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An Analysis of VDOT's Sight Distance Requirements Relative to Context-Sensitive Designs

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An Analysis of VDOT's Sight Distance Requirements Relative to Context-Sensitive Designs

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Abstract:

Intersection sight distance (ISD) requirements are intended to enhance safety by ensuring visibility at intersections. However, in dense urban areas, these requirements can preclude elements of the urban streetscape, such as street trees, on-street parking, and transit infrastructure, and can restrict compact mixed-use developments, such as traditional neighborhood developments. Although literature on the safety impacts of ISD is plentiful, little of it is tailored to low-speed urban environments, an area of interest to the Virginia Department of Transportation (VDOT). Accordingly, this study examined the existing state of practice on ISD guidelines and conducted a safety analysis focused on low-speed urban intersections. This report first reviews literature and policies across state departments of transportation (DOTs) and localities. Second, it presents findings from a survey of 17 state DOTs, 34 Virginia localities, and 24 VDOT residencies on current practices related to implementing ISD standards. Then, it provides details of a safety analysis examining how ISD impacts crash occurrence for 359 intersections in Virginia, distinguishing between T-intersections and four-leg intersections and stratifying by speed ranges (low speed ≤ 25 mph and high speed ≥ 30 mph).

Although most state and local agencies align their ISD requirements closely with the American Association of State Highway and Transportation Officials' *Green Book* guidelines, variations appear in their application regarding design flexibility, multimodal considerations, and obstructions. About one-half of the state DOTs have provisions for design exceptions or waivers when ISD requirements cannot be met. Roughly one-third of state DOTs provide multimodal guidance, with limited consideration given to ISD guidelines specific to traditional neighborhood developments. In Virginia, most localities follow VDOT guidance directly, with only a few reporting modified standards. Localities are more involved in development plan approvals and tend to enforce ISD more strictly for new developments, although enforcement is less consistent in older or constrained areas. Residencies noted that ISD-related recordkeeping is often informal or inconsistent, but many reported encountering intersections, especially in older downtown areas, where ISD was not met, and about one-half expressed safety concerns at such locations.

Negative-binomial regression using 2020–2024 Virginia crash data shows that limited sight distance to the right, which is needed for left turns, correlates with higher crash counts for both T-intersections and four-leg intersections, particularly on low-speed roadways. Meeting ISD guidance set by VDOT is negatively correlated with crashes. For intersections with posted speeds less than or equal to 25 miles per hour, increasing sight distance to the right by 100 feet reduced crashes by approximately 9.24% at T-intersections and 15.8% at four-leg intersections on average. Crash cost analysis showed potential average annual savings of approximately $1,683 per T-intersection and $3,100 per four-leg intersection for each additional sight distance leg meeting VDOT's threshold at an intersection. These findings confirm that maintaining adequate sight distance to the right provides a clear safety benefit and that compliance with VDOT sight-distance standards is associated with fewer crashes.

FINAL REPORT

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ABSTRACT

Intersection sight distance (ISD) requirements are intended to enhance safety by ensuring visibility at intersections. However, in dense urban areas, these requirements can preclude elements of the urban streetscape, such as street trees, on-street parking, and transit infrastructure, and can restrict compact mixed-use developments, such as traditional neighborhood developments. Although literature on the safety impacts of ISD is plentiful, little of it is tailored to low-speed urban environments, an area of interest to the Virginia Department of Transportation (VDOT). Accordingly, this study examined the existing state of practice on ISD guidelines and conducted a safety analysis focused on low-speed urban intersections. This report first reviews literature and policies across state departments of transportation (DOTs) and localities. Second, it presents findings from a survey of 17 state DOTs, 34 Virginia localities, and 24 VDOT residencies on current practices related to implementing ISD standards. Then, it provides details of a safety analysis examining how ISD impacts crash occurrence for 359 intersections in Virginia, distinguishing between T-intersections and four-leg intersections and stratifying by speed ranges (low speed $\leq$ 25 mph and high speed $\geq$ 30 mph).

Although most state and local agencies align their ISD requirements closely with the American Association of State Highway and Transportation Officials' *Green Book* guidelines, variations appear in their application regarding design flexibility, multimodal considerations, and obstructions. About one-half of the state DOTs have provisions for design exceptions or waivers when ISD requirements cannot be met. Roughly one-third of state DOTs provide multimodal guidance, with limited consideration given to ISD guidelines specific to traditional neighborhood developments. In Virginia, most localities follow VDOT guidance directly, with only a few reporting modified standards. Localities are more involved in development plan approvals and tend to enforce ISD more strictly for new developments, although enforcement is less consistent in older or constrained areas. Residencies noted that ISD-related recordkeeping is often informal or inconsistent, but many reported encountering intersections, especially in older downtown areas, where ISD was not met, and about one-half expressed safety concerns at such locations.

Negative-binomial regression using 2020–2024 Virginia crash data shows that limited sight distance to the right, which is needed for left turns, correlates with higher crash counts for both T-intersections and four-leg intersections, particularly on low-speed roadways. Meeting ISD guidance set by VDOT is negatively correlated with crashes. For intersections with posted speeds less than or equal to 25 miles per hour, increasing sight distance to the right by 100 feet reduced crashes by approximately 9.24% at T-intersections and 15.8% at four-leg intersections on average. Crash cost analysis showed potential average annual savings of approximately $1,683 per T-intersection and $3,100 per four-leg intersection for each additional sight distance leg meeting VDOT's threshold at an intersection. These findings confirm that maintaining adequate sight distance to the right provides a clear safety benefit and that compliance with VDOT sight-distance standards is associated with fewer crashes.

EXECUTIVE SUMMARY

Introduction

Adequate sight distance at intersections is essential for motorists to safely perceive and respond to approaching vehicles. The American Association of State Highway and Transportation Officials' (AASHTO) *Green Book* provides national guidelines for establishing intersection sight distance (ISD) (AASHTO, 2018), and state departments of transportation (DOTs) and local jurisdictions across the United States generally rely on these standards when developing their own requirements.

In urban settings, the application of conventional ISD standards can limit desirable design features such as on-street parking, street trees, and compact building setbacks, creating conflicts with multimodal and context-sensitive design goals. Guidance on how agencies address these challenges remains limited, particularly regarding the use of design flexibility, multimodal considerations, or adaptations for compact developments such as traditional neighborhood developments, which emphasize walkability and mixed land uses. Macdonald et al. (2006) noted that applying ISD standards in urban areas can be ambiguous, and strict interpretations could eliminate key streetscape elements from all but the center of city blocks. Although ISD requirements are intended to improve safety by maximizing visibility, they may unintentionally encourage higher vehicle speeds in urban contexts, undermining pedestrian safety and multimodal access (NACTO, 2013). Agencies such as AASHTO and the Virginia Department of Transportation (VDOT) promote context-sensitive design principles that allow for flexible solutions, but the guidelines remain unclear.

Although previous research has examined the safety impacts of ISD, much of it has focused on rural or higher speed environments, with limited attention to low-speed (e.g., ≤ 25 mph) urban contexts. For instance, recent studies by Eccles et al. (2018) and Yang (2024) analyzed intersections primarily on higher speed corridors, with crash modification factors (CMFs) developed only for the 3560 mph range. Both studies noted difficulties in collecting field data at compact, low-speed sites due to obstructions and pedestrian activity, leading to the exclusion of such locations. As a result, empirical evidence for ISD in low-speed urban contexts is limited, and existing CMFs provide little coverage for posted speeds below 30 mph.

Purpose and Scope

The purpose of this study was to address VDOT's need to evaluate existing ISD practices in urban contexts and to assess their associated safety impacts. Specific objectives were to (1) determine ISD standards used by state DOTs and Virginia localities, (2) determine how deviations from ISD standards are managed, and (3) evaluate the safety implications of not meeting ISD standards at low-speed Virginia intersections. The research combined literature and policy review, survey data collection, and a crash-based safety analysis. This study focused on Case B intersections (intersections with stop control on the minor road), and the safety analysis specifically examined low-speed urban intersections.

Methods

To meet the objectives of this project, four tasks were undertaken:

1. Reviewing relevant literature.
2. Reviewing policy documents.
3. Surveying existing practices.
4. Collecting ISD data and conducting crash-based safety analysis.

The first task was to review relevant literature. This review examined past research on the safety effects of ISD, the availability of CMFs, and data collection methods such as field measurements, aerial imagery, and light detection and ranging (LiDAR). It identified how ISD has been evaluated across different contexts.

The second task was to review policy documents. This task involved examining national guidance from AASHTO's *Green Book*, design manuals from state DOTs, and policies from local jurisdictions. Emphasis was placed on how standards define ISD requirements, address multimodal considerations, provide guidance for traditional neighborhood developments, and incorporate design flexibilities. This effort provided the background needed to tailor subsequent tasks, develop survey questions, and establish the basis for the overall study.

The third task was to administer surveys to state and local agencies to document existing practices. The researchers conducted three separate surveys targeting other state DOTs, Virginia localities, and VDOT residencies. The surveys sought to capture how agencies define and apply ISD requirements, whether they allow adjustments or waivers when standards cannot be met, and the extent to which multimodal and context-sensitive elements are considered. Agencies were also asked about recordkeeping practices, enforcement in constrained urban areas, and safety concerns or experiences with intersections that do not meet current ISD guidance. The findings provided direct insights into the state of practice, highlighted both consistencies with AASHTO guidance and areas where flexibility or alternative approaches have been adopted, and informed the design of the subsequent data collection effort.

