1, P2, P3, P4 and P5). These are all cross-referenced by a unique crash id (in this example C1000).

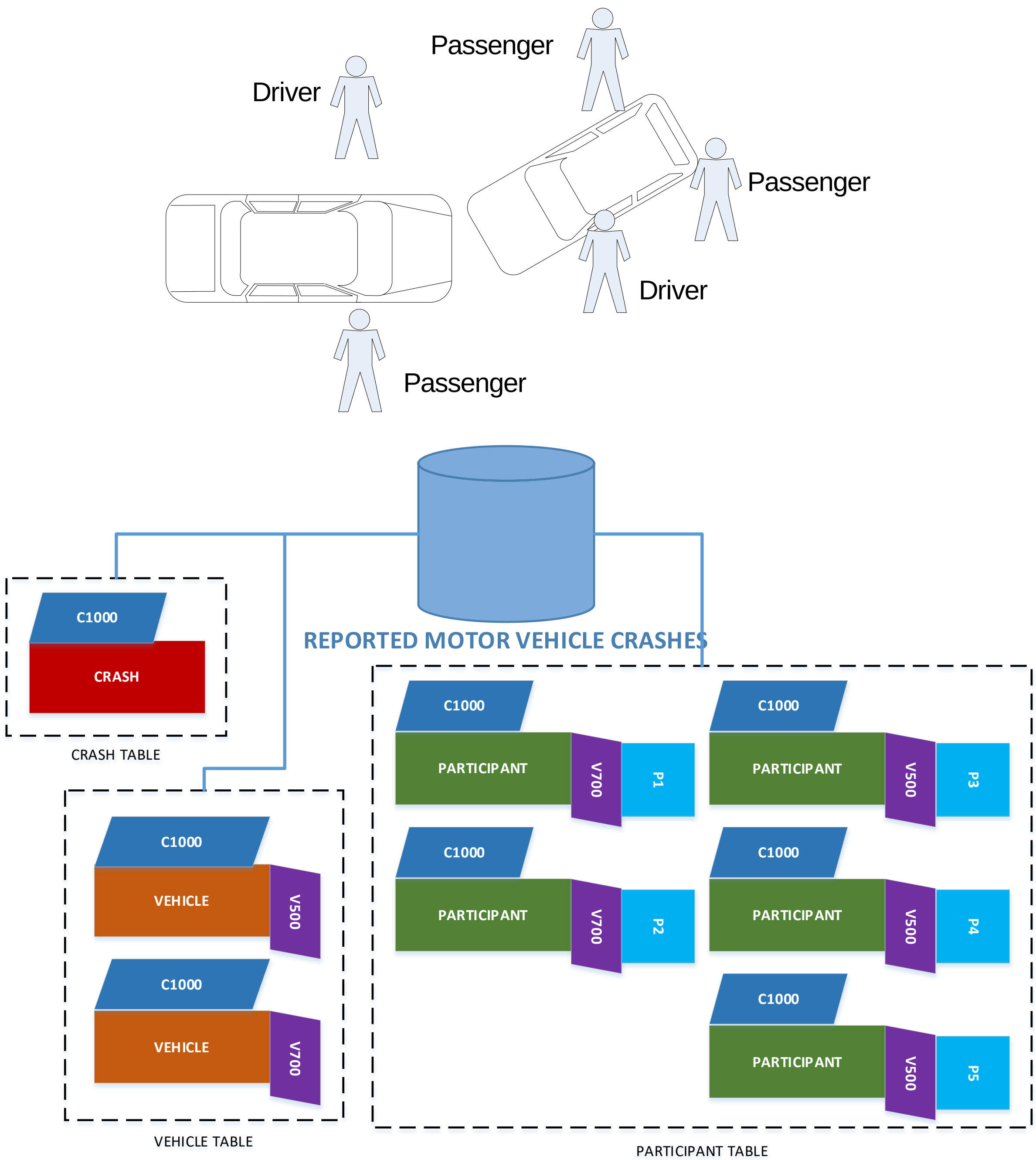
- Crash Severity

Injury severity is first coded to each person involved in the crash. All injuries are scored on a five-point scale often referred to as KABCO which is defined as:

- K, fatal injury;
- A, suspected serious injury – Prevents person from walking includes severe lacerations, broken limbs, abdominal injuries;
- B, suspected minor injury - Evident to observers, lump on head, bruises, cuts;
- C, possible injury - Limping, momentary unconsciousness; and
- O, no injury (property damage only).

Injuries are defined as suspected because research has shown that injury severities in reported crash data do not always align with actual medical outcomes or injury severity scores. For example, if 2 persons are involved in a crash, they will each be coded with an injury severity. The most severe of these injuries is used to determine the overall severity of the crash. When presenting severities, it is important to keep the distinction between persons injured and the count of crash-level severity.

Figure 3-2: Crash Database Schematic



To demonstrate the data structure using **Figure 3-2** schematic with the following additional information:

- Vehicle 1: Driver with A-injury; Passenger with A-injury, Passenger with B-injury;
- Vehicle 2: Driver with fatal injury; passenger with C-injury;

This crash would be coded as a fatal crash (the highest severity) but five people were injured (2 A-injury, 1 B-injury, 1 C-injury, and 1 fatal injury).

It is important to be consistent in descriptions to limit confusion. Normally, the following syntax should be used in text descriptions:

- Fatal crashes (counting crashes);
- Fatalities (counting persons fatally injured);
- Severe injury crash (counting crashes);
- Severe injuries (counting persons injured).

Most often, the investigator will be dealing with information at the crash-level, not at the person- level. The primary justification for the crash-level approach in highway safety investigations is to not bias investigations of a location because of the number of vehicle occupants in particular crash (which can be random). It is appropriate, though, to report the number of injuries.

- Accessing the Crash Data

The ODOT *Transportation Data Section (TDS) Crash Reports* can be accessed through the following web site:

https://tvc.odot.state.or.us/tvc/

The data are available in a number of different formats that are helpful to the investigator. Reports are available by year, location, and direction.

- 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 Product Representation Compact (PRC)-11x17 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.
- Vehicle Direction: A report that includes a single line per crash with the direction of each vehicle involved (from : to) and other information

- Characteristics RRR: A report that includes a single line per crash with counts of vehicles, pedestrians, and bicycles involved and select summary crash information.

These are available in print out text form or downloaded in Excel format for further analysis. A helpful Excel macro – the "Crash Graphing Tool" - has been written that creates summaries of the crash data for state highways from the "Direction (Vehicle) Report." The use of this tool can supplement the worksheets described in more detail in **Chapter 4**.

https://www.oregon.gov/odot/Engineering/Docs_TrafficEng/Crash_De-Coder.zip

If the investigator has questions about the meaning of a particular code or short abbreviation, the ODOT *Motor Vehicle Traffic Crash Analysis and Code Manual* is a helpful reference.

- Locating Crashes

ODOT crash data is located on the roadway network with the linear referencing systems as well as the latitude and longitude position. Online geographic information system (GIS) maps and tools are available to visualize these locations (see **Section 3.18**). However, filtering or using the crash data often requires an understanding of the ODOT's highway inventory system and nomenclature. State highway crashes are located using this nomenclature. To identify a unique location, a combination of six elements is needed. These are:

- HWY_NO: Three digit code representing state highway index number;
- RDWY_NO: One digit code to identify roadway direction (add, non-add);
- HWY_COMPNT_CD: One digit code characterizing the highway structure where crash occurred (State Highway, Frontage Road, Couplet, Connection);
- RD_CON_NO: Connection number (if crash occurred on connection); The connection number will need to be determined from the interchange diagrams (see **Section 3.1.4**);
- MLGE_TYP_CD: Code for mileage portion of highway where crash occurred (Regular, Temp., Spur, Overlapping); and
- MP_NO: Milepost of crash.

- Filed Police and Citizen Reports

In some cases, it may be helpful to obtain a copy of a police report which could include a narrative and sketch. Unfortunately, there is no automated manner in which this can be done at this time, this requires a special request to CAR who must then request and obtain the report from the DMV. If the crash is a fatal, an

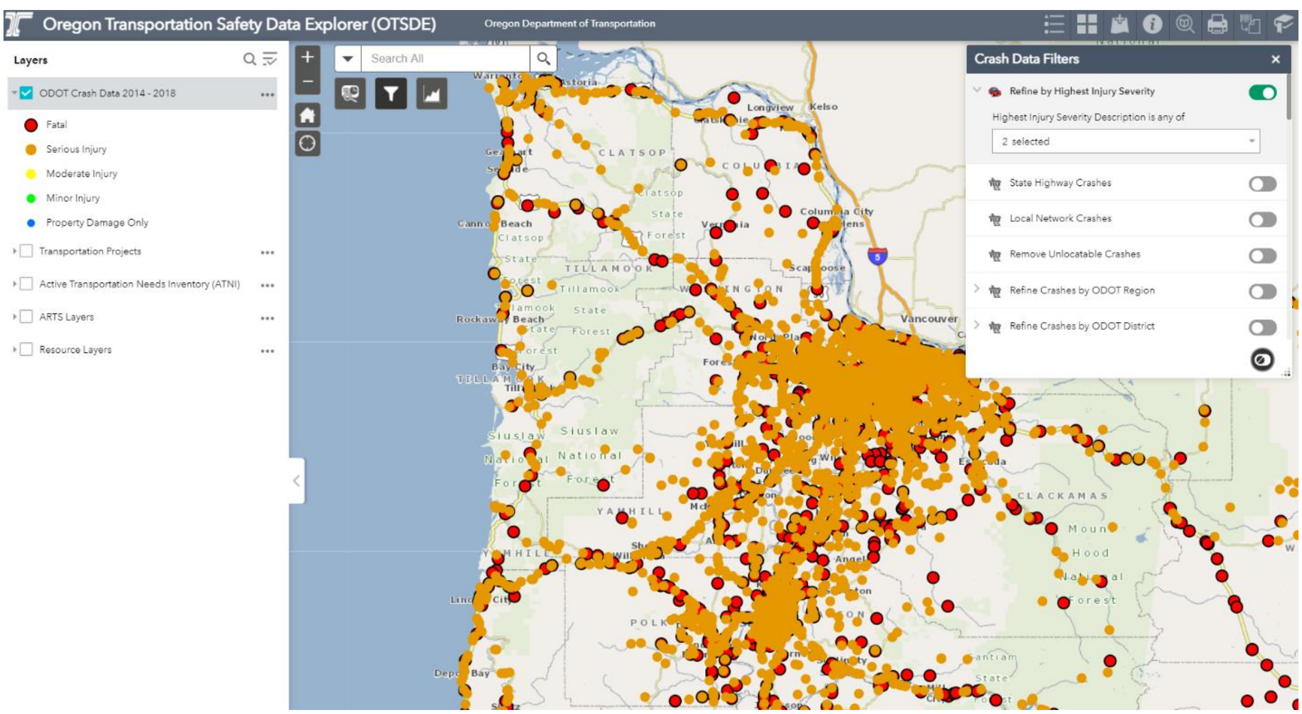
ODOT maintenance/ risk management report may be available. These reports may trigger the need for an investigation. Citizen reports, due to confidentiality rules in *Oregon Revised Statues 802.220(5)*, are not generally available as part of any request.

3.1.2 *Oregon Traffic Safety Data Explorer*

The Oregon Transportation Safety Data Explorer (OTSDE) is a publicly accessible, web-based GIS tool that supports ODOT work in safety and multi modal work, helping users see connections to leverage efforts across programs. The tool is designed for all skill levels and has an easy to learn interface. Tutorials are also available. **Figure 3-3** shows a screenshot of the OTSDE interface. The tool has the ability to display and interact with data and to see its spatial relationship to other features and to apply easy filters to the crash data. In addition, local city street networks, aerial photography, digital relief backgrounds and other useful layers are available. The TransGIS has additional GIS layers and has a portal that can be accessed at (see also **Section 3.1.8**):

- https://www.oregon.gov/odot/Data/Pages/TransData-Portal.aspx

Figure 3-3: Oregon Traffic Safety Data Explorer



3.1.3 *Safety Priority Index System*

The SPIS is a method "to perform network screening on the state highway network and to identify and prioritize those sites that have promise as sites for potential safety improvements and merit further investigation."

The SPIS score is based on three years of crash data and considers crash frequency (25%), crash rate (25%), and crash severity (50%). A roadway segment becomes a SPIS site if a location has three or more injury crashes or one or more fatal or serious injury crashes over the three-year period. PDO crashes are excluded from SPIS calculations. Each location is defined as a 0.10 mile section of state highway. The maximum score is 100.

The SPIS is processed every year after the crash data have been finalized. The reports are named for the year they are produced but will be calculated using the three most currently available years of crash data. For example, the 2018 SPIS Reports use crash data from 2015, 2016 and 2017in their calculation.

For each year beginning in 2018, a "Top 15%" cutoff score is determined. This cutoff score is the score for which 85% of all 0.10-mile sections (with a calculated SPIS score) are below. As an example, if there were 100 SPIS sites and these were sorted from highest to lowest, the "Top 15%" cutoff score would be the score that was the 15 highest (100*0.15 = 15).

In an effort to adequately screen the highway network, the SPIS uses a "sliding window" approach to calculations. This is accomplished by recalculating a SPIS score in 0.01 mile steps. For example, if the first SPIS site is milepost 5.00-5.10 another calculation will be performed for milepost 5.01-5.11. This means that one problem location will have more than one SPIS "site" but the investigator should consider the range of highway identified.

An example of the SPIS report is shown in **Figure 3-4**. More information about current and past years SPIS reports is available on ODOT's SPIS Reports webpage.

- https://www.oregon.gov/ODOT/Engineering/Pages/SPIS-Reports-On-State.aspx

Figure 3-4: Sample SPIS Report

Oregon Department of Transportation

Region 3

2019 - On-State, Top 15% SPIS Sites - By Hwy, MP

Rte	Rdwy	BMP	EMP	ADT	Crash	Fatal	A	B	C	City	County	Connection	Percent	SPIS
001 Pacific														
I-5	1	1.36	1.45	16,500	2	0	2	0	0		Jackson		85	40.07
I-5	1	19.90	20.00	38,900	3	0	2	0	1		Jackson		85	42.72
I-5	1	19.91	20.01	38,900	3	0	2	0	1		Jackson		85	42.72
I-5	1	19.92	20.02	38,900	3	0	2	0	1		Jackson		85	42.72
I-5	1	19.93	20.03	38,900	3	0	2	0	1		Jackson		85	42.72
I-5	1	19.95	20.04	38,900	3	0	2	0	1		Jackson		85	42.72
001YB	1	24.59	24.67	10,600	3	0	2	1	0	Phoenix	Jackson		85	44.67
001YB	1	24.60	24.68	10,600	3	0	2	1	0	Phoenix	Jackson		85	44.67
001YB	1	24.61	24.69	10,600	3	0	2	1	0	Phoenix	Jackson		85	44.67
001YB	1	24.61	24.70	10,600	3	0	2	1	0	Phoenix	Jackson		85	44.67
001YB	1	24.63	24.71	10,600	3	0	2	1	0	Phoenix	Jackson		85	44.67
001YB	1	24.64	24.72	10,600	3	0	2	1	0	Phoenix	Jackson		85	44.67
001YB	1	24.65	24.73	10,600	3	0	2	1	0	Phoenix	Jackson		85	44.67
001YB	1	24.65	24.74	10,600	3	0	2	1	0	Phoenix	Jackson		85	44.67
001YB	1	24.66	24.75	10,600	3	0	2	1	0	Phoenix	Jackson		85	44.67
001YB	1	24.67	24.76	10,600	3	0	2	1	0	Phoenix	Jackson		85	44.67
001WU	1	26.93	27.02	24,200	14	0	0	6	8	Medford	Jackson		85	41.92
001WU	1	26.94	27.03	24,200	14	0	0	6	8	Medford	Jackson		85	41.92
001WU	1	26.95	27.04	24,200	14	0	0	6	8	Medford	Jackson		85	41.92
001WY	1	27.86	27.91	5,200	12	0	1	1	10	Medford	Jackson		95	61.41
I-5	1	44.52	44.61	40,800	4	1	1	1	1		Jackson		90	45.72
I-5	1	44.53	44.62	40,800	4	1	1	1	1		Jackson		90	45.72
I-5	1	44.54	44.63	40,800	4	1	1	1	1		Jackson		90	45.72
I-5	1	44.55	44.64	40,800	4	1	1	1	1		Jackson		90	45.72
I-5	1	44.56	44.65	40,800	4	1	1	1	1		Jackson		90	45.72
I-5	1	44.57	44.66	40,800	4	1	1	1	1		Jackson		90	45.72
I-5	1	44.58	44.67	40,800	4	1	1	1	1		Jackson		90	45.72
I-5	1	44.59	44.68	40,800	4	1	1	1	1		Jackson		90	45.72
I-5	1	44.60	44.69	40,800	5	1	1	2	1		Jackson		90	48.54
I-5	1	47.22	47.31	39,500	3	0	2	0	1		Jackson		85	42.71
I-5	1	47.23	47.32	39,500	3	0	2	0	1		Jackson		85	42.71
I-5	1	47.24	47.33	39,500	3	0	2	0	1		Jackson		85	42.71
I-5	1	47.25	47.34	39,500	3	0	2	0	1		Jackson		85	42.71
I-5	1	51.92	52.01	38,100	5	0	2	1	2		Jackson		90	48.62
I-5	1	51.93	52.02	38,100	4	0	2	0	2		Jackson		90	45.79
I-5	1	51.94	52.03	38,100	4	0	2	0	2		Jackson		90	45.79

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3.1.4 *Highway Inventory Reports*

The Public Road Inventory is a valuable resource for the location of intersections, other features, basic site geometry and other information. Most of these data are routinely accessed by the "State Highway Inventory Reports" interface. These reports are:

- Highway Inventory Summary Report;
- Highway Inventory Detail Report;
- Lane Report;
- Vertical Grade Report;
- Horizontal Curve Report;
- Traffic Volumes and Vehicle Classification Report;
- Equations and Milepost Range Report;
- State Highway Names Reports.

These reports can be accessed in either web-report or Excel versions.

https://www.oregon.gov/odot/data/pages/road-assets-mileage.aspx#reports

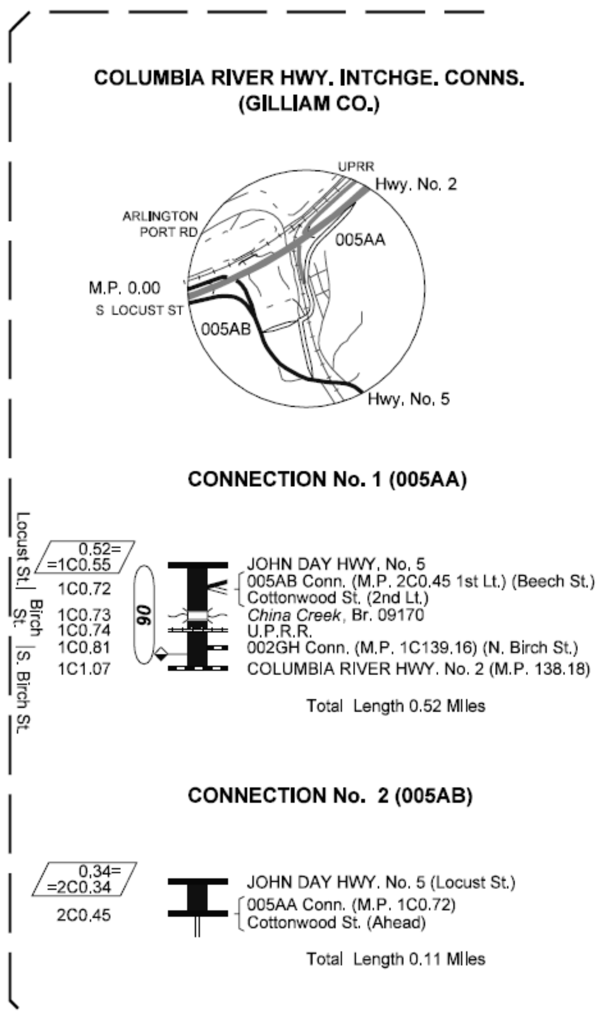
In some cases, the investigator is primarily concerned about the location of intersections, ramps, or other facilities. For complicated connections and interchanges, the investigator will need to obtain an interchange diagram or access TransGIS to obtain detailed information. These diagrams provide an easy way to identify the complicated numbering of connections and ramps that occur at interchanges. These are needed to extract the appropriate crashes.

