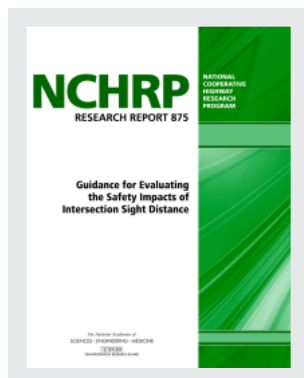


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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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## NCHRP RESEARCH REPORT 875

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# Guidance for Evaluating the Safety Impacts of Intersection Sight Distance

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TRANSPORTATION RESEARCH BOARD

2018

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## NCHRP RESEARCH REPORT 875

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## FOREWORD

By **Stephan A. Parker**

Staff Officer

Transportation Research Board

*NCHRP Research Report 875: Guidance for Evaluating the Safety Impacts of Intersection Sight Distance* is a resource for practitioners involved in the planning, design, operations, and traffic safety management of stop-controlled intersections. It provides information on how to estimate the effect of intersection sight distance (ISD) on crash frequency at intersections and describes data collection methods and analysis steps for making safety-informed decisions about ISD. The guidance also provides basic information on the importance of ISD that can be shared with decision makers and other stakeholders.

Accompanying the report, *NCHRP Web-Only Document 228: Safety Impacts of Intersection Sight Distance* documents the methodology and presents the results from the underlying research on estimating the safety effects of ISD at stop-controlled intersections. To establish the relationship between ISD and safety at stop-controlled intersections, crash, traffic, and geometric data were collected for 832 intersection approaches with minor-road stop control in North Carolina, Ohio, and Washington.

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The provision of appropriate ISD is an important element in intersection design. The approach to the determination of ISD in AASHTO's *A Policy on Geometric Design of Highways and Streets* (known as the "Green Book") is based on gap-acceptance developed in the 1996 *NCHRP Report 383: Intersection Sight Distance*. That approach includes the ability to more easily calculate ISD for both passenger cars and trucks by allowing the selection of an ISD "design vehicle." Calculations of ISD using that approach yield different results from those calculated with earlier methods. However, past research efforts to analyze and quantify the safety impacts of ISD have produced inconsistent results, making it difficult to fully evaluate the different approaches. The quantification of safety impacts allows better design evaluations that include variations in available ISD. It also provides the opportunity to evaluate the potential safety impacts of the ISD criteria in the Green Book.

Under NCHRP Project 17-59, a team led by VHB was asked to (1) identify appropriate definitions and methods to measure ISD, (2) quantify the relationship between safety and available ISD (i.e., crash modification factors and other appropriate functions), and (3) develop guidance for transportation agencies on how to apply these functions to evaluate the safety impacts of available sight distance. The project team undertook a phased approach to gather information to develop the guidance. First, they reviewed existing ISD practices and relationships. Next, they developed a study design for quantifying the relationships of ISD and safety, along with a data collection plan. The team used the approved research plan to conduct a critical review of the current practices in uncontrolled intersection methodology, to collect field data, and to assemble and model the data collected. Models were refined through additional data collection and in testing the draft guidance with key stakeholders.

The team received comments from the NCHRP Project 17-59 panel on key deliverables in each stage of the guidelines' development. These comments were integral to shaping the structure and content of the guidance.

The guidance and methodology report (*NCHRP Web-Only Document 228* and a Power-Point presentation describing the entire project) are available at [www.TRB.org](http://www.TRB.org) by searching for "*NCHRP Research Report 875*."



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## SUMMARY

# Guidance for Evaluating the Safety Impacts of Intersection Sight Distance

Most multiple-vehicle crashes at three- and four-leg intersections with stop control on the minor road can be classified as either gap-acceptance crashes or traffic control device violations (e.g., stop sign violations), with gap-acceptance crashes generally occurring more frequently. Gap-acceptance crashes include several crossing-path crash types: right turn into path, left turn into path, left turn across path, and straight crossing path. Intersection sight distance (ISD) is a key design element at intersections. It contributes to the ability of drivers on the minor road to identify an appropriate gap for departing from the intersection and entering or crossing the major road. Designs that provide adequate ISD also allow drivers on the major-road approach to see stopped vehicles on the minor-road approach so that they can be more aware and prepare to slow or stop if needed.

*A Policy on Geometric Design on Highways and Streets*, 6th Edition, also known as the Green Book (AASHTO 2011), provides design criteria for minimum sight distances, including ISD. The ISD criteria in the Green Book vary according to the minor-road traffic control, design speed of the major road, and turning movement from the minor road. The minimum ISD values are based on driver gap-acceptance behavior. Assumptions are made on physical conditions (e.g., object height and driver eye height), vehicle performance capabilities, and driver behavior. Designing an intersection with the minimum required ISD or above does not necessarily mean that crashes related to gap-acceptance behavior will not occur. Available ISD may change over time (e.g., through development of adjacent land parcels, overgrown vegetation, or seasonal crop growth). Additional sight distance may also be needed in certain situations. Finally, adequate ISD alone is not all a driver needs to identify and use a suitable gap.

The overall objectives of this research were to (1) estimate the relationship between available ISD and safety and (2) develop guidelines for transportation agencies to use when making decisions about ISD.

Data were gathered from a total of 832 intersections in North Carolina, Ohio, and Washington. Variables characterizing crash experience, roadway features, and traffic/operations were collected using geographic information system (GIS) databases, Highway Safety Information System (HSIS) data files, and field measurements. The data were then analyzed using multivariable count regression models. The safety effects of available ISD differed by two-way annual average daily traffic (AADT) on the major roadway as well as by speed limit on the major roadway; therefore, main effects and interaction terms were included in final model specifications. Target crashes were defined as those where a vehicle on the minor road collided with a vehicle on the major road. Target crash counts were associated with specific, measured values of an approach-level ISD (i.e., one observation of crash frequency in the database represents the crash frequency for one minor-road and major-road approach combination).

## 2 Guidance for Evaluating the Safety Impacts of Intersection Sight Distance

Estimation results for two multivariable count regression models are reported:

- Total (i.e., all severities) target crashes, and
- Target fatal and injury crashes.

Models for target fatal and incapacitating injury crashes, target angle crashes, and target daytime crashes were also explored and uncovered similar trends between the frequency of these crash types and ISD. In some cases, the statistical significance of estimated model parameters decreased due to the smaller numbers of these more refined target crash type definitions.

Results suggest that the expected number of target crashes is associated with available ISD. Target crash frequencies increase as available ISD decreases. The results of this research also suggest that ISD is associated with expected crash frequency in a nonlinear fashion. The sensitivity of the expected number of target crashes to changes in ISD is highest when ISD is shorter, and decreases as ISD increases (i.e., the safety benefit of increasing ISD from 300 to 600 ft is substantially larger than the safety benefit of increasing ISD from 1,000 to 1,300 ft). The results also suggest that the impacts of ISD on crash frequencies vary as a function of the major- and minor-road traffic volumes and the major-road speed limit. The sensitivity of the expected number of crashes to changes in ISD increases as traffic volumes and speed limits increase. Crash modification functions (CMFunctions) for each of the target crash types were estimated using the regression models. Applicability of the CMFunctions varies by available ISD, major-road AADT, and speed limits available in the dataset.

The final step in the study was to translate the research results into a series of charts for practitioners to efficiently reference when conducting an intersection safety analysis focused on ISD. The following charts are provided:

- ISD CMFunctions for the expected number of total (i.e., all severities) target crashes at minor-road, stop-controlled intersections with major-road speed limits of 35, 40, 45, 50, 55, and 60 mph; and
- ISD CMFunctions for the expected number of target fatal and injury crashes at minor-road, stop-controlled intersections with major-road speed limits of 35, 40, 45, 50, 55, and 60 mph.

The charts are included in this guidance document, which also includes a summary of key background information on ISD and step-by-step instructions on how and when to use the ISD CMFunction charts. Additional information on low-cost countermeasures and other ISD-related resources is also provided for practitioners to assist them in identifying other measures that may be applicable for making intersection safety improvements.

## CHAPTER 1

# Introduction

## Purpose of the Guidance

Intersection sight distance (ISD) is a key design element at intersections. ISD is the actual, measurable unobstructed view a driver has of an intersection, including traffic control devices and views along the intersecting roadways. Adequate ISD at intersections with stop control on the minor road contributes to the ability of drivers stopped on the minor road to identify an appropriate gap for departing from the intersection and entering or crossing the major road. Designs that provide adequate ISD also allow drivers on the major-road approaches to see stopped vehicles on the minor road and prepare to slow or stop if needed. *A Policy on Geometric Design of Highways and Streets*, 6th Edition, also known as the Green Book, provides design criteria for different types of sight distances, including ISD (AASHTO 2011). The ISD criteria in the Green Book vary according to traffic control on the minor road, design speed of the major road, and turning movement from the minor road. Minimum ISD values are based on driver gap-acceptance behaviors. Assumptions based on field observations are made about physical conditions (e.g., object height and driver eye height), vehicle performance capabilities, and driver behavior. Information does not currently exist in the Green Book or the *Highway Safety Manual* (HSM; AASHTO 2010) on how ISD affects the expected frequency and severity of intersection crashes.

*NCHRP Research Report 875: Guidance for Evaluating the Safety Impacts of Intersection Sight Distance* has been developed as a resource for practitioners who are involved in evaluating intersection safety. It describes data collection methods and analysis steps for making safety-informed decisions about ISD. The safety performance evaluation methods draw on concepts from the HSM; therefore, a general understanding of the HSM methods is important for the appropriate application of the crash modification factors (CMFs) for ISD.

## Intended Audience

This guidance is intended for practitioners involved in the planning, design, operation, and traffic safety management of stop-controlled intersections. It provides information for practitioners on how to estimate the effect of ISD on crash frequency at intersections. The guidance also provides basic information on the importance of ISD that can be shared with decision makers and other stakeholders.

## Guidance Organization

Following the introduction and overview, the guidance presents ISD material in four main sections:

- Measuring available ISD and other critical information,
- Safety performance and ISD,

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- Example applications of the content of this guidance, and
- Other countermeasures and resources.

The final chapter provides the base equations from the research.

### Guidance Development and Research Objective

This guidance is a product of NCHRP Project 17-59, “Safety Impacts of Intersection Sight Distance.” The overall objectives of this research project were to determine the relationship between safety (measured as expected crash frequency) and available ISD and to develop guidelines for transportation agencies to consider when making decisions about ISD. The objectives were accomplished through several research activities centered on extensive field testing and analysis of data collected in North Carolina, Ohio, and Washington. The data were modeled to explore the relationship between the field-measured ISD and expected crash frequency at minor-road stop-controlled intersections. While the information presented in subsequent chapters focuses on a limited number of variables and intersection characteristics, many different types of sites and risk factors were included in the model development. The studied sites were diverse in characteristics such as area type, number of major-road lanes, number of intersection legs, presence of a median on the major road, and speed limit. This allows the information provided in this guidance to be applied to a myriad of intersections with a range of characteristics.

A summary of all the research activities conducted as part of this project can be found in the technical report for NCHRP Project 17-59, published as *NCHRP Web-Only Document 228*.

### Scope of This Guidance

The information presented in this guidance is intended for three- and four-leg intersections with stop control on the minor-road approaches. It is applicable to both planned and existing conditions.

### How to Use This Guidance

The entire guidance document should be reviewed before application. “Practitioner Tips” text boxes throughout the document provide information and simple step-by-step instructions on how to put the information into practice.

#### Practitioner Tips: Determine Appropriateness of the Guide

This guidance will be useful if one or more of the following situations exist:

- Sight distance has previously been noted as an issue or factor related to crashes, and countermeasures to improve ISD are being considered. Sight distance issues can be identified informally through public feedback or more formally through safety reviews such as road safety audits.
- There is a proposed change that may affect intersection sight distance at a specific intersection.
- Design alternatives are being considered that vary in ISD, and a comparison of the expected crash performance of the alternatives is needed.
- An agency is considering systemic approaches to improve intersection safety.

This guidance can be used to inform decision making that is part of the following activities:

- Conducting performance-based planning and design,
- Making Highway Safety Improvement Program project selections,
- Performing traditional and systemic road safety management, and
- Implementing recommendations stemming from road safety audits.

Additionally, it can be used as part of alternatives analysis when considering multiple options for treatment (e.g., informing an economic analysis of tree removal versus implementing geometric changes).

Engineering judgment should be used in interpreting and implementing the results of this guidance. There are many variables that must be considered when examining ISD, and the practitioner should balance the information presented here with his or her knowledge and understanding of a particular intersection.

## Definitions and Acronyms

Understanding the terms discussed in this section is essential for any practitioner interested in putting this guidance to use.

Drivers on the minor-road approach of an intersection with minor-road stop control must judge the speed and distance of approaching vehicles to select an appropriate gap in traffic before entering or crossing the major road. *Gap-acceptance* crashes are crashes that result at these intersections when drivers on the stop-controlled approach attempt to enter an insufficient gap in traffic on the major road and enter the intersection into the path of an oncoming vehicle. A driver's ability to select an appropriate gap is affected in part by the available *intersection sight distance*, which is the actual, measurable unobstructed view a driver has of an intersection, including traffic control devices and views along the intersecting roadways. Adequate ISD at intersections with minor-road stop control contributes to the ability of drivers stopped on the minor road to identify an appropriate gap for departing from the intersection and entering or crossing the major road. Designs that provide adequate ISD also allow drivers on the major-road approaches to see stopped vehicles on the minor road and prepare to slow or stop if needed.

This guidance refers to several considerations related to ISD. *Design ISD* is the minimum ISD as identified in the Green Book. *Existing (or available) ISD* is the ISD as measured in the field. *Proposed ISD* is the ISD that is being considered and is expected to result from a change in the intersection environment such as the removal of trees or other objects in the sight triangle.

For the purpose of this guidance, the *minor road* is the roadway that is stop controlled at the intersection. Drivers on the minor-road approaches must yield to vehicles approaching on the *major road*, which is uncontrolled at the intersection. The minor road defined in this way usually has lower traffic volumes than the major road. This guidance is still applicable if the minor road has a higher traffic volume than the major road if the ratio between the volumes of the major road and minor road is close to 1.00. Judgment should be used if the volume of the minor road significantly exceeds that of the major road.