The fourth task was to analyze a crash-based safety to empirically evaluate the relationship between ISD and safety outcomes. Virtual data collection methods—including LiDAR, Google Earth, and Google Maps—were explored, and ISD measurements were ultimately collected for 359 urban intersections across Virginia using Google Earth and Maps. These measurements were combined with crash data from 2020 to 2024 obtained from VDOT's public crash database (VDOT, 2025a). Negative binomial regression models were applied to assess how variations in sight distance affected crash frequency, with results stratified by intersection type (T-intersections and four-leg intersections) and by speed group (≤ 25 mph and ≥ 30 mph). The analysis also evaluated whether intersections that met VDOT's ISD guidelines experienced fewer crashes compared with those that did not and included the development of CMFs for low-speed roadways (25 mph and lower).

Key Results

Literature and Policy Review

- Most (approximately 90%) of agencies base their ISD requirements on AASHTO's *Green Book*.
- Approximately 50% of state DOTs allow design exceptions or waivers when ISD cannot be met.
- Roughly one-third of agencies provide multimodal guidance, and fewer than 10% reference ISD standards for traditional neighborhood developments.
- Guidance on permanent obstructions such as vegetation and buildings is common, but fewer than 25% of agencies explicitly address parked vehicles or temporary barriers.
- CMFs from prior studies are limited to speeds in the 35–60 mph range, with no estimates available for intersections below 30 mph.

Survey of Existing Practices

- Responses were obtained from 17 state DOTs, 34 Virginia localities, and 24 VDOT residencies.
- Nearly all state DOTs follow AASHTO's ISD standards, but approximately one-third have provisions allowing adjustments based on site-specific conditions.
- Approximately 30% of state DOTs reported having ISD guidance that addresses multimodal needs, with approximately 18% including specific requirements for pedestrians and bicyclists.
- In Virginia, 28 of 34 localities (≈ 82%) apply VDOT's ISD standards directly, and 6 localities (≈ 18%) reported using modified standards.
- Roughly 70% of localities reported stricter enforcement of ISD in new developments and enforcement in older constrained areas as inconsistent.
- Approximately 45% of state DOTs allow adjustments in decision points or sight triangles. Among Virginia localities, fewer than 30% reported allowing such adjustments.
- Twelve of 24 VDOT residencies (50%) reported intersections, particularly in older downtown areas, not meeting ISD requirements, and a similar share indicated safety concerns at those sites.
- More than 75% of residencies described ISD recordkeeping as informal, with little systematic documentation.

Safety Analysis

- Limited sight distance to the right (SDR) was significantly associated with higher crash counts at both T- and four-leg intersections.
- Sight distance to the left was not a significant predictor when using all sites but showed significance when considering only low-speed sites (≤ 25 mph).
- For intersections with posted speeds of 25 mph or less, increasing SDR by 100 feet reduced crashes by approximately 9.24% at T-intersections and 15.8% at four-leg intersections on average.

- In the higher speed group (≥ 30 mph), SDR effects were weaker and less consistent. Meeting VDOT's ISD guidelines was associated with lower crash frequency across both intersection types.
- CMFs were developed for SDR at 25 mph or less, covering both T- and four-leg intersections.

Key Conclusions

- *ISD standards are generally derived from AASHTO guidance, with some modifications.* Most agencies adopt requirements from AASHTO's *Green Book*, although about 40% of state DOTs reported establishing their own sight triangle dimensions rather than relying strictly on AASHTO values.

- *ISD standards tend not to include multimodal and compact development considerations.* Roughly one-third of agencies reference multimodal factors, and fewer than 10% provide ISD guidance for traditional neighborhood developments.

- *Allowance of deviations from ISD standards varies across agencies.* About one-half of state DOTs allow design exceptions or waivers when standards cannot be met. In Virginia, more than 80% of localities apply VDOT standards directly, with only limited modifications.

- *Recordkeeping on ISD compliance is limited.* Most VDOT residencies indicated that ISD evaluations are tracked informally, with no systematic documentation available for future reference.

- *Safety concerns were reported at locations not meeting ISD standards.* Nearly one-half of VDOT residencies noted intersections, particularly in older constrained areas, where ISD was not satisfied and crash risks were observed. Several Virginia localities also reported similar concerns.

- *Meeting ISD standards is associated with fewer crashes.* Intersections that satisfied VDOT's ISD requirements experienced lower crash frequencies compared with those that did not.

- *Improved SDR is linked to safety benefits in low-speed environments.* At speeds of 25 mph or lower, each average 100-foot increase in SDR (up to 600 feet) was associated with a 9.34% reduction in crashes at T-intersections and a 15.8% reduction at four-leg intersections.

Recommendations

1. *VDOT's Location and Design Division should continue to apply the ISD values in Tables 2 through 5 in Appendix F of its* Road Design Manual*, particularly for urban low-speed intersections (posted speed limits of 25 mph and below).* The study found that reduced sight distance—especially SDR—and failure to meet the ISD standards in the VDOT

(2025b) *Road Design Manual* were statistically associated with higher crash counts at urban low-speed intersections. This recommendation does not preclude site-specific modifications, as design exception or waiver requests must still be submitted in accordance with VDOT (2024a) IIM-LD-27, *Design Exceptions/Design Waivers*.

2. *With the support of an appropriate research advisory committee, the Virginia Transportation Research Council should initiate a project to develop a mobile LiDAR data collection tool.* This recommendation would involve developing a research needs statement for a research advisory committee presentation that proposes a pilot project to collect mobile LiDAR data in an urban environment within a VDOT district. The objective of this pilot would be to establish a scalable ISD measurement tool capable of analyzing multiple scenarios and producing more accurate ISD data.

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INTRODUCTION

Sight distance in roadway design refers to the length of roadway visible to a driver and includes three common types: intersection sight distance (ISD), stopping sight distance (SSD), and passing sight distance. For intersections, ISD and SSD are the two critical design measures. *ISD* is defined as the distance motorists can see approaching vehicles before an obstruction near the intersection blocks their line of sight, and *SSD* is defined as the distance needed for drivers to see an object on the roadway ahead and bring their vehicles to a safe stop before colliding with the object. The provision of adequate sight distance at an intersection is crucial to motorists' ability to operate their vehicles safely. Poor sight distance can lead to vehicle crashes on the approach to and within intersections because motorists may be unable to see and react to traffic control devices or approaching vehicles. Although previous research has examined the safety effects of ISD, much of it is focused on rural or higher speed environments, with limited attention to low-speed urban contexts. Moreover, the application of conventional ISD standards in urban areas can limit desirable urban design elements, such as on-street parking, street trees, or compact building setbacks, raising concerns about compatibility with multimodal and context-sensitive design goals.

Common Intersection Sight Distance Guidelines

The American Association of State Highway and Transportation Officials' (AASHTO) *Green Book* provides national guidelines for establishing ISD (AASHTO, 2018). State departments of transportation (DOTs) and municipal jurisdictions in the United States generally refer to these guidelines when developing their own requirements. AASHTO ISD guidelines vary by intersection type. Of the seven intersection types, Case B intersections—intersections with stop control on the minor road—have the highest ISD requirements, which are calculated based on the assumption that the intersection should allow for an uninterrupted flow of traffic on the major road. Hence, the sight distance along the major road is given as the product of (1) the design speed of the major road, (2) the time it takes for the design vehicle stopped on the minor road to accelerate and clear the intersection, and (3) a conversion factor shown in Equation 1. Because Case B1, a left turn from the minor road, requires the longest time for the design vehicle to clear the intersection, Case B1 governs ISD requirements for Case B intersections. Table 1 shows the SSD and ISD design guidance for Case B intersection types based on the following assumptions (AASHTO, 2018):

- Minor road approaches are stop controlled.
- Driver eye heights and object heights used are those associated with passenger cars.
- Both minor and major roads are at level grade.
- A left turn from the minor road is considered the worst-case scenario (i.e., requiring the most sight distance).
- The major road is an undivided, two-way, two-lane roadway with no turn lanes.

$$ISD = 1.47V_{major}t_g \quad \text{(Eq. 1)}$$

Where:
ISD = length of the sight triangle along the major road (feet).
V_{major} = design speed of major road (mph).
t_g = time gap for minor road vehicles to enter the major road (seconds).

Table 1. Sight Distance Values for Case B Intersections

Design Speed (mph)	Stopping Sight Distance (feet)	Design Intersection Sight Distance for Passenger Cars (feet)[a]	
		Case B1	Cases B2 and B3
15	80	170	145
20	115	225	195
25	155	280	240
30	200	335	290
35	250	390	335
40	305	445	385
45	360	500	430
50	425	555	480
55	495	610	530
60	570	665	575
65	645	720	625
70	730	775	670
75	820	830	720
80	910	885	765

[a] Intersection sight distance shown is for a stopped passenger car to turn left onto a two-lane highway with no median and grades 3 percent or less. For other conditions, the time gap should be adjusted and the sight distance recalculated (AASHTO, 2018).

The distance b in Figure 1 represents ISD along the major road. The decision point (DP) in Figure 1 is the point of the sight triangle where the vehicle's driver on the minor road is located. Based on AASHTO's (2018) *Green Book*, the DP location for Case B intersections should be 14.5 feet from the edge of the major road traveled way. Where practical, the distance should increase to 18 feet.