An example interchange diagram is shown in **Figure 3-5**. To find a crash that happened on connection 1 at the Union Pacific Railroad (UPRR) crossing the following location information in **Table 3-1** would be need:

Table 3-1: Example Location Information for Identifying Crashes

HWY_NO	005
RDWY_NO	1
HWY_COMPNT_CD	6 -- Connection
RD_CON_NO	1
MLGE_TYP_CD	0 -- Regular
MP_NO	0.74

Figure 3-5: Sample Interchange Diagram



3.1.5 *Facility Functional Classification*

The functional classification of a highway segment is defined by the amount of traffic and type of access (or service) that a facility provides. Each functional classification is defined as either rural or urban based on the Federal-Aid Urban Boundary (FAUB). Areas with populations greater than 5,000 are defined as urban (*11*). The highest class of facility is "Interstate" while the lowest class is "Local." These classifications are defined and maintained by the Road Inventory and Classification Services Unit (RICS) of ODOT and are periodically updated. Currently, the state highway system is classified as one the following (with an urban or rural designation):

- Interstate;
- Other Freeway & Expressway;
- Other Principal Arterial;

- Minor Arterial;
- Major Collector;
- Minor Collector;
- Local.

By defining the functional classification of a highway segment, the investigator will be able to draw comparisons between the highway under investigation and all other similar highways. A current list of all highways and their classification can be found at:

- https://www.oregon.gov/odot/Data/Documents/FC_NHS_State_Highway_List.pdf

3.1.6 *Traffic Volumes*

Traffic volumes are a key input in the safety investigations process. The Transportation Systems Monitoring Unit (TSM) collects and reports traffic volumes in an accessible format. Volumes are available by highway and milepost on ODOT's Traffic Counting webpage:

- https://www.oregon.gov/odot/Data/Pages/Traffic-Counting.aspx

In several instances, traffic volumes on the minor approach of an intersection are required but unavailable. It is recommended the investigator consult with ODOT Transportation Planning and Analysis Unit (TPAU) to determine the appropriate methodology for estimating Annual Average Daily Traffics (AADT) before analysis, especially if AADTs are approximated. In some situations, travel demand models or nearby volumes may provide adequate estimates for minor street AADTs. Estimating volumes from the major road AADT to minor road AADT ratio of similar intersections provides another possible starting point. If the minor road is isolated, Institute of Transportation Engineers (ITE) trip generation rates may be appropriate (*8*).

It is also important to consider the potential influence that roadways with low AADT may have on safety investigations. In rural cases particularly, segment length, traffic volumes, and observation periods are critical considerations in identifying safety indicators (*12*). Overrepresentation may occur, in which longer segment lengths may be required.

3.1.7 *Digital Video Log*

The Digital Video Log (DVL) is the online record of digital images from the driver's perspective for every 0.01 of mile. The recent video logs also include images that allow roadside features to be viewed. The highway can be viewed in both increasing and decreasing mileposts. Past year logs are also available. These past year logs can be helpful to review the location for consistency. The DVL can be accessed internally at https://www.oregon.gov/odot/Data/Pages/Road-Assets-Mileage.aspx#DVL

3.1.8 TransGIS

Investigators can also access information and data using TransGIS. This web-based tool contains detailed information including transportation management system's data, asset inventory, Statewide Transportation Improvement Program (STIP) projects and environmental data that are accessible for analysis, planning and research needs. TransGIS also includes a link to the FACS-STIP tool with additional detail on STIP projects. TransGIS can be accessed online at:

https://gis.odot.state.or.us/transgis/

3.1.9 Virtual Highway Corridor Tool

The Virtual Highway Corridor (VHC) is a web-based tool that integrates ODOT's 3D mobile mapping panoramic photos and Light Detection and Ranging (LIDAR) data with ODOT's GIS data. Accurate measurements on the highway network for any attribute can be made from the office. The VHC pulls from multiple data sources including the DVL, speed limits, functional classifications, traffic counts, the Bridge Log, culvert inventory, pavement condition and material, Americans with Disabilities Act (ADA) and bike facilities inventory, and many other data layers. The VHC application is located online at:

https://vhc.odot.state.or.us/tds.

3.1.10 Aerial Maps

High-quality aerial photography is available from many commercial websites such as Google Map's interface. The Google Map also includes a useful measuring tool. Currently, you can access the distance measurement tool in Google Maps by right-clicking on a point to bring up the menu and select "measure distance." Additional help can be found by searching "google maps measure distance".

3.1.11 Traffic Signal Timing Information

There is no central resource for this information. In order to obtain current timing information, the investigator will need to contact the Region signal operations engineer.

3.1.12 As Built Plans

If plan-level detail is needed, it may be possible to obtain a set of as-built roadway plans. This is especially true if there has been a recent project that has been constructed. Plan sheets and as-built can be found at the following links:

https://ecmnet.odot.state.or.us/mapcenter

- https://ecmnet.odot.state.or.us/TrafficPlans/TrafficPlanSearch

3.1.13 AskODOT and Maintenance Dispatch Records

AskODOT is a potential source for citizen input and inquiries related to traffic safety. Reports are sent to Ask.ODOT@odot.oregon.gov. Some AskODOT reports require a response from the Region Traffic office and are stored and processed differently in each of the ODOT Regions. Ask the regional traffic manager for information regarding the storage and use of AskODOT reports and how to access this information. Dispatch records serve as another source for crash reports.

3.1.14 Other Sources

There are a variety of "other" data and information sources that may be useful for the investigator to obtain:

- Recent and past newspaper or other media related to the location;
- Mobile LIDAR Point Cloud Data;
  - Geometronics Unit collects 3D point-cloud data that may be useful for many site investigation tasks. This can be accessed using the Virtual Highway Corridor Tool (**Section 3.1.9**).
- Local police agency input and or reports;
  - Local or State police officers report directly to crashes and may offer insight on driver trends or problem areas. Their input may be helpful in identifying potential countermeasures for safety concerns. Reports give detailed information about specific crashes.
- Maintenance records or input;
  - Maintenance personnel may see remnants of unreported crashes or have field knowledge of common driver behavior at specific locations. They may identify potential problem areas within the transportation system that engineers, or other safety employees may be unaware of.
- Anecdotal information from nearby residents and businesses;
- Blueprint for Urban Design;
  - The Blueprint for Urban Design (BUD) serves as a 'bridging document' between the ODOT *Highway Design Manual* (HDM) and current urban design practices. This document provides urban design guidelines for Oregon highways until other design manuals are updated.

- Transportation Safety Action Plan;
  - The TSAP outlines Oregon's goals, policies, and strategies that aim to eliminate fatal and serious-injury crashes by 2035. The document identifies four emphasis areas: risky behaviors, infrastructure, vulnerable users, and improved systems.
- All Roads Transportation Safety;
  - The ARTS program provides extensive information regarding the safety needs of Oregon roadways. This includes crash reduction factors (CRF), analysis tools, and additional resources. ARTS also defines and provides additional resources for Hotspot and Systemic approaches for identifying countermeasures for increased safety.
- ODOT Safety Implementation Plans;
  - There are three ODOT implementation plans: the *Pedestrian and Bicycle Safety Implementation Plan*, the *Oregon Intersection Safety Implementation Plan*, and the *Oregon Roadway Departure Implementation Plan*.
- Regional Integrated Transportation Information System.
  - Regional Integrated Transportation Information System (RITIS) provides performance measures, incident data, and analytical tools to gain situational awareness and understand system operations. More information can be found at the following link:

https://www.oregon.gov/odot/Data/Pages/RITIS.aspx

3.2 FIELD DATA

Though in-office data is invaluable for determining historic trends and conditions at a site, a safety assessment may also include a site investigation (see **Chapter 5** for more detail about site investigations and companion data to collect). There is a wide variety of field data that may be acquired during a site visit, but consistent documentation of site characteristics is critical. **Chapter 5** addresses the various data elements that can and should be collected in the field; however, a standard source for documenting the location, orientation, and placement of field data is through the creation of a condition diagram (see **Figure 3-6** for one example) (*13*).

The condition diagram does not have to be drawn to scale, but should always include the following basic information:

- North arrow;
- Road name;
- Drawing of location complete with dimensions. This includes road, curb or shoulder, sidewalks, ditches, walls, etc.;

- Traffic control devices (marking, signage, signals) and their relative placement;
- Adjacent land use;
- Type of pavement;
- Date and time of site visit (if conducted); and
- Site investigator name.

Figure 3-6: Example Condition Diagram

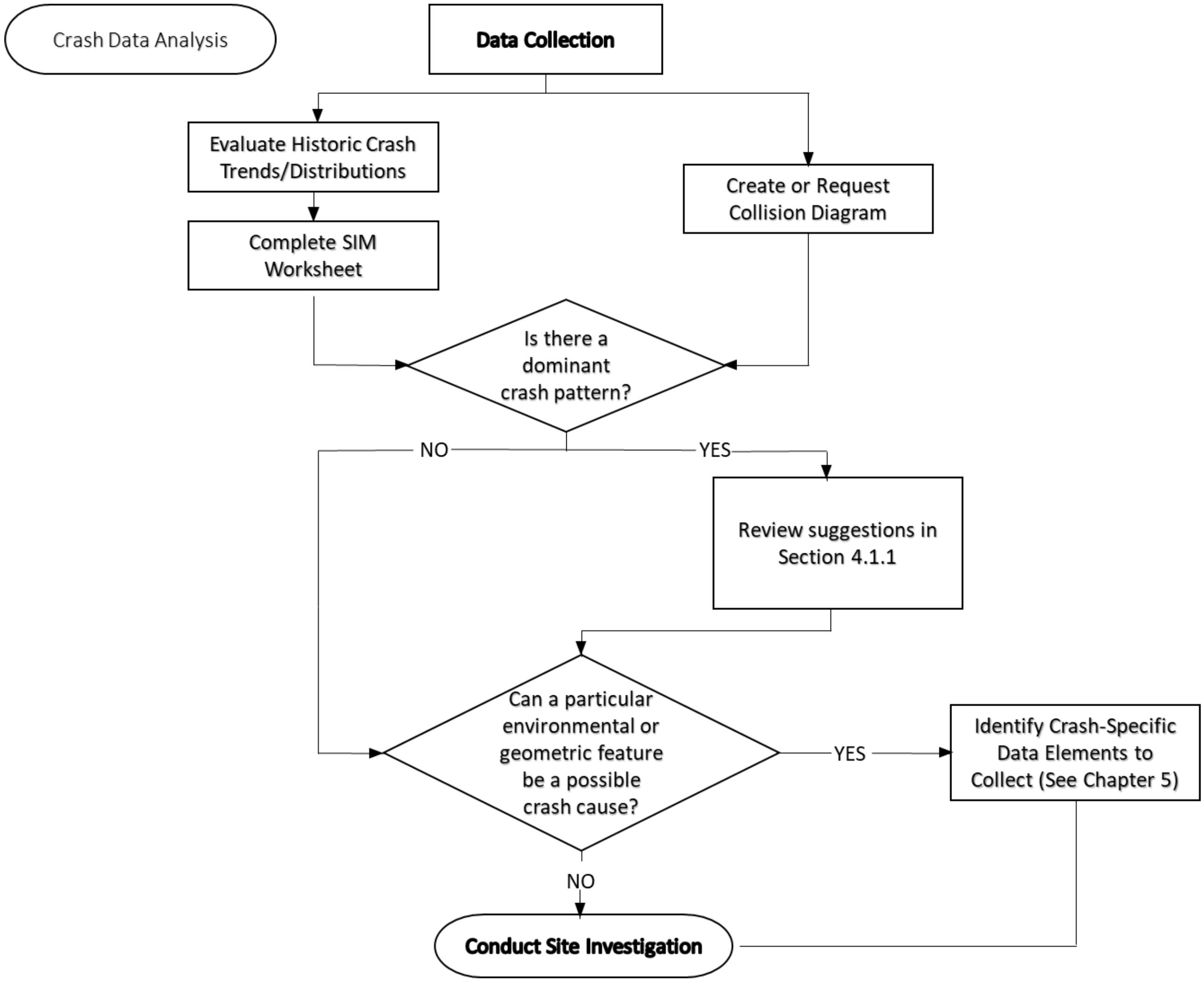
Chapter 4 Diagnosing Crash Patterns

The primary goal of a safety investigation is to diagnose the safety issues at the location and recommend improvements. These recommendations are based on a detailed review of in-office data, field reviews, and other input. This investigation process has an element of detective work and requires putting together information that is, at times, incomplete. While crash data is not the only input to this process, it is generally the starting point for investigations. As stated in the safety investigations basics, our investigative efforts are searching for a pattern of crashes that is "out of the ordinary." The purpose of this chapter is to document a methodology that can be used to help uncover unusual crash patterns.

In addition to the "Patterns" tabs created as part of the SIM Worksheets presented in the following section, there are several software packages that provide data analysis and visualization tools for safety investigators. These include Crash Magic and ODOT's VHC. Crash Magic provides the ability to create crash diagrams, hot spot locations, and pin and heat maps while generating charts and reports (*14*). The VHC is ODOT's web-based application that implements Lidar mapping to provide geometric data.

The general process for this crash data analysis is demonstrated in the flowchart shown in **Figure 4-1**. Crash patterns refer to the percentage of each crash characteristic present in the data or spatial patterns. Data patterns can be diagnosed using the crash pattern worksheet, described in **Section 4.1**. Spatial patterns are detected from collision diagrams (**Section 4.2**). Crash data is the primary input. After collecting the data and exploring basic trends and summaries, the safety investigator should complete the SIM Worksheet and prepare a collision diagram. Patterns can be evaluated and guide both the site investigation efforts (**Chapter 5**) and countermeasure selection and recommendations (**Chapter 6**).

Figure 4-1: Flowchart of Procedure to Analyze Crash Data



4.1 CRASH PATTERN WORKSHEET

To assist the investigator in diagnostic efforts, a pattern diagnostic worksheet has been created. The "Patterns" tabs on the SIM Worksheet is based on the direct diagnostics work by Kononov and Janson (*15*). There are patterns for segments and intersections. They suggest that an overrepresentation of one type of crash relative to other crash types is a better indicator of possible improvements than a high frequency relative to other locations. For example, a high proportion of fixed-object crashes relative to all crashes on a highway segment might mean the location is a good candidate for shoulder rumble strips or enhanced delineation.

The strength of this approach is that the investigator compares the location under investigation to an average of similar locations. In doing this, the investigator can contrast the observed crash patterns at the location to what is "typical" at similar intersections or segments (by functional classification and land use). Any unusual patterns are easily highlighted and can be the basis for more investigation. Each crash data element is tested separately. These unusual crash types can also be explored in the field visits. The ability to contrast crash frequency, crash severity, crash rates, and similar metrics creates a basis for justification resulting from engineering judgment when a conventional crash rate analysis does not provide the same focus as these alternative crash statistics.

To do this, a tabulation of typical distributions for various crash classifications has been developed. These tabulations are developed separately for segments (by functional classification) and intersections (by urban/rural, configuration, and traffic control) for state highway crashes. The worksheet already contains these distributions. These expected proportions were generated for segments by considering all state highway crashes for a five-year period. The distributions in the worksheet as of publication are for 2015-2019 data.

The method calculates the probability that an observed percentage of a crash classification will exceed the average percentage distribution for a similar facility. For example, say there have been 20 rear-end crashes out of 61 total crashes observed at a location that is a rural 4-leg signalized intersection. The question for the investigator should be is it "normal" to have 32.8% (20/61) of the total crashes be rear-end?

The probability that this proportion is "typical" can be calculated assuming crashes are Bernoulli trials with the following formula (for use in spreadsheet calculations presented later):

$$P(X \geq x) = 1 - \sum_{i=0}^{x-1} \frac{n!}{(n-i)!\,i!} p^i (1-p_i)^{n-i}$$

Where,

x = the observed count of the crash type to test
n= total number of crash types at the location
p = the expected proportion of the crash types

In the above example, the observed percentage is 32.8% (20/61). All rural principal arterials had 18.9% rear-end crashes. Thus, the calculation determines how likely is 32.8% rear-end crashes if the average of all rural principal arterials is 18.9%. Using the formula, the probability of observing these 20/61 rear-ends crashes at a "normal" rural principal arterial section is:

$$P(X \geq x) = 1 - \sum_{i=0}^{20-1} \frac{61!}{(61-i)!\,i!} 0.189^i (1-0.189)^{61-i} = 0.007\text{, or } 0.7\%$$

In other words, there is a very small chance that this proportion, 20/61, would be observed at a "typical" location and so 32.8% can be considered unusual.

To illustrate, a sample of the SIM Worksheet from Appendix C.1 is shown in **Figure 4-2**. The worksheets calculate the probability that the observed proportion is "normal" in the P(Norm) column. Probabilities less than 5% (chosen as the threshold) are conditionally formatted bold and highlighted in orange. This threshold has been set based on experience but should not be considered an absolute value. These crash parameters should be considered for further investigation.

In **Figure 4-2**, a number of different crash trends are highlighted in grey (PNorm is less than 5%) as being potentially unusual:

- Turn collision type
- Frequency of crashes in January
- Crashes with older drivers involved
- Crashes with the cause code of "Not Yielding"

These patterns could also be potentially useful to an investigator to explore potential solutions. They are explored in full detail in the case study in **Appendix C** and the online training modules.

Figure 4-2: Crash Pattern Worksheet

OREGON DEPARTMENT OF TRANSPORTATION
SAFETY INVESTIGATIONS MANUAL
CRASH PATTERN WORKSHEET - INTERSECTION

Prepared By:	NAME	Title:	TITLE	Date Compiled:	10/1/2021
City:	Portland	County:	Multnomah	District:	0
Crash Date From:	1/1/2011	to	12/31/2016		
Highway Number:	003	Route Number:	OR43	Hwy Name:	OR-43 (Oswego Highway)
MP At:	0.00				
Road Character:	URBAN	Intersection Type:	0	Intersection Name:	OR-43 and Richardson

CRASH TOTALS

Severity	Crash	Obs %	Ex %	P(Norm)
Fatal+ Inj A	1	4.8%	2.9%	46.4%
Injury B+C	12	57.1%	50.7%	35.5%
PDO	8	38.1%	46.4%	83.7%
	21	100.0%	100.0%	

Light Condition	Crash	Obs %	Ex %	P(Norm)
Dawn	1	4.8%	2.1%	36.1%
Daylight	18	85.7%	74.6%	18.1%
Dark-Lighted	0	0.0%	13.0%	
Dark-Lighted	1	4.8%	5.4%	69.1%
Dusk	1	4.8%	4.6%	62.5%
UNK	0	0.0%	0.2%	
	21	100%	100%	

TRAFFIC VOLUME	MAJ	24,583	MNR	-

RATES	Invs. Rate	Peer Rate	Critical Rate	Flag?
All Crashes	#######	0.14	#######	#VALUE!