In the field, available ISD is measured on the approach from the minor road. The *decision point (DP)* is defined as the location where drivers on the minor road stop their vehicles, view approaching traffic, and decide when to enter the intersection. *Clear sight triangles* extending from the decision point must be provided along both the major and minor approaches. This

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is illustrated in Figure 1. The Green Book includes a detailed discussion of how the minimum design ISD for an approach is determined (AASHTO 2011).

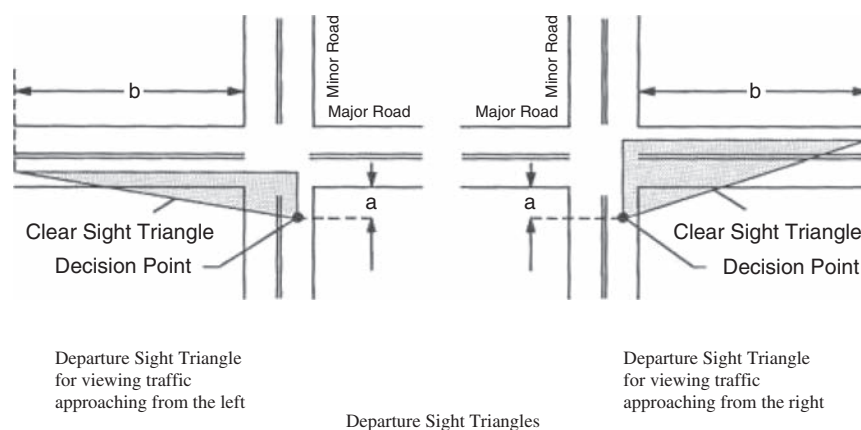
This guidance provides practitioners useful *crash modification factors* for estimating the change in the expected number of crashes after implementing a given countermeasure at a specific site—in this case, increasing or decreasing ISD. A CMF is an index of the expected change in safety performance following a modification in a traffic control strategy or design element. CMFs can be used to compare the safety effectiveness of changes to available ISD or to compare different decisions as part of an alternatives analysis. More information on implementing CMFs can be found at the FHWA's webpage for CMFs in Practice (<http://safety.fhwa.dot.gov/tools/crf/resources/cmf/>).

The CMFs included in this guidance take the form of *CMFunctions* that consider the following characteristics of ISD:

- The sensitivity of the expected number of target crashes to changes in ISD is expected to be highest when ISD is shorter and decrease as ISD increases (e.g., the safety benefit of increasing ISD from 300 to 600 ft is expected to be substantially larger than the safety benefit of increasing ISD from 1,000 to 1,300 ft).
- The sensitivity of the expected number of target crashes to changes in ISD depends on major-road speed limit and two-way average annual daily traffic (AADT).

CMFunctions are based on cross-sectional regression models developed from numerous observations to estimate the effect on expected crash frequency based on changes in key variables. In this case, the CMFunctions were developed by collecting data (including ISD) at more than 800 intersection approaches and comparing the number of crashes that occurred across these intersections.

The CMFs in this guidance are applied at the *intersection approach level*. There are two different ISDs for each minor-road approach leg of an intersection: one looking left and one looking right. At a four-leg intersection, there are four different minor approach ISDs. These ISDs can vary greatly. Improvement to the ISD at an intersection would involve consideration of each direction on each approach separately in the selection of a countermeasure. Therefore, the CMFs in this guidance are intended to be applied to crashes associated with an individual approach direction.



Source: AASHTO 2011

**Figure 1. Sight triangles.**

The CMFs in this guidance are applied to *target crashes*. Target crashes are defined as crashes involving a vehicle from the major road colliding with a vehicle entering from a minor road. This guidance also provides tools to analyze subsets of target crashes. For example, a *target fatal and injury crash* in this document is defined as a target crash that results in at least one injury or fatality.

In addition to the terms discussed in this section, practitioners should familiarize themselves with the following acronyms and abbreviations used throughout the guidance:

AADT	Average annual daily traffic
CMF	Crash modification factor
CP	Critical point
GIS	Geographic information system





## CHAPTER 2

# Measuring Sight Distance and Other Critical Information

The purpose of this chapter is to provide users with instructions on collecting field data for the available ISD as well as other relevant data needed to use the guidance. The focus of this guidance is on existing intersections; however, the same field-collected values described here could be determined as part of the design process for a proposed intersection. There are two different scenarios in which the guidance could be used at the design stage. In the first, changes are proposed to the design of an existing intersection or the surrounding environment. This may include removing an obstruction that has been identified either by the public as a hazard or by a high crash rate. The second is when considering alternatives for a new or reconstructed alignment or intersection.

**Tool Box: Standard ISD**

The CMFs/CMFunctions in this guidance are based on the ISD measured at a point on the minor road that is set 14.5 ft back from the edge of the closest through-vehicle travel lane on the major road, as described in the Green Book (AASHTO 2011).

There are three primary areas of focus in this chapter: ISD, traffic volumes, and intersection characteristics. Each subsection includes detailed instructions on the best practices for data collection, measurement methods, and other information needed for determining a CMF.

The information presented in this chapter was developed based on the results of an extensive evaluation and data collection effort aimed at identifying a method to cost-effectively yet consistently collect ISD, volume, and intersection characteristics in the field. Additional detail is published in *NCHRP Web-Only Document 228*.

**Practitioner Tips: Recommended Equipment**

- Laser rangefinder with 4x magnification scope mounted 42 in. above the ground using a monopod or similar. This is the sighting height.
- Metal target that is 14 in. by 14 in., such as a slow-moving-vehicle sign or sign similar in size and color, mounted on a post or stick so that the target can be positioned 42 in. above the ground. This is the target height.
- A measuring wheel.
- Safety vests for all members of the field collection team.
- Cell phones, two-way radios, or similar devices for the field collection team members.
- Any necessary traffic-control measures (such as portable survey crew signs or flaggers), depending on the characteristics of the intersection and the operating procedures of the collecting agency.



## Data Collection Approach

Two staff members are required to collect ISD in the field using the approach described here. One person is called the *targeter*, and the other is the *sighter*. The two-person team assembles the required equipment before heading out to the field.

Data collection starts at the intersection by the sighter measuring a point on the minor-road approach that is 14.5 ft back from the edge of the closest vehicle travel lane of the major road and 4 ft to the right of the centerline of the minor-road approach. The Green Book refers to this as the decision point, as previously defined (AASHTO 2011). This point is illustrated in Figure 2 and represents the location from which drivers on the minor approach, stop, and view traffic to select an appropriate gap and enter the intersection.

The sighter is positioned at the DP with the laser range finder placed 42 in. high using a monopod or similar device. The targeter walks away from the intersection on the shoulder of the major road in the direction that is being measured carrying the metal target and the measuring wheel. The targeter stops periodically to communicate with the sighter over the radio about the sight distance (e.g., “can you still see me?”). The targeter stops when the point is reached where the full metal target (positioned in the center of the nearest major-road through lane) just begins to disappear from the view of the sighting person while looking through the rangefinder’s scope. This location becomes the critical point (CP) for that direction of view.

If the major road between the CP and DP is characterized as a tangent (i.e., it lacks horizontal curvature), then the rangefinder is used to measure the distance between the two. This is the ISD. If the major road includes one or more horizontal curves between the CP and DP, then the targeter uses the measuring wheel to measure the ISD by walking along the major road from the CP to the DP.

If the target is still in view beyond a quarter of a mile (1,320 ft) from the DP, the ISD is considered more than sufficient. This establishes a practical limit for field collection.

The field collection process is summarized in Figure 3.

All field personnel should exercise caution when collecting this information. If traffic volumes or other conditions render it unsafe to position the equipment at the intended locations of the CP or DP, then the data collectors can:

- Reposition themselves as close to the intended positions as possible,
- Employ traffic control measures for a short period of time while the ISD is measured, or
- Use a three-person field team with one person working as a spotter for traffic.

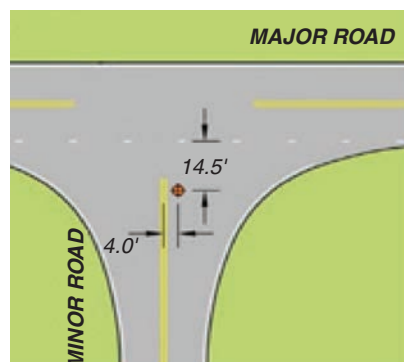
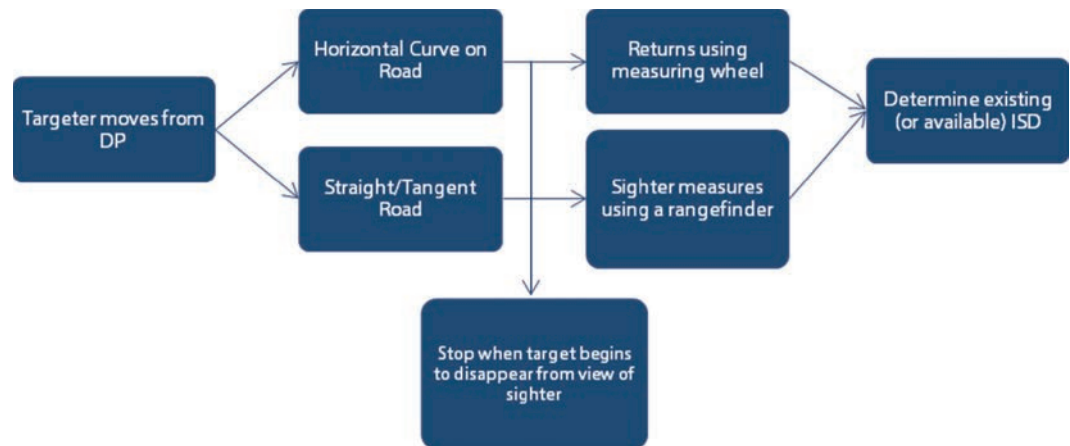


Figure 2. Decision point.

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**Figure 3.** Data collection approach for measuring intersection sight distance.

### Traffic Volumes

The safety effect of ISD is influenced by two-way AADT and the speed limit on the major street. Generally, the number of crashes increases as the major-road and minor-road volumes increase. Safety performance is expected to be more sensitive to ISD when the major-road AADT and speed limit are higher. To use the CMF graphics in Chapter 3 of this guidance, major-road traffic volumes and speed limits are needed. AADT is needed for the major road; however, a detailed turning movement count is not needed.

There are two overarching strategies for gathering traffic volumes: use of existing data sources and data collection. Traffic volumes can also be estimated for design applications or future analysis.

### Existing Data Sources

Practitioners are encouraged to access local or state databases before exploring options for field data collection. Many states, metropolitan planning organizations, rural planning organizations, and regional transportation planning organizations, as well as some local agencies, maintain detailed GIS maps of traffic volumes expressed as AADT or, potentially, vehicle miles traveled. These may be available in online databases, maps, or other documentation.

### Collecting Traffic Volume

If no existing source has volume data available, a short-term traffic count can be conducted to collect volume on one or both roads. The *ITE Manual of Transportation Engineering Studies* (Schroeder et al. 2010) provides a detailed description of several methods to collect traffic volumes, including information on how to convert a short-term count to AADT.

### Crash History

For the intersection of interest, 3 to 5 years (5 years preferred) of crash data are necessary for safety analysis. Each multiple-vehicle crash occurring during the identified years should be reviewed to determine:

- Initial approaches for vehicles involved in the crash,
- Travel directions for vehicles, and
- Maximum severity of injuries to drivers or occupants involved in the crash.

**Practitioner Tips: Other Considerations**

There are many factors that affect safety at an intersection. While in the field measuring ISD, the data collection team may also want to make other observations, including use of photographs and an intersection sketch for further discussion in the office. Relevant observations include:

- Posted speed limits;
- Approach speeds (e.g., 85th percentile speeds);
- Intersection configuration, including number of lanes and the presence of turn lanes;
- Observations of vehicle type (e.g., presence of slow-moving farm vehicles or many trucks);
- Intersection skew;
- Observations of driver behavior that may affect safety (e.g., rolling stops);
- The ability to judge the speed of approaching vehicles (i.e., are there sufficient reference points so that drivers at the DP can gauge the speed and position of approaching vehicles);
- Photographs of obstructions to sight distance such as fences, trees, signs, and buildings;
- Traffic control device visibility and conspicuity; and
- Evidence of near miss or unreported crashes (e.g., skid marks or the presence of debris.)

The reviewer should also identify target crashes using these criteria:

- Whether the location of the crash has a milepost within 250 ft of the intersection, and
- Whether the crash involved a vehicle on the major road and a vehicle on the minor road.

ISD is considered and analyzed by approach direction (or directional analysis unit), and therefore target crashes should be identified by the directional analysis unit that is being considered. Figure 4 provides an example three-leg intersection. If a vehicle on the minor-road approach collides with the vehicle approaching from the left, then the crash is associated with the left-directional analysis unit. For four-leg intersections, there are a total of four analysis units considered. Each analysis unit is associated with an ISD value for crash analysis. It is important to locate the crashes properly to determine the impact on crash frequency of changing the specific ISD.

Crash severity is used to further identify injury crashes (K, A, B, and C on the KABCO scale) as a subset of target crashes.

All crash types should be summarized by associated minor-road approach and major-road approach. The summary may consist of the sum of crash counts over a given period or may consist of crash frequency (crashes per year).