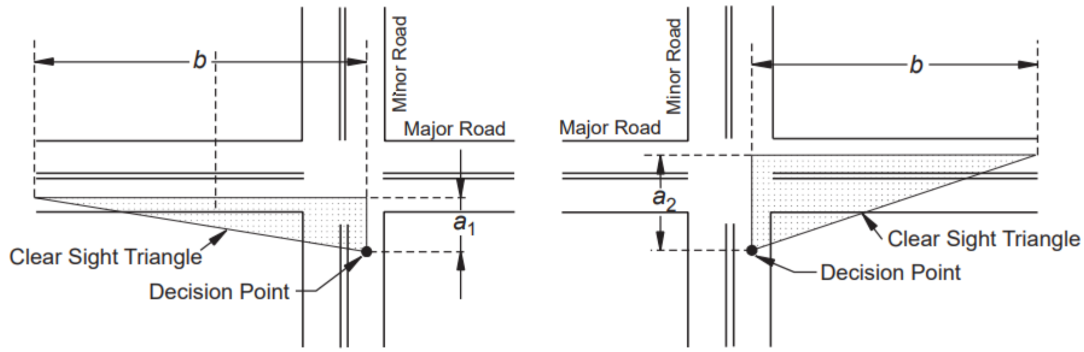


Figure 1. Departure Sight Triangles for Case B Intersections. Distance a_1 to the left and a_2 to the right illustrate the distance from the major road, along the minor road. Distance b illustrates the length of this leg of the sight triangle. Reprinted with permission from AASHTO (2018).

The Virginia Department of Transportation (VDOT) distinguishes between sight distance to the right (SDR) and sight distance to the left (SDL), prescribing separate values for each direction of observation based on roadway characteristics, as Figure 2 shows. Both AASHTO and VDOT define ISD as a function of speed and maneuver type, and both require the corresponding sight triangles to remain unobstructed.

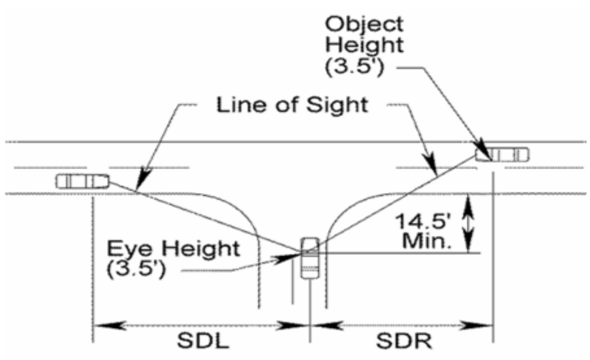


Figure 2. Sight Triangle for Case B Intersections (VDOT, 2025b: Appendix A1, Geometric Design Standards). SDL = sight distance to the left; SDR = sight distance to the right.

Unique Considerations for Intersection Sight Distance in Urban Areas

In urban areas, DP is often set back to accommodate a crosswalk. Thus, the resulting required sight triangle can preclude elements of the urban streetscape. Macdonald et al. (2006) found that the application of these standards to urban areas can be ambiguous. Urban elements potentially affected by sight distances and sight triangles include on-street parking, street trees, bus shelters, and, in extreme instances, buildings approaching the public right-of-way. Given the large distances involved, a strict interpretation of ISD requirements would eliminate these elements from all but the very center of city blocks.

Furthermore, although ISD requirements are intended to improve safety by maximizing visibility at intersections, by precluding urban-style intersection forms, they might actually result in higher-than-desirable automobile speeds at urban intersections. Some cities have employed the related concept of "daylighting" intersections to improve lines of sight (National Association of City Transportation Officials [NACTO], 2013), but recommended parameters (e.g., remove parking within 25 feet of an intersection, or approximately one parking space) differ widely from VDOT parameters—where even a waiver to use a lower distance based on SSD can result in the loss of multiple parking spaces.

Context-sensitive design in an urban area requires planners to employ strategies to promote walkability and low-speed automobile travel, such as street-facing buildings built to the property line and tight intersection layouts. AASHTO promotes context-sensitive design principles that encourage flexible solutions, including alternative traffic management strategies like turn restrictions and signalization, when conventional intersection designs face urban constraints (AASHTO, 2004, 2018). However, examining the current state of practice for ISD standards, the extent to which they incorporate contextual design considerations, and the safety effects of these standards on low-speed urban roadways is needed. This research investigates the current state of practice on ISD standards across state DOTs and local jurisdictions and evaluates the safety effects of ISD at low-speed urban intersections in Virginia.

Unknown Safety Effects of Intersection Sight Distance at Low-Speed Environments

ISD is based on the design speed of the major road and the time gap needed for a driver to complete a turning or crossing maneuver. Prior to 2001, AASHTO guidance relied on the assumption that one driver would accelerate, and the other would decelerate to avoid conflicts. However, this speed-adjustment-based approach was later reconsidered because of safety concerns. Subsequent policy updates, particularly those influenced by National Cooperative Highway Research Program (NCHRP) 383 (Harwood et al., 1996), emphasized providing sufficient stopping-based ISD, where drivers can perceive, react, and come to a stop if necessary, representing a more conservative and safety-focused standard.

Numerous studies have investigated the safety effects of ISD, particularly at stop-controlled intersections. In rural settings, the literature tends to support longer sight distances. Morris et al. (2019), using driving simulators, identified approximately 1,000 feet as an optimal ISD threshold that improves driver decision-making and reduces mental workload. Similarly, Himes et al. (2018), based on an analysis of 832 stop-controlled intersections, reported that crash frequency increased significantly when ISD dropped below 300 feet but showed diminishing marginal safety benefits beyond 1,000 feet. However, the findings have not always been consistent. For example, Charlton (2004) observed that excessive sight distance in rural environments may prompt riskier driving behavior because of overconfidence in identifying acceptable gaps, whereas Souleyrette et al. (2006) found that restricted sight lines were not a significant factor in multivehicle crashes at low-volume rural intersections.

In urban environments, the relationship between ISD and safety is more nuanced. Studies such as Poch and Mannering (1996) found that reduced ISD was strongly associated with increased angle crash frequency at urban stop-controlled intersections. Retting et al. (2003) also documented that a large proportion of crashes at urban intersections involved drivers failing to detect cross traffic, often because of obstructed views. Meanwhile, some design guidelines, such as those provided from NACTO (2013), caution that excessively open sight triangles may inadvertently contribute to higher vehicle speeds, potentially undermining pedestrian safety and reducing driver attention to vulnerable users.

A substantial gap remains in understanding the effects of ISD in low-speed urban contexts. Recent studies have also concentrated on rural or higher speed roads, with limited inclusion of compact urban intersections where posted speed limits are 30 mph or lower. One of the most comprehensive studies to date, NCHRP Report 875 (Eccles et al., 2018), collected data from intersections with speeds ranging from 20 to 70 mph (mean ≈ 48 mph) across three study states. However, the crash modification factors (CMFs), which allow one to estimate changes in crash frequency resulting from a change in ISD, were limited to sites in the 35–60 mph range. The report cautions against applying CMFs outside the 35–60 mph range, noting that urban intersections in the dataset primarily reflected suburban corridors rather than traditional downtown grids. Moreover, the study acknowledged difficulties in collecting field measurements in dense urban areas because of obstructions, such as parked vehicles, narrow rights-of-way, and high pedestrian activity, conditions that led to the exclusion of such sites from the analysis (Eccles et al., 2018).

These limitations are present in Yang (2024), a study that analyzed 230 intersections across Alabama’s state highway system with posted speed limits ranging from 30 to 65 mph (mean: 52.1 mph). Yang’s (2024) analysis highlights critical constraints in current ISD research methods and data availability, particularly the lack of applicability of existing CMFs, to lower speed and locally variable urban conditions.

Overall, although ISD has been widely studied, especially in rural and suburban settings, research has not adequately addressed its safety implications in lower speed urban environments, a limitation Yang (2024) and Eccles et al. (2018) noted. The absence of crash models and CMFs for these areas reflects a persistent gap in understanding how ISD interacts with crash risk in contexts where space constraints and multimodal activity often make traditional designs challenging to implement.

PURPOSE AND SCOPE

The purpose of this study was to address VDOT’s need to evaluate existing ISD practices in urban contexts and to assess their associated safety effects. Specific objectives were to (1) determine the ISD standards state DOTs and Virginia localities use, (2) determine how deviations from ISD standards are managed, and (3) evaluate the safety implications of not meeting ISD standards at low-speed Virginia intersections. This research combined literature and policy review, survey data collection, and a crash-based safety analysis. The study focused on Case B intersections (intersections with stop control on the minor road), and the safety analysis specifically examined low-speed urban intersections.

METHODS

To meet this project's objectives, the researchers undertook the following tasks:

1. Reviewing data collection literature.
2. Reviewing policy documents.
3. Surveying existing practices.
4. Conducting crash-based safety analysis based on ISD measurements.

Literature Review for Data Collection Methods

Because ISD is not routinely available, the literature review examined the evolution of data collection techniques, ranging from traditional field surveys to light detection and ranging (LiDAR)-based and imagery-supported approaches. This information supported the ISD measurements used in the following crash-based safety analysis.

Effective evaluation of ISD requires accurate data collection methods that capture the visibility conditions between conflicting road users. Over time, these methods have evolved from traditional field-based measurements to remote sensing and image-based techniques, offering varying levels of precision, scalability, and practicality.

Traditional Field Surveys

The most conventional approach to ISD measurement involves in-person, rod-and-target surveys, as specified in the AASHTO (2018) *Green Book*. This process positions personnel at decision and target points, typically 14.5 feet from the edge of the major road, to manually measure unobstructed sight lines. These measurements are based on fixed-eye and object heights, often 42 inches, and rely on a two-person crew using tools like laser rangefinders or measuring wheels. Although field surveys provide direct, ground-truth observations, they are labor-intensive, pose safety risks in active traffic, and are often impractical in high-volume or urban environments. They also fail to account for variability in driver behavior, vehicle types, and dynamic obstructions like parked vehicles or vegetation (Eccles et al., 2018; Olsen et al., 2013).

LiDAR and Remote Sensing Approaches

LiDAR systems emit laser pulses to generate detailed three-dimensional (3D) representations of the built environment, allowing analysts to simulate driver sightlines and detect visual obstructions with high spatial accuracy. Recent advancements in LiDAR technology and their integration with geographic information systems (GIS) have enabled virtual assessments of ISD across large roadway networks. Two broad types of LiDAR are available, which are discussed in the following sections.