Cause Codes	Proj	Obs %	Ex %	P(Norm)
CARELESS	0	0.0%	3.0%	
DEF BRKE	0	0.0%	0.3%	
DEF STER	0	0.0%	0.1%	
DIS TCD	0	0.0%	0.1%	
DIS--RAG	0	0.0%	0.3%	
FATIGUE	0	0.0%	0.6%	
IMP LN C	0	0.0%	1.8%	
IMP-OVER	0	0.0%	1.6%	
IMP-TURN	0	0.0%	8.1%	
IN RDWY	0	0.0%	0.5%	
INATTENT	0	0.0%	5.3%	
LEFT-CTR	0	0.0%	0.7%	
LOADSHFT	0	0.0%	0.0%	
MECH-DEF	0	0.0%	0.1%	
NO-YIELD	18	85.7%	53.3%	0.2%
NT VISBL	0	0.0%	0.3%	
OTHER	0	0.0%	0.4%	
OTHR-IMP	1	4.8%	3.5%	52.2%
PAS-STOP	1	4.8%	4.8%	64.7%
PHANTOM	0	0.0%	0.7%	
RECKLESS	0	0.0%	2.3%	
SPEED	0	0.0%	0.8%	
TOO-CLOS	0	0.0%	6.7%	
TOO-FAST	1	4.8%	4.6%	62.8%
WRNG WAY	0	0.0%	0.2%	
	21	100%	100%	

CRASH PATTERNS

Collision Type (All)	Crash	Obs %	Ex %	P(Norm)
Angle	1	4.8%	5.3%	68.4%
Head-on	0	0.0%	0.5%	
Rear	1	4.8%	27.0%	99.9%
Sideswipe-Meet	0	0.0%	0.4%	
Sideswipe-Over	0	0.0%	2.0%	
Turn	18	85.7%	52.2%	0.1%
Parked	0	0.0%	0.3%	
NonCollision	0	0.0%	0.4%	
Backing	0	0.0%	1.3%	
Pedestrian	0	0.0%	2.2%	
Fixed Object	1	4.8%	8.0%	82.7%
Other	0	0.0%	0.3%	
	21	100%	100%	

Surface Condition	Crash	Obs %	Ex %	P(Norm)
Dry	12	57.1%	71.9%	95.5%
Ice	1	4.8%	2.4%	40.2%
Wet	8	38.1%	22.0%	7.1%
Snow	0	0.0%	0.8%	
UNK	0	0.0%	2.8%	
Total	21	100%	100%	

Weather Condition	Crash	Other	Crash
Clear	14	SPEEDING	1
Cloudy	1	ALCOHOL	0
Rain	5	DRUGS	0
Sleet/Freezing Rain/Hail	0	MARIJUANA	0
Fog	1	SCHOOL ZONE	0
Snow	0	WORK ZONE	0
Dust	0		1
Smoke	0		
Ash	0		
Unknown	0		
	21		

Collision Type (F+A)	Crash	Obs %	Ex %	P(Norm)
Angle	0	0.0%	7.3%	
Head-on	0	0.0%	2.0%	
Rear	0	0.0%	10.2%	
Sideswipe-Meet	0	0.0%	0.8%	
Sideswipe-Over	0	0.0%	1.6%	
Turn	1	100.0%	57.8%	57.8%
Parked	0	0.0%	0.0%	
NonCollision	0	0.0%	2.2%	
Backing	0	0.0%	0.2%	
Pedestrian	0	0.0%	8.6%	
Fixed Object	0	0.0%	9.2%	
Other	0	0.0%	0.2%	
	1	100%	100%	

Driver Age	Drivers	Obs %	Ex %	P(Norm)
<15	0	0.0%	0.0%	
15-18	0	0.0%	4.2%	
19-21	1	2.4%	4.7%	85.9%
22-24	4	9.8%	4.5%	11.0%
25-34	8	19.5%	12.9%	15.0%
35-44	6	14.6%	10.3%	24.7%
45-54	7	17.1%	8.7%	6.3%
55-64	2	4.9%	7.9%	84.4%
65-74	4	9.8%	4.8%	13.6%
>74	3	7.3%	2.7%	10.0%
Not Stated	6	14.6%	39.2%	100.0%
	41	100%	100%	

Time	Crash	Obs %	Ex %	P(Norm)
12 -3 AM	0	0.0%	2.3%	
3 -6 AM	1	4.8%	1.6%	28.5%
6 -9 AM	5	23.8%	11.7%	9.0%
9-Noon	3	14.3%	13.5%	55.6%
12-3 PM	5	23.8%	20.9%	45.4%
3 -6 PM	3	14.3%	30.2%	97.4%
6-9 PM	3	14.3%	14.0%	58.1%
9-Mid	1	4.8%	5.2%	67.8%
UNK	0	0.0%	0.6%	
	21	100%	100%	

Bike & Ped	Crash	Obs %	Ex %	P(Norm)
Bike	0	0.0%	2.8%	
Pedestrian	0	0.0%	2.1%	
Other	21	100.0%	0.3%	0.0%
	21	100.0%	2.3%	

Weekday	Crash	Obs %	Ex %	P(Norm)
Sunday	0	0.0%	9.1%	
Monday	3	14.3%	14.2%	59.0%
Tuesday	6	28.6%	15.8%	10.0%
Wednesday	4	19.0%	16.7%	47.5%
Thursday	4	19.0%	15.6%	41.9%
Friday	2	9.5%	17.2%	89.8%
Saturday	2	9.5%	11.5%	71.2%
	21	100%	100%	

Ped-Involved	Crash	Obs %	Ex %	P(Norm)
Ped-Involved	0	0	2.2%	
NA	21	1		
	21	100.0%	2.2%	

Wildlife-Involved	Crash	Obs %	Ex %	P(Norm)
Crash Event	0	0.0%	0.2%	
NA	21	100.0%		
	21	100.0%	0.2%	

Bike/Ped Struck	Crash	Obs %	Ex %	P(Norm)
Bike/Ped Struck	0	0.0%	4.9%	
NA	21	100.0%		
	21	100.0%	4.9%	

Wildlife-Involved	Crash	Obs %	Ex %	P(Norm)
Vehicle Event	0	0.0%	0.1%	
NA	21	100.0%		
	21	100.0%	0.1%	

Month	Crash	Obs %	Ex %	P(Norm)
January	9	42.9%	8.0%	0.0%
February	1	4.8%	7.0%	78.3%
March	2	9.5%	7.3%	45.7%
April	1	4.8%	8.2%	83.6%
May	0	0.0%	8.2%	
June	3	14.3%	8.4%	25.4%
July	0	0.0%	8.3%	
August	1	4.8%	8.4%	84.0%
September	4	19.0%	8.3%	9.1%
October	0	0.0%	10.0%	
November	0	0.0%	8.9%	
December	0	0.0%	9.1%	
UNK	0	0.0%		
	21	100%	100%	

Older Drivers Involved	Crash	Obs %	Ex %	P(Norm)
Older Drivers Involved	7	17.1%	7.6%	3.3%
NA	34	82.9%		
	41	100.0%	7.6%	

Truck-Involved	Crash	Obs %	Ex %	P(Norm)
Truck-Involved	1	4.8%	2.8%	44.6%
NA	20	95.2%		
	21	100.0%	2.8%	

Older Peds Involved	Crash	Obs %	Ex %	P(Norm)
Older Peds Involved	0	#DIV/0!	11.3%	
NA	0	#DIV/0!		
	0	#DIV/0!	11.3%	

Motorcycle-Involved	Crash	Obs %	Ex %	P(Norm)
Motorcycle-Involved	0	0.0%	2.1%	
NA	21	100.0%		
	21	100.0%	2.1%	

4.1.1 *Using the Crash Pattern Worksheet*

A three-part online training module "SIM Worksheet Overview" provides a narrated, detailed, step-by-step guide for using the worksheets including downloading the crash data and entering it in the worksheet. In addition, there are notes in the SIM Worksheet, and additional instructions and field definitions is included in **Appendix B**.

The crash pattern worksheet compares the proportions of various crash variables for the study location versus long-run averages for similar roadway segments or intersections. For example, if the study segment (a rural principal arterial) has 10% head-on crashes, it would be compared to all other rural principal arterials that have an average of 3.6% head-on crashes and will most likely be flagged as "unusual." The primary advantage of the worksheet is the tabulation of these averages which has been done for all functional classifications and intersection types for the investigator. The primary advantage of the worksheet is its ability to tabulate the averages for all functional classifications and intersection types.

There are two critical elements to using the crash pattern worksheets:

- The crash patterns have been calculated for segments (excluding intersection crashes) and intersection crashes. It is very important to prepare the PRC data such that segment crashes and each associated intersection to be investigated are separated.
- Select the appropriate "Road Character" and "Functional classification" for the segments and the "Intersection Type" on the SIM Worksheet "Cover" tab. This selection is critical because the observed crash frequencies are compared to the proportions of the matching road character, functional classification, and intersection type that is selected.

4.1.2 *Interpreting the Crash Patterns*

A short description of the "clues" offered by overrepresentation of each category or pattern is provided below. These are not meant to be exhaustive but rather illustrative of use of the worksheet to interpret potential causes.

- Crash Totals by Severity

  If one or more severity groupings are overrepresented, the investigator should look in-depth at these crash types.

- Collision Types (All and Fatal And A-injury)

  If one or more severity groupings are overrepresented, the investigator should look in-depth at these crash types. The collision type is often a good indication of crash contributing factors. In many locations, there are not enough fatal and A-injury crashes to test for overrepresentation by type. Note that for rural 3-leg signalized and urban 4-leg unsignalized intersections, there were insufficient fatal and A-injury crashes to develop patterns by collision types.

- Driver Age

  An overrepresented age group is likely related to a nearby traffic generator (e.g., school). The investigator should consider the possible relationship to other causal factors if one age group, such as younger or older drivers, is overrepresented.

  With the older driver population estimated to near 70 million people by 2030, it is important to consider them in the countermeasure selection process (*16*). Various skills necessary for safe driving deteriorate as people age. These include perception reaction times, range of motion, and visual and cognitive functions. Countermeasures proposed in areas with high rates of older-driver crashes must plan for the aging population by reducing their risk of injury and improving competency in driving. This includes implementing engineering solutions that minimize confusion and emphasize clarity for drivers, as described in SPR 828 (*17*).

- Month

  An overrepresented crash count in a month may be associated with weather, recreational travel, or lighting conditions (if winter months with more darkness are overrepresented).

- Time of Day

  These patterns normally follow traffic volumes (with a majority in the afternoon peak period (3-6 p.m.)). If a particular time period is identified, the investigator could consider possible relationships to congestion, significant traffic generators (e.g., a school), or perhaps sun-glare conditions.

- Light Conditions

  Typically, the investigator is interested in determining whether the crashes at the investigation location are overrepresented in dark conditions. This may guide the investigator to conduct further investigations or field studies related to lighting.

- Surface / Weather Conditions

  The investigator may be primarily interested in identifying locations with an unusual amount of wet or snow/ice crashes. An overrepresentation of wet crashes may indicate pavement friction or drainage issues. An overrepresentation of snow/ice crashes may indicate a possible driver awareness issue. The investigator should keep in mind that the proportions are for a statewide average – locations with more winter weather may be different. Further field studies may be needed.

- Day of Week

  Like the time-of-day summary, the investigator should consider possible relationships to key traffic generators (e.g., recreational route, school). Patterns usually follow traffic volumes, so Saturday or Sunday flagged time periods may indicate recreational or shopping generator influences.

- Cause

  For each crash record, several possible crash contributing factors may be listed. A detailed list of these potential causes is provided in the crash coding manual. These cause codes are another indication of potential crash causations. These codes often are correlated with other data already summarized (rear-end crashes often get coded as "Too Closely" or "Too Fast"). The proportions for these cause codes were generated considering all three possible codes for each crash. For that reason, the total cause errors will not match the total crash counts.

- Involved Flags
  - Bicycle/Pedestrian Struck – Any crash in which the participant type in the participant file is denoted as bicycle or pedestrian;
  - Pedestrian-Involved – If collision type is denoted as "PED";
  - Older-Driver-Involved – Total number of older drivers involved;
  - Older-Pedestrian-Involved – Total number of older pedestrians involved;
  - Wildlife-Involved – Counts of crash/vehicle events coded as involving wildlife;
  - Truck-Involved – Number of crashes that involved a truck;
  - Motorcycle-Involved – Number of crashes that involved a motorcycle.
- Off Printed Page Patterns

  Three patterns are calculated but not shown on the page if printed. These are:
  - *Residence of Driver* - The investigator may be primarily looking to determine if non-local drivers were overrepresented, indicating that driver expectancy or other unfamiliar situations might be contributing factors to the crash patterns.
  - *Gender of Driver* - It is not likely that an overrepresentation by gender is useful for crash diagnostic purposes. However, an overrepresentation may be related to a nearby traffic generator and could be useful for non-engineering countermeasures.

- *Number of Vehicles Involved* - Single vehicle crashes will be related to fixed-object or non-collision crash types, while multiple vehicle crashes are head-on or intersection-related.

4.1.3 LIMITATIONS OF THE PATTERNS WORKSHEET

Because this worksheet tests whether a particular distribution of crashes is different, crash locations with a small number of crashes will not be easily tested with this worksheet. It is recommended that a minimum of 10 crashes should be observed before using this worksheet. Caution should also be used for pattern categories that have few crashes (for example if there are fewer than five fatal and A-injury crashes, analysis of the patterns is not that useful).

Another issue is that for long analysis segments, an unusual crash pattern might be disguised in an overrepresented crash type in an isolated area. The investigator should always use the collision diagram to help evaluate these isolated locations.

4.1.4 CRASH RATES

There are two locations in the SIM Worksheet that calculate crash rates. These are described in the following sections.

- Pattern Worksheets

  The pattern worksheet tab calculates the crash rate for total crashes and the critical crash rate using the peer rate for similar facilities. These rates and calculations were described in **Section 2.4**.
  - Investigation (Invs.) Rate - crash rate of the project intersection or segment
  - Peer Rate - expected crash rate for that facility type (from ODOT Crash Rate tables for segments and ODOT SPR 667 for intersections)
  - Critical Rate - cutoff value that determines when the project segment or intersection crash rate is higher than expected.

  The "Flag" cell is highlighted if the Invs Rate exceed the Critical Rate. This is indication that the segment or intersection has a high crash rate.

- Crash Rate Calculator Tabs
  - Intersection Crash Rate Calculator

    The intersection crash rate tab computes two crash rates and an intersection crash density based on the analysis period, number of entering vehicles (minor and major approach), and severity. The first crash rate is the overall intersection crash rate, while the second is a severity-based crash rate in which weights can be given to each severity based on the context of the analysis. The intersection crash density is computed by considering only the total number of crashes at the intersection and the analysis period. These rates are computed for each of the 10 intersection tabs.

- Segment Crash Rate Calculator

  The segment crash rate tab computes two crash rates, a segment crash density, and an estimated crash cost based on the analysis period, average number of daily vehicles, segment length, and severity. The first crash rate is the overall segment crash rate, while the second is a severity-based crash rate in which weights can be given to each severity based on the context of the analysis. These crash rates are based on milepost marker numbers as given in the PRC data, which may need to be checked with the Highway Inventory database to ensure they are correct. The segment crash density is computed by considering only the total number of crashes on the segment and the analysis period. Crash costs are determined based on the ARTS benefit/cost crash costs. These rely on facility type, severities of crashes, and whether the segment being analyzed is in an urban or rural environment

4.2 Collision Diagrams

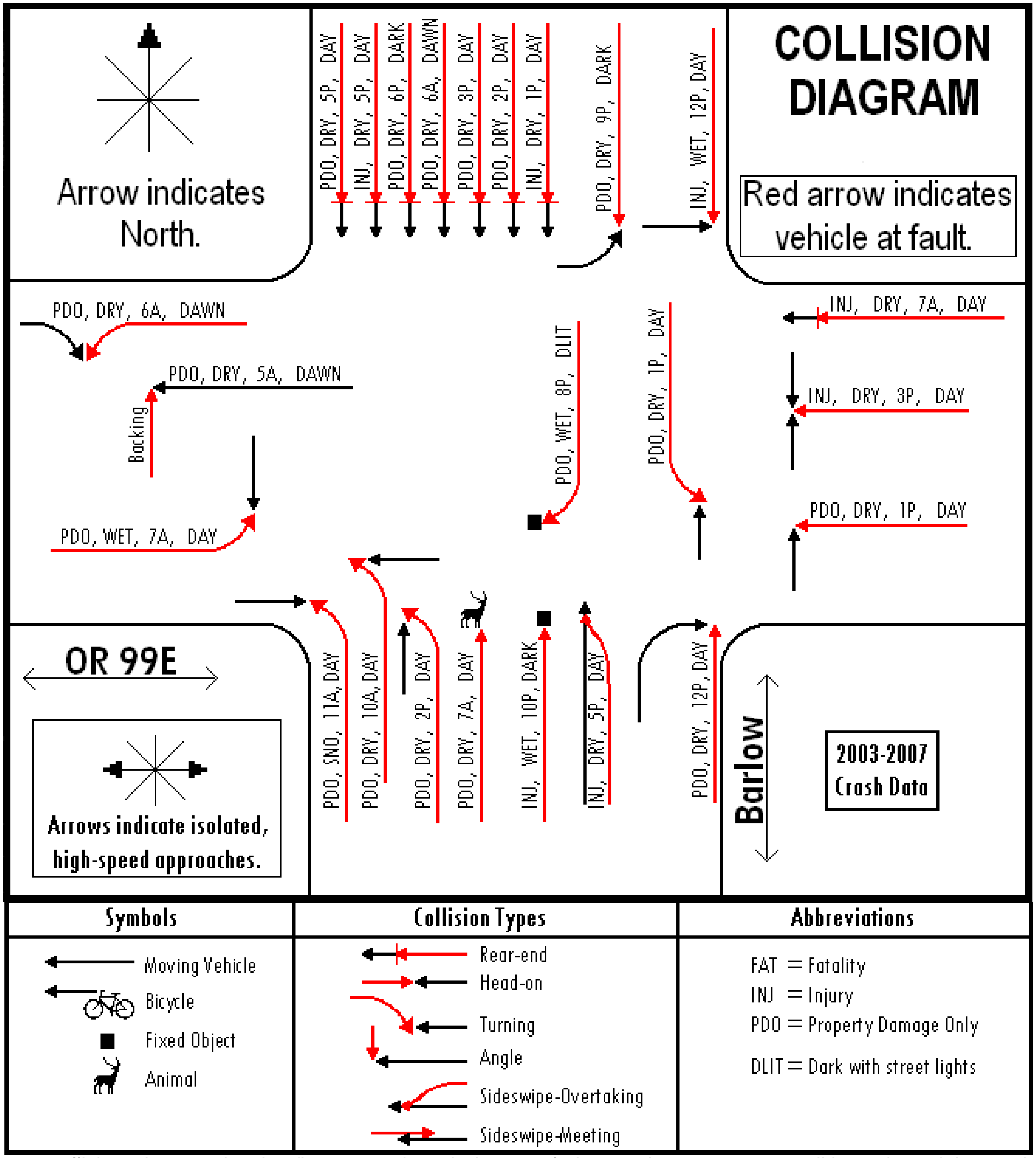
In addition to patterns of crash by type, it is also important to consider the spatial patterns of the crashes. One common and easy way to do this is to construct a collision diagram. A collision diagram is a schematic representation of all crashes occurring on a simple plan view at a given location. A sample collision diagram for an intersection is shown in **Figure 4-3**.

Collision diagrams are generally not drawn to scale. Crashes are placed in the general location of a crash and arranged in groups of various crash types. Arrows are used to show the paths of vehicles and symbols are used to convey other information such as crash type, injury severity, and other parameters. Each collision at the site is represented by a set of arrows -- one for each vehicle or pedestrian involved. Text notations are used to indicate other information such as the date and time, environmental conditions, and other parameters. In general, at least 3 years of crash data should be used. It is also helpful to include a summary table on the diagram.

A collision diagram is useful because it is a graphical representation of crash patterns and this format allows for easy interpretation. In the sample **Figure 4-3**, it is clear that the southbound crashes are primarily rear-end crashes and this trend does not occur on the other intersection approaches.

If there are relatively few crashes, a diagram may be drawn by hand. Some simple templates are provided in **Appendix B**. Otherwise, a collision diagram can be created using the Crash Magic software.

Figure 4-3: Sample Collision Diagram



Collision Diagram showing five years of crash data. Include severity, pavement conditions, time of day, and light conditions. Indicate vehicle at fault with red arrow. Include description of symbols/abbreviations.

Chapter 5 Site Investigations

A site investigation can be an essential component of a safety assessment. Most or all data can be collected remotely via modern data tools. An in-person site visit, however, can reveal issues not uncovered by a desktop review. The site investigation includes an evaluation of physical road and roadside conditions, prevailing traffic conditions, and road user characteristics. Extra data that does not directly address the observed historic crash patterns, however, is not cost effective or necessary. In some cases, the historic crash data may be typical for the site conditions (such as rear-end crashes at signalized intersection locations) and a site investigation would potentially not be required unless crash statistics show an unexpected trend.

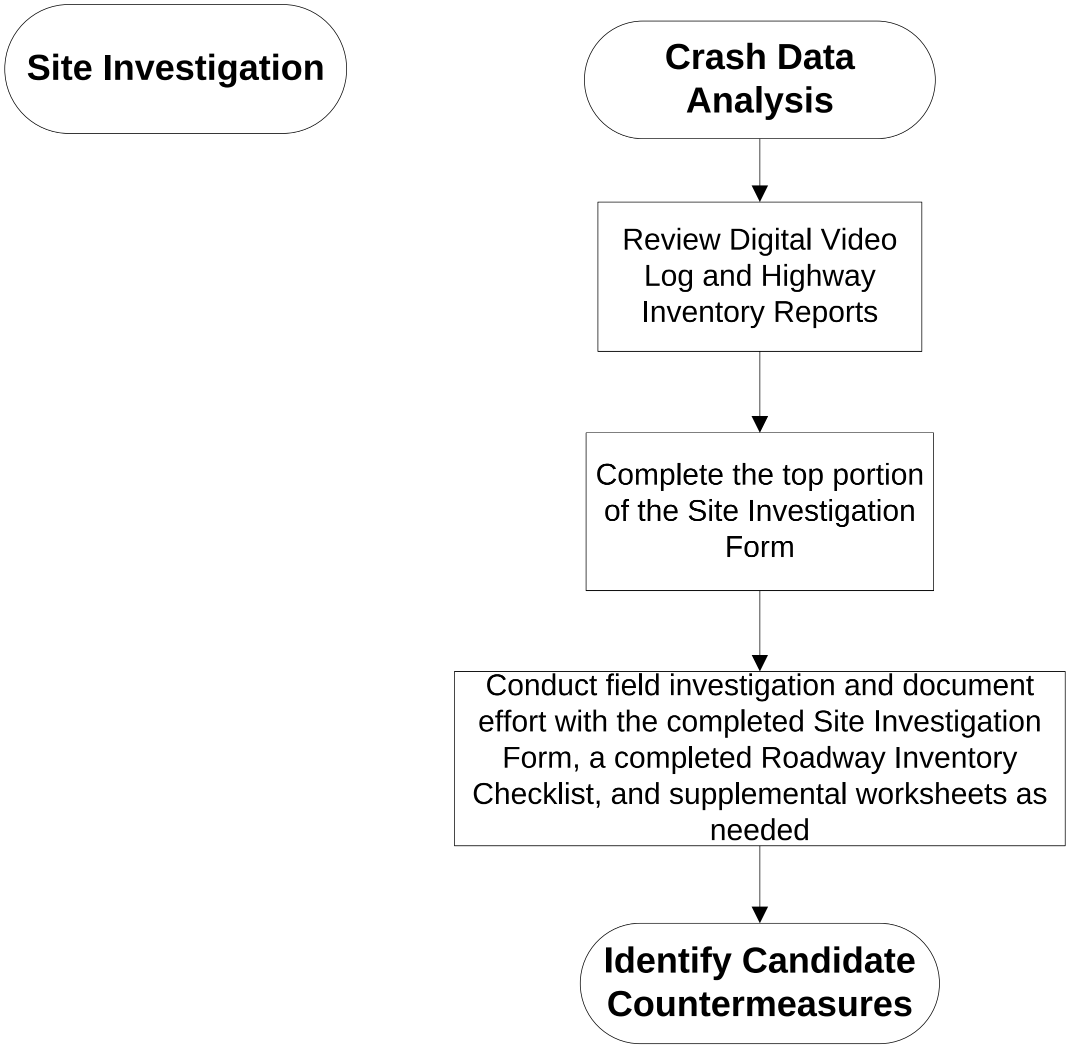
To perform a successful site investigation, it is important that the data collection team members are safe and do not inadvertently alter the normal traffic operations. At some locations, a set of general data elements is required; however, it is also important for the investigator to identify unique site characteristics and acquire sufficient data that will enable the diagnosis of problems at a road segment or intersection.