Crash diagrams are useful tools for consistently characterizing and visually representing crashes. Due to the complexity of analysis, crash diagrams focused on target crashes will help the practitioner identify the appropriate approach direction for each crash, especially for four-leg intersections. Since target crashes are relatively rare events at stop-controlled intersections, each crash can be represented individually, with the severity symbolized for each. Target crashes can

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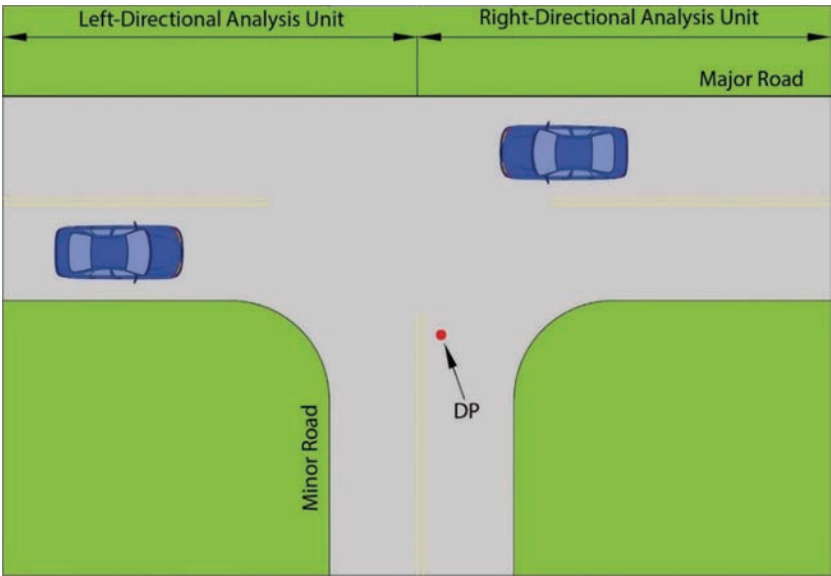


Figure 4. Three-leg intersection for minor-road approach.

be placed on the schematic by approximate location, grouped by accident type, or grouped by intersection sight distance association. Crash diagrams may also be used to help verify whether crashes were target crashes.

Figure 5 is an example crash diagram for a three-leg intersection that graphically depicts all crashes in a given time frame. In this example, there are two potential ISD triangles to consider, left- and right-looking from the northbound minor road. It is important to carefully review

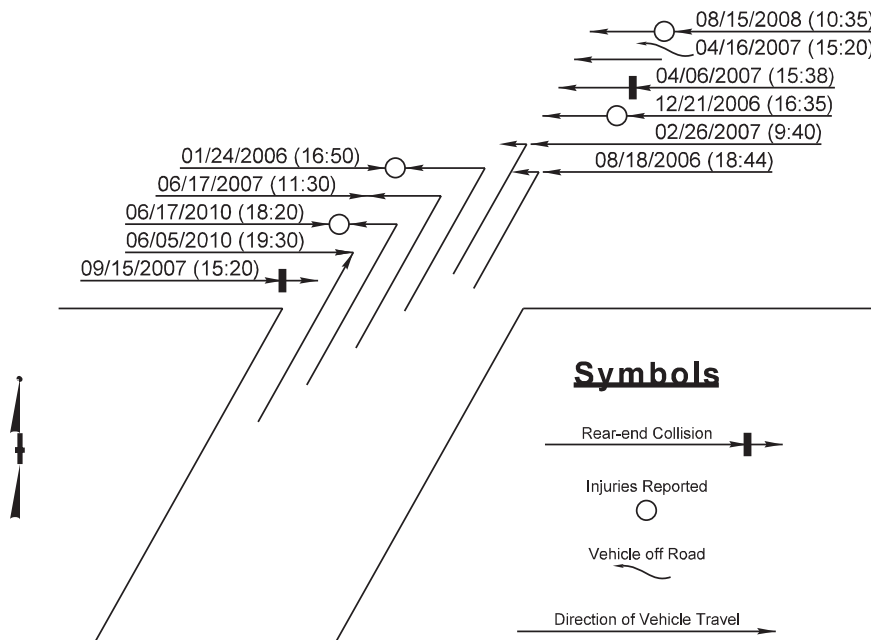


Figure 5. Example crash diagram.

all crashes to determine which are target crashes associated with ISD and which may be single-vehicle crashes or do not involve a vehicle from the minor road. There are four target crashes in this example associated with the left sight triangle, as represented with two arrows pointing at each other.

Additionally, the crash reports can further identify whether crashes are due to sight distance or gap-acceptance issues, or whether the driver failed to obey the traffic control device. Reviewing the vehicle speeds at impact can help to identify intersection sight distance issues. However, if the intersection is being considered for changes, all target crashes or target fatal and injury crashes should be included in the CMF-based analysis, regardless of ISD relation.



## CHAPTER 3

# Safety Performance and Intersection Sight Distance

The purpose of this chapter is to provide practitioners information on the anticipated impact on crashes at an intersection from changing the sight distance (e.g., lengthening the distance at an intersection from 400 ft to 750 ft by removing a sight distance obstruction). The results can be applied to both existing and design-stage intersections.

### Determining the CMF

The following pages contain a series of charts depicting CMFs for target crashes and target fatal and injury crashes. Charts A-1 to A-6 present CMFunctions for target crashes. Charts B-1 to B-6 present CMFunctions for target fatal and injury crashes. The charts are based on the CMFunctions developed from the research and provided for reference in Chapter 6. Detailed instructions are provided in the Practitioner Tips: Detailed Instructions for Using CMFs text-box to help practitioners use these charts in practice, with the key steps identified on the sample chart (Figure 6).

For the purposes of these charts, there are several important notes. First, the charts are separated by major-road posted speed from 35 mph to 60 mph. Each chart refers to a specific posted speed. The minimum ISD for each posted speed corresponds to the design ISD based on left turns for an equivalent design speed minus 250 ft (as data were limited below this distance). The maximum ISD value is one-quarter mile (1,320 ft), which is the base condition assumed in the charts. However, direct comparisons may be made between two alternative CMFs on a chart, as shown in the examples. Additionally, outcome crashes are all target crashes (i.e., a crash involving a vehicle on the major road and a vehicle on the minor road). Therefore, it is essential that the approach and direction of travel be known.

For example, left-looking sight distance on one approach is only applicable for crashes involving a vehicle from that minor approach and a vehicle from the major road entering from the left. For a four-leg intersection, the vehicle entering from the minor road needs to be applied to the correct minor-road approach leg. More detailed scenario examples—as well as an in-depth look at how to plot existing and proposed ISD and how to calculate the appropriate CMF—are provided in Chapter 4.

**Practitioner Tips: Detailed Instructions for Using CMFs**

The following information provides step-by-step guidance on how to use the charts to determine the crash impact from changing the existing ISD to a new proposed ISD. A sample graph (Figure 6) is also provided to help illustrate the following steps. Steps 1 through 6 correspond to a red number in Figure 6.

**Step 1.** Identify the minor-road approach sight distance of interest (left-looking or right-looking) for which a new ISD is proposed. Measure the sight distance along the major road for that direction using the method in Chapter 2. This is the *existing* ISD for the approach and direction.

**Step 2.** Identify the type of crash of interest for the analysis: target or target fatal or injury crash.

- Target crashes are defined as a crash involving a vehicle from the major road and a vehicle entering from the minor road.
- Target fatal and injury crashes are a subset of target crashes that involve one or more injuries or fatalities.

**Step 3.** Identify the appropriate chart type based on the type of crash and major-road posted speed.

**Step 4.** Identify the curve that corresponds to the appropriate major-road AADT range.

- Three ranges of major-road AADT are used for target crashes.
- Two ranges of major-road AADT are used for target fatal and injury crashes.

**Step 5.** Using the selected curve, plot the *existing* and the *proposed* ISD. If any ISD exceeds 1,320 ft, use 1,320 ft in the chart since this is the maximum.

**Step 6.** Calculate the CMF for changing the site distance from the existing to the proposed by dividing the CMF from the chart for the *proposed* ISD by the CMF from the chart for the *existing* ISD.

**Step 7.** Apply the resulting CMF to the crashes of interest associated with the corresponding direction.

These steps are undertaken for each approach and direction of interest at the intersection. When analyzing the whole intersection, carry out this process for each minor approach and direction (left-looking or right-looking) and combine the results. For a four-leg intersection, these steps would be undertaken four times.



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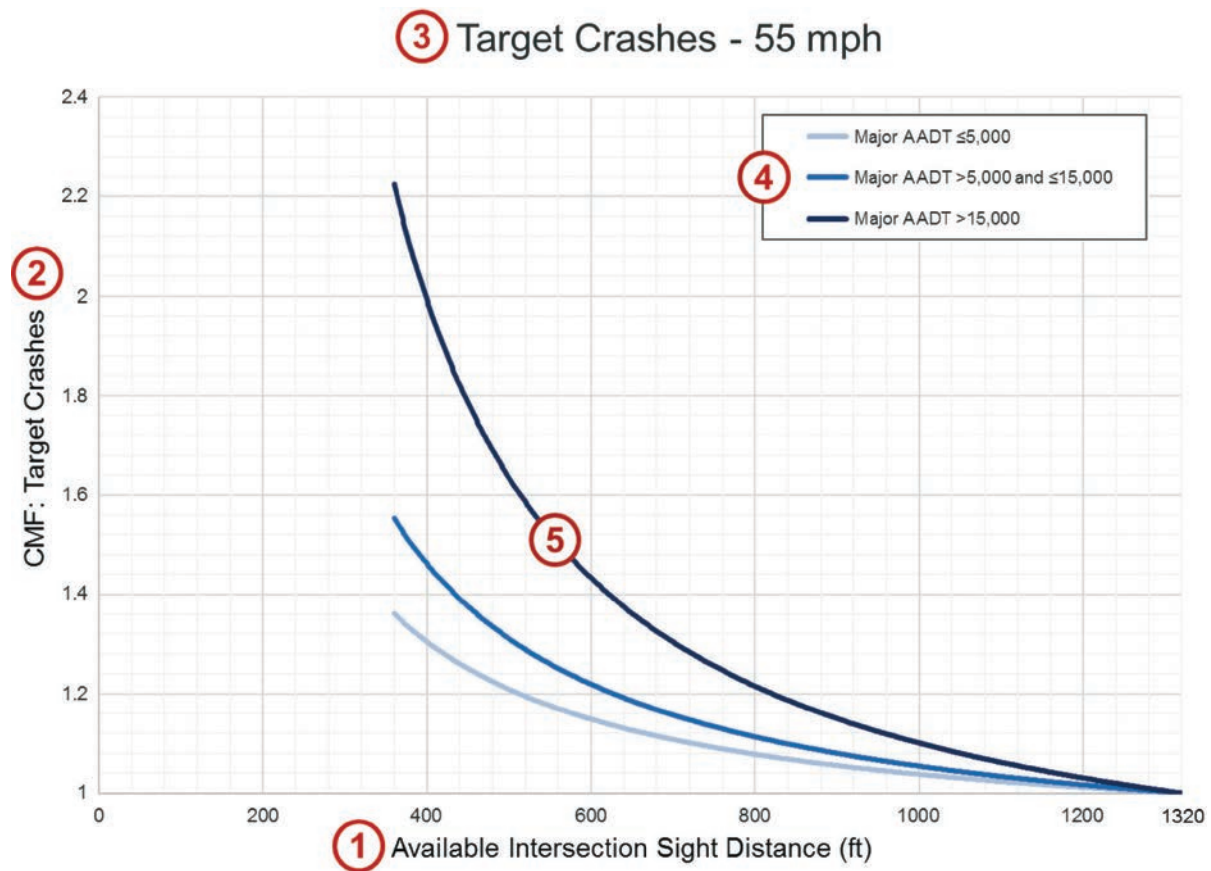


Figure 6. Sample chart.