Aerial LiDAR refers to laser scanning systems mounted on aircraft that collect elevation data to generate large-scale 3D surface models of the roadway environment. Several researchers have explored aerial LiDAR for ISD extraction, with varying degrees of success and different methodological approaches. Khattak et al. (2003) were among the first to demonstrate the feasibility of using airborne laser scanning data to detect ISD obstructions, utilizing GIS line-of-sight methods with first and last return digital terrain models. Their methodology involved processing raw LiDAR point clouds to generate digital terrain models and digital surface models, then applying GIS-based line-of-sight algorithms to identify potential visibility obstructions along intersection sight triangles.

Khattak and Shamayleh (2005) advanced this methodology by developing GIS viewshed methods to detect road sight distance obstructions using digital surface models derived from aerial LiDAR data. Their technical approach involved creating 3D surface representations from LiDAR point clouds, establishing observer and target points based on AASHTO sight distance criteria, and executing viewshed analyses to determine visible and obstructed areas within intersection sight triangles. The methodology demonstrated computational efficiency for broad-area coverage but revealed limitations in capturing fine-scale obstructions. Tsai et al. (2011) further refined these techniques by developing GIS-based methods to not only detect ISD obstructions but also quantify their severity using digital surface models from airborne laser scanning. Their approach incorporated obstruction height calculations, visibility percentage assessments, and severity classification algorithms that ranked obstructions based on their effect on available sight distance.

Aerial LiDAR systems face significant limitations for detailed ISD extraction. The technology’s lower point density (typically 1–10 points per square meter) and inability to capture near-ground-level features such as fences, shrubs, and parked cars limit its effectiveness in dense urban settings. Aerial systems often fail to capture the complete vertical structure of environments because of occlusion issues, particularly where overlapping features can obscure measurements. The digital surface models used in aerial LiDAR applications do not fully represent the geometry of 3D objects, which can adversely influence sight distance analyses by not accounting for visible space underneath objects such as tree crowns, building overhangs, signs, and power lines.

Mobile LiDAR refers to laser scanning systems mounted on moving vehicles that collect high-resolution 3D point cloud data of roadways and surrounding features. Mobile LiDAR systems have emerged as a superior technology for detailed ISD extraction, offering higher resolution and better capture of roadway-level features critical to sight distance analysis. Jung et al. (2018) developed advanced 3D virtual ISD analysis methodologies using static terrestrial laser scanning at an intersection in Corvallis, Oregon, collecting data from nine independent setups with 360-degree panoramic coverage at 0.05-degree sampling resolution. Their methodology involved establishing multiple scan positions around the intersection perimeter, registering point clouds using reflective targets, and developing custom algorithms to simulate driver sight lines through the 3D point cloud environment. The study found that conventional field measurements significantly overpredicted visible areas that could be important to a driver’s response, whereas the LiDAR-based approach captured detailed obstructions that traditional methods missed.

Olsen et al. (2013) developed the Sight Distance Analysis using LiDAR algorithm specifically for 3D sight distance analysis using point cloud data. The Sight Distance Analysis using LiDAR methodology incorporated ray-casting algorithms that traced sight lines through point cloud data, obstruction detection algorithms that identified intervening objects, and visibility calculation routines that quantified available sight distances for various vehicle configurations. The Sight Distance Analysis using LiDAR algorithm showed significantly more detail than conventional results, with traditional approaches overpredicting visible areas because of their reliance on a few discrete measurements.

Yang's (2024) Alabama ISD study is a comprehensive application of mobile LiDAR for systematic sight distance measurement, covering 230 intersections along the state highway system. Using platforms that captured more than 1,000 points per square meter, the study enabled high-resolution geometric analysis of intersection sight triangles. Yang developed automated workflows for point cloud preprocessing, ground plane extraction, and obstruction identification to distinguish relevant visual obstructions from background features. Ray-casting techniques were applied to simulate driver sight lines and compute maximum available sight distances, which ranged from 209 to 1,320 feet. Validation against field survey data showed strong agreement and also revealed consistent overestimation in manual methods. The study concluded that mobile LiDAR offers both the spatial precision and scalability needed for accurate ISD evaluation and represents state of the practice for safety analysis and geometric design.

Mobile LiDAR applications also face certain limitations, including higher operational costs compared with aerial systems, weather dependency, and requirements for specialized equipment and technical expertise for operation and data interpretation. Yang (2024) noted additional challenges, including data storage requirements for large point cloud datasets, computational processing demands for automated analysis algorithms, and the need for specialized software and hardware infrastructure.

Google Earth and Google Maps

Satellite imagery platforms like Google Earth have become widely used for ISD assessments, especially in studies for which LiDAR data or field access is unavailable. Researchers use Google Earth's overhead and oblique views to estimate sightlines, measure distances, and verify the presence of obstructions. Despite being based on static imagery, Google Earth has demonstrated acceptable accuracy for many transportation applications.

Quan et al. (2021) developed a method to measure sight distance at U-turns using existing tools in Google Earth and perspective grid software. To validate their approach, they used a GoPro camera in the field to identify the furthest visible point along the road, then located that point in Google Earth and measured the corresponding sight distance using the platform. Quan et al. (2021) emphasized the need to develop a method that allows transportation practitioners to estimate sight distance using publicly accessible tools like Google Earth because other techniques can be resource intensive.

In ISD research, Google Earth has also been used to validate obstruction detection algorithms and correct vegetation-related false positives (Yang, 2024). Yang (2024) further notes that Google Earth provides a safe and efficient alternative to collecting ISD data in the field. Harrington et al. (2017) found that Google Earth can achieve a mean measurement error below

0.5% for distances more than 500 feet, indicating a high level of accuracy for transportation-related distance estimation. Studies such as Yang (2024) and Quan et al. (2021) have effectively used Google Earth as a reliable reference for validating sight distance measurements.

Computational Enhancements and Automation

Alongside advances in sensing hardware, Jung et al. (2018) and Yang (2024) showed that ISD analysis has benefited from improvements in data processing and automation. These studies applied machine-learning techniques to classify obstructing elements in street-level imagery and employed LiDAR-driven algorithms to simulate sight triangles and viewsheds, accommodating variability in geometry, slope, and obstruction types. Although these methods are still emerging, they offer promising avenues for enhancing consistency and reducing labor costs in large-scale evaluations.

ISD data collection has progressed from manual field methods to technologically enhanced systems involving LiDAR and image-based tools. Traditional rod-and-target surveys offer high accuracy at a local scale but are limited by safety and practicality. Terrestrial and mobile LiDAR provide detailed 3D visibility analysis, whereas airborne LiDAR is suitable for regional screening in less obstructed areas. Google Earth remains a valuable and accessible tool, particularly when LiDAR data are unavailable, offering consistent results in urban and low-speed contexts. These tools, when combined with automated processing algorithms, support efficient and scalable ISD assessments in diverse roadway environments.

Policy Document Review

This section explored how state and local DOTs provide dimensions for sight triangles (DP location and ISD), define visual obstructions, and restrict the size of objects within the sight triangle. It also investigated whether those DOTs have any provisions for design exceptions or waivers in situations for which the necessary ISD guidelines cannot be met. Subsequently, the study focused on how these sources designate object height, eye height, and field data collection procedures and then explored the appropriate method of data collection in the field. Furthermore, the review considered multimodal considerations and traditional neighborhood design guidelines from state DOTs and localities to identify any context-sensitive solutions they may offer. The information from the review was used to establish questionnaires for the surveys of state DOTs and localities within Virginia.

A detailed examination was conducted of different documents available on the websites of state and local agencies relevant to the research scope. Types of documents included road design manuals, complete streets design guides, access management standards, traditional neighborhood design guidelines, local street design guides, and so on. The subsequent sections explain the policies of the state DOTs and localities studied.

The review looked at policy documents from state DOTs that, like Virginia, own the secondary system of roadways and from state DOTs that own the most lane miles. Lane miles refer to the total length of lanes on a roadway, a measure that accounts for all lanes of traffic. On the other hand, centerline miles measure the total length of a road from its starting point to its endpoint, regardless of the number of lanes it has. Lane miles can be obtained by multiplying the centerline miles by the number of lanes. Table 2 shows the five state DOTs that own their secondaries, along with the District of Columbia, which also owns all of its roads. Among these states, Virginia, West Virginia, North Carolina, and South Carolina have more rural lane miles than urban lane miles. Delaware has more urban lane miles, and the District of Columbia has entirely urban roads. Also, North Carolina has the most lane miles of the states that own the secondary system of roadways.

Table 2. State Departments of Transportation that Own the Secondary System of Roadways

State	Lane Miles[a]		
	Rural	Urban	Total
Virginia	102,133	62,637	164,769
West Virginia	65,643	14,492	80,135
North Carolina	136,247	93,920	230,167
South Carolina	112,770	53,798	166,568
Delaware	6,016	8,149	14,164
District of Columbia	0	3,460	3,460

[a] Federal Highway Administration (2023a)

State DOTs managing a large number of lane miles likely encounter diverse roadway conditions and traffic scenarios. Examining their policy documents provides a comprehensive understanding of ISD standards across a wide range of contexts. Table 3 shows the state DOTs with the most lane miles. Among these states, California and Florida have more urban roads than rural roads. All the other eight state DOTs have more rural lane miles than urban lane miles. Of all the states in Table 3, Texas has the largest number of lane miles.