This chapter provides guidance to the site investigator as to how to perform a site investigation, document the findings, and ultimately use this data for countermeasure evaluation. **Figure 5-1** depicts the basic procedure for performing site investigations.

5.1 Safe Data Collection Procedures

When a site visit (in-person) is conducted, investigators should drive and walk the location from all travel directions to gain perspective of all road users. A high crash location can be a challenging site for field data collection. Investigators should try and collect as much data as possible away from traffic such as corner parking lot or an elevated location overlooking the site. Prior to a site visit, it is important for the investigator to fill out a *Jobsite Hazard Assessment* and understand what to expect and be aware of in the field.

Figure 5-1: Flowchart of Procedure for Site Investigations



This includes understanding roadway conditions and geometry, retrieving information of the surrounding areas, and being prepared for citizen interactions. This will help ensure their personal safety as well as limit any influence their presence may have on active traffic.

For basic data collection, the investigator should ensure personal safety by limiting how often he or she enters the active travel lanes. Investigators should follow the appropriate temporary traffic control procedure when conducting site visits.

Methods to collect data include safely and unobtrusively using video data, floating car analysis methods (this requires a minimum of two investigators – a driver and a data recorder – traveling in a vehicle in the traffic stream and replicating the behavior of other vehicles and logging data such as speed and travel times), and by remote observation. Remote observation could include video images taken unobtrusively and watched later in the office. This allows for a longer observation period and the possibility of re-reviewing the analysis.

For operational studies, the influence of an investigator in close proximity to the road may cause the driver to alter typical driving behavior. This influence could result in incorrect measurement of typical operational characteristics. If data such as speed information is required, the investigator should be as discreet as possible. One method of achieving this (when using a radar or laser gun) is to measure speed as a vehicle departs a location so that the driver is not aware of the speed measurement. If performing speed studies, it may be appropriate to turn off vehicle "rotobeams" to minimize distractions that may cause vehicles to slow down and generate inaccurate speed distributions. Also consider informing local law enforcement of speed checks to ensure they are not actively enforcing. Leaving time gaps between observations might also limit the likelihood that drivers with radar-detection equipment will detect the sampling effort.

Note that the Virtual Highway Corridor tool allows accurate measurements from the computer and is the preferred method for gathering measurement of in-lane data. For some locations, it may be necessary for an investigator to enter the active travel lanes to collect distance measurements. To limit exposure time in traffic, use a wheel measuring device and always use caution when entering the roadway.

5.2 General Data Collection

All site investigations should include collection of a basic set of information about the site. This field data should be documented so that a record of the current conditions is available for subsequent investigations. There are numerous site features that an investigator should evaluate. **Table 5-1** depicts a wide variety of site features and items available for inspection at each site (*18*, *19*, *20*, *21* and *22*). As shown in **Table 5-1,** some site features, such as speed or visibility, may require more extensive data collection. Upon arrival at a site, the investigator should develop a condition diagram as reviewed in **Chapter 3**, **Figure 3-6**. This schematic documents road geometry conditions, lane configurations, traffic control devices, and similar physical site characteristics.

To help investigators collect only essential data for their specific site analysis, this manual includes data collection prompts. The *Equipment Checklist* (see **Figure 5-2**) is included so site investigators can easily verify that they have the required data collection equipment prior to the site visit.

The following sections provide specific information about unique conditions or specific study types appropriate for the site.

Table 5-1: General Site Investigation Items

Site Feature	Item to Inspect	
General Road	• Functional Classification • Road Width • Divided/Undivided • Number & Width of Lanes • Medians & Access Points	• Shoulder Type & Width • Rumble Strips • Curbs • Drainage facility locations & type • Pavement Edge Drop-off
Road Surface	• Type • Presence of Loose Material	• Pavement Quality • Surface Drainage
Road Geometry	• Horizontal Curvature • Superelevation / Cross-slope • Vertical Grade	• Crest vertical curve • Sag vertical curve • Combination of features
Intersection	• Type • Number of Approaches • Channelization & Pedestrian Refuge	• Turn Lanes • Curb Return Radii • Lane Alignment through intersection
Signs and Markings	• Inventory of Signs • Legibility • Conspicuity	• Adequate Signage and placement • Pavement markings • Delineators
Traffic Signals	• Compliance with MUTCD • Timing & Actuation (obtain from Signal Timing plans	• Turn Control • Pedestrian signal
Pedestrians/ Bicycles	• Crosswalk configurations • Presence of Sidewalk & Width • Refuge islands/traffic separators	• Bicycle facility (type & width) • Curb ramps • Proximity to transit
Lighting	• Presence and type	• Location (lateral placement)
Parked Vehicles	• On-street parking • Off-street parking & Access • Delivery vehicle loading zones • Parking distance from intersections	• Visibility • Bus Stops • Time constraints for parking
Speed	• Posted Speed	• Operating Speed*
Sight Distance	• Stopping Sight Distance • Decision Sight Distance	• Passing Sight Distance
Environment	• Adjacent Land Use	
Roadside	• Poles, posts, mailboxes, etc. • Safety barrier, guard rail, etc. • Rocks, trees, other obstacles	• Side slopes • Culverts • Bridge railings
Visibility	• Intersection Sight Distance*	• Traffic control device visibility*
Evidence of Problems	• Broken glass, debris • Skid Marks* • Evidence of cars in ditch	• Damaged road furniture, poles, etc. • Rub marks on barriers • Rub marks/hits on trees
*Data element not required unless associated with specific crash types.		

Figure 5-2: Equipment Checklist

Equipment Checklist

Basic Equipment for All Investigations

- ☐ Clipboard
- ☐ Required Worksheets
- ☐ Pencil with Eraser & Pen
- ☐ Ruler or Straight Edge
- ☐ Calculator
- ☐ Soft cap (required), Safety Vest, Safety Glasses
- ☐ Hard hat (required in areas with risk of falling items)
- ☐ Manual or Smart Level
- ☐ Measuring Tape
- ☐ Measuring Wheel
- ☐ Digital Camera or Recorder
- ☐ Compass or GPS
- ☐ Reflective Tapes

Night Study:

- ☐ White Clothing
- ☐ Night Reflective Vest
- ☐ Flashlight

Speed Studies

- ☐ Radar or Laser Gun
- ☐ Stopwatch

Volume Studies

- ☐ Traffic Counter

Other Special Studies

- ☐ Chalk or String Line
- ☐ Spray Paint
- ☐ Tape Recorder
- ☐ Spare Batteries
- ☐ Height Targets (2 ft, 3.5 ft, and 4.25 ft as needed)

5.3 Identifying Unique Site Features That Influence Appropriate Study Types

The successful execution of a site investigation may require the investigator to identify unique features or specific site influences at or near a high crash location. These features or influences may, in some way, contribute to increased safety concerns. Examples of unique conditions could include schools, high pedestrian volumes, businesses, or railroad crossings. These conditions often come with unique challenges. **Table 5-2** depicts some common site-specific studies that may be appropriate at study locations (*18*, *22*, *23*, *24*, *25* and *26*). Prior to visiting the site, the investigator should attempt to identify any unique site influences. Many of these conditions are apparent based on crash history information and aerial photography (acquired during the office analysis phase of review). Once the investigator has evaluated potential site conditions and identified supplemental field studies that may be needed, he or she will be equipped with the necessary data collection information prior to visiting the site.

Table 5-2: Common Field Studies for Unique Site or Operational Conditions

Study Type	Summary of Study
General Studies	
Roadway Inventory	Survey of the roadway physical features. Recommended for use in all situations.
Bicycle	Investigates bicycle facility sight distances, traffic control devices, physical dimensions, capacity, speeds, and volumes to assess level of safety.
Pedestrian	Uses pedestrian traffic control devices, physical dimensions, pedestrian volumes, crossing delays, traffic control devices, and pedestrian related conflicts to assess level of safety.
Highway Lighting	Identifies inconsistencies between the site and lighting design standards. Use when crash statistics identify darkness or nighttime as a contributor.
Sight Distance	Assesses available sight distance at the location. Includes stopping sight distance, passing sight distance, decision sight distance, and sign legibility/message comprehension distance.
Unique Site-Specific Studies	
School Crossing	Uses pedestrian road crossing widths, traffic control device information, pedestrian volumes and delays to assess the safety of facilities surrounding schools. Accounts for level of understanding experienced by students.
Railroad Crossing	Assesses safety of at-grade crossings.
Operational Studies	
Traffic Control Device	Uses signal warrant studies, stop-yield sign studies, and law observance studies to assess safety of current and potential traffic control devices.
Volume	For intersections, evaluate entering traffic volume, turning movement, pedestrian movement, and lane distribution information during the peak and non-peak periods. For roadway segments, perform directional counts along with an analysis of vehicle classification.

Study Type	Summary of Study
Speed	Analyze available sight distance at intersection approaches to determine the safe entering speed. Comparing these values with the location's speed limits or the 85th percentile speed to determine current speed distributions. Speed studies particularly useful when high speeds or speed differentials may be contributors to crash statistics.
Travel Time and Delay	Estimate required time for traversing roadway segments and any encountered delays such as traffic signals. Use when congestion is a possible contributor to crash statistics.
Roadway and Intersection Capacity	Estimates the location's ability to handle current or future traffic demands. Use when congestion is a possible contributor to crash statistics.
Conflict Studies	Conflict analysis highlights evasive maneuvers taken by drivers at the site to avoid potential collisions. The number and types of evasive actions experienced may help provide insights into crash conditions and expected frequency. One common method for performing conflict studies is to video the road user interactions for later evaluation if needed. Automated methods are now becoming available through 3rd party vendors.
Gap Studies	Measures gaps between successive vehicles. Use to evaluate traffic mergers.
Traffic Lane Occupancy	Uses vehicle lengths, volumes, and speeds to evaluate facility operations. Use when congestion is a possible contributor to crash statistics.
Queue Length	Measure of intersection approach performance. Use when congestion is a possible contributor to crash statistics
Road Surface, Environment, or Weather-Related Studies	
Roadway Serviceability	Evaluates pavement surface at site.
Skid Resistance	Uses ASTM standards to determine whether sufficient traction is provided between road surface and tires. Use when crash statistics identify wet-weather as a contributor.
Weather Related	Checks for increased hazard during specific weather conditions. Examples are fog or ice.

5.4 Mapping Crash Patterns to Data Needs and Potential Countermeasures

As demonstrated in **Table 5-2**, there are a wide variety of potential field studies that an investigator may elect to perform at a given site. Supplemental information is helpful to select appropriate study types. Selection of the applicable field studies can largely be determined prior to the site visit. The investigation and diagnosis of crash patterns can be divided into the four general categories:

- Intersection Crashes (see **Table 5-3**) (*20*, *21*, *26* and *36*),
- Mid-Block Crashes (see **Table 5-4**) (*20*, *21*, *26* and *36*),
- Fixed-Object and Run-off-Road Crashes (see **Table 5-5**) (*20*, *21*, *26* and *36*), and
- Environmental Condition-Related Crashes (see **Table 5-6**) (*20*, *21*, *26* and *36*).

Many of the candidate traffic studies can be performed using practical experience or standard traffic engineering studies from texts such as ITE's *Manual of Transportation Engineering Studies* or the ODOT *Traffic Manual*. To successfully identify the applicable field studies, the investigator should have some ideas about the probable cause of crash patterns. For example, if a site has a disproportionate percent of a crash type at an intersection, the investigator can refer to **Table 5-3** to review the crash pattern, identify a probable cause, determine what to document, and identify some general countermeasures that may help to reduce crashes.

5.4.1 Signalized Intersections

General timing information and guidance aimed to increase safety at signals is available from sources such as the *Signal Timing Manual – Second Edition* (STM). Additionally, the STM includes the following guidance to increase safety at signalized intersections (*27*):

- A flashing yellow arrow (FYA) is effective at reducing the critical false 'go' interpretations by users that result in yellow trap conditions. FYA reduces crashes up to 20% of crashes in comparison to traditional, five-section signals (*28*). When considering traffic volumes, crash history, and user types, FYA can also reduce angle/rear end crashes. FYA can be used during permitted phases for left and right turns.
- Downhill approaches require longer breaking distances due to gravitational forces, whereas uphill approaches require shorter distances (*29*). The yellow change interval should range between 3 and 6 seconds. It may be appropriate to increase yellow change intervals by 0.1 seconds per 1% downgrade and decrease yellow change intervals by 0.1 seconds per 1% upgrade.
- Fluctuate minimum green duration during peak and off-peak hours. However, ITE recommends maintaining progression on coordinated systems to avoid excessive stops or delay (*29*).
- Consider leading pedestrian intervals at intersections with high pedestrian volumes or with pedestrian safety issues (such as high volumes of turning vehicles) to reduce interactions between vehicles and pedestrians. ITE also recommends implementing exclusive pedestrian phasing and adding bicycle and pedestrian detection for intersections prioritizing active transportation (*29*). It is also important to note that right-turn-on-red rules may limit leading pedestrian interval effectiveness (*30*).
- Implementing red clearance intervals may induce significant reduction in right-angle crashes. It may be used to clear permissive left turning vehicles and/or clear other motorists proceeding the intersection at the end of a phase (*29*).
- If there are a number of left turn crashes per year at an intersection operated with protected-permitted phasing or protected-only left turn crashes, more restrictive left turn operations would most likely create safer turning conditions.

Additionally, the following outlines ODOT suggested practices for safety investigations at signalized intersections:

- For rear-end collisions, check the location of the crashes. Are they isolated to just the intersection or is excessive queuing occurring?
  - Isolated: review coordination, maximum green times, and vehicle detection health.
  - Excessive Queuing: review the above items, vehicle volumes, saturation flowrate, and capacity. If the signal is operating over capacity, a larger project may be required.
- For left turn crashes, document the phasing type.
  - Pedestrian Crashes: If permissive only, consider protected-permissive timing with a not-pedestrian feature. Consider a leading pedestrian interval if left turn lanes are not available. If protected-permissive, consider a not-pedestrian mode with FYA.
  - Failure to Yield: If permissive only, consider protected-permissive timing with a not-pedestrian feature. If protected-permissive, determine if left turn phasing fits within parameters from the *Traffic Signal Policy and Guidelines*. Consider a gap-dependent FYA based on time of day.
- For angle crashes, a traffic analysis may be required.
  - Review coordination parameters, maximum green times, and vehicle detection health. Also review vehicle volumes, saturation flowrate, and capacity. If the signal is operating over capacity, a larger project may be required.
- For pedestrian crashes: Consider leading pedestrian intervals based on *Manual on Uniform Traffic Control Devices* (MUTCD) guidance and/or protected or protected-permissive phasing when appropriate.

Several other signal timing resources exist as well. For example, the *Intersection Safety Strategies: Second Edition* pamphlet provides potential solutions to common issues seen at signalized and unsignalized intersections (*31*). Other manuals specific to signal timing include the *Signalized Intersections Informational Guide* (*32*) and the “Signalization Principles” chapter in the *Urban Street Design Guide* (*33*).

5.4.2 Pedestrian and Bicycle Risk Factors

Areas with pedestrian and cyclist concerns often have small data sets compared to vehicular crashes, fewer systemically applied, low-cost countermeasures, and limited exposure data because travel patterns are individual-dependent (*34*). Crash reports involving pedestrians and cyclists also lack information that vehicular crash reports often include, such as locations of involved parties, how the crash occurred, etc. Nonetheless, several known risk factors for pedestrians and bicyclists exist. These include, principal and minor arterials, number of lanes, high-access density, limited sidewalks and bike lanes, high speeds above 30 mph, mixed use zoning, proximity to schools and transit, and high populations of people older than 64 (*35*).

5.5 Performing Data Collection for Specific Field Studies

Many data collection methods for site investigation are well documented and readily available in current ODOT publications. For example, the *Speed Zone Investigation Manual* addresses how to perform speed studies. As a result, this manual does not include detailed worksheets for the majority of field studies; however, there are some unique situations that merit investigation, but do not have readily available worksheets. One such unique condition is a field evaluation of available intersection sight distance. This manual includes a set of worksheets for assessment of this intersection sight distance condition. These intersection sight distance worksheets apply only to intersection locations and should not be used for the evaluation of sight distance at driveway locations. If an investigator suspects that a driveway has poor sight distance, he or she should contact the Access Management Unit (AMU).

Appendix A of this manual includes the *Intersection Sight Distance* worksheet instructions, example problems and forms.