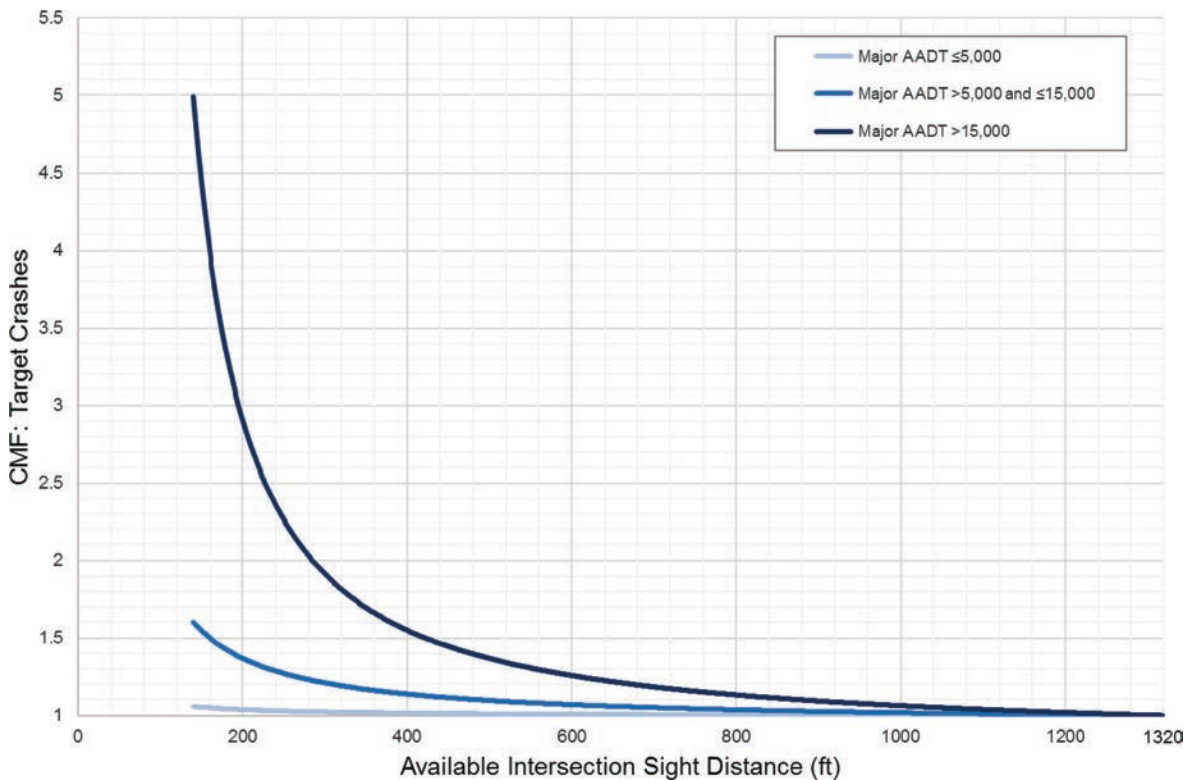
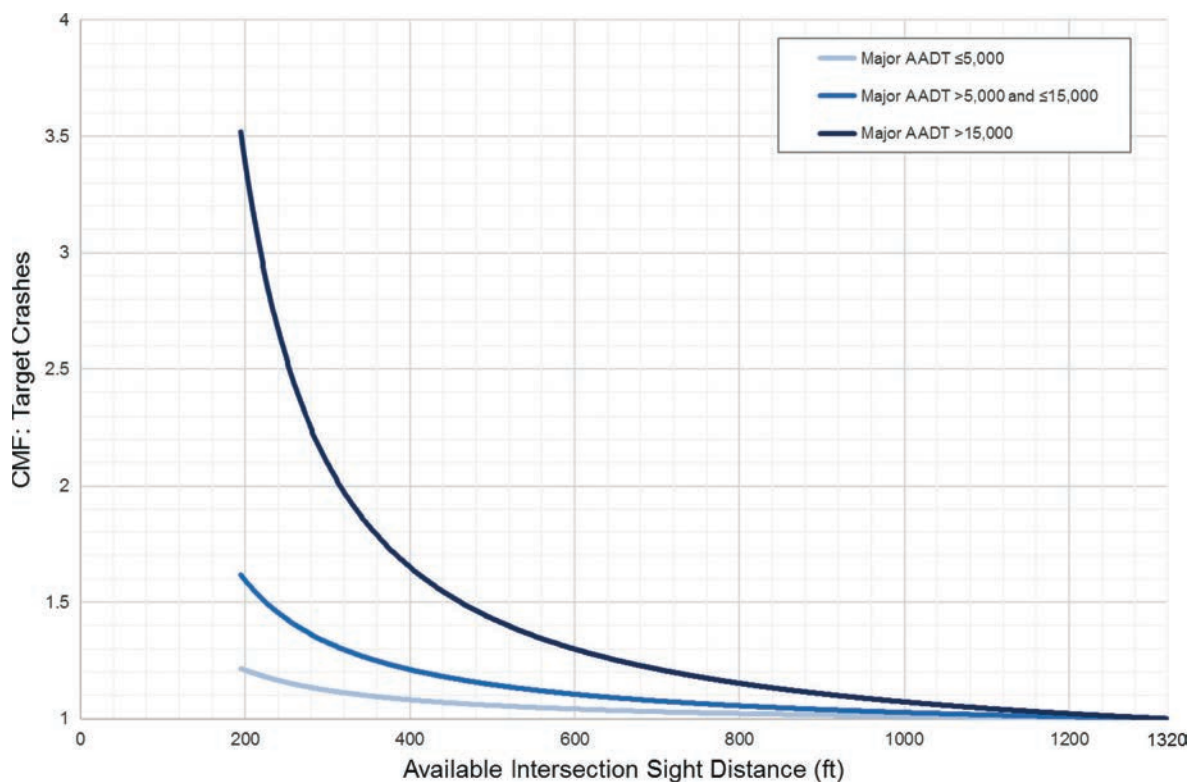
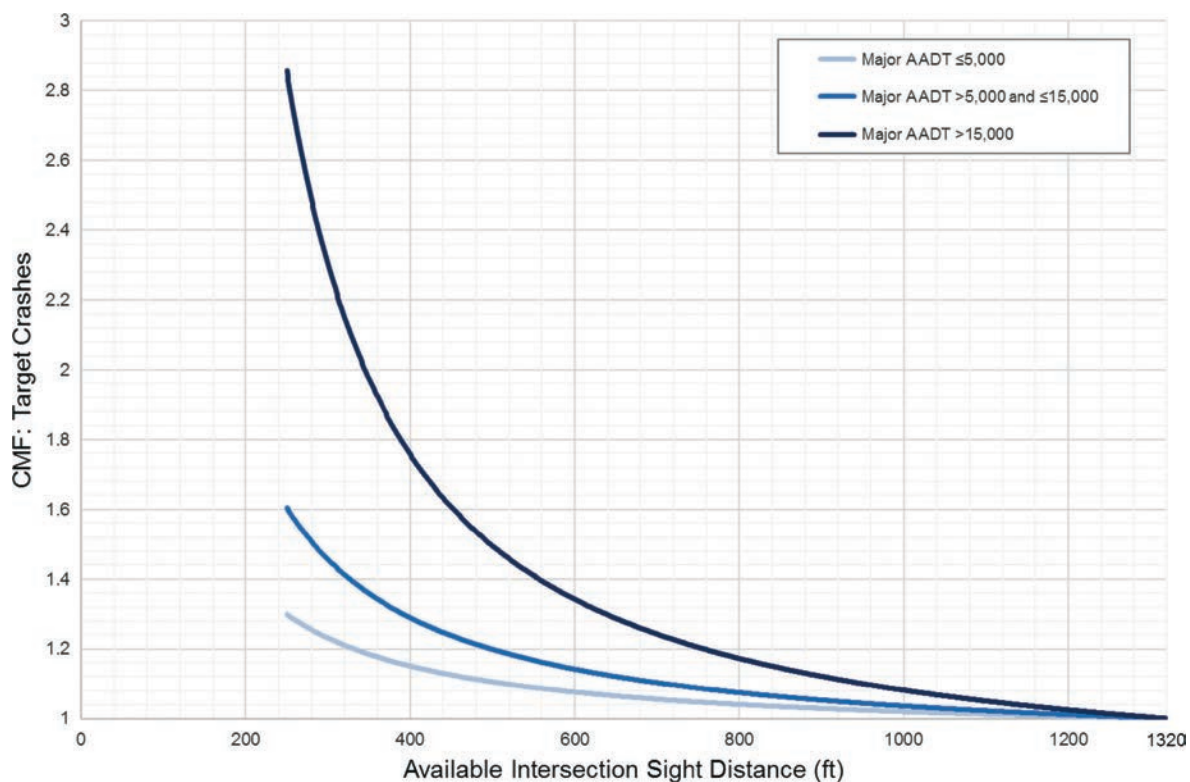


Chart A-1. CMFs for target crashes when posted speed equals 35 mph.