Table 3. State Departments of Transportation with the Most Lane Miles

State	Lane Miles[a]		
	Rural	Urban	Total
Texas	431,303	267,535	698,839
California	156,642	243,575	400,218
Illinois	195,702	111,100	306,802
Minnesota	240,993	52,794	293,787
Kansas	253,357	30,886	284,244
Missouri	221,028	57,550	278,578
Florida	77,948	198,892	276,841
Georgia	155,694	111,908	267,602
Ohio	153,394	108,678	262,072
Michigan	170,394	85,780	256,174

[a] Federal Highway Administration (2023a)

The review then looked at policies from selected localities found to be inclusive of specific details on ISD standards. The aim was to compare the ISD standards between localities and those set by state DOTs, as well as disparities between localities within Virginia and those outside Virginia. Within Virginia, the review focused on the Cities of Virginia Beach and Charlottesville, as well as Henrico and Arlington Counties, which, unlike other Virginia counties, maintain their own road networks. The review also analyzed policies from localities covered in the NCHRP Report 875 (Eccles et al., 2018), such as the City of Scottsdale, Carroll County, and the City of Kirkland, given the relevance of this report to the research project. Policies from major cities, such as New York, Los Angeles, and Chicago, were also reviewed.

Table 4 shows the localities studied, along with their populations and the lane miles they manage. Centerline miles are mentioned for the localities whose data on lane miles managed was unobtainable.

Table 4. Localities Reviewed

Locality	Lane Miles	Population[a]
City of Charlotte, NC (2024)	2,500[b]	874,579
City of Scottsdale, AZ (2024)	3,380	241,361
Carroll County, MD (Maryland DOT, 2023)	1,405	172,891
City of Kirkland, WA (2024)	648	92,175
Arlington County, VA (VDOT, 2025c)	359	238,643
Henrico County, VA (VDOT, 2025c)	1,279	334,389
City of Charlottesville, VA (2023)	158	46,553
City of Virginia Beach, VA (2025)	3,600	459,470
New York City DOT, NY (2025a)	6,300[b]	8,804,190
Los Angeles DOT, CA (2024)	2,8000	3,898,747
Chicago DOT, IL (2024)	More than 4,000[b]	2,746,388
City of Morgantown, WV (2019)	100[b]	30,347
Charleston County, SC (Brack, 2022)	4,182	408,235
City of Newark, DE (2014)	130	30,601

DOT = departments of transportation. [a] U.S. Census Bureau (2020a); [b] Centerline miles.

To ensure comprehensive representation, localities were selected from states where DOTs manage secondary roads and from states where localities own their secondaries. For states where the DOTs manage their secondary roads, the analysis focused on standards from the most populous cities and counties where ISD standards and policies were both available and accessible. When the policy documents for the most populous city or county were not accessible, the study shifted to the next most populous area. For example, in the case of West Virginia, Charleston is the most populous city (Federal Highway Administration [FHWA], 2023a). However, because the relevant documents for Charleston were not found and similarly for the next largest city, Huntington, the study then moved to the City of Morgantown, the subsequent largest city, for its review.

Survey of Existing Practices

A survey of state DOTs and localities in Virginia was conducted to gain a deeper understanding of their ISD standards, how these standards differ from the AASHTO guidelines or state DOT guidelines (in the case of localities), the design flexibilities offered, and whether they maintain ISD and safety data for intersections where the required ISD standards are not met. Three distinct surveys were conducted: state DOTs, Virginia localities, and VDOT residencies. VDOT residencies were included because a technical review panel member indicated that they might keep records of ISD data. All surveys were designed using Qualtrics, with detailed descriptions of each survey provided in the following sections.

State Departments of Transportation Survey

The state DOT survey aimed to understand the ISD standards across different state DOTs and how they align with AASHTO (2018) *Green Book* guidelines. The survey explored how states incorporate AASHTO guidance into their ISD standards, define sight triangle dimensions

(DP location and ISD), define obstructions, restrict objects within the sight triangle, address multimodal considerations (such as bicycle and pedestrian sight distance), and whether they offer different ISD guidance for multimodal users. It also inquired about whether their documents address traditional neighborhood developments (TNDs) and if they provide different ISD guidance for TNDs, the design flexibilities available when ISD standards cannot be met, the factors considered in such cases, and the DOT's role in approving design modification requests. Given that state DOTs may be less familiar with the development plan review process and the handling of ISD data in urban areas (the project's focus), the questions were kept general and related to design standards. In addition, respondents were asked to suggest localities and contacts within their states for further surveying. The survey design can be seen at a high level in the form of a flowchart in Figure 3, and Appendix A details the survey questions asked.

The survey was initially distributed via the AASHTO listserv, generating responses from 12 state DOTs. From the list of DOTs that manage secondary roads and those with the most lane miles (see Table 3), the research team identified those that had not responded through the listserv. Those DOTs were then selected and emailed the survey directly. Survey contacts for those state DOTs were identified from state DOT websites, targeting professionals in key roles such as roadway design engineers, transportation planners, state highway engineers, or directors of design and planning divisions. This effort gathered responses from an additional 5 DOTs, bringing the total to 17 responses (Table 5).

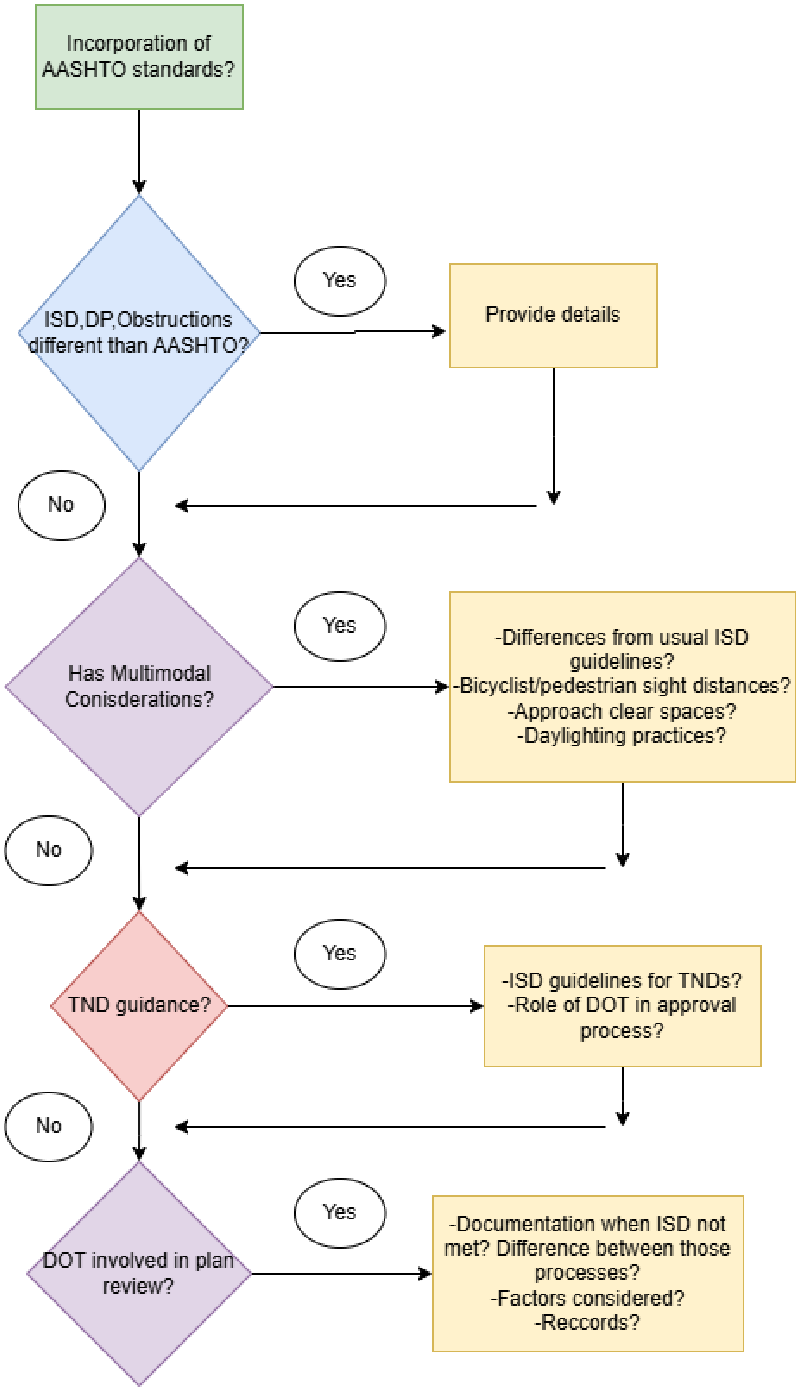


Figure 3. State DOT Survey Flowchart. AASHTO = American Association of State Highway and Transportation Officials; DOT = department of transportation; DP = decision point; ISD = intersection sight distance; TND = traditional neighborhood developments.

Table 5. State Departments of Transportation that Responded to the Survey

AASHTO Listserv Responses	Email Responses
Michigan	Delaware
South Dakota	District of Columbia
Indiana	Pennsylvania
Kentucky	Missouri
Vermont	Ohio
Arkansas	
Connecticut	
North Carolina	
Maryland	
Arizona	
Illinois	
New Jersey	

AASHTO = American Association of State Highway and Transportation Officials.

Virginia Locality Survey

A separate survey was designed and conducted, specifically targeting towns and cities within Virginia. This survey had similar topic areas to the state DOT survey, but the design was different, with more branching based on the options selected. Initially, respondents were asked whether they had their own ISD guideline documents and how they incorporated the VDOT (2025b) *Road Design Manual* (RDM) and AASHTO (2018) *Green Book* into their standards. For those without their own ISD standards, the survey included only a few questions on ISD guidelines before moving on to topics such as TNDs, design modifications, ISD data, and safety. For respondents with their own ISD standards, questions focused on how their guidelines (ISD, DP location, obstructions, and multimodal considerations) differed from those of VDOT or AASHTO, depending on the options they selected earlier.