Table 5-3: Investigation and Diagnosis for Intersection Crashes

Crash Pattern	Probable Cause	What to Document	General Countermeasures
Right-angle collisions at unsignalized intersections	• Restricted sight distance • Large total intersection volume • High approach speed • Sun glare issues • Compliance at stop-controlled approach	• Sight obstructions • Parking at corners • Visibility and placement of stop/yield signs • Visibility and placement of advanced warning signs • Lighting • Peak hour, 4-hour, and 8-hour traffic volumes • Pedestrian volumes • Upstream operating speeds for high-speed approaches • Orientation to sunrise and sunset	• Remove sight obstructions • Restrict parking near corners • Install stop signs or oversize and dual signs (if present already) • Install warning signs • Provide markings to supplement signs • Install hazard beacons • Install/improve street lighting • Reduce speed limit on approaches • Install signals • Install yield signs • Channelize intersection • Install signals • Re-route through traffic • Install rumble strips (non-urban locations) • Install traffic calming infrastructure (speed humps, bump-outs, etc.) • Install roundabout or traffic circle

Crash Pattern	Probable Cause	What to Document	General Countermeasures
Right-angle collisions at signalized intersections	• Poor visibility of signals • Signal timing • Failing vehicle detection • Dilemma Zone Unprotected (max outs, coordination)	• Location and visibility of signal heads • Location and visibility of advanced warning signs • Signal timing and operating sequence • Coordination, gap time, max green times, % max outs • v/c ratios of each movement	• Install advanced warning devices • Install 12-inch signal lenses • Install overhead signals • Install visors • Install back plates • Improve location of signal heads • Add additional signal heads • Reduce speed limit on approaches • Adjust/Extend amber or all-red • Provide all-red clearance phases • Add multi-dial controller • Re-time signals • Provide signalized progression • Install signal actuation • Provide protective movement phases • Check equipment malfunction • Replace signal with roundabout

Crash Pattern	Probable Cause	What to Document	General Countermeasures
Rear-end collisions at unsignalized intersections	• Pedestrian crossing • Driver not aware of intersection • Large volume of turning vehicles • Poor visibility	• Location and visibility of crosswalks and stop bars • Location and visibility of stop/yield signs • Location and visibility of advance warning signs • Sight distance obstructions • Peak hour, 4-hour, and 8-hour traffic volumes • Pedestrian volumes • Upstream operating speeds for high-speed approaches • Sight distance obstructions • Conspicuity of pavement marking and signs	• Install/improve signing or marking of pedestrian crosswalks • Reduce number of crosswalks • Relocate crosswalk • Install/improve standard & advance warning signs • Reduce speed limit on approaches • Install hazard beacons • Create left- or right-turn lanes • Prohibit turns • Increase curb radii • Remove sight obstructions • Prohibit parking • Review striping needs • Install traffic calming infrastructure (speed humps, bump-outs, etc.) • Install roundabout or traffic circle

Crash Pattern	Probable Cause	What to Document	General Countermeasures
Rear-end collisions at signalized intersections	• Poor visibility of signals • Signal timing • Pedestrian crossings • Unwarranted signals • Large volume of traffic or turning volumes • Over capacity vehicle movements	• Location and visibility of signal heads • Location and visibility of advance warning signs • Signal timing and operating sequence • Location and visibility of crosswalks and stop bars • Peak hour, 4-hour, and 8-hour traffic volumes • Pedestrian volumes • Curb return geometry • Coordination, gap time, max green times, % max outs • v/c ratios of each movement	• Install/improve advance warning devices • Install overhead signals • Install 12-inch signal lenses • Install back plates or visors • Relocate signals or signal heads • Add additional signal heads • Lengthen mast arms • Remove sight obstructions • Reduce speed limits on approaches • Adjust/Extend amber or all-red phase • Provide progression through a set of signalized intersections (coordination) • Signal/loop malfunction • Need additional loops • Revise red/green timing • Install/improve signing or marking of pedestrian crosswalks • Reduce number of crosswalks • Provide pedestrian "WALK" phase • Create left- or right-turn lanes • Prohibit turns • Add left turn phase • Increase curb radii • Remove signals • Replace signal with roundabout

Crash Pattern	Probable Cause	What to Document	General Countermeasures
Left-turn collisions at intersections	• Large volume of traffic or left turns • Restricted sight distance • Over capacity vehicle movements	• Number of lanes / lane width / lane usage • Traffic signal timing and operating sequence • Location and visibility of signs related to lane usage or turning movements • Sight distance obstructions • Coordination, gap time, max green times, % max outs • v/c ratios of each movement	• Provide left-turn signal phases • Prohibit left turns • Increase/add left turn lane and provide left-turn signal if warranted • Re-route left-turn traffic • Provide adequate channelization • Create one-way streets • Install "STOP" signs • Adjust signal timing or install traffic signal • Improve approach visibility • Widen road • Adjust/Extend amber or all-red • Prohibit parking • Reduce number of pedestrian crossings • Remove obstacles • Install warning signs • Reduce speed limit on approaches • Replace signal with roundabout
Right-turn collisions at intersections	• Short turning radii • Signal timing • Poor visibility	• Number of lanes / lane width / lane usage • Traffic signal timing and operating sequence • Location and visibility of signs related to lane usage or turning movements • Sight distance obstructions	• Increase curb radii • Adjust signal timing or install traffic signal • Improve approach visibility • Widen road • Adjust/Extend amber or all-red • Restrict right-turn on red

Crash Pattern	Probable Cause	What to Document	General Countermeasures
Sideswipe collisions at intersections	• Roadway design inadequate • Poor visibility • Passing at intersection	• Number of lanes / lane widths / lane usage • Location / description / measurement of median • Shoulder type / width and condition • Location and visibility of advance warning signs • Roadway type and condition	• Improve pavement marking • Increase curb radii • Remove on-street parking near intersection • Install / Improve directional signing • Restrict driveway access near intersection
Pedestrian crashes at intersections	• Restricted sight distance • Inadequate protection for pedestrians • Inadequate signals • Improper signal phasing • Uncontrolled school crossing area	• Number of lanes, lane widths, lane usage • Right turn on red • Sight distance obstructions • Location and operation of pedestrian push buttons • Locations and measurements of pedestrian refuge islands • Signal timing and sequence-exclusive pedestrian phase	• Remove sight obstructions • Install pedestrian crossings • Improve/install pedestrian crossing signs • Restrict parking • Re-route pedestrian paths • Add pedestrian refuge islands • Install pedestrian signals • Add pedestrian "WALK" phase • Change timing of pedestrian phase • Use school crossing guards
Collisions at railroad crossings	• Restricted sight distance	• Sight distance obstructions • Measure profile grade • Crossing hardware	• Remove sight obstructions • Reduce grades • Install train actuated signals • Install stop signs • Install bus lanes • Install gates • Install advance warning signs

Table 5-4: Investigation and Diagnosis for Mid-Block Crashes

Crash Pattern	Probable Cause	What to Document	General Countermeasures
Sideswipe collisions between vehicles traveling in opposite directions or head-on collisions	• Roadway design for traffic conditions • Insufficient passing zones • Two-way left-turn lanes	• Number of lanes / lane widths / lane usage • Location / description / measurement of median • Shoulder type / width and condition • Location and visibility of advance warning signs • Roadway type and condition	• Install/improve pavement markings • Channelize intersections • Create one-way streets • Restrict parking • Install median divider / barrier • Widen lanes
Collisions between vehicles traveling in same direction such as sideswipes, turning or lane changing	• Roadway design for traffic conditions • Insufficient passing zones • Passing on shoulders	• Location and description of traffic islands • Pavement widths • Lane widths	• Widen lanes • Channelize intersections • Add capacity (other program) • Right/left turn lane • Provide turning bays • Install advance route or street signs • Install/improve pavement lane lines • Restrict parking • Reduce speed limit
Collisions with parked cars or cars being parked	• Large parking turnovers • Roadway design inadequate for present conditions	• Number of lanes / lane widths / lane usage • Parking configuration type	• Prohibit parking or move off-street • Change from angle to parallel parking • Re-route through traffic • Create one-way streets • Reduce speed limit • Widen lanes • Add back-in angle parking

Crash Pattern	Probable Cause	What to Document	General Countermeasures
Collisions at driveways	• Left-turning vehicles • Right-turning vehicles • Large volume of through traffic • Large volume of driveway traffic • Restricted sight distance	• Number of lanes / lane widths / lane usage • Location and measurement of median openings • Location and description of driveway width and geometry, surface type, condition of driveway • Shoulder type, width and condition • Location and visibility of advance warning signs • Sight distance obstructions • Lighting • Confirm the driveway is an ODOT permitted driveway	• Install raised median to limit access • Prohibit left-turns • Install two-way left turn • Provide right-turn lanes • Restrict parking near driveways • Increase the width of the driveway • Widen through lanes • Increase curb radii • Provide acceleration or deceleration lanes • Move driveway to side street • Combine driveways where applicable • Construct a local service road • Re-route through traffic • Add traffic signal • Signalize or channelize driveway • Remove sight obstructions • Install/improve street lighting • Reduce speed limit • Install hazard beacons
Pedestrian crashes between intersections	• Driver has inadequate warning of frequent mid-block crossings • Pedestrians on roadway • Long distance to nearest crosswalk	• Location and visibility of mid-block crosswalks • Location and visibility of advance warning signs • Sight distance obstructions • Lighting • Shoulder type / width / condition • Presence and location of sidewalks	• Prohibit parking • Install warning signs • Lower speed limit • Install pedestrian barriers in the median • Install sidewalks • Install pedestrian crosswalk • Install pedestrian actuated signals • Install bulb-outs/curb extensions
Pedestrian crashes at driveway crossings	• Sidewalk too close to travelway	• Lane widths, curb width, landscape buffer width, and sidewalk width • On-street parking	• Move sidewalk laterally away from road • Restrict parking

Table 5-5: Investigation and Diagnosis for Fixed-Object and Run-off-road Crashes

Crash Pattern	Probable Cause	What to Document	General Countermeasures
Fixed-object collisions and/or vehicles running off roadway (may also include head-on crashes in some cases)	• Objects near travelway • Roadway design for traffic conditions • Poor delineation • Signing/striping/delineation • Guardrail • Pavement edge drop-off	• Ball bank curves • Location and description of fixed objects • Roadway type width and condition • Location and visibility of advance warning signs • Presence/condition of guardrail and/or energy absorbing device • Location and visibility of pavement markings and post-mounted delineators • Height of pavement edge drop-off	• Remove /relocate obstacles from clear recovery area • Install barrier curbing • Install breakaway feature to light poles, signpost, etc. • Reduce number of utility poles • Protect objects with guardrail or attenuation device • Widen lanes / add capacity • Relocate islands • Re-align • Check superelevation • Close curb lane • Improve/install pavement markings include edgeline • Contrast treatment • Rumble strips • Install roadside delineators • Install/improve standard or advance warning signs • Install a paved safety edge

Table 5-6: Investigation and Diagnosis for Crashes Linked to Environmental Conditions

Crash Pattern	Probable Cause	What to Document	General Countermeasures
Night crashes	Poor visibility	• Lighting • Location and visibility of regulatory and warning signs • Location and visibility of pavement markings and delineators	• Install/improve street lighting • Remove sight obstructions • Install/improve delineation markings • Install/improve warning signs
Wet pavement crashes	Slippery pavement	• Pavement type and condition including skid test • Location and conditions of drainage facilities • Location and visibility of advance warning signs	• Overlay/groove pavement • Open graded asphalt concrete • Provide adequate drainage • Chip seal • Reduce speed limit • Review Skid test • "SLIPPERY WHEN WET" signs • Improve delineation
Crashes on grade	Sun glare or unexpected icy spots on road	• Sun angles • Locations with poor drainage	• Additional warning sign • Modify superelevation as well as shoulder recovery area
Reduced visibility collisions	Poor visibility (usually due to weather)	• Conspicuity of pavement marking and signs	• Provide fog or smoke warning • Improve delineation

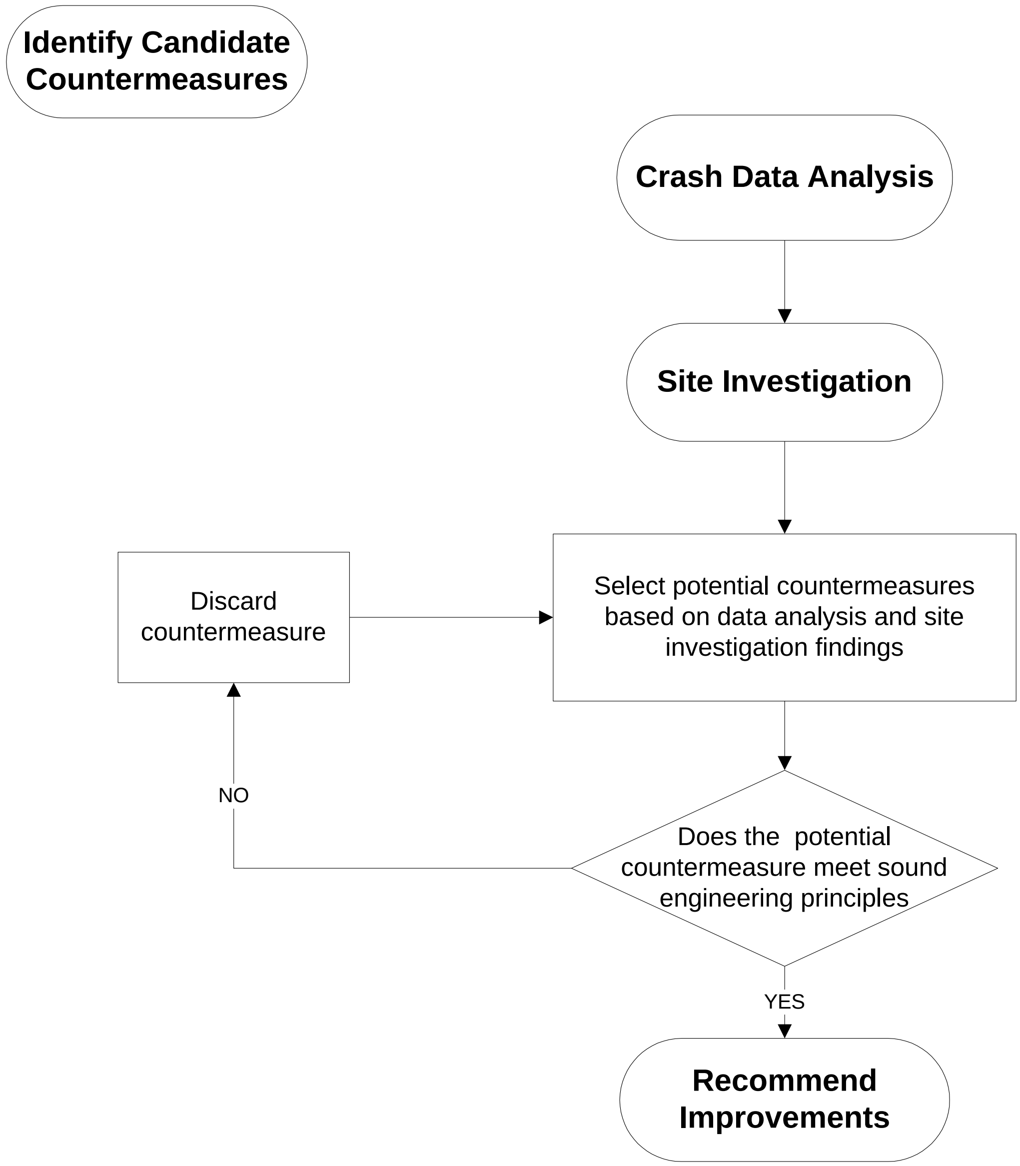
Chapter 6 Countermeasure Selection and Recommend Improvements Analysis

Following data analysis and field investigation, the investigator should have a clear idea of what types of crashes are overrepresented and some ideas of which types of crashes might be preventable. The next step in the investigations is to select the likely "cure" for the crash contributing factors. This is done by developing a set of candidate countermeasures that may reduce the identified crash problem highlighted by an overrepresented crash type. For many projects, more than one countermeasure or set of countermeasures may be feasible. How to do this is described in **Sections 6.1** and **6.2**.

Once candidate countermeasures have been identified, the investigator will have to decide which improvements are feasible, which ones are cost-effective, and if more than one option is available, which one returns the largest benefit. Guidance on these decisions is provided in the remaining sections of the chapter. The basic procedure to identify candidate countermeasures is shown in **Figure 6.1**. It is also extremely important to ensure recommended countermeasures have required delegated authority processes, as detailed in the *Traffic Manual*.

Two approaches can be taken when choosing countermeasures for a given location. Investigators can choose to identify countermeasures based on overrepresented crash types or by strictly considering crash reductions. In many cases, the agency's goal is to reduce a specific type of crash at a location, such as run-off-road or right-angle crashes. Different countermeasures may be more appropriate for specific environmental conditions or injury types common at the location of interest. Strictly considering crash-reducing countermeasures may correspond with lower Crash Modification Factors (CMF), but budget and other resource limitations may restrict the application of such improvements.

Figure 6-1: Flowchart of Procedure to Identify Candidate Countermeasures



6.1 Principles of Countermeasure Selection

A “countermeasure” can be defined as a modification, improvement, or action designed to reduce crash frequency or severity. In the context of this manual, a countermeasure generally refers to an engineering or operational improvement but there can also be educational, enforcement, or emergency service-related countermeasures.

A good countermeasure should reduce either the frequency or severity of dominant crash types. The implemented countermeasure should not have any significant undesirable consequences in traffic efficiency or environmental terms, though tradeoffs between safety and other competing decision elements should be expected. The countermeasure should be cost-effective under most circumstances.

All countermeasures should be based on sound engineering judgment and should conform to applicable ODOT and Federal Highway Administration (FHWA) policies and procedures. It is important to check if recommended solutions have delegated authority processes.

6.2 Identify Candidate Countermeasures

6.2.1 Useful Resources for Countermeasures

There are a growing number of very useful resources for the investigator to obtain countermeasures and identify their expected effectiveness. The FHWA Safety Emphasis Area websites provide useful starting points:

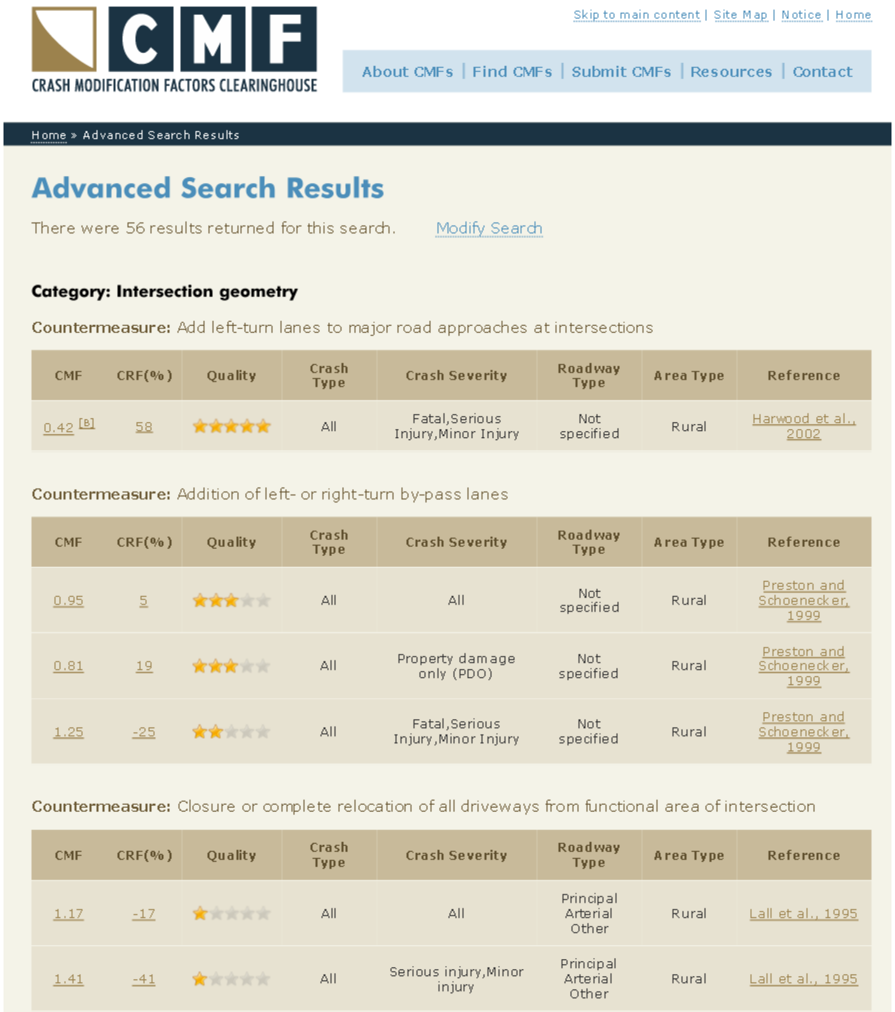
- https://safety.fhwa.dot.gov/intersection/
- https://safety.fhwa.dot.gov/roadway_dept/
- https://safety.fhwa.dot.gov/ped_bike/
- https://safety.fhwa.dot.gov/local_rural/
- https://safety.fhwa.dot.gov/older_users/

Section 5.4, "Mapping Crash Patterns to Data Needs and Potential Countermeasures", provided helpful tables mapping the crash patterns to possible countermeasures. In addition, **Section 5.4.1**, "Signalized Intersections", identified some signal timing and other considerations specifically at intersections to consider.

The identification of potential countermeasures involves mapping the correctable crash type to a possible countermeasure. For example, if rear-end crashes on a rural highway near an intersection were identified as the correctable crash type, the investigator would need to identify a countermeasure that might reduce these crashes.

This "mapping" can be done in a number of ways. There are published checklists or summary tables that identify candidate countermeasures based on crash patterns and probable causes (see **Table 5-3**, **5-4**, **5-5**, and **5-6** in **Chapter 5**). It is recommended to develop a list of all prospective countermeasures for the problem location and identify the corresponding CMFs.

Figure 6-2: Screen Capture of FHWA CMF Clearinghouse



CRASH MODIFICATION FACTORS CLEARINGHOUSE

Skip to main content | Site Map | Notice | Home

About CMFs | Find CMFs | Submit CMFs | Resources | Contact

Home » Advanced Search Results

Advanced Search Results

There were 56 results returned for this search. Modify Search

Category: Intersection geometry

Countermeasure: Add left-turn lanes to major road approaches at intersections

CMF	CRF(%)	Quality	Crash Type	Crash Severity	Roadway Type	Area Type	Reference
0.42 [B]	58	★★★★★	All	Fatal,Serious Injury,Minor Injury	Not specified	Rural	Harwood et al., 2002

Countermeasure: Addition of left- or right-turn by-pass lanes

CMF	CRF(%)	Quality	Crash Type	Crash Severity	Roadway Type	Area Type	Reference
0.95	5	★★★☆☆	All	All	Not specified	Rural	Preston and Schoenecker, 1999
0.81	19	★★★☆☆	All	Property damage only (PDO)	Not specified	Rural	Preston and Schoenecker, 1999
1.25	-25	★★☆☆☆	All	Fatal,Serious Injury,Minor Injury	Not specified	Rural	Preston and Schoenecker, 1999

Countermeasure: Closure or complete relocation of all driveways from functional area of intersection

CMF	CRF(%)	Quality	Crash Type	Crash Severity	Roadway Type	Area Type	Reference
1.17	-17	★☆☆☆☆	All	All	Principal Arterial Other	Rural	Lall et al., 1995
1.41	-41	★☆☆☆☆	All	Serious injury,Minor injury	Principal Arterial Other	Rural	Lall et al., 1995

For bicycle and pedestrian crashes there are two interactive tools developed by FHWA that might prove useful (though there is limited information on effectiveness):

- BIKESAFE: http://pedbikesafe.org/bikesafe/
- PEDSAFE: http://www.pedbikesafe.org/pedsafe/

6.2.2 *Selecting Appropriate Context*

When applying a countermeasure, the investigator needs to pay close attention to the conditions and crash types to which the CRF/CMF applies. Nearly all CRFs/CMFs were developed from before-after safety analysis for a specific case or condition and one must be careful to match these conditions as close as possible. A simple way to think of this is:

- What are the existing conditions at the location before the countermeasure?