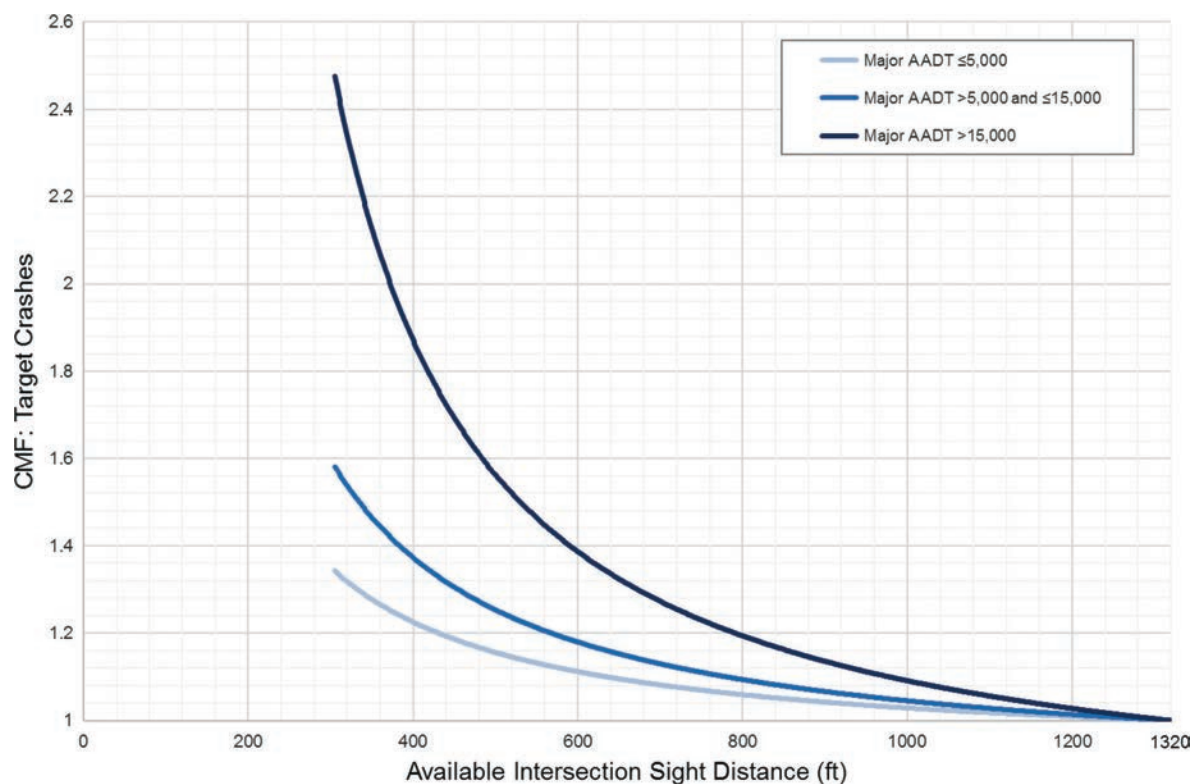


**Chart A-2.** CMFs for target crashes when posted speed equals 40 mph.

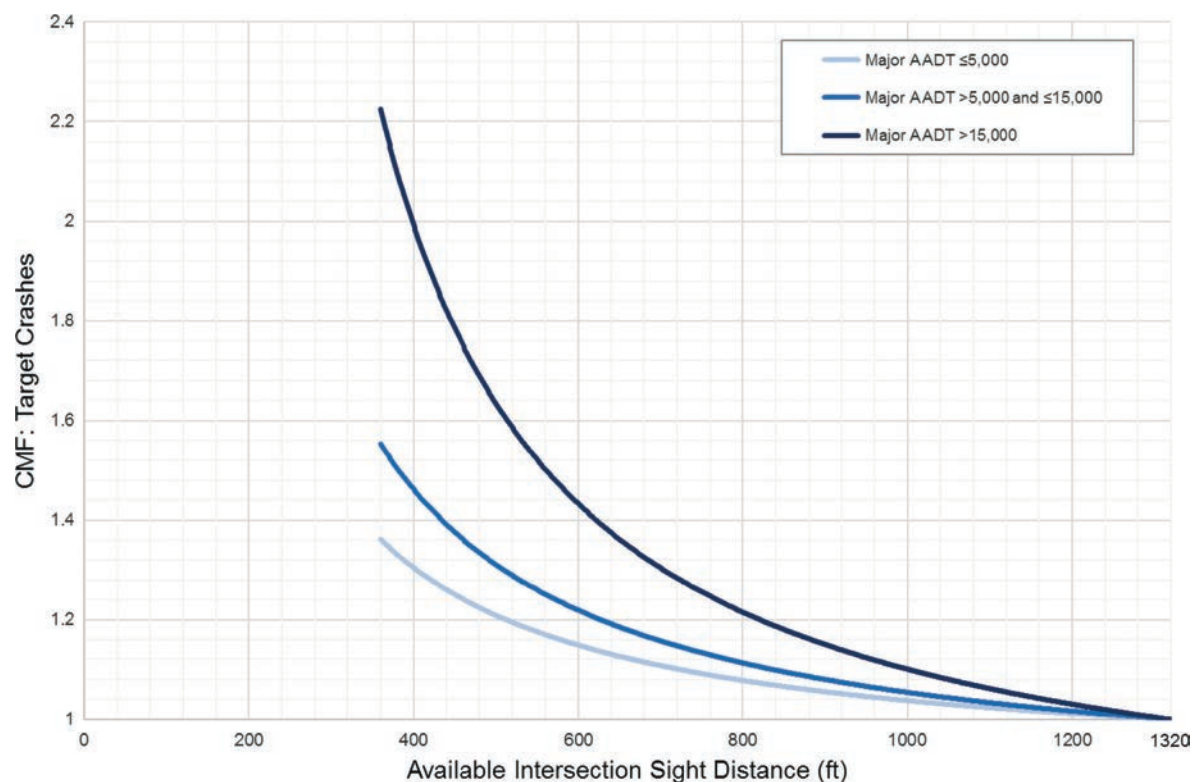


**Chart A-3.** CMFs for target crashes when posted speed equals 45 mph.

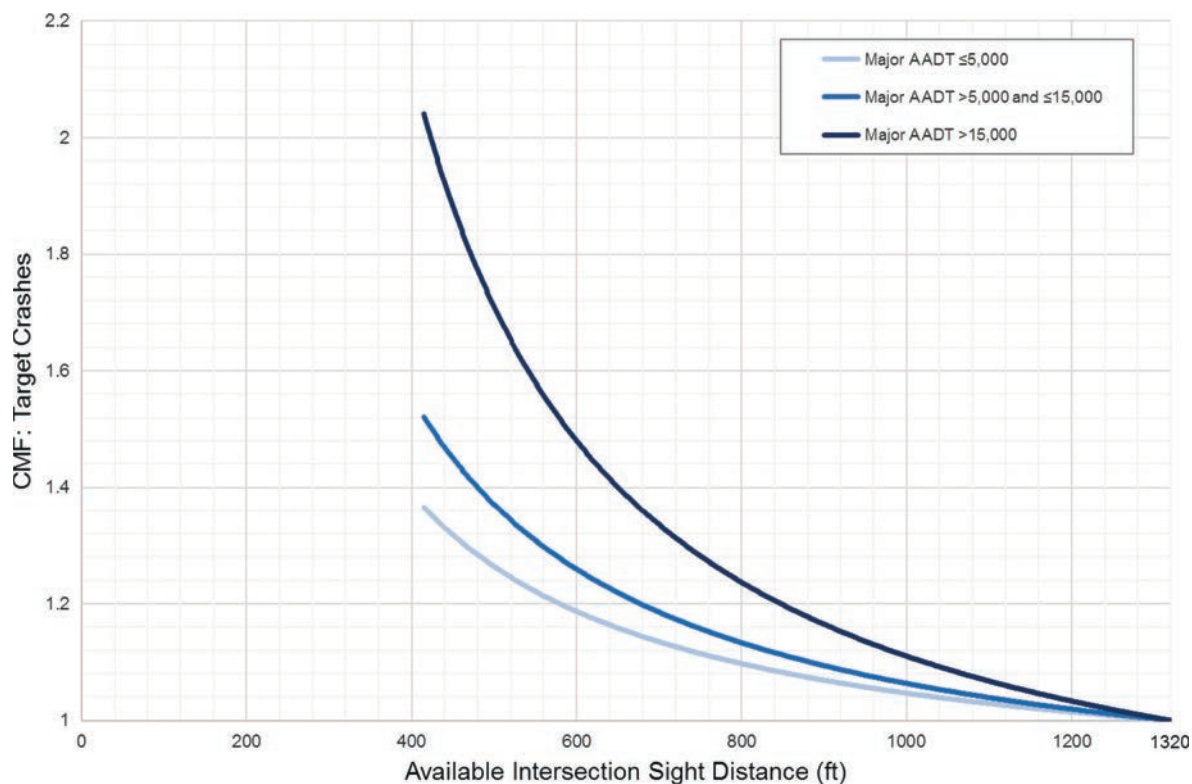
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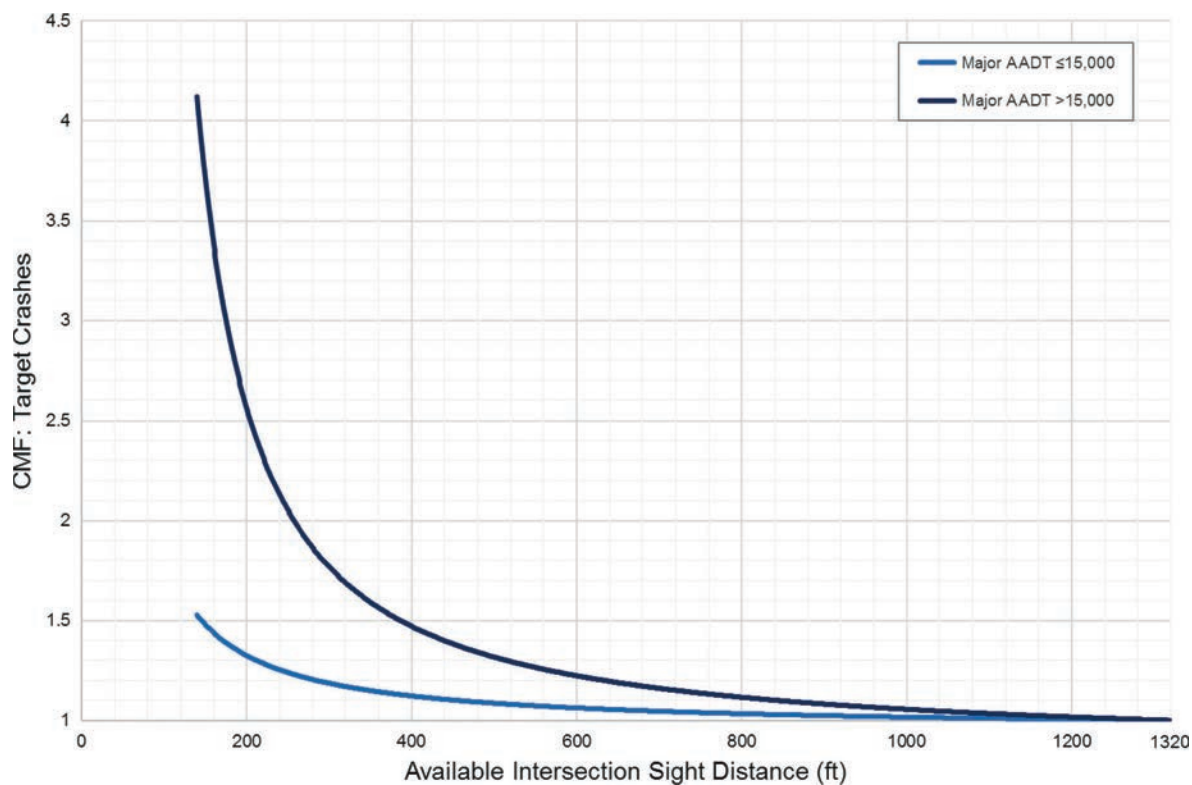
**Chart A-4.** CMFs for target crashes when posted speed equals 50 mph.



**Chart A-5.** CMFs for target crashes when posted speed equals 55 mph.

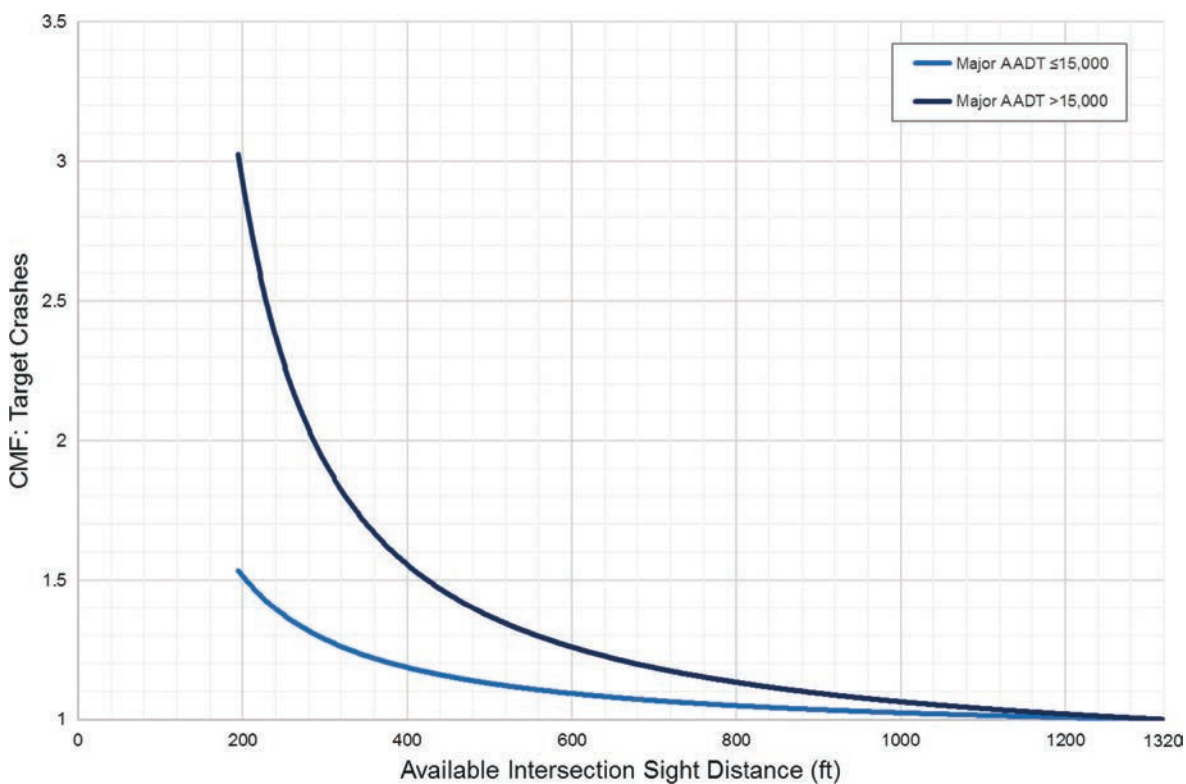


**Chart A-6.** CMFs for target crashes when posted speed equals 60 mph.

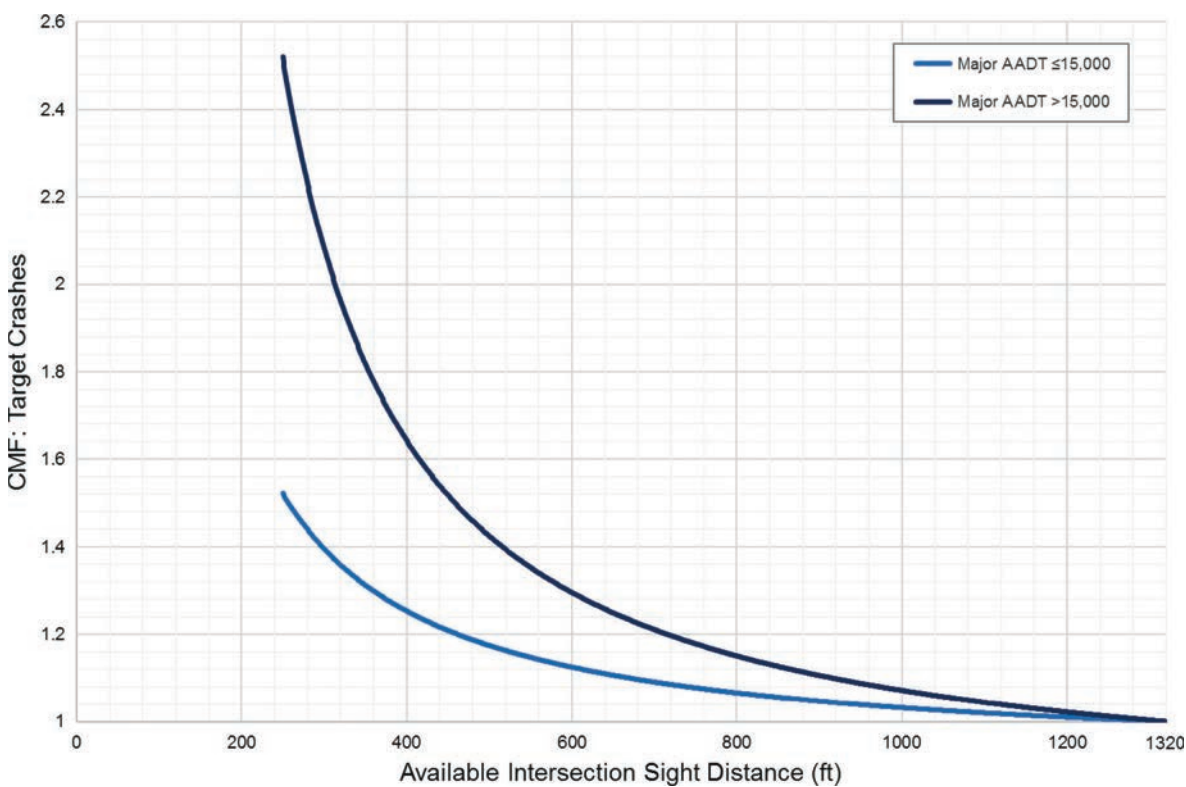


**Chart B-1.** CMFs for target fatal and injury crashes when posted speed equals 35 mph.

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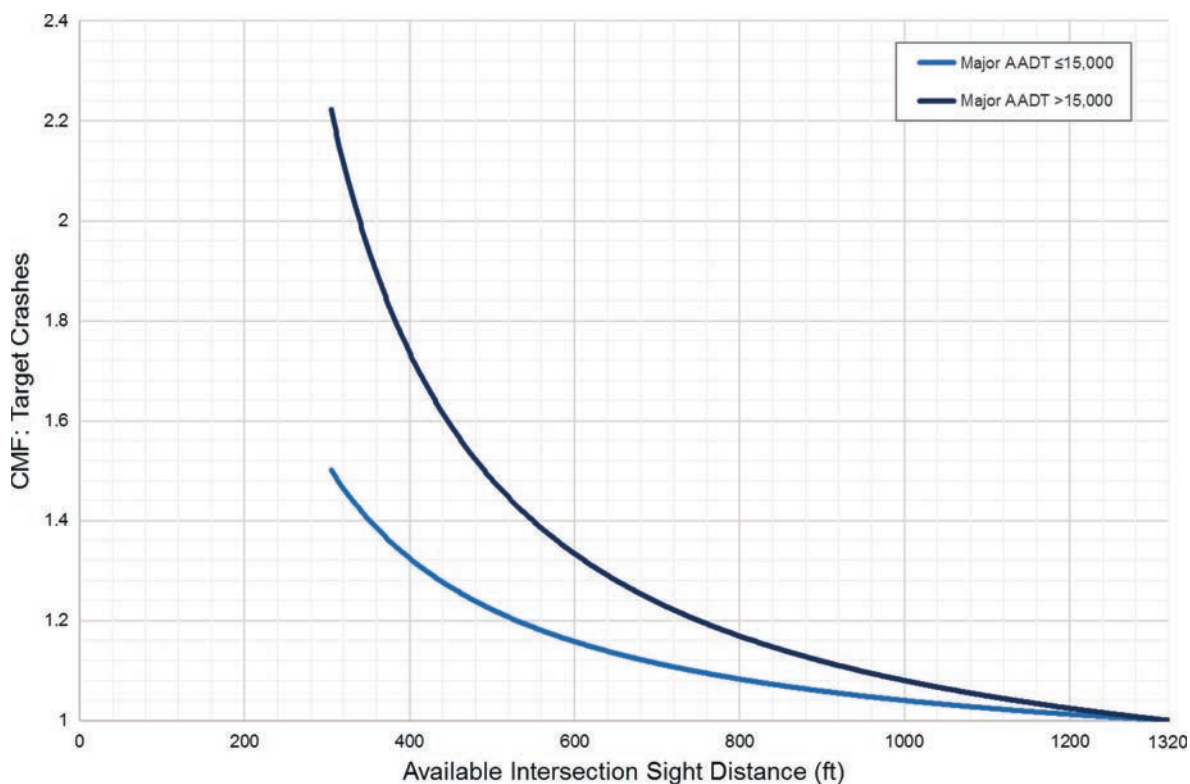