The survey then explored more in-depth topics, including ISD data, design modifications, and the development plan approval processes, because these areas typically involve localities. Respondents were asked if they had instances when ISD requirements were not met, whether they maintained ISD records, whether they had reduced ISD requirements, and if ISD restrictions affected urban streetscape elements. Finally, respondents were asked an open-ended question about their thoughts on the effect of ISD requirements on urban street safety and character. Figure 4 shows the survey flowchart, and Appendix B contains the complete survey questions.

A list of localities was developed with populations exceeding 3,500 persons, and survey contacts were obtained from locality websites by exploring departments such as planning, engineering, and public works. The contact was initiated by calling and leaving phone messages, followed by emails, and then the survey link was sent to selected localities via email, providing a 2-week response window. The survey was sent to the localities that responded to the initial contact and expressed interest. For those localities that did not respond within 2 weeks, a follow-up email was sent. In sum, 64 localities were contacted by email, 50 of these localities responded to the email and thus received a survey, and then 34 of those localities responded to the survey (Table 6).

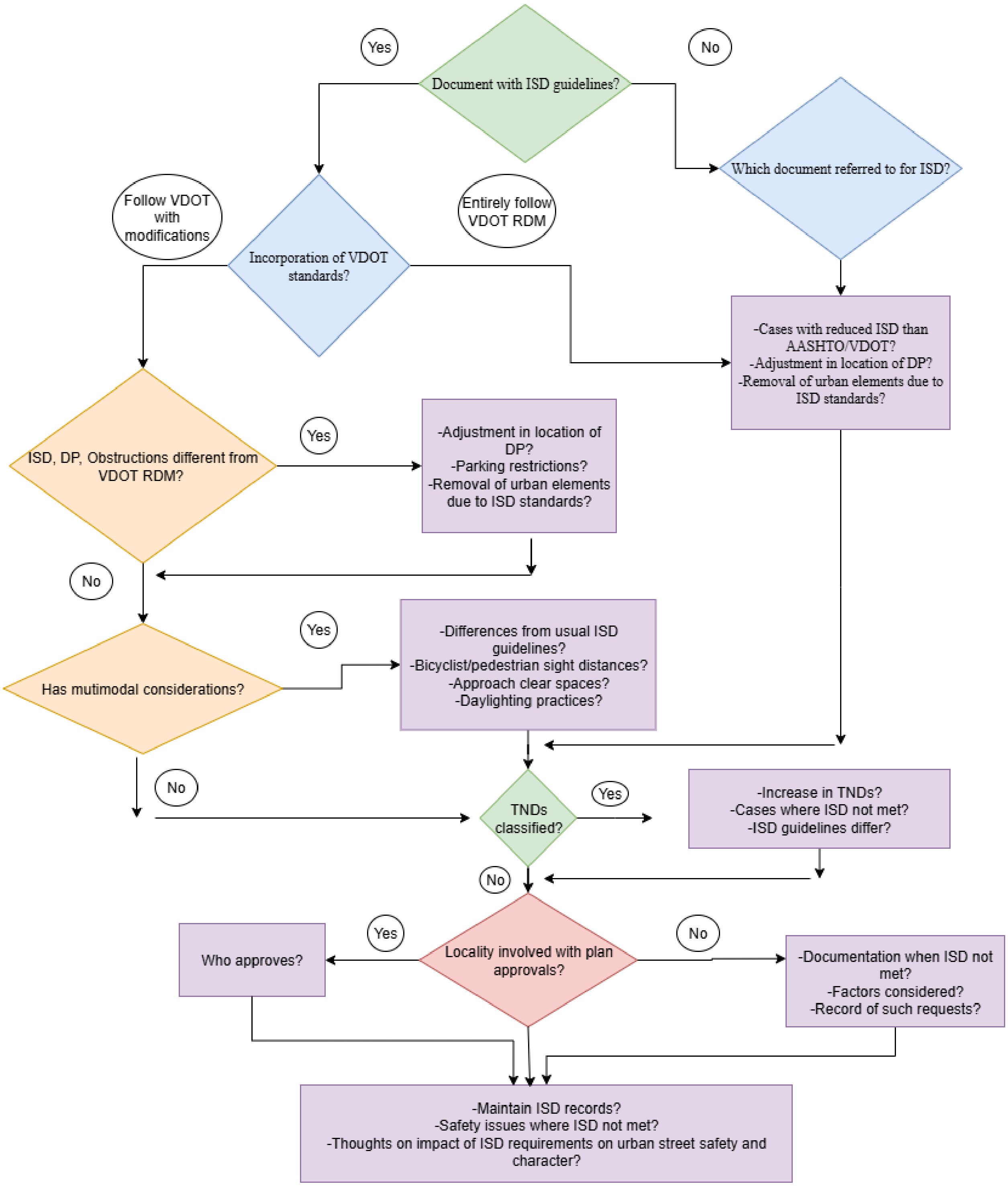


Figure 4. Virginia Locality Survey Flowchart. AASHTO = American Association of State Highway and Transportation Officials; DP = decision point; ISD = intersection sight distance; RDM = *Road Design Manual*; TND = traditional neighborhood developments.

Table 6. Virginia Localities Respondents

Locality
Town of Berryville
Town of Luray
City of Martinsville
Town of Strasburg
City of Winchester
Town of Culpeper
Town of Marion
City of Buena Vista
City of Chesapeake
Town of Wytheville
Town of Bluefield
Town of Bridgewater
City of Manassas Park
City of Staunton
City of Lexington
City of Harrisonburg
Town of Smithfield
City of Hopewell
City of Petersburg
City of Roanoke
City of Salem
Henrico County
Town of Christiansburg
City of Norfolk
City of Lynchburg
City of Manassas
City of Bristol
Town of Blacksburg
Town of Farmville
Town of Vienna
Town of Purcellville
Town of Leesburg
City of Colonial Heights
City of Alexandria

VDOT Residency Survey

This survey was primarily conducted to determine whether VDOT residencies were involved in the development approval process and if they maintained ISD records that could be valuable for future project tasks. The questions focused on whether the residency participated in the development approval process, whether ISD was a criterion evaluated, whether ISD values were submitted on plans, and whether the residency kept ISD records. If records were maintained, respondents were asked whether these records applied only to VDOT roads or to all roads. Additional questions explored whether the residencies had encountered safety issues in areas with limited ISD and how they managed design modification requests. Appendix C details the survey questions.

Survey contacts were obtained from the respective VDOT residency websites. Initial contact was made via phone calls, followed by emails with the survey link. A total of 24 residency responses were received (Table 7).

Table 7. VDOT Residency Survey Respondents

District	Residency
Bristol	Abingdon
	Wise
	Wytheville Residency
Culpeper	Charlottesville
	Warrenton
Hampton Roads	Franklin
	Accomack
	Williamsburg
Lynchburg	Appomattox
	Farmville
	Halifax
Staunton	Edinburg
	Harrisonburg
	Lexington
Salem	Bedford
	Salem
	Christiansburg
	Martinsville
	Saluda
	Northern Neck
	South Hill
	Chesterfield Maintenance
	Petersburg
Northern Virginia[a]	Fairfax
	Loudoun

[a] The response was obtained from the Northern Virginia Traffic Engineering Department. The response did not indicate if it was made on behalf of the Fairfax Residency, Loudoun Residency, or both. For the purposes of data tabulation, it was treated as one response.

Safety Analysis

A quantitative safety analysis to evaluate the effect of ISD requirements on crash outcomes at Case B1 intersections in Virginia was performed. Using VDOT crash data from 2020 to 2024, intersections were grouped by type (T and four-leg) and analyzed for the full dataset and stratified by speed group (low speed ≤ 25 mph and high speed ≥ 30 mph). The 25-mph speed limit was used to stratify urban low-speed conditions because it is commonly applied in Virginia's urban, residential, and business districts, as VDOT and the Code of Virginia outline. It is also the default and maximum speed limit in those areas unless otherwise posted (VDOT, 2025d; Virginia State Law § 46.2-874). T-intersections and four-leg intersections were analyzed separately because of their distinct geometric configurations and differing conflict dynamics. T-intersections involve fewer conflict points and simpler vehicle interactions, whereas four-leg intersections introduce additional crossing and turning movements that can affect sight distance and crash risk.

Crash counts were analyzed in relation to key variables: posted speed limit, average annual daily traffic (AADT), number of lanes, presence of median, SDR, and SDL. Negative binomial regression was used to study the relationship between crash frequency and these variables. The results show that increasing ISD is negatively correlated with crash counts, with a stronger effect observed at low-speed intersections, particularly for SDR.

Four sub-tasks composed the steps needed to accomplish the safety analysis:

- Establishing the study area.
- Collecting data.
- Devising a sampling strategy.
- Analyzing crash data.

Study Area

The study was conducted within the state of Virginia, focusing on Case B1 intersections, which are intersections with stop control on the minor road and no control on the major road. Although VDOT maintains GIS layers for all intersections and signalized intersections on VDOT-maintained roads, no data were available for the location of stop signs. Initially, likely Case B1 intersections were identified using signal warrant criteria. Filters were applied to the unsignalized intersection layer from the linear referencing system and the signalized intersections layer. The focus was on locations where a significant speed limit difference existed between intersecting roads and where the major road had AADT of at least 6,000, which are conditions that typically warrant a stop sign on the minor approach according to FHWA's *Manual on Uniform Traffic Control Devices* (FHWA, 2023b). However, manual review of a random sample of 50 intersections from this filtered set showed that only approximately one-half met the Case B1 definition. In addition, this method captured only intersections on VDOT-maintained roads and excluded those on locality-maintained roads, so this approach was deemed inadequate.