  For example, if one was considering adding a left-turn bay on a major road to eliminate the rear-end crashes, the following "before" conditions are available:
  - Add Left-Turn Bay on Major Road, Signalized, 3-leg Intersection
  - Add Left-Turn Bay on Major Road, Signalized, 4-leg Intersection
  - Add Left-Turn Bay on Major Road, Unsignalized, 3-leg Intersection
  - Add Left-Turn Bay on Major Road, Unsignalized, 4-leg Intersection

  Also, many countermeasures were developed from data and either apply to "TOTAL" crashes or a specific crash type. The investigator needs to be sure that he or she applies the CRF to the appropriate crash type.

- To what crash types should the countermeasure apply?

  Continuing the above example, if the left-turn lane was to be added to a signalized, 4-leg urban intersection, the investigator would have the choice of CRFs that apply to fatal crashes, injury crashes, or all crashes.

Table 6-1: CRF for Different Crash Types

Road Character	Crash Type	Fatal	Injury	PDO	All Crash Severity
Rural	All Crash Types	-	-	-	18%
Urban	All Crash Types	9%	9%	-	10%

6.3 Expected Effectiveness of Countermeasures

6.3.1 Terminologies for Countermeasure Effectiveness

For each countermeasure, the most important information is the expected effectiveness (How well will the countermeasure work?). The estimated reduction is key to estimating the cost-effectiveness of countermeasure and severity trade-offs. There are currently two common terminologies:

- Crash Modification Factor
  - A multiplicative factor representing the fraction of the total crashes expected after the countermeasure
- Crash Reduction Factor
  - A percent reduction in the "before" crashes after implementing the countermeasure

Currently, the ODOT resources and terminology use "CRF" while the 2010 American Association of State Highway and Transportation Officials (AASHTO) *Highway Safety*

Manual (HSM) uses the CMF terminology. In most cases, the values are interchangeable using this simple conversion:

CRF = (1-CMF)

6.3.2 *Sources for CRF or CMF and CRF calculation*

For most investigations, the investigator should use the ARTS Program Crash Reduction Factor List located at the following address under the "Crash Reduction Factors" tab:

- https://www.oregon.gov/odot/engineering/pages/arts.aspx

There is also an *ARTS Countermeasure Search Tool* found on the same webpage that supports the *Crash Reduction Factor List* and *Crash Reduction Factor Appendix* and helps users select countermeasures by location type, crash type and cause, lighting and pavement conditions, etc.

A CRF estimates the percent decrease in crashes after applying a given countermeasure. The countermeasures included in this list are typically physical changes to the roadway or intersection infrastructure, such as signage, pavement markings, signals, or geometric design. The countermeasures defined in the list are categorized as hotspot countermeasures, systemic intersection countermeasures, systemic bike & pedestrian countermeasures, and systemic roadway departure countermeasures. For more information, see the ARTS Crash Reduction Factor Appendix.

Another source for understanding countermeasure effectiveness is FHWA's Crash Modification Factors Clearinghouse located at:

- http://www.cmfclearinghouse.org/

The CMF is a multiplicative value that estimates the safety influence of a specific countermeasure. Before using a CMF, the analyst should determine the base conditions of the CMF and should only use a CMF for evaluation of similar base conditions. For example, base conditions for a CMF where the countermeasure considers adding lighting to a road segment may be based on locations without any available street lights. If the site evaluated is a location that does have streetlights but their spacing or intensity is in question, the CMF with the "no lights" base condition could not be used for this assessment. CMF quality can also vary. The FHWA web site uses both a star rating system where more stars indicate a more reliable CMF and a point rating system where higher points indicate a more reliable CMF.

When multiple countermeasures are applied to a location, a simple formula is used to calculate a composite CRF. This formula is given as

CRF = CRF1 +(1-CRF1)CRF2+[(1-CRF1)(1-CRF2)CRF3…]

However, this formula is not based on a known interaction between CRFs and should be used with caution. While mathematically an infinite number of CRFs could be applied to achieve a total 100% reduction, as a practical matter, the investigator should use this formula sparingly. In fact, most investigations will reveal one or at most 2 complementary countermeasures. The order of the CRFs does not matter in the formula.

A composite CMF is not needed. CMFs can be multiplied together to determine a composite effectiveness.

Example 6.1:

A location has 14 crashes per year. Two countermeasures have been selected with a CRF1 = 10%, CRF2 = 30% (or CMF1 = 0.90 and CMF2 = 0.70)

a) How many crashes will be reduced?
b) How many crashes will occur per year after the countermeasure?

With CRF
First, calculate the composite CRF = 0.1+(1-0.1)(0.3) = 0.37 or 37%
[Note: 0.1 is 10% in decimal form and 0.3 is 30% in decimal form.]

a) crashes to be reduced = 14[0.37]=5.18 crashes
b) crashes expected after countermeasure = total – reduced = 14 - 5.18 = 8.82 crashes

With CMF
CMF1 = 0.90, CMF2 = 0.70, with CMF b) is easier to answer first

a) crashes expected after countermeasure = (14 crashes)(0.9)(0.7) = 8.82 crashes
b) crashes to be reduced = total – expected after = 14 - 8.82 = 5.18 crashes

6.3.3 What to Do If the Countermeasure Does Not Have A CRF or CMF Value

In an ideal world, all countermeasures would have a CRF or CMF associated with them. There has been a significant amount of effort in recent years to sift through countermeasures to determine “valid” CRFs. “Valid” CRFs have been determined from well-designed research studies including efforts within Oregon to develop CRFs for Oregon and to adapt CRFs from other states. Unfortunately, there are many treatments where adequate CRFs have still not been developed.

If the investigator identifies a countermeasure without a CRF value, he or she should work with Headquarters to determine an appropriate acceptable value (if any), especially since research work is ongoing and new CRFs are being produced. New CRFs can be requested by filling out a form provided by the ARTS program. This form is found on the ARTS homepage under the “Crash Reduction Factors” tab.

https://www.oregon.gov/ODOT/Engineering/Pages/ARTS.aspx

In the event a reasonable CRF or CMF still cannot be located, the investigator may want to work with ODOT Transportation Research Program to develop a problem statement for future research efforts.

6.4 Recommend Improvements

Once a countermeasure or a set of countermeasures have been selected, the investigator must evaluate the economic feasibility of the countermeasure. While safety improvements and their benefits may be considered as part of larger projects, this worksheet is specifically for use on safety projects. Benefits are considered as savings in crashes over life of project, either in reduction in frequency or severity. Costs include the initial capital investment of the project. Because the benefits accrue over the life of the improvement and money has time-value, a discount rate must be applied to future benefits. The ARTS program has benefit cost and cost effectiveness worksheets available.

6.5 Stating the Problem and Writing the Recommendation

Clear identification of issues at an identified location can be critical for diagnosis and determination of successful site recommendations. It is essential, therefore, to clearly identify site issues and document these conditions for current and future assessment.

As a general rule, a location that is a candidate for a safety enhancement project will have a specific set of identifiable countermeasures that may be applicable. These potential recommendations can include iterative solutions. These recommendations are a culmination of the investigations process. The final recommendation is the improvement or set of improvements that should be implemented. These improvements have been identified by the crash data analysis, field investigation, and were determined to be cost effective.

The text of the recommendation should be written such that there is a clear link established between the identified crash or safety problem and the proposed solution.

Chapter 7 Documentation and Implementation

Documentation of the safety investigation and subsequent recommendations is important for a number of reasons. First, by properly documenting the evaluation and project recommendations the implemented improvements can be more easily evaluated for effectiveness. This documentation will also allow ODOT to easily complete and compile the federal reporting requirements for the Highway Safety Improvement Program (HSIP). Second, a well-organized investigations file and its summary document, the *Safety Investigations Manual Report* (SIM Report), serve as important tools for improving safety considerations in project discussions. Lastly, in the case of tort liability, the file and summary report could prove useful in defending the Department's actions.

7.1 Investigations File

It is important to keep an organized investigations file following the procedures for each Region's traffic office. All worksheets that are completed as part of the investigations should be saved and named in a systematic format. Investigators are encouraged to use the statewide electronic "T"-filing system:

- http://ecmicn/navigator/

7.2 SIM Report

The SIM Worksheet contains a SIM Report tab that is to be the final summary of the investigation process. The form is intended to also serve as a tracking mechanism for corrective action. Nearly all of the information required for the report should have been obtained or analyzed as a part of the investigations process. Much of the report form is populated from other data entered or calculated in the SIM Workbooks. This includes existing crash, volume, rates, SPIS scores. **Figure 7-1** shows a screen capture of this form. Instruction for completing this form are provided in **Appendix B**.

Figure 7-1: Example Completed SIM Report

5%

Region 2
2018 SPIS
(Safety Priority Index System)

Date: 7/10/2020 Prepared By: Mariana Montes Title: Traffic Investigator

LOCATION INFORMATION

District: 3 City: None County: Polk

Road Character: RURAL Functional Class: RURAL PRINCIPAL ARTERIAL

Crash Dates: 1/1/2013 to 12/31/2017

Willamina-Salem

Highway No.:	030		
Route No.:	OR-22		
MP From:	11.70	to	11.88

Street Name		MP	ADT
Perrydale	@	11.79	12600
	@		
	@		
	@		

APPROVALS

Approved By: ______ Approved Date: ______

CRASH RATE & NOTABLE CRASHES

- Segment crash rate above peer and critical rates
- Intersection crash rate below and critical rates

- 1 INJA in 2016 at MP 11.79 (Perrydale). Angle crash resulted from SB vehicle failing to yield to EB vehicle in wet and dark conditions.
- 1 INJA in 2016 at MP 11.79. Turn crash resulted from LT (S-W) vehicle (with 65 yr. old driver) failing to yield to EB vehicle. WB vehicle was also involved.
- 1 INJA in 2014 at MP 11.79. EB Fixed Object crash (with 72 yr. old driver) resulted from failure to maintain lane in wet and dark conditions.
- 1 INJA in 2014 at MP 11.79. Angle crash resulted from NB vehicle (with 79 yr. old driver) disregarding stop sign and colliding with WB vehicle.
- 1 INJA in 2014 at MP 11.79. Angle crash resulted from NB vehicle (with 68 yr. old driver) failing to yield to WB vehicle in dlit conditions.
- 1 INJA in 2014 at MP 11.79. Turn crash resulted from LT (S-W) vehicle failing to yield to EB vehicle.

NOTES (CRASH PATTERNS/IMPROVEMENTS)

(continued)
Bike Crash
- 1 INJC Angle crash in 2014 at MP 11.84. EB vehicle (with 80 yr. old driver) struck EB cyclist in not visible/dark clothing. Alcohol and drugs were involved.

Segment
- Primary crash pattern: Angle (41%) and Turn (27%)
- Higher than expected F&A, INJB&C, Angle, Turn, 3-6pm, no yield, and drivers >74 years of age
- 2 crashes (Fixed Object and SS-O) resulted from passing maneuvers from MP 11.85-11.88.

Perrydale Rd (16 crashes)
- Primary crash pattern: Angle (56%) and Turn (38%)
- Higher than expected F&A crashes
- All INJA crashes occurred at intersection
- 5/9 Angle crashes had errant vehicle in NB direction and 4/9 Angle crashes had errant vehicle in SB direction
- 5/6 Turn crashes resulted from LT (S-W) vehicle failing to yield to EB vehicle

- TRAWS approved by STRE Nov, 2019 as interim solution. TRAWS activated in May, 2020 using Safety Quick Fix funding - see attached email.

RECOMMENDATION NARRATIVE

(continued)
- ODOT's report "Addressing Oregon's Rise in Deaths & Serious Injuries for Senior Drivers and Pedestrians" identifies that older driver F&A crashes primarily occur at intersections and primarily result in fixed object and turn crashes. Some identified recommended countermeasures are addressing limited sight distance and roundabout. See attached excerpt.

- Perrydale roundabout didn't make '22-'24 ARTS 100% list. County recommends rerouting north leg to Kings Valley Hwy roundabout and configuring Perrydale as a perpendicular T-intersection. Perform B/C analysis of both alternatives prior to '24-'27 ARTS

- OR22 from MP 5-15 was designated a Safety Corridor that went into effect May, 2020.

- 2021 roadway departure grant awarded for OT enforcement on Hwy 30 from MP 4.00-15.02

Implementation: No recommendation

Type:

CRASH RATE SUMMARIES

Rates All Crashes	Invs. Rate	Peer Rate	Critical Rate	Flag?
Segment	6.16	0.78	1.68	YES
Intersection*	0.37	0.43	0.61	NO

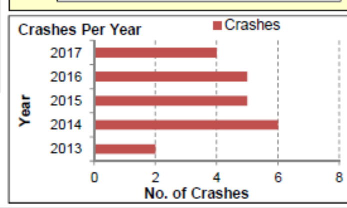
Intersection crash rate is only for the first intersection listed above

SEGMENT CRASH TOTALS

Severity	5 yrs	Obs %	Flag
Fatal & Inj A	6	27.27%	YES
Injury B & C	14	63.64%	YES
PDO	2	9.09%	NO
TOTAL	22		

SPIS

Year	2015	2016	2017	2018
SPIS Score	73.42	72.42	73.48	71.80



GEOMETRY AND OPERATIONS

Posted Speed 55 mph No. Thru Lanes 3 (LTL)

Wide Shoulders Yes[6]

Signalized? No RT Lane? Yes

Left Turn Phasing LT or TWLTL? Yes

Highway Bike Lane? No

Side Street

FIELD VISIT

Was a field investigation conducted? Yes

If yes, date 8/12/2016

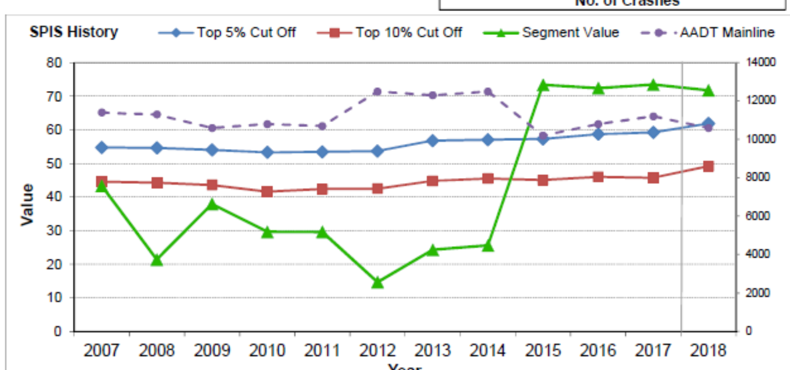
If yes, participants J. Schmidt, A. Salyer

Last Investigated

HISTORICAL INFORMATION

Are there any previously approved SPIS investigations of this location on record? Yes ☑ No ☐

If yes, date 2017 Highway Safety Investigations Report 09/2009 CMM;



*Note: X-axis shows SPIS year, not ADT year (2018 SPIS = 2017 ADT) **PDO crashes omitted from SPIS score calculation starting 2018

1 of 2 7/28/2021 1:24 PM

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Appendix A Sight Distance Evaluation

A.1 Instructions for Evaluating Intersection Sight Distance

The information included in this section is based on the procedures identified in the AASHTO *A Policy on Geometric Design of Highways and Streets, 2004*. More information is available in this source on pages 654-661. This approach is for intersections and should not be applied for analysis at ODOT driveway locations.

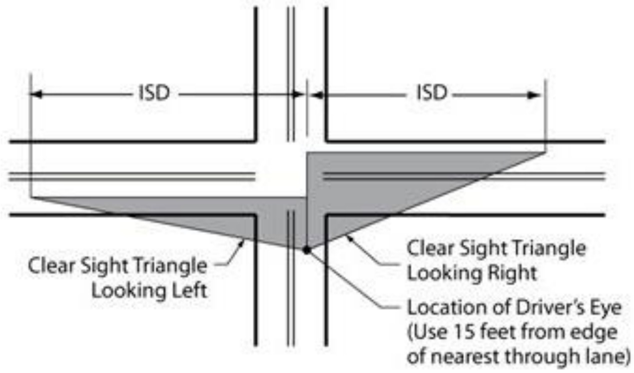
- What is Intersection Sight Distance?

  Intersection sight distance is the distance drivers stop at a minor approach needs to see (either to the left or right) for them to make a safe turning maneuver onto a cross street. It is commonly evaluated at four-legged approaches with stop control on the minor street or at driveway locations. Intersection sight distance differs depending on intersection and maneuver types, such as stop control and turning movements.

  For right turn movements, intersection sight distance is measured to the left, since drivers making right turns will need to check for gaps in the approaching traffic (which is approaching from their left). Likewise, for left turns or through movements, intersection sight distance is measured to the right and to the left (since the vehicle needs to cross in the path of vehicles approaching from both directions).

  In intersection sight distance, a 2-dimensional *sight triangle* is created. The first leg of the triangle extends from the stopped driver's eye position (on the minor street) forward until reaching the center of the lane the driver will turn into. The second leg of the triangle runs down the center of the lane of the approaching vehicles (either to the left or right) for the full distance of the required intersection sight distance. The end of the intersection sight distance represents the position of the object (in this case an approaching car) the driver must be able to see. The third leg of the triangle is the hypotenuse and runs from the end of the required stopping sight distance length to the stopped driver's eye position. The area of this triangle represents the entire space a driver needs to have clear from obstructions to complete a safe turning maneuver. At the stopped vehicle position, drivers must be able to see the entire roadway surface of this triangle at all locations.

Figure A-1: Sight Triangles at Intersection



- When to Evaluate

  An over-representation of right-angle collisions or rear-end collisions at a site indicates that intersection sight distance should be evaluated. Proper intersection sight distance is important for maintaining safely operating intersections. Locations that do not have proper intersection sight distance prevent drivers from being able to safely execute turns. When sight distance is limited, drivers cannot correctly assess gaps in oncoming traffic. Drivers then run the risk of turning in front of a vehicle without the space necessary to complete their turning maneuver and/or accelerate to the roadway operating speed before that vehicle reaches them.

- In Office Work

  Before visiting the site, it is important to identify the presence of key geometrical features. These features include horizontal and vertical curves. Horizontal curves can be identified using aerial photographs. These are often available through the services of Google Maps and Google Earth. When identifying a horizontal curve, determine a map scale, locate the point of curvature, point of tangent, and determine the approximate radius of the curve. This information may also be available from archived as-build drawings.

- Field Work

  After completing the in-office work, a site visit is necessary to conduct field observations. These observations include measuring out the appropriate intersection sight distance triangle and checking to see that the entire area is clear of sight distance obstructions. The following step-by-step instructions demonstrate how to measure and check an intersection sight distance triangle.

- ***Step 1: Roadway Slope:*** From Position A, walk 250 feet to the left/right next to the major roadway. Place the SmartLevel on ground and record slope to determine if the slope exceeds 3%.
- **Step 2: Approach Speed:** At this same 250 feet location, measure vehicle operating speeds. Use procedures consistent with the ODOT Speed Zone Investigation Manual.
- **Step 3: Required Sight Distance:** Using **Table A-1** or **Table A-2**, look up the required sight distance for the approach.
- **Step 4: Stopped Driver Eye Position (A):** Measure 14.5 feet back from edge of major roadway or, if present, edge of crosswalk farthest from major roadway. While having someone look out for approaching traffic, position yourself in center of approach lane. Unroll 3.5 feet long measuring tape. Position end of tape on roadway surface. Hold tape vertical. Top of tape represents stopped driver's eye position.
- **Step 5: Roadway Object Position (B or C):** Position self in major road through lane closest to (for measurements to the left) or farthest from (for measurements to the right) the minor approach. Walk required distance to the left/right and along path of lane. At required distance away from approach, unroll 3.5 feet long measuring tape. Position end of tape on roadway surface. Hold tape vertical. Tape represents an entire object the driver's eye should be able to see. Hold an object (such as a clip board) at this 3.5 feet height for easy visibility.
- **Visibility Check:** Person at Position A (with eye at top of tape) should look left/right towards Position B or C. They should have full visibility of the object (tape) at that point and any other location along the roadway surface between them and Position B or C.

If Position A provides clear visibility of the measuring tape at location B or C (and all points between), then visibility is met to the Left (Position B) or Right (Position C).