**Chart B-2.** CMFs for target fatal and injury crashes when posted speed equals 40 mph.

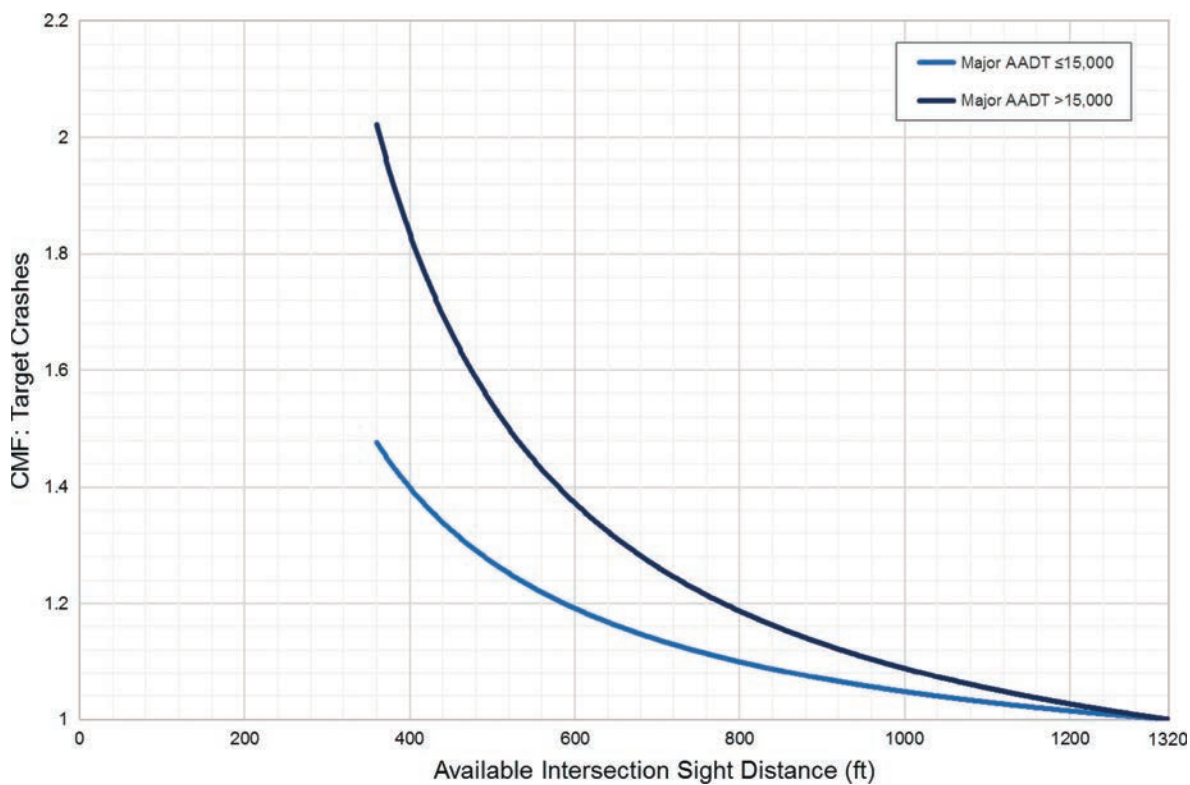


**Chart B-3.** CMFs for target fatal and injury crashes when posted speed equals 45 mph.



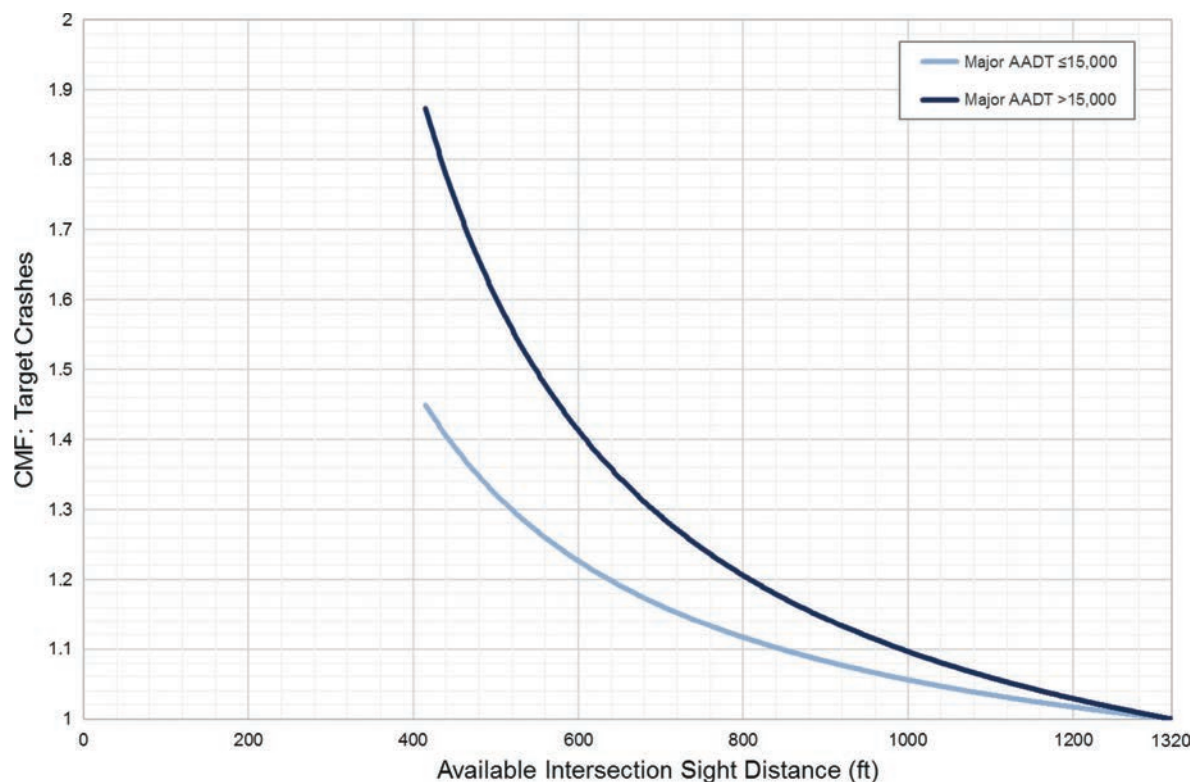


**Chart B-4.** CMFs for target fatal and injury crashes when posted speed equals 50 mph.



**Chart B-5.** CMFs for target fatal and injury crashes when posted speed equals 55 mph.

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**Chart B-6. CMFs for target fatal and injury crashes when posted speed equals 60 mph.**

### Analyzing More Than One Approach

The crash modification factor for intersection-level target crashes can be calculated using the following equation:

$$CMF_{IT} = \frac{\sum CMF_{T_i} \times T_i}{\sum T_i}$$

where:

$CMF_{IT}$  = crash modification factor for intersection-level target crashes,

$CMF_{T_i}$  = crash modification factor for target crashes for approach direction  $i$ , and

$T_i$  = target crashes for approach direction  $i$ .

If the intersection has three legs, there will be two approach directions. If the intersection has four legs, there will be four approach directions. If only one ISD is being changed, only one  $CMF_{T_i}$  need be calculated. A value of 1.0 may be used for the other approach directions. Example 4 presents the calculation of an intersection-level total crashes CMF from the target crashes application. Note that if no crash data exist for the intersection, the CMF for intersection-level target crashes can be determined by averaging the CMFs for all approach directions.

To determine the CMF for total intersection crashes, use the following equation:

$$CMF = (CMF_{IT} - 1.0) \times P_T + 1.0$$

where:

$CMF$  = crash modification factor total intersection crashes, and

$P_T$  = proportion of total intersection crashes that are target crashes.

This equation assumes that only target crashes will be affected by the change to ISD and requires the CMF for intersection-level target crashes and the proportion of total intersection crashes that are target crashes. An average proportion for the intersection type may be used if the proportion is unknown for the analysis intersection.



## CHAPTER 4

# Examples

The examples presented in this chapter demonstrate how practitioners can apply the charts presented in Chapter 3.

### Example 1: One Direction ISD Upgrade

A three-leg intersection with stop control on the minor-road approach has a major-road AADT of 7,000 and a major-road posted speed of 55 mph. A practitioner is interested in estimating the change in average target crash frequency when increasing left-looking ISD from an existing condition of 400 ft to a proposed condition of 750 ft.

Using Chart A-5 for 55 mph (shown here as Figure 7 with some annotation), the CMF for the proposed ISD of 750 ft is 1.13. The CMF for the existing ISD of 400 ft is 1.46. Therefore, the target crashes CMF for improving ISD is  $1.13/1.46$ , or 0.77. This factor applies to multi-vehicle crashes involving vehicles from the minor road and vehicles approaching from the left. The increase in sight distance from 400 ft to 750 ft in this example would reduce target crashes on the left-looking direction of the approach by 23%.

### Example 2: Upgrading Both Left and Right Departure Sight Triangles from Different Values

A four-leg intersection with stop control on the minor road has a major-road AADT of 20,000 and posted speed of 40 mph. The intersection was selected for potential improvement due to a history of gap-acceptance-related crashes. Figure 8 presents a crash diagram of target crashes and their severities for the three most recent years of crash data. The crash diagram shows that the northbound minor-road approach has four crashes associated with the left-looking ISD and five crashes associated with the right-looking ISD. The northbound left-looking ISD is being considered for improvement from an existing ISD condition of 250 ft to a proposed ISD condition of 600 ft. Additionally, the right-looking ISD is being considered for improvement from an existing ISD condition of 300 ft to a proposed ISD condition of 600 ft. A practitioner wants to determine the intersection-level target crash CMF and intersection-level target fatal and injury crash CMF.

### Target Crashes

Each direction for the approach is analyzed separately, starting with the left-looking ISD. Using Chart A-2 (shown here as Figure 9 with some annotation), the left-looking direction CMF



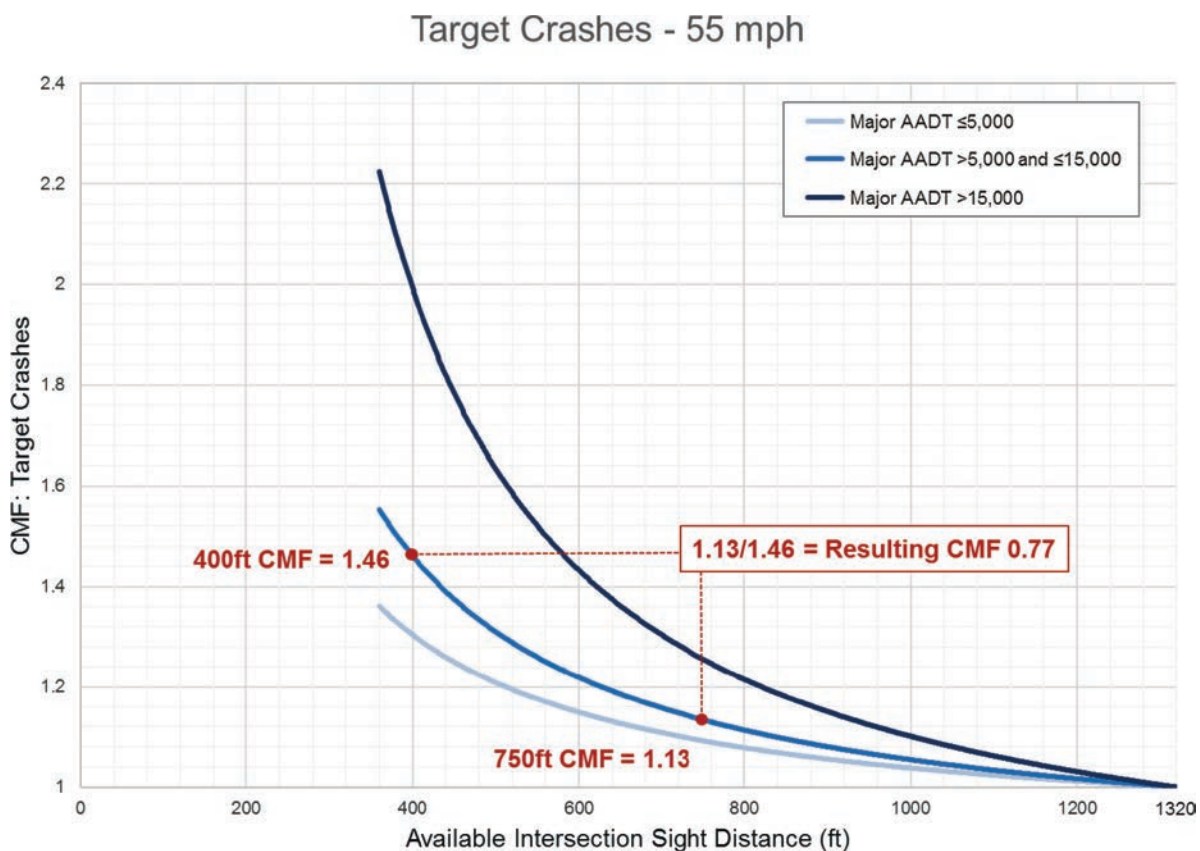


Figure 7. Example 1: target crashes.