Based on a recommendation from VDOT staff, OpenStreetMap (OSM) was explored as a potential data source for identifying the location of Case B1 intersections. In OSM, intersections tagged as both "stop" and "minor" were queried. This approach yielded 1,847 intersections. To assess the reliability of this dataset, a random sample of 20 intersections was selected and verified using Google Maps Street View. All 20 were confirmed to be stop-controlled intersections on the minor road, indicating 100% accuracy for the sample. Figure 5 shows the spatial distribution of the 1,847 identified Case B1 intersections across Virginia using OSM data. As expected, most of the intersections are in urban areas, reflecting the tendency for OSM's crowdsourced data to be more complete in densely populated regions. This distribution aligns with the goals of the study, which focus on low-speed urban intersections. Therefore, the OSM-derived intersection population was used for the analysis.

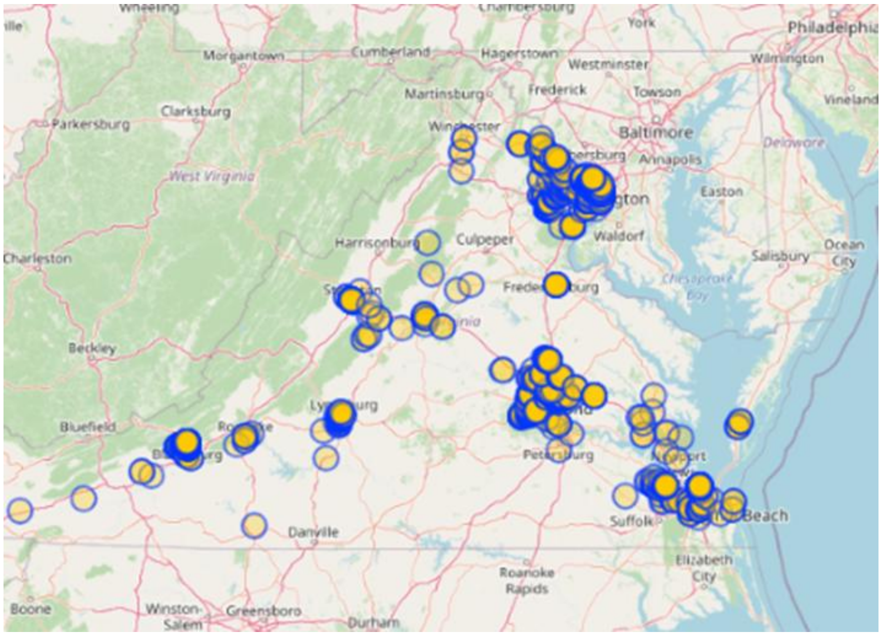


Figure 5. Screenshot of the Locations of all Case B1 Intersections (OpenStreetMap, 2025)

Data Collection

Based on a review of the literature and an evaluation of available techniques, two virtual methods were explored for collecting ISD data: the LiDAR method and the Google Earth or Maps method. Field-based data collection was ruled out early in the process because of safety concerns and high resource demands, particularly in dense urban areas. The goal was to establish a virtual method that could be validated through a small sample of field measurements.

LiDAR and ArcGIS Pro

LiDAR is a technology that uses laser pulses to measure distances and generate detailed 3D maps of the ground and surrounding features. Two main types exist—airborne LiDAR, which is collected from aircraft and covers large areas, and terrestrial LiDAR, which is collected from ground-based equipment and provides more detailed, close-range scans. The availability of existing LiDAR datasets in Virginia was explored. Aerial LiDAR data from the Virginia Geographic Information Network (VGIN), most of which were collected in 2018 and organized by tile, were explored for this research. Figure 6 shows the coverage of VGIN's aerial LiDAR data across Virginia along with the corresponding acquisition dates.

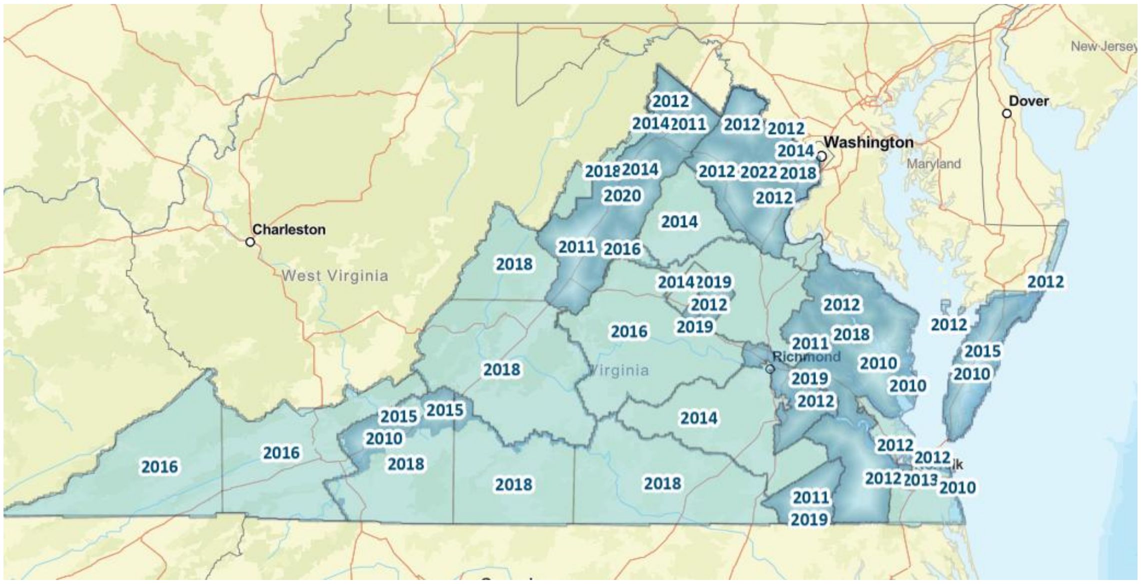


Figure 6. Aerial LiDAR Data Coverage and Data Acquisition Dates (VGIN, n.d.). LiDAR = light detection and ranging.

Because aerial LiDAR is collected from an elevated platform, it may not adequately capture intersection-level obstructions, particularly those relevant to driver sight lines. Therefore, the availability of mobile LiDAR was investigated. Mobile LiDAR is collected using sensors mounted on vehicles and offers higher resolution data and more accurate obstruction detection, which allow for detailed ISD assessments, especially in urban areas (Yang, 2024).

To understand the availability of mobile LiDAR in Virginia, VDOT and some larger localities were contacted. In most cases, jurisdictions either relied on VGIN data or had limited LiDAR coverage that did not include mobile LiDAR. Figure 7 shows the areas where VDOT has collected mobile LiDAR since 2014. The following summarizes the findings.

- Henrico County and the cities of Chesapeake, Norfolk, and Alexandria: No response received or no additional data beyond VGIN.
- City of Richmond: Possesses some LiDAR data, but they are classified only as bare earth and have limited usability.
- Prince William County: Data collected in 2022, publicly available via the U.S. Geological Survey but not mobile based.
- Arlington County: Collected leaf-on aerial LiDAR in September 2023, including both bare earth and vegetation returns.
- Fairfax County: Hosts aerial LiDAR and surface models on its website but has not collected terrestrial or mobile LiDAR.

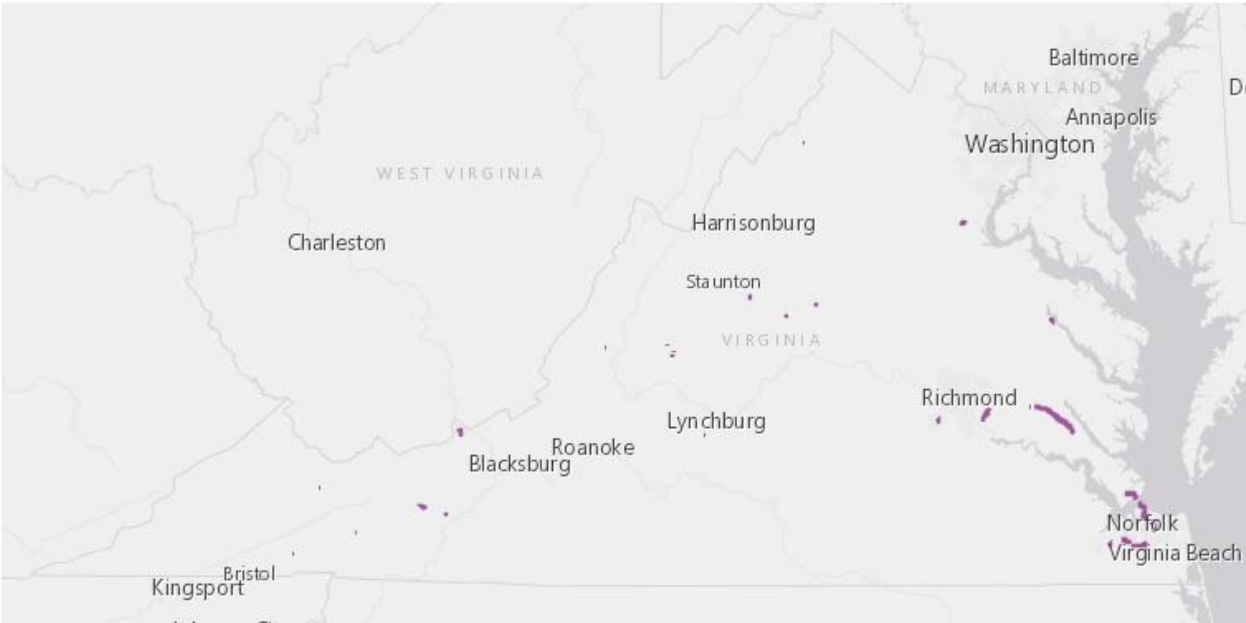


Figure 7. Mobile LiDAR Data Collected by VDOT Geospatial since 2014. Imagery copyright of Esri, HERE, Garmin, U.S. Geological Survey, Environmental Protection Agency, and VDOT Information Technology Department, Business Enablement Group. Source boundary data for counties provided by VITA, VGIN, Esri, HERE, and VDOT Information Technology Department, Business Enablement Group. Source boundary data for counties provided by VITA and VGIN. LiDAR = light detection and ranging. VGIN = Virginia Geographic Information Network; VITA = Virginia Information Technology Agency.