- Intersection Sight Distance Tables

Table A-1: For Grades Less Than 3% (Driver Eye Height and Object Height of 3.5′)

Approach Speed (mph)	Distance to Left (feet)	Distance to Right (feet)
15	145	170
20	195	225
25	240	280
30	290	335
35	335	390
40	385	445
45	430	500
50	480	555
55	530	610
60	575	665
65	645	720
70	730	775
75	820	830
80	910	910

Values from *AASHTO 2004 Policy on Geometric Design of Highways and Streets*, Exhibit 9-55, Design Intersection Sight Distance-Case B1-Left Turn from Stop, Exhibit 9-58, Design Intersection Sight Distance-Case B2-Right Turn from Stop

Table A-2: For Grades Exceeding 3% (Driver Eye Height of 3.5′ and Object Height of 6′)

Approach Speed (mph)	Stopping Sight Distance (feet)					
	Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%
20	158	165	173	147	143	140
25	205	215	227	200	184	179
30	257	271	287	237	229	222
35	315	333	354	289	278	269
40	378	400	427	344	331	320
45	446	474	507	405	388	375
50	520	553	593	469	450	433
55	598	638	686	538	515	495
60	682	728	785	612	584	561
65	771	825	891	690	658	631
70	866	927	1003	772	736	704
75	965	1035	1121	859	817	782

A.2 Intersection Sight Distance Example Problems

A.2.1 ISD Example Problem 1: Typical Conditions 1

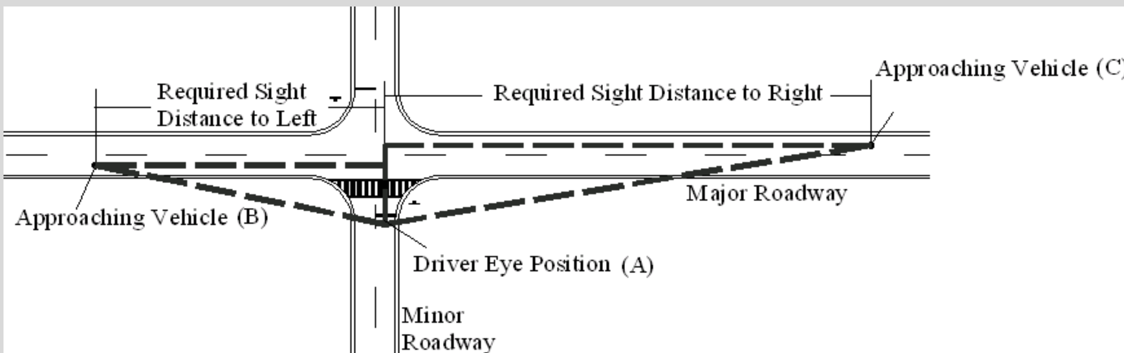
- **Question**
  Does the intersection approach provide clear right turn and left turn sight distance?
- **Site Characteristics**
  - Four-legged approach
  - 90 degree intersection angle
  - All vertical approaches are less than 2% slope and no vertical curves are present (i.e. level terrain)
  - Two-way stop control (minor streets)
  - Sidewalks on all approaches
  - Crosswalks present at minor street approaches
  - Studied approach is the Northbound approach (Southbound approach performed separately)
- **Methodology**
  After identifying key site characteristics, roadway slope and approach operating speed values are used to determine the required sight distance for each approach. This distance is then measured at the site to determine if the required site distance for right and left turns is provided.

Intersection Sight Distance to the LEFT: Calculated Values		
Roadway Slope: Starting at the driver position, walk 250 feet to the left alongside the major roadway. At end, place SmartLevel on ground and record slope.	1%	
Approach Speed: Remaining 250 feet away, measure vehicle speeds. Use procedures in speed study section of ODOT Safety Investigation Manual.	44 mph (round to 45 mph)	
Required Sight Distance: Using the provided table, look up the required sight distance.	430 feet	
Approach Speed (mph)	Distance to Left (feet)	Distance to Right (feet)
40	385	445
45	**430**	500
50	480	555
Visibility Check	Visibility is provided for entire distance.	
Is Visibility Met?	Yes	

Intersection Sight Distance to the RIGHT: Calculated Values		
Roadway Slope: Starting at the driver position, walk 250 feet to the right alongside the major roadway. At end, place SmartLevel on ground and record slope..	1.5 %	
Approach Speed: Remaining 250 feet away, measure vehicle speeds. Use procedures in speed study section of ODOT Safety Investigation Manual.	40 mph	
Required Sight Distance: Using the provided table, look up the required sight distance.	445 feet	
Approach Speed (mph)	Distance to Left (feet)	Distance to Right (feet)
35	335	390
40	385	**445**
45	430	500
Visibility Check	Visibility is provided for entire distance.	
Is Visibility Met?	Yes	

- **Completed Worksheet**

General Information	
Analyst Julia Roberts Agency ODOT Date Performed December 13, 2007	Time of Day 2:00 PM Analysis Year 2007 Jurisdiction Benton County
Site Characteristics	**In Office Work**
Crosswalk at Approach (Y/N) Y Sidewalk (Y/N) Y Vertical Curve (Y/N) N	Horizontal Curve (Y/N) N Approximate Radius (if present) N/A
Plan Figure	



Required Sight Distance to LEFT	**Required Sight Distance to RIGHT**
Roadway Slope to Left 1% Left Approach Operating Speed 44mph Required Sight Distance 430 feet	Roadway Slope to Right 1.5% Right Approach Operating Speed 40 mph Required Sight Distance 445 feet

Visibility LEFT	**Visibility RIGHT**
Clear Sight Distance Left (Y/N) Y List of Obstructions: None	Clear Sight Distance Right (Y/N) Y List of Obstructions: None

If the Stopped Driver Eye Position provides clear visibility of the measuring tape at the Roadway Object Position (and all points between that position and the Stopped Driver Eye Position), then visibility is met to the LEFT/RIGHT.

Site Sketch
Include: lanes, crosswalks, sidewalks, horizontal curves, vehicle movements, etc.

A.2.2 ISD EXAMPLE PROBLEM 2: TYPICAL CONDITIONS 2

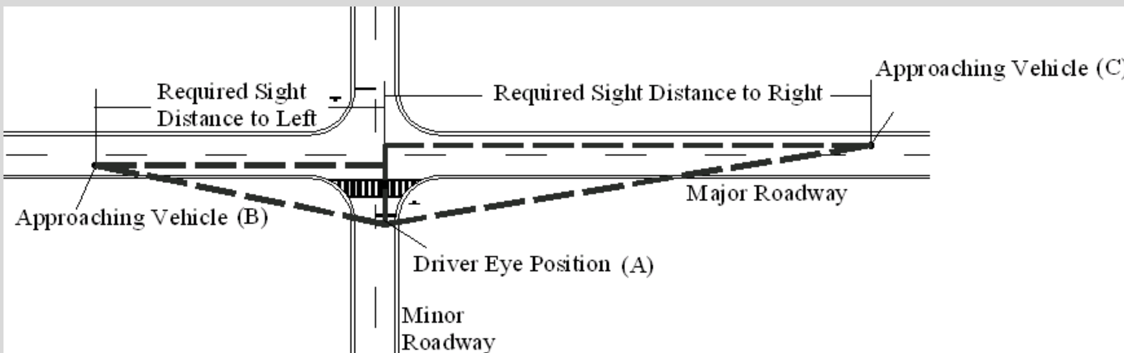
- **Question**
  Does the intersection approach provide clear right turn and left turn sight distance?
- **Site Characteristics**
  - Four-legged approach
  - 90 degree intersection angle
  - All vertical approaches are less than 2% slope and no vertical curves are present (i.e. level terrain)
  - Two-way stop control (minor streets)
  - Sidewalks on all approaches
  - Crosswalks present at minor street approaches
  - Studied approach is the Northbound approach (Southbound approach performed separately)
- **Methodology:**
  After identifying key site characteristics, roadway slope and approach operating speed values are used to determine the required sight distance for each approach. This distance is then measured at the site to determine if the required site distance for right and left turns is provided.

Intersection Sight Distance to the LEFT: Calculated Values		
Roadway Slope: Starting at the driver position, walk 250 feet to the left alongside the major roadway. At end, place SmartLevel on ground and record slope.	1.5%	
Approach Speed: Remaining 250 feet away, measure vehicle speeds. Use procedures in speed study section of ODOT Safety Investigation Manual.	33 mph (round to 35 mph)	
Required Sight Distance: Using the provided table, look up the required sight distance.	335 feet	
Approach Speed (mph)	Distance to Left (feet)	Distance to Right (feet)
30	290	335
35	**335**	390
40	385	445
Visibility Check	Visibility is provided for entire distance.	
Is Visibility Met?	Yes	

Intersection Sight Distance to the RIGHT: Calculated Values		
Roadway Slope: Starting at the driver position, walk 250 feet to the right alongside the major roadway. At end, place SmartLevel on ground and record slope.	2 %	
Approach Speed: Remaining 250 feet away, measure vehicle speeds. Use procedures in speed study section of ODOT Safety Investigation Manual.	35 mph	
Required Sight Distance: Using the provided table, look up the required sight distance.	390 feet	
Approach Speed (mph)	Distance to Left (feet)	Distance to Right (feet)
30	290	335
35	335	**390**
40	385	445
Visibility Check	Fence is blocking portion of sight triangle	
Is Visibility Met?	No	

- **Completed Worksheet**

General Information	
Analyst Clint Eastwood Agency ODOT Date Performed January 20, 2008	Time of Day 4:00 PM Analysis Year 2008 Jurisdiction Benton County
Site Characteristics	**In Office Work**
Crosswalk at Approach (Y/N) Y Sidewalk (Y/N) Y Vertical Curve (Y/N) N	Horizontal Curve (Y/N) N Approximate Radius (if present) N/A
Plan Figure	



Required Sight Distance to LEFT	**Required Sight Distance to RIGHT**
Roadway Slope to Left 1.5% Left Approach Operating Speed 35 mph Required Sight Distance 335 feet	Roadway Slope to Right 2% Right Approach Operating Speed 35 mph Required Sight Distance 390 feet
Visibility LEFT	**Visibility RIGHT**
Clear Sight Distance Left (Y/N) Y List of Obstructions: None	Clear Sight Distance Right (Y/N) N List of Obstructions: Obstruction to sight triangle by fence. Check into ownership to have relocated
If the Stopped Driver Eye Position provides clear visibility of the measuring tape at the Roadway Object Position (and all points between that position and the Stopped Driver Eye Position), then visibility is met to the LEFT/RIGHT.	

Site Sketch
Include: lanes, crosswalks, sidewalks, horizontal curves, vehicle movements, etc.

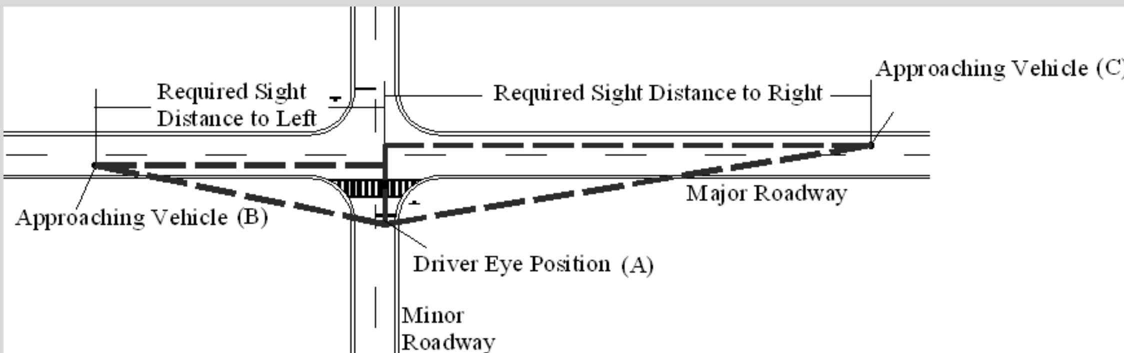
A.2.3 ISD EXAMPLE PROBLEM 3: HORIZONTAL CURVE 1

- **Question**
  Does the intersection approach provide clear right turn and left turn sight distance?
- **Site Characteristics**
  - Three-legged approach
  - 90 degree intersection angle
  - All vertical approaches are less than 2% slope and no vertical curves are present (i.e. level terrain)
  - One-way stop control (minor street)
  - Sidewalks on all approaches
  - Crosswalks present at minor street approach
  - Studied approach is the Eastbound approach (Westbound approach performed separately)
- **Methodology**
  After identifying key site characteristics, roadway slope and approach operating speed values are used to determine the required sight distance for each approach. This distance is then measured at the site to determine if the required site distance for right and left turns is provided. For the horizontal curve, measure the approximate radius in office using an aerial photograph.

Intersection Sight Distance to the LEFT: Calculated Values		
Roadway Slope: Starting at the driver position, walk 250 feet to the left alongside the major roadway. At end, place SmartLevel on ground and record slope.	2%	
Approach Speed: Remaining 250 feet away, measure vehicle speeds. Use procedures in speed study section of ODOT Safety Investigation Manual.	33 mph (round to 35 mph)	
Required Sight Distance: Using the provided table, look up the required sight distance.	335 feet	
Approach Speed (mph)	Distance to Left (feet)	Distance to Right (feet)
30	290	335
35	**335**	390
40	385	445
Visibility Check	Visibility is provided for entire distance.	
Is Visibility Met?	Yes	

Intersection Sight Distance to the RIGHT: Calculated Values		
Roadway Slope: Starting at the driver position, walk 250 feet to the right alongside the major roadway. At end, place SmartLevel on ground and record slope.	3 %	
Approach Speed: Remaining 250 feet away, measure vehicle speeds. Use procedures in speed study section of ODOT Safety Investigation Manual.	35 mph	
Required Sight Distance: Using the provided table, look up the required sight distance.	390 feet	
Approach Speed (mph)	Distance to Left (feet)	Distance to Right (feet)
30	290	335
35	335	**390**
40	385	445
Visibility Check	Visibility is provided for entire distance.	
Is Visibility Met?	Yes	

- **Completed Worksheet:**

General Information	
Analyst Tom Hanks Agency ODOT Date Performed January 20, 2008	Time of Day 3:00 PM Analysis Year 2008 Jurisdiction Benton County
Site Characteristics	**In Office Work**
Crosswalk at Approach (Y/N) Y Sidewalk (Y/N) Y Vertical Curve (Y/N) N	Horizontal Curve (Y/N) Y Approximate Radius (if present) 730 feet and 790 feet
Plan Figure	
	
Required Sight Distance to LEFT	**Required Sight Distance to RIGHT**
Roadway Slope to Left 2% Left Approach Operating Speed 35 mph Required Sight Distance 335 feet	Roadway Slope to Right 3% Right Approach Operating Speed 35 mph Required Sight Distance 390 feet
Visibility LEFT	**Visibility RIGHT**
Clear Sight Distance Left (Y/N) Y List of Obstructions: None	Clear Sight Distance Right (Y/N) Y List of Obstructions: None
If the Stopped Driver Eye Position provides clear visibility of the measuring tape at the Roadway Object Position (and all points between that position and the Stopped Driver Eye Position), then visibility is met to the LEFT/RIGHT.	
Site Sketch	
Include: lanes, crosswalks, sidewalks, horizontal curves, vehicle movements, etc.	

A.2.4 *ISD EXAMPLE PROBLEM 4: HORIZONTAL CURVE 2*

- **Question**
  Does the intersection approach provide clear right turn and left turn sight distance?

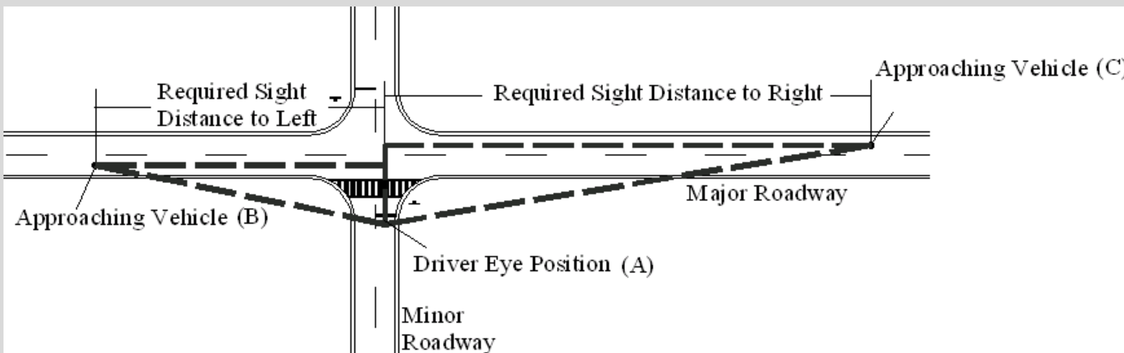
- **Site Characteristics**
  - Three-legged approach
  - 90 degree intersection angle
  - All vertical approaches are less than 2% slope and no vertical curves are present (i.e. level terrain)
  - One-way stop control (minor street)
  - Sidewalks on all approaches
  - Crosswalks present at minor street approach
  - Studied approach is the Eastbound approach (Westbound approach performed separately)

- **Methodology**
  After identifying key site characteristics, roadway slope and approach operating speed values are used to determine the required sight distance for each approach. This distance is then measured at the site to determine if the required site distance for right and left turns is provided. For the horizontal curve, measure the approximate radius in office using an aerial photograph.

Intersection Sight Distance to the LEFT: Calculated Values		
Roadway Slope: Starting at the driver position, walk 250 feet to the left alongside the major roadway. At end, place SmartLevel on ground and record slope.	3%	
Approach Speed: Remaining 250 feet away, measure vehicle speeds. Use procedures in speed study section of ODOT Safety Investigation Manual.	25 mph	
Required Sight Distance: Using the provided table, look up the required sight distance.	240 feet	
Approach Speed (mph)	Distance to Left (feet)	Distance to Right (feet)
20	195	225
25	**240**	280
30	290	335
Visibility Check	Visibility is provided for entire distance.	
Is Visibility Met?	Yes	

Intersection Sight Distance to the RIGHT: Calculated Values		
Roadway Slope: Starting at the driver position, walk 250 feet to the right alongside the major roadway. At end, place SmartLevel on ground and record slope..	3 %	
Approach Speed: Remaining 250 feet away, measure vehicle speeds. Use procedures in speed study section of ODOT Safety Investigation Manual.	24 mph (round to 25 mph)	
Required Sight Distance: Using the provided table, look up the required sight distance.	280 feet	
Approach Speed (mph)	Distance to Left (feet)	Distance to Right (feet)
20	195	225
25	240	**280**
30	290	335
Visibility Check	No	
Is Visibility Met?	Presence of shrubs blocks ability to see more than 260 feet down roadway.	

- **Completed Worksheet**

General Information	
Analyst Meg Ryan Agency ODOT Date Performed January 22, 2008	Time of Day 10:00 AM Analysis Year 2008 Jurisdiction Benton County
Site Characteristics	**In Office Work**
Crosswalk at Approach (Y/N) Y Sidewalk (Y/N) Y Vertical Curve (Y/N) N	Horizontal Curve (Y/N) Y Approximate Radius (if present) 425 feet
Plan Figure	
	
Required Sight Distance to LEFT	**Required Sight Distance to RIGHT**
Roadway Slope to Left 3% Left Approach Operating Speed 25 mph Required Sight Distance 240 feet	Roadway Slope to Right 3% Right Approach Operating Speed 25 mph Required Sight Distance 280 feet
Visibility LEFT	**Visibility RIGHT**
Clear Sight Distance Left (Y/N) Y List of Obstructions: None	Clear Sight Distance Right (Y/N) N List of Obstructions: Location of shrubbery prevents ability to see more than 260 feet to the right. Look into removal.
If the Stopped Driver Eye Position provides clear visibility of the measuring tape at the Roadway Object Position (and all points between that position and the Stopped Driver Eye Position), then visibility is met to the LEFT/RIGHT.	

Site Sketch
Include: lanes, crosswalks, sidewalks, horizontal curves, vehicle movements, etc.

A.2.5 ISD EXAMPLE PROBLEM 5: VERTICAL CURVE

- **Question**
  Does the intersection approach provide clear right turn and left turn sight distance?
- **Site Characteristics**
  - Four-legged approach
  - 90 degree intersection angle
  - Two-way stop control (minor streets)
  - Sidewalks on all approaches
  - Crosswalks present at minor street approaches
  - Studied approach is the Southbound approach (Northbound approach performed separately)
- **Methodology**
  After identifying key site characteristics, roadway slope and approach **operating** speed values are used to determine the required sight distance for each approach. This distance is then measured at the site to determine if the required site distance for right and left turns is provided.