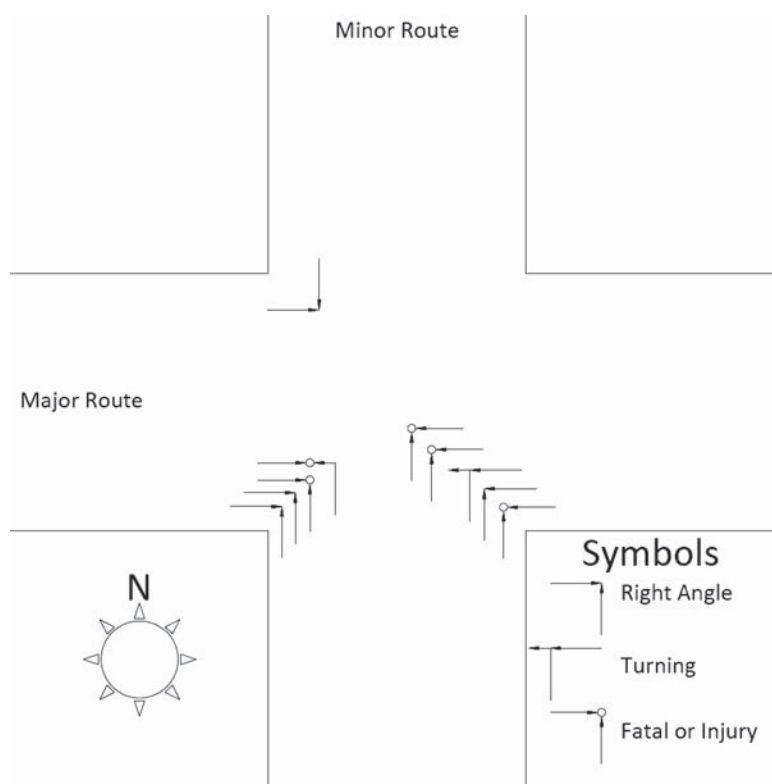
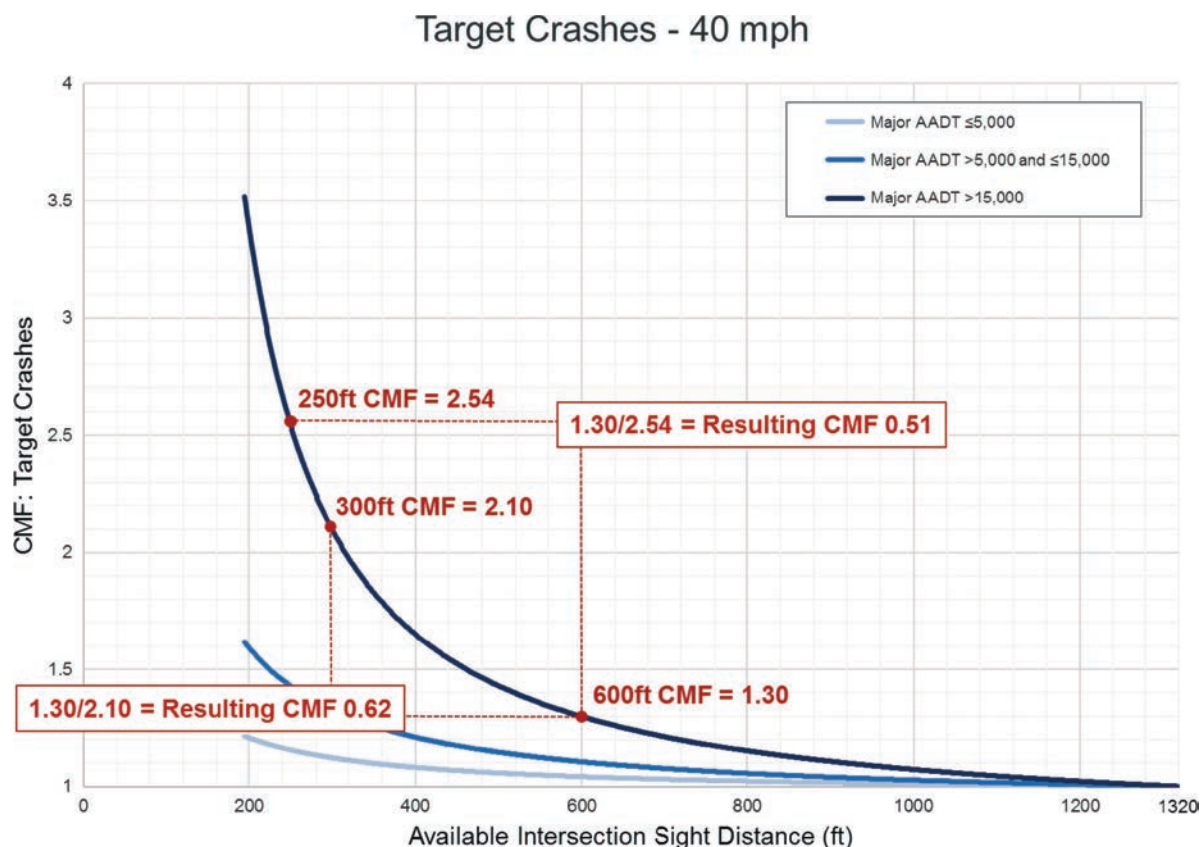


Figure 8. Example 2: crash diagram.



**Figure 9. Example 2: target crashes.**

for the proposed ISD of 600 ft is 1.30. The CMF for the existing ISD of 250 ft is 2.54. Therefore, the CMF for target crashes for improving the left-looking ISD on the approach is  $1.30/2.54$ , or 0.51. This CMF applies only to the four crashes in Figure 8 involving vehicles on the minor road and vehicles on the major road approaching from the left.

The right-looking direction CMF is calculated from the same chart. The CMF for the proposed ISD of 600 ft is 1.30. The CMF for the existing ISD of 300 ft is 2.10. Therefore, the CMF for target crashes for improving the right-looking ISD on the approach is  $1.30/2.10$ , or 0.62. This CMF applies only to the five crashes in Figure 8 involving vehicles on the minor road and vehicles on the major road approaching from the right.

### Combining CMFs

Once the practitioner has the left-looking CMF and the right-looking CMF for the approach, he or she may want to combine those to obtain a target crash CMF for the entire intersection. For this example, two of the four approach directions were modified. The following equation computes the intersection-level CMF for target crashes based on the individual approach direction CMFs and target crash history.

$$CMF_{IT} = \frac{(0.51 * 4 \text{ crashes}) + (0.62 * 5 \text{ crashes}) + (1 * 1 \text{ crash}) + (1 * 0 \text{ crashes})}{(4 + 5 + 1 + 0)}$$

The resulting intersection-level CMF for target crashes is 0.61.

## Target Fatal and Injury Crashes

The same steps are undertaken if the practitioner is interested in target crashes that resulted in a fatality or injury. Instead of Chart A-2 (which was for all target crashes), Chart B-2 is used because it is applicable for target fatal and injury crashes with a posted speed limit of 40 mph. The chart is annotated and included here as Figure 10. Again, each approach is analyzed separately. The left-looking direction CMF for the proposed ISD of 600 ft is 1.26. The CMF for the existing ISD of 250 ft is 2.27. Therefore, the CMF for target fatal and injury crashes for improving the left-looking ISD on the approach is  $1.26/2.27$ , or 0.56. This CMF applies only to the two fatal and injury crashes involving vehicles on the minor road and vehicles on the major road approaching from the left.

The right-looking direction CMF is calculated from the same chart. The CMF for the proposed ISD of 600 ft is 1.26. The CMF for the existing ISD of 300 ft is 1.92. Therefore, the CMF for improving the right-looking ISD on the approach is  $1.26/1.92$ , or 0.66. This CMF applies only to the three fatal and injury crashes involving vehicles on the minor road and vehicles on the major road approaching from the right.

Using the same equations and methods to combine the CMFs to get an intersection-level CMF for target fatal and injury crashes, the resulting calculation is:

$$CMF_{IT} = \frac{(0.56 * 2 \text{ crashes}) + (0.66 * 3 \text{ crashes}) + (1 * 0 \text{ crashes}) + (1 * 0)}{(2 + 3 + 0 + 0)}$$

The resulting intersection-level CMF for target fatal and injury crashes is 0.62.

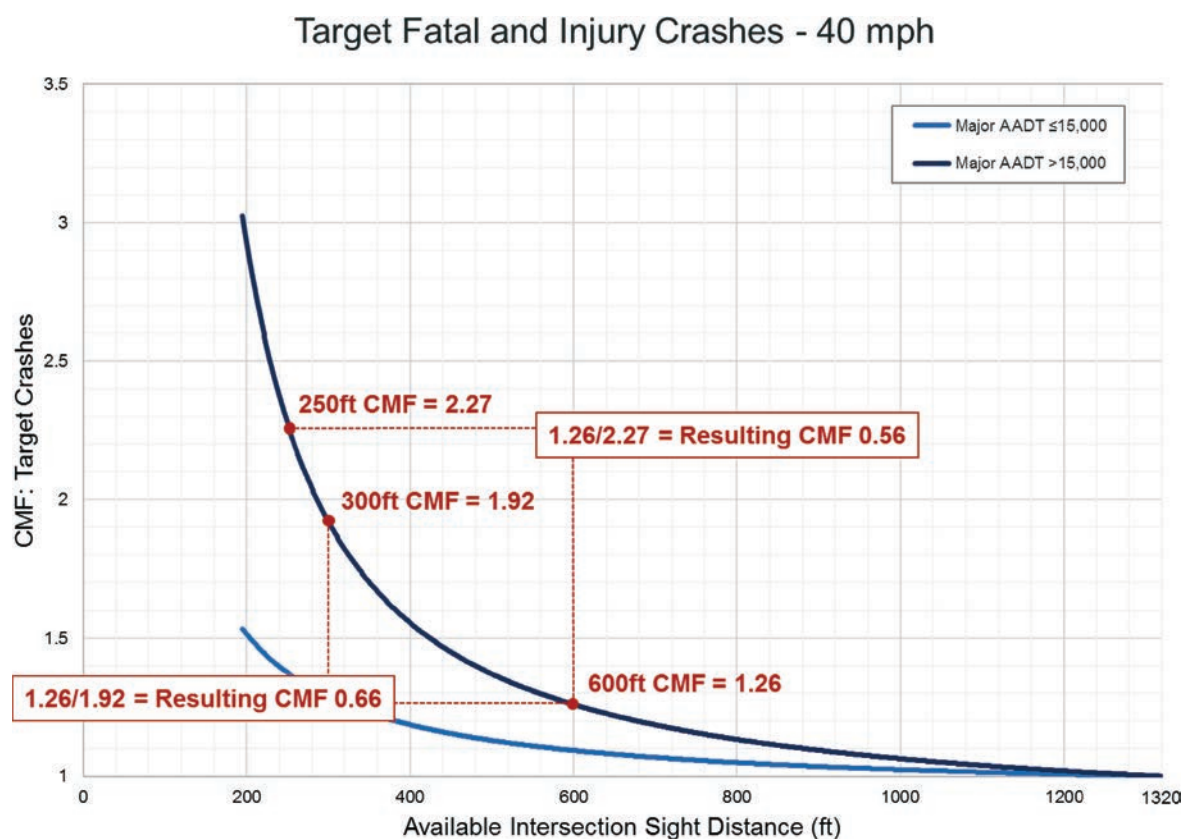


Figure 10. Example 2: target fatal and injury crashes.

### Example 3: Calculation of Total Crashes CMF

A four-leg intersection with stop control on the minor road has a major-road AADT of 17,500 and a posted speed of 60 mph. In a 3-year period, the southbound left-looking ISD from the minor road has experienced five target crashes, the right-looking ISD has experienced seven target crashes, and the intersection has experienced 16 target crashes. The remaining four crashes involved the left-looking northbound approach. The right-looking northbound approach has not experienced any target crashes. The southbound minor-road approach is being considered for improvements that would increase the existing left-looking ISD condition from 525 ft to a proposed ISD condition of 1,320 ft. Additionally, the right-looking ISD is being considered for improvements that would increase the existing ISD condition from 610 ft to a proposed ISD condition of 1,320 ft. A practitioner is interested in calculating the CMFs for target crashes for each of the ISD improvements as well as an estimate of the intersection-level total crash CMF for these improvements based on data indicating that 55% of the total intersection crashes are target crashes.

Using Figure 11, the left-looking direction CMF for the proposed ISD of 1,320 ft is 1.00. The CMF for the existing ISD of 525 ft is 1.64. Therefore, the CMF for improving left-looking ISD is  $1.00/1.64$ , or 0.61. This CMF applies only to multi-vehicle crashes involving vehicles on the minor road and vehicles on the major road approaching from the left. The right-looking direction CMF for the proposed ISD of 1,320 ft is 1.00. The CMF for the existing ISD of 610 ft is 1.46. Therefore, the CMF for improving the right-looking ISD is  $1.00/1.46$ , or 0.68. This CMF applies only to multi-vehicle crashes involving vehicles on the minor road and vehicles on the major road approaching from the right.

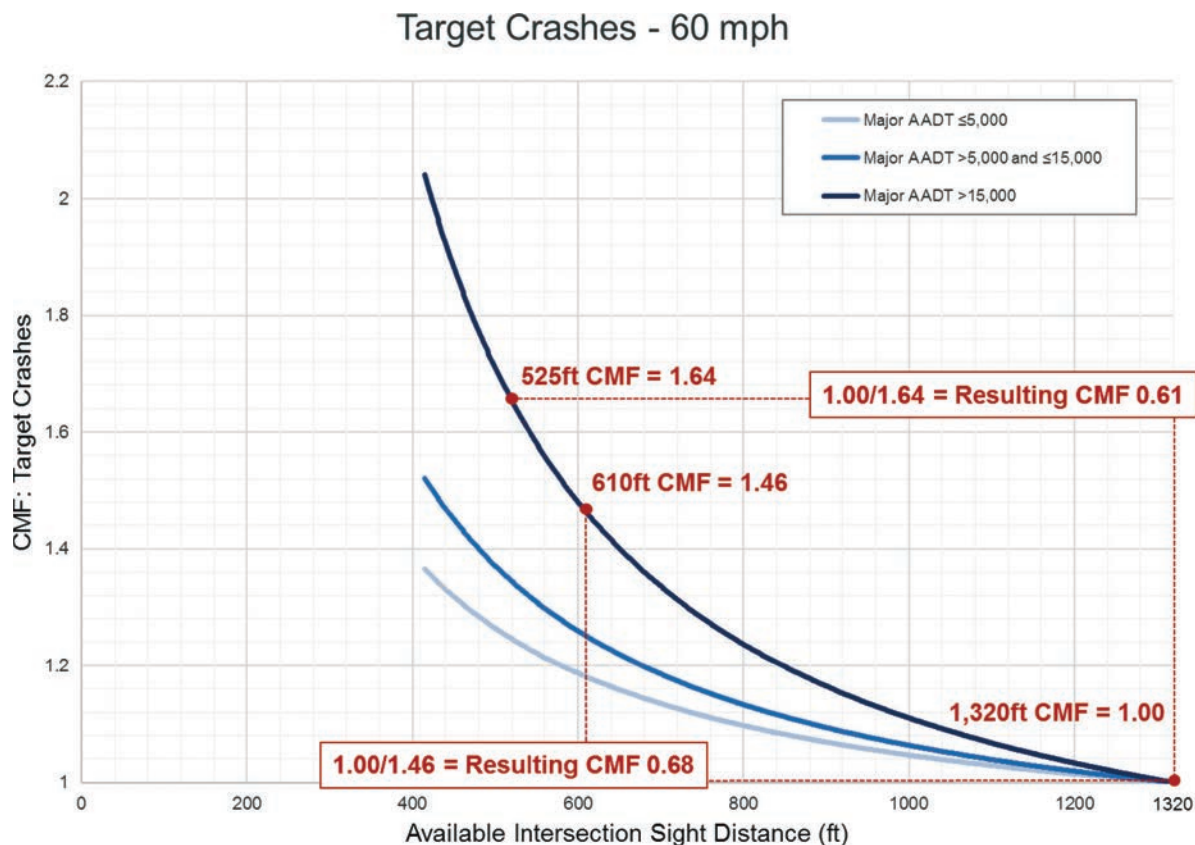


Figure 11. Example 3: target crashes.