Given the geographical limitations of mobile LiDAR availability, the research team proceeded to test the accuracy of ISD extraction from VGIN aerial LiDAR data because it would determine whether automated ISD data retrieval could be feasible at scale. The workflow involved downloading raw point cloud data from the VGIN website, converting it into surface models in ArcGIS Pro, and applying the Line of Sight tool. This tool used the surface model as input and calculated the visible and obstructed portions of a sight line drawn from an observer point to a target point at a certain elevation above the ground surface.

The process began with raw 3D point cloud data from VGIN, which represents terrain, buildings, vegetation, and other surface features. Figure 8, which displays the raw LiDAR point cloud in an area in Fairfax, shows an example. The point cloud was filtered to remove noise, and a surface model was generated in ArcGIS Pro. This surface model was then used as the input for the Line of Sight tool in the subsequent steps.

Figures 8 through 16 were created with ArcGIS® software by Esri. ArcGIS and ArcMap™ are the intellectual property of Esri and are used under license (Copyright of Esri).

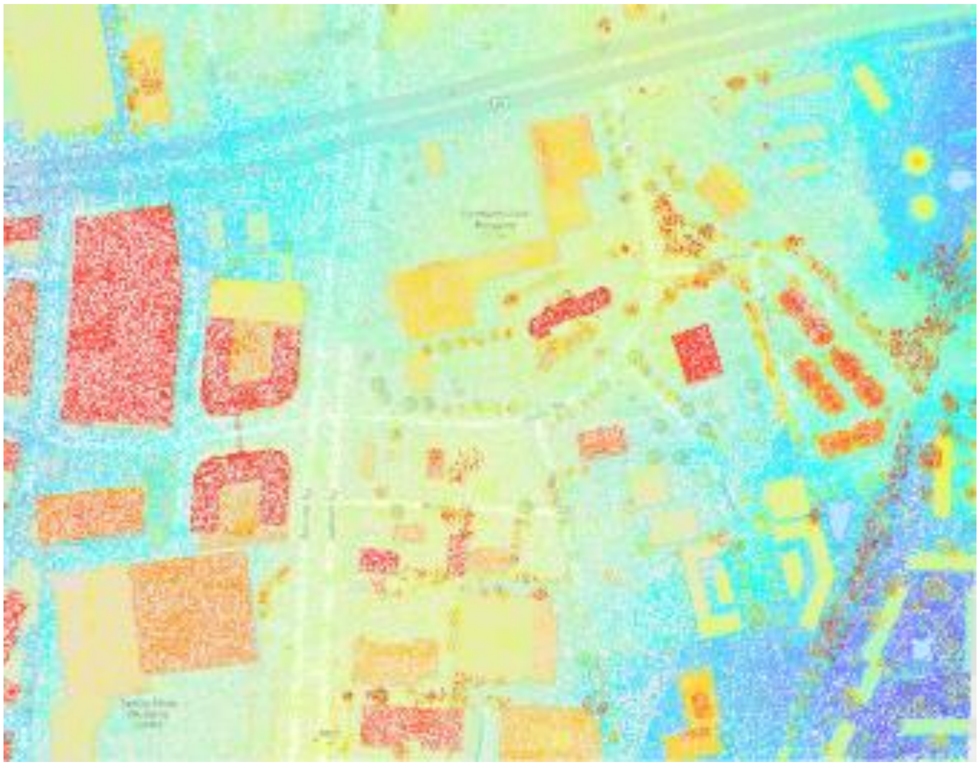


Figure 8. Point Cloud Returns from VGIN LiDAR in Fairfax County. Imagery copyright of the Commonwealth of Virginia, Maxar Technologies, and Microsoft. LiDAR = light detection and ranging; VGIN = Virginia Geographic Information Network.

The Line of Sight tool in ArcGIS Pro takes a surface model, provided as a raster dataset, as input and allows the user to draw a sight line from an observer at a specified height to a target point at a given elevation. It then calculates the visible and obstructed portions of the sight line, returning the total length, whether the target is visible, and the distance to the first obstruction. Figure 9 shows an example output from a Line of Sight analysis, featuring one observer point annotated as a yellow dot and two target points annotated as green dots. The green segment represents the visible portion of the sight line, the red segment indicates the obstructed portion, and the white node marks the location of the first obstruction.

Figure 9. Example Output from Line of Sight Analysis in ArcGIS Pro. Imagery Copyright of the Commonwealth of Virginia, Maxar Technologies, and Microsoft.

Several limitations emerged when using the surface model derived from aerial LiDAR provided by VGIN. As expected, the use of aerial rather than mobile LiDAR raised concerns about accuracy. Figure 10a on the left shows a street view of an intersection in Fairfax, and Figure 10b on the right shows the output from the Line of Sight tool in ArcGIS Pro based on aerial LiDAR data. The tool treats tree canopies as obstructions, causing the sight line to change from green to red. However, it does not reflect the actual sight distance, as the street view clearly shows a high canopy that would not typically be considered an obstruction in practice.

(a) **(b)**

Figure 10. (a) Intersection in Google Maps (Imagery Copyright of 2025 Airbus, Maxar Technologies, Map Data); (b) Line of Sight Output (Imagery Copyright of the Commonwealth of Virginia, Maxar Technologies, and Microsoft)

To address this issue, a separate surface model was created using only LiDAR points classified as buildings. Figure 11 shows the point cloud returns classified as buildings, extracted from the full point cloud shown in Figure 8. This approach allowed for the isolation of building-related obstructions, which are typically more common in dense urban areas, while excluding complex features such as trees, light poles, and utility poles. These features are often misclassified as obstructions by the Line of Sight tool, even when they do not actually block the line of sight. Surface models generated using only these building-classified points were then used for further analysis.

Figure 11. LiDAR Point Clouds in Figure 4 Classified as Buildings. Imagery copyright of the Commonwealth of Virginia, Maxar, and Microsoft. LiDAR = light detection and ranging.

Observer points on the minor road were manually collected at intersections using Google Earth, positioned at a minimum distance of 14.5 feet from the edge of the major roadway. Each observer point was placed at a height of 3.5 feet above the road surface, and the same height was used for the target point.

The Line of Sight tool in ArcGIS Pro, automated through ArcPy scripting, was used to evaluate visibility between observer and target points. Target points were placed at regular intervals of 15 feet along the centerline of the major road, extending outward from the intersection point up to the required sight distance based on VDOT guidelines, as Figure 12a shows. The Line of Sight tool was run from the observer point to each target point. When examining the sight lines in reverse order, starting from the farthest target point to the nearest, the first line that resulted in a visible target was identified. The length of this line was defined as the available ISD.

Figure 12a illustrates the generation of multiple target points from a single observer point, where the sight line transitions from red to green as it approaches the intersection, indicating that the obstruction clears. Figure 12b shows a sample output from the Python script.

(a) (b)

Figure 12. (a) Example of Line of Sight Analysis with Multiple Targets from an Observer Point; (b) Python Script Output. Imagery copyright of the Commonwealth of Virginia, Maxar Technologies, and Microsoft.

Ten Case B1 intersections in the Mosaic District of Fairfax were evaluated using the LiDAR-based method described previously, and the results were compared with sight distance measurements obtained from Google Earth and Google Maps, which have served as reliable benchmarks in previous studies (Harrington et al., 2017; Quan et al., 2021).

As Table 8 shows, the comparison includes ISD values derived from both the LiDAR method and Google Earth or Maps. For each approach, a "Full" designation was noted if the measured distance exceeded the sight distance required by VDOT. The LiDAR method produced inconsistent values, even when considering only building obstructions. The noticeable discrepancies between the two methods raise concerns about the reliability of using aerial LiDAR alone for precise ISD analysis at urban intersections.

Table 8. Comparison of Intersection Sight Distance Measurements Obtained from LiDAR and Google Earth Methods[a]

Coordinates	LiDAR SDR	Google Earth SDR	VDOT-Req. SDR	LiDAR SDL	Google Earth SDL	VDOT-Req. SDL
38.86922737, -77.23329318	70	Full	315	80	78	295
38.86913126, -77.23279251	102	245	280	31	115	280
38.86840130, -77.23392958	168	265	280	Full	Full	280
38.86895020, -77.23223382	76	170	280	136	230	280
38.87004700, -77.23282500	206	210	315	67	138	295
38.87081835, -77.23245096	69	215	315	115	290	295
38.87342800, -77.23119800	85	Full	360	95	Full	315
38.87237692, -77.23043358	90	Full	315	100	210	295
38.87275718, -77.23148127	88	Full	360	92	74	315
38.86893340, -77.22402255	121	Full	280	138	Full	280

Full = measured distance exceeded VDOT-required sight distance; LiDAR = light detection and ranging; Req. = required; SDL = sight distance to the left; SDR = sight distance to the right. [a] Except for the latitude and longitude coordinates in degrees, all measurements are in feet.

Another limitation of the LiDAR-based method was the need for manual collection of observer and target coordinates. Although the possibility of automating this process was explored, existing GIS layers for intersections and roadway centerlines lacked the precision necessary to reliably generate accurate points. Misalignments and inconsistencies in the available datasets made automation impractical. Given the time and resource constraints and the continued need for manual effort, the data collection process was ultimately shifted to using Google Maps and Google Earth.

Google Earth and Google Maps

Although several previous studies have treated Google