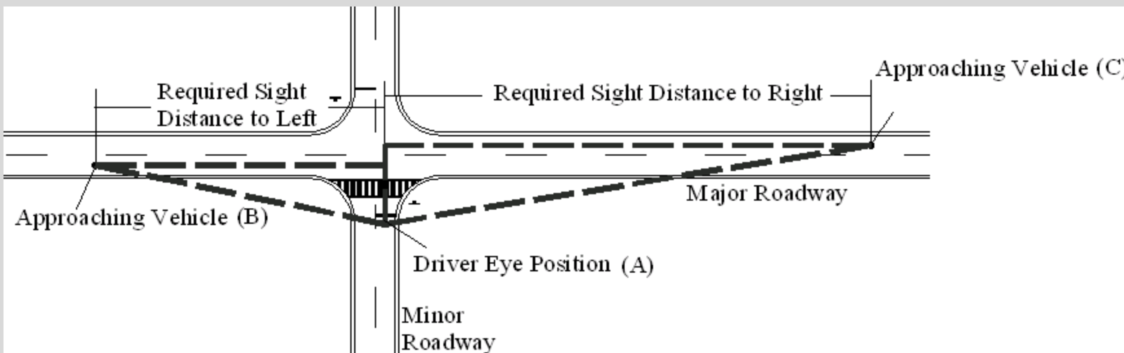
<table>
<tr><td colspan="3">Intersection Sight Distance to the LEFT: Calculated Values</td></tr>
<tr><td colspan="2">Roadway Slope: Starting at the driver position, walk 250 feet to the left alongside the major roadway. At end, place SmartLevel on ground and record slope.</td><td>3%</td></tr>
<tr><td colspan="2">Approach Speed: Remaining 250 feet away, measure vehicle speeds. Use procedures in speed study section of ODOT Safety Investigation Manual.</td><td>35 mph</td></tr>
<tr><td colspan="2">Required Sight Distance: Using the provided table, look up the required sight distance.</td><td>335 feet</td></tr>
<tr><td>Approach Speed (mph)</td><td>Distance to Left (feet)</td><td>Distance to Right (feet)</td></tr>
<tr><td>30</td><td>290</td><td>335</td></tr>
<tr><td>35</td><td>335</td><td>390</td></tr>
<tr><td>40</td><td>385</td><td>445</td></tr>
<tr><td colspan="2">Visibility Check</td><td>Visibility is provided for entire distance.</td></tr>
<tr><td colspan="2">Is Visibility Met?</td><td>Yes</td></tr>
</table>

<table>
<tr><td colspan="4">Intersection Sight Distance to the RIGHT: Calculated Values</td></tr>
<tr><td colspan="2">Roadway Slope: Starting at the driver position, walk 250 feet to the right alongside the major roadway. At end, place SmartLevel on ground and record slope..</td><td colspan="2">- 6 %</td></tr>
<tr><td colspan="2">Approach Speed: Remaining 250 feet away, measure vehicle speeds. Use procedures in speed study section of ODOT Safety Investigation Manual.</td><td colspan="2">35 mph</td></tr>
<tr><td colspan="2">Required Sight Distance: Using the provided table, look up the required sight distance.</td><td colspan="2">333 feet</td></tr>
<tr><td rowspan="2">Approach Speed (mph)</td><td colspan="3">Downgrades</td></tr>
<tr><td>3%</td><td>6%</td><td>9%</td></tr>
<tr><td>30</td><td>257</td><td>271</td><td>287</td></tr>
<tr><td>35</td><td>315</td><td>333</td><td>354</td></tr>
<tr><td>40</td><td>378</td><td>400</td><td>427</td></tr>
<tr><td colspan="2">Visibility Check</td><td colspan="2">No</td></tr>
<tr><td colspan="2">Is Visibility Met?</td><td colspan="2">Assuming a car height of 3.5 feet, the sag curve to the right limits visibility of cars more than 75 feet away from intersection.</td></tr>
</table>

- **Completed Worksheet:**

General Information	
Analyst: Richard Gere Agency: ODOT Date Performed: January 22, 2008	Time of Day: 1:00 PM Analysis Year: 2008 Jurisdiction: Benton County
Site Characteristics	**In Office Work**
Crosswalk at Approach (Y/N): Y Sidewalk (Y/N): Y Vertical Curve (Y/N): Y	Horizontal Curve (Y/N): N Approximate Radius (if present): N/A

Plan Figure



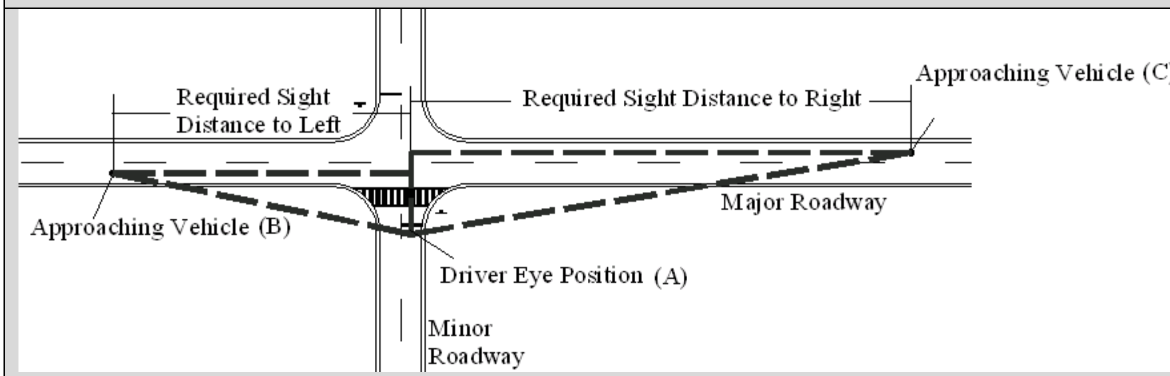
Required Sight Distance to LEFT	**Required Sight Distance to RIGHT**
Roadway Slope to Left: 3% Left Approach Operating Speed: 35 mph Required Sight Distance: 335 feet	Roadway Slope to Right: - 6% Right Approach Operating Speed: 35 mph Required Sight Distance: 333 feet
Visibility LEFT	**Visibility RIGHT**
Clear Sight Distance Left (Y/N): Y List of Obstructions: None	Clear Sight Distance Right (Y/N): N List of Obstructions: Assuming a car height of 3.5 feet, the sag curve to the right limits visibility of cars more than 75 feet away from intersection.

If the Stopped Driver Eye Position provides clear visibility of the measuring tape at the Roadway Object Position (and all points between that position and the Stopped Driver Eye Position), then visibility is met to the LEFT/RIGHT.

Site Sketch

Include: lanes, crosswalks, sidewalks, horizontal curves, vehicle movements, etc.

A.3 Intersection Sight Distance Worksheet

General Information	
Analyst ________________ Agency ________________ Date Performed ________________	Time of Day ________________ Analysis Year ________________ Jurisdiction ________________
Site Characteristics	**In Office Work**
Crosswalk at Approach (Y/N) _______ Sidewalk (Y/N) _______ Vertical Curve (Y/N) _______	Horizontal Curve (Y/N) _________ Approximate Radius (if present) ____
Plan Figure	
	
Required Sight Distance to LEFT	**Required Sight Distance to RIGHT**
Roadway Slope to Left ___________ Left Approach Operating Speed _____ Required Sight Distance ___________	Roadway Slope to Right ___________ Right Approach Operating Speed _____ Required Sight Distance ___________
Visibility LEFT	**Visibility RIGHT**
Clear Sight Distance Left (Y/N) _____ List of Obstructions: ______________ ____________________________ ____________________________	Clear Sight Distance Right (Y/N) ____ List of Obstructions: ______________ ____________________________ ____________________________

If Position A provides clear visibility of the measuring tape at location B or C (and all points between that), then visibility is met to the left (Position B) and/or right (Position C).

INTERSECTION SIGHT DISTANCE WORKSHEET (continued)

Required Sight Distance Table (less than 3% grade)

Approach Speed (mph)	Distance to Left (feet)	Distance to Right (feet)	Additional Comments
15	145	170	
20	195	225	
25	240	280	
30	290	335	
35	335	390	
40	385	445	
45	430	500	
50	480	555	
55	530	610	
60	575	665	
65	645	720	
70	730	775	
75	820	830	
80	910	910	

Site Sketch
Include: lanes, crosswalks, sidewalks, horizontal curves, vehicle movements, etc.

A.4 Other types of Sight Distance

In addition to intersection sight distance, four other types of sight distance exist: decision sight distance, stopping sight distance, passing sight distance, and sign legibility/message comprehension distance. These are further explained in the following sections, as according to AASHTO *A Policy on Geometric Design of Highways and Streets, 2018*.

A.4.1 Stopping Sight Distance

Stopping sight distance (SSD) is the distance to an obstacle or hazard necessary when traveling at the design speed of the roadway to stop at before reaching the stopping requirement. It is defined as the sum of perception reaction time (PRT) is and the amount of time to completely stop. Due to any roadway location potentially acting as a hazard, stopping sight distance should always be provided during safety investigations. Stopping sight distance is particularly important in high-priority locations, as suggested in *NCHRP Report 600*:

- Changes in lane width
- Lateral Clearance reductions
- Hazardous side slopes
- Narrow bridges
- Roadside hazards
- Unmarked crossovers
- Crosswalks (Unlit and high-volume)
- Areas with nearby parked vehicles
- Crest vertical curves
- Horizontal curves
- Driveway

It is important to note that if operating speeds exceed design speeds, SSD calculations may be inadequate. Several roadway characteristics, such as lane width, alignment, and other roadside elements, effect operating speed and should be considered when determining stopping sight distance.

A.4.2 Decision Sight Distance

Decision sight distance (DSD) represents a longer distance than stopping sight distance to consider complex or instantaneous decisions in situations difficult to perceive and/or with unexpected maneuvers. These extra layers of complexity introduce extra components to consider when determining DSD. These include the distance to perceive the situation, distance to select a speed and path, and distance to initiate the maneuver. As a result, using DSD is appropriate in challenging situations in which drivers require extra time to plan and perform a maneuver or compensate for any errors in doing so. Such situations may include sites with high traffic volumes, poor weather conditions, high driver workload (reading signs, merging, etc.) or limited views from trucks or off-road clutter.

A.4.3 PASSING SIGHT DISTANCE

Passing sight distance (PSD) defines the distance required for a following vehicle to overtake the leading vehicle without cutting off the passed vehicle and without interfering with oncoming traffic. PSD contains two components: a perception reaction time (beginning with available PSD and ending when the right tire crosses the center line) and the maneuver time (ending when the left tire crosses the centerline). Passing sight distance is most appropriate in the context of two-lane highways often in rural areas.

A.4.4 SIGN LEGIBILITY/MESSAGE COMPREHENSION DISTANCE

Legibility distance is the distance at which a sign must be readable and comprehendible. According to the MUTCD, legibility distance must consider several factors, such as inattention, blocked views, poor weather, inferior eyesight, and other reasons leading to slowed reading speeds. Sign legibility and comprehension distance is particularly appropriate in situations pertaining to letter height.

Appendix B Instructions for Using SIM Workbook

A three-part online training module "SIM Worksheet Overview" provides a narrated, detailed, step-by-step guide for using the worksheets including downloading the crash data and entering it in the worksheet. The following is additional documentation for completing the worksheets. Investigators need to complete data entry on the yellow highlighted tabs in the list below. The worksheet contains the following tabs:

- **Cover**
  - Summary information and selections
- **SIM Report**
  - Documentation of investigation
- SimWork_Segment
  - Patterns analysis based on functional classification selected on Cover tab.
- SimWork_Int1, SimWork_Int2, … SimWork_Int10
  - Note tabs are unhidden based on checkbox on Cover tab.
  - Patterns analysis based on intersection type selected on Cover tab.
- **RAW_SEG**
  - Paste in raw crash data for segment
- **RAW_INT1, RAW_INT2….. RAW_INT10.**
  - Note tabs are unhidden based on checkbox on Cover tab.
  - Paste in raw crash data for segment.
- DATA_SEG
  - Macro completes crash data processing and frequency
- DATA_INT, DATA_INT2, …DATA_INT10
  - Note tabs are unhidden based on checkbox on Cover tab.
  - Macro completes crash data processing and frequency
- CrashRate_Calc-Intersection
  - Calculations based on data,
- CrashRate_Calc-Segment
  - Calculations based on data
- Segments-Patterns
  - Input and reference data only. Patterns for all functional class roadways
- Intersection-Patterns Input and reference data only
  - Input and reference data only. Patterns for all functional classification roadways

B.1 Cover Tab

The cover sheet contains the project summary information. Data entered on this sheet is propagated to other tabs in the worksheet. The "RESET" button will clear all the yellow-shaded cells. The investigator should complete the information that defines the location for investigation on the "COVER" tab.

In the SIM Worksheet, cells are color coded with the following:

Green	Auto-Populated Field
Yellow	Recommended (Optional) Field
Light red	Required Field

The investigator should complete all light red (required) and relevant yellow (optional) shaded cells.

- ***Location Information**:* The basic information about the project location.
- ***Segment and Crash Data Milepoints***: A critical selection to using the worksheets requires the investigator to select the appropriate "Road Character" and "Functional classification" from the drop-down selection. This selection is critical because the observed crash frequencies are compared to the proportions of the matching road character, functional classification, and intersection type that is selected. Note that in a limited number of situations a investigator may want to compare the roadway to a specific functional classification. For example, a roadway segment near the urban boundary that is functionally classed as RURAL may be more comparable to an URBAN functional classed roadway. The investigator should make a note of this in the worksheet and select the most appropriate comparison.
- ***Intersections*** – The name and type of up to 10 can be included in the workbook. The analyst should enter the intersection name, then click the check box next to the intersection AADT value. This will unhide the tab "SimWork_Int#" and "RAW_INT#" where # is the intersection number.
- ***SPIS Information*** - A history of the SPIS values can be entered in this section. This information will appear on the SIM Report Tab.
- ***High Risk Rural Road*** - can be selected by the investigator if it meets the MAP21 criteria: "*any roadway functionally classified as a rural major or minor collector, or a rural local road*"

The traffic volume information is used to calculate rates. For segments, enter the AADT for the segment. Each intersection can have a volume entered. The investigator should enter the average of three years of AADT if available, or as many years as available. The three most recent years of traffic volumes are needed for the crash rate calculation. This data can be obtained where described as follows:

- ***AADT - Segments***: If the segment spans multiple AADT ranges, compute a weighted average of the ADT. A weighted average of AADT can be calculated using the length and ADT values. For example, if a 2-mile section has an ADT of 5,000 and a 1 mile section has an ADT of 6,000 the weighted average is (2 x 5000 + 1 x6000)/ (2+1) = 5,333 ADT.
- ***AADT (entering) for Intersections:*** Be sure to calculate the entering volume. Minor street volume may be difficult to obtain and may require contacting the local jurisdictions. See the examples in the SIM Manual for determining entering volumes.

B.2 RAW DATA TABS AND CRASH DATA PREPARATION

The crash patterns have been calculated for segments (excluding intersection crashes) and for intersection crashes. It is very important to prepare the PRC data such that segment crashes and each associated intersection to be investigated are sorted.

B.2.1 PRC REPORT DOWNLOADING

Download the PRC Report in Excel Format for the mile point range to be considered.

- Segment Crashes – to download crash data for segments, follow these steps:
  - Go to the TDS – Crash Reports website

    https://tvc.odot.state.or.us/tvc/

  - For State Highways, obtain data from the "Highways" tab
    1. Select highway segment, based on the Oregon highway name and number, from drop-down menu.
    2. Enter beginning mile point number and ending mile point number.
    3. Enter date range.
    4. Select "Excel Format."
    5. Download data by selecting the report type "Comprehensive PRC-11x17 CDS380."
- Intersection Crashes – to download crash data for intersections, follow the same steps outline above.

Investigators should note that the crash database does not have information regarding jurisdictional transfers or changes due to construction. It is a good idea to explore whether significant changes have been made to the highway during the period investigated before using the crash pattern worksheets.

B.2.2 CRASH DATA ENTRY

The crash data should be entered as described below:

- Crash data is entered in the “RAW_SEG” or “RAW_INT1”, “RAW_INT2”, to “RAW_INT10” tabs. Tabulation of the crash data onto the SIM worksheets is automated. To enter the data, complete these steps:
  - Download the PRC Report in Excel Format (must use Internet Explorer or Microsoft Edge).
  - Copy the entire PRC report by selecting the entire sheet using either CTRL+C or the COPY option in Excel.
  - Select the appropriate “RAW_” tab in the SIM Worksheet.
  - Move the Excel selection box to cell A1.
  - Paste the PRC data in cell A1.
  - Click the “Extract Month” button .
  - Return to the “DATA_” tab in the SIM Worksheet.
  - Click the "Process Copied Data" button .
- Next, select the worksheet tab for the appropriate facility (either “SIMWork_Segment” for segments or “SIMWork_IntX” for intersections).

B.3 SIM REPORT TAB

The SIM Workbook contains a SIM Report tab that is to be the final summary of the investigation process. The form is intended to also serve as a tracking mechanism for corrective action. Nearly all of the information required for the report should have been obtained or analyzed as a part of the investigations process.

- ***Location information***: The information is pulled from the Cover tab. The information includes Region; District; County; City (optional); Route Number; Hwy Name; Road Character; Facility Type. If the investigation is at an intersection, there is space to note the intersection locations (up to 4).
- ***Approvals*** - The approval section contains the date the investigator completed the form, who (if anyone) reviewed and approved the investigation and recommendation, and their approval date. It is important to check if recommended solutions have delegated authority processes.
- ***Crash Rate and Notable Crashes****:* - The investigator should note analysis and interpretation of the crash rate in this area. If there were notable crashes, they can be described here.
- ***Notes (Crash Patterns/Improvements)*** - The investigator should for a narrative description of the problem that was identified by the investigations. Possible or alternative recommendations can also be described. The narrative should be clear and concise and summarize the results of the diagnosis and field investigations. For future before-after evaluations, it is important to clearly define the type of

crashes and the location that was being targeted. For example, if the addition of a left-turn lane was proposed for a rural highway, target crashes would likely be rear-end, turning, and possibly angle crash types.

- ***Recommendation Narrative -*** The purpose of this section is to document the progress of implementing the recommended solutions. The recommendation narrative should be written such that there is a clear link established between the crash or safety problem identified and the proposed solution (see Section 6.5). A possible recommendation is "NO WORK." The milepost range should define the area where the safety improvement was constructed. If the location cannot be described simply by milepost, additional notes can be added about the location.
- ***Implementation*** - The type of work recommended (maintenance, as part of project, stand-alone, quick-hit, or no work) is needed. The improvement types are broad categories required for the Federal reporting requirements. If more than one type of improvement is proposed, the work that is the greatest percentage of the total project budget should be entered. The corrective action can be performed in a number of ways:
  - Maintenance action – if the recommended improvement is relatively minor and low cost, the work can be done as part of normal maintenance crew activities.
  - Quick-hit safety improvement – a lower cost improvement that exceeds maintenance budgets but can be funded from an allocation from the Highway Safety Engineering Committee (HSEC).
  - Improvements as part of a larger project - if a known STIP project will be undertaken near the investigated section in the near future, it may be possible to integrate the improvements. If the recommendation meets all requirements, the improvement can be funded from safety funds.
  - ARTS project funding
  - Stand-alone safety project – a stand-alone STIP project funded from safety funds that must meet all of the specified requirements.
- ***Segment Crash Totals*** – Summary information, note if any of the severity categories are high and should be "flagged".
- ***Geometry and Operations*** Basic operational data can be captured and noted in this section
- ***Field Visit and Historical Information -*** Whether or not a field visit was conducted for this particular investigation should be documented in this section. Whether or not a previous investigation was conducted should also be noted here.

Appendix C Online Training Materials Case Studies

Three case studies have been prepared to demonstrate how to use the SIM process and worksheets. These case studies are taken from actual investigations performed by Region traffic investigators. The online training materials provide a self-paced, step-by-step example of using the worksheet and the investigative process. The slide PDFs include additional helpful data such as images, collision diagrams, and other data.

C.1 Case Study #1 – OR-43 and Richardson Ct.

- **Description**
  Using a case study, this training module provides a detailed process on the use of the Safety Investigation Manual Worksheet. This process includes downloading the necessary crash data, obtaining site-specific information (functional classification, traffic volume), gathering images of current conditions, interpreting output from the worksheet and comparing to the corresponding collision diagram, and using specific resources to identify potential countermeasures.
- **Slides**
  Case Study #1 (pdf)
- **Supplemental Materials:**
  Crash Data at OR-43 and Richardson Ct.

C.2 Case Study #2 – US-20 and Barclay Dr

- **Description**
  This training module introduces a case study location and study period. For training, you will complete all steps detailed in Case Study #1. Upon completion, this module will summarize findings of the safety investigation.
- **Slides**
  Case Study #2 (pdf)
- **Supplemental Materials**
  Crash Data at US-20 and Barclay Dr.

C.3 Case Study #3 – OR-22 and Perrydale Rd

- **Description**
  This training module introduces a case study location and study period. For training, you will complete all steps detailed in Case Study #1. Upon completion, this module will summarize findings of the safety investigation.

- **Slides**
  Case Study #3 (pdf)
- **Supplemental Materials**
  Crash Data at OR-22 and Perrydale Rd (segment)
  Crash Data at OR-22 and Perrydale Rd (intersection)