Example 2 illustrated how to combine the CMFs to determine an intersection-level CMF for the target crashes. The same approach is taken in this example. The CMF for intersection-level target crashes is calculated using the following equation:

$$CMF_{IT} = \frac{(0.61 \times 5) + (0.68 \times 7) + (1 \times 4) + (1 \times 0)}{5 + 7 + 4 + 0}$$

Therefore, the CMF for intersection-level target crashes is 0.74.

The practitioner is also interested in calculating an intersection-level CMF for all crashes, not just target crashes. This is accomplished by applying the CMF for intersection-level target crashes to the following equation.

$$CMF = (CMF_{IT} - 1.0) \times P_T + 1.0$$

The proportion of target crashes to total crashes is given as 0.55. Substituting these values yields the following equation.

$$CMF = (0.74 - 1.0) \times 0.55 + 1.0$$

The CMF for total crashes is 0.86. This indicates that the upgrades to two quadrants of ISD will result in a 26% reduction in target crashes and a 14% reduction in total crashes.

## Example 4: Design Deviation Using Equations

The charts presented in Chapter 3 are based on the CMFunctions that were developed from the research. The equations are included in Chapter 6 for reference. All the CMFs developed from this research can be extracted from the charts without the use of the equations. However, for the practitioners' reference, this example illustrates how the equations are used.

A three-leg intersection with stop control on the minor road has a major-road AADT of 1,200 and a posted speed of 50 mph. Due to the presence of a roadside embankment, a practitioner is estimating the potential safety impact of having a right-looking available ISD of 465 ft in comparison to a design ISD of 555 ft. The analysis focuses on directly applying the target crashes and target fatal and injury crashes CMFunctions.

### Target Crashes

Use the following to compute the CMF for target crashes of interest, either for proposed or existing conditions:

$$CMF_{Ti} = \frac{\exp \left( -0.021 \times PSL + \frac{7.194 \times PSL}{ISD_i} + \frac{-243.009 \times LowAADT_{maj}}{ISD_i} + \frac{-177.826 \times MidAADT_{maj}}{ISD_i} \right)}{\exp \left( -0.021 \times PSL + \frac{7.194 \times PSL}{ISD_{base}} + \frac{-243.009 \times LowAADT_{maj}}{ISD_{base}} + \frac{-177.826 \times MidAADT_{maj}}{ISD_{base}} \right)}$$

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The following conditions apply:

- The posted speed is 50 mph,
- This site uses the LowAADT for the major road (i.e.,  $\text{LowAADT}_{\text{maj}} = 1.0$ ),
- The proposed ISD is 465 ft for this analysis,
- The existing ISD is 555 ft based on the design ISD, and
- The base ISD is 1,320 ft.

This results in the following CMF for the proposed ISD condition:

$$CMF_{T_1} = \frac{\exp\left(-0.021 \times 50 + \frac{7.194 \times 50}{465} + \frac{-243.009 \times 1}{465} + \frac{-177.826 \times 0}{465}\right)}{\exp\left(-0.021 \times 50 + \frac{7.194 \times 50}{1,320} + \frac{-243.009 \times 1}{1,320} + \frac{-177.826 \times 0}{1,320}\right)} = 1.18$$

The CMF for the existing ISD condition is:

$$CMF_{T_2} = \frac{\exp\left(-0.021 \times 50 + \frac{7.194 \times 50}{555} + \frac{-243.009 \times 1}{555} + \frac{-177.826 \times 0}{555}\right)}{\exp\left(-0.021 \times 50 + \frac{7.194 \times 50}{1,320} + \frac{-243.009 \times 1}{1,320} + \frac{-177.826 \times 0}{1,320}\right)} = 1.13$$

The target fatal and injury crashes CMF is calculated as:

$$CMF_T = \frac{1.18}{1.13} = 1.04$$

The target fatal and injury crashes CMF for having an ISD of less than the design ISD is 1.04. This factor applies to multi-vehicle crashes involving vehicles from the minor road and major-road vehicles approaching from the right. Note that the CMF can also be computed directly by using the existing ISD as the base ISD as follows:

$$CMF_T = \frac{\exp\left(-0.021 \times 50 + \frac{7.194 \times 50}{465} + \frac{-243.009 \times 1}{465} + \frac{-177.826 \times 0}{465}\right)}{\exp\left(-0.021 \times 50 + \frac{7.194 \times 50}{555} + \frac{-243.009 \times 1}{555} + \frac{-177.826 \times 0}{555}\right)} = 1.04$$

### Target Fatal and Injury Crashes

Use the following equation to compute the CMF for target fatal and injury crashes:

$$CMF_{TFI_i} = \frac{\exp\left(-0.009 \times PSL + \frac{6.335 \times PSL}{ISD_i} + \frac{-155.504 \times \text{LowMidAADT}_{\text{maj}}}{ISD_i}\right)}{\exp\left(-0.009 \times PSL + \frac{6.335 \times PSL}{ISD_{\text{base}}} + \frac{-155.504 \times \text{LowMidAADT}_{\text{maj}}}{ISD_{\text{base}}}\right)}$$

The following conditions apply:

- The posted speed is 50 mph,
- This site uses the LowMidAADT for the major road (i.e.,  $\text{LowMidAADT}_{\text{maj}} = 1.0$ ),
- The proposed ISD is 465 ft for this analysis,
- The existing ISD is 555 ft based on the design ISD, and
- The base ISD is 1,320 ft.



This results in the following CMF for the proposed ISD condition:

$$CMF_{TFI_1} = \frac{\exp\left(-0.009 \times 50 + \frac{6.335 \times 50}{465} + \frac{-155.504 \times 1}{465}\right)}{\exp\left(-0.009 \times 50 + \frac{6.335 \times 50}{1,320} + \frac{-155.504 \times 1}{1,320}\right)} = 1.25$$

The CMF for the existing ISD condition is:

$$CMF_{TFI_2} = \frac{\exp\left(-0.009 \times 50 + \frac{6.335 \times 50}{555} + \frac{-155.504 \times 1}{555}\right)}{\exp\left(-0.009 \times 50 + \frac{6.335 \times 50}{1,320} + \frac{-155.504 \times 1}{1,320}\right)} = 1.18$$

The target fatal and injury crashes CMF is calculated as:

$$CMF_T = \frac{1.25}{1.18} = 1.06$$

The target fatal and injury crashes CMF for having an ISD of less than the design ISD is 1.06. This factor applies to fatal and injury multi-vehicle crashes involving vehicles from the minor road and major-road vehicles approaching from the right. Note that the CMF can also be computed directly by using the existing ISD as the base ISD as follows:

$$CMF_{TFI} = \frac{\exp\left(-0.009 \times 50 + \frac{6.335 \times 50}{465} + \frac{-155.504 \times 1}{465}\right)}{\exp\left(-0.009 \times 50 + \frac{6.335 \times 50}{555} + \frac{-155.504 \times 1}{555}\right)} = 1.06$$



## CHAPTER 5

# Other Considerations and Resources

### Countermeasures

ISD is just one consideration for intersection enhancement—in fact, there are many other effective countermeasures available to practitioners. The countermeasures for ISD can be categorized with other measures, discussed in the following, that improve intersection safety and may be considered in a comprehensive approach to intersection safety.

**Clear sight triangles as much as possible without geometric improvements.** Sometimes the sight distance restriction is caused or exacerbated by the presence of overgrown foliage or other natural occurrences. Common examples are high corn crops close to the intersection and tree limbs limiting the corner sight triangle. Also, allowing parking too close to the intersection will limit ISD.

**Geometric improvements to improve ISD.** Often, changes at the major road may address ISD issues. For example, right-turning vehicles on the major road may block the line of sight for turning vehicles from the minor road. In this instance, the use of an offset right turn lane instead of a conventional right turn lane would address this ISD issue. Flattening or realigning a curve is another example.

**Increase awareness and visibility of the intersection.** Giving motorists a good view of the intersection ahead can help put them on the alert and enable them to respond to conditions more quickly. Measures under this category include tree trimming and removing unnecessary signs on the approach to the intersection, as well as:

- Enhanced delineation leading up to the intersection,
- Larger regulatory and warning signs at the intersection,
- Splitter islands on the minor-road approaches,
- Intersection lighting, and
- Overhead flashing beacons.

**Warn drivers of presence of conflicting vehicles.** For some particularly hazardous intersections, it might be beneficial to employ advanced technology devices to warn motorists on the minor road of the suitability of available gaps. Similar technology could be employed to warn motorists on the major road of the presence of vehicles approaching from the minor road.

**Choose appropriate traffic control.** In some cases, it may be appropriate to change from yield to stop control, from stop control to a multi-way stop, or even to signal control if other measures do not solve the crash problem.

**Better accommodations for pedestrians and bicyclists.** In some cases, the limited sight distance may be a problem to pedestrians or bicyclists. In this case, warnings to approaching motorists through signing or pavement markings may be effective.



## Resources

AASHTO has produced several resources that provide practitioners the basic technical information needed when examining ISD-related issues. The *Highway Safety Manual* and *A Policy on Geometric Design of Highways and Streets*, 6th Edition (AASHTO 2011, often referred to as the Green Book) may be reviewed by practitioners prior to using this guidance. HSM tools and resources are available online (<http://www.highwaysafetymanual.org/Pages/default.aspx>), and the Green Book is available for purchase through the AASHTO Bookstore ([https://bookstore.transportation.org/collection\\_detail.aspx?id&equals;110](https://bookstore.transportation.org/collection_detail.aspx?id&equals;110)).

The *Unsignalized Intersection Improvement Guide* (UIIG) was developed to assist practitioners—specifically local transportation agencies—in selecting countermeasures at unsignalized intersections to reduce the number and severity of crashes. The UIIG provides useful information on 75 countermeasures that focus on the safety, operation, and accessibility of unsignalized intersections. More information is available at: <http://www.ite.org/uiig/default.asp>.

The Crash Modification Factors Clearinghouse is a web-based database to help practitioners identify the most appropriate countermeasure for their safety needs using CMFs. More information is available on the website <http://www.cmfclearinghouse.org/index.cfm>.

*NCHRP Report 600: Human Factors Guidelines for Road Systems*, Second Edition (Campbell, Lichty, et al. 2012), outlines other behavioral considerations that may affect crashes at intersections. Issues such as reaction times and gap acceptance are discussed in this resource. The report can be accessed at <http://www.trb.org/Main/Blurbs/167909.aspx>.



## CHAPTER 6

## Base Equations for Reference

**CMFunctions**

Charts A-1 to A-6 present CMFunctions based on the following equation for target crashes:

$$CMF_{Ti} = \frac{\exp \left( -0.021 \times PSL + \frac{7.194 \times PSL}{ISD_i} + \frac{-243.009 \times LowAADT_{maj}}{ISD_i} + \frac{-177.826 \times MidAADT_{maj}}{ISD_i} \right)}{\exp \left( -0.021 \times PSL + \frac{7.194 \times PSL}{ISD_{base}} + \frac{-243.009 \times LowAADT_{maj}}{ISD_{base}} + \frac{-177.826 \times MidAADT_{maj}}{ISD_{base}} \right)}$$

where:

$CMF_{Ti}$  = target crash CMF for condition of interest  $i$ ;

$PSL$  = posted speed (in mph);

$LowAADT_{maj}$  = 1 if major-road AADT  $\leq 5,000$ ; otherwise 0;

$MidAADT_{maj}$  = 1 if  $5,000 < \text{major-road AADT} \leq 15,000$ ; otherwise 0;

$ISD_i$  = proposed or existing available intersection sight distance for the condition of interest  $i$  (in feet); and

$ISD_{base}$  = base intersection sight distance for an approach direction (in feet); for practical applications, this value is assumed to be 1,320 ft.

Charts B-1 to B-6 present CMFunctions based on the following equation for target fatal and injury crashes:

$$CMF_{TFI_i} = \frac{\exp \left( -0.009 \times PSL + \frac{6.335 \times PSL}{ISD_i} + \frac{-155.504 \times LowMidAADT_{maj}}{ISD_i} \right)}{\exp \left( -0.009 \times PSL + \frac{6.335 \times PSL}{ISD_{base}} + \frac{-155.504 \times LowMidAADT_{maj}}{ISD_{base}} \right)}$$

where:

$CMF_{TFI_i}$  = target fatal and injury crash CMF for condition of interest  $i$ ; and

$LowMidAADT_{maj}$  = 1 if major-road AADT  $\leq 15,000$ ; otherwise 0.

Caution should be used for posted speeds outside of the 35 to 60 mph range used to develop the charts. Additionally, ISDs used in the CMFunctions should only consider the ranges provided

in the charts. The minimum ISD for each posted speed corresponds to the design ISD based on left turns for an equivalent design speed minus 250 ft. The maximum ISD value is one-quarter mile (1,320 ft), which is the base condition assumed in the provided charts.

## Unknown AADT

If AADT and posted speed are known, the charts provide a more informed estimate of safety impacts. Reduced versions of the CMFunctions may be applied for situations where major AADT and posted speed are unknown. The equations can be assessed for target crashes and target fatal and injury crashes.

**Target crashes:** The impact of changing ISD can be assessed for target crashes using the following equation:

$$CMF_T = e^{\left(203.368 \times \left(\frac{1}{ISD_{proposed}} - \frac{1}{ISD_{existing}}\right)\right)}$$

For example, the CMF for increasing ISD from an existing ISD condition of 400 ft to a proposed ISD condition of 750 ft is calculated as:

$$CMF_T = e^{\left(203.368 \times \left(\frac{1}{750} - \frac{1}{400}\right)\right)}$$

This results in a CMF of 0.79, or a 21% decrease in target crashes.

**Target fatal and injury crashes:** The impact of changing ISD can also be assessed for target fatal and injury crashes using the following equation:

$$CMF_{TFI} = e^{\left(195.791 \times \left(\frac{1}{ISD_{proposed}} - \frac{1}{ISD_{existing}}\right)\right)}$$

The CMF for increasing ISD from an existing ISD condition of 400 ft to a proposed ISD condition of 750 ft is calculated as:

$$CMF_{TFI} = e^{\left(195.791 \times \left(\frac{1}{750} - \frac{1}{400}\right)\right)}$$

This results in a CMF of 0.80, or a 20% decrease in fatal and injury target crashes.



## References

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*Abbreviations and acronyms used without definitions in TRB publications:*

A4A	Airlines for America
AAAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI-NA	Airports Council International-North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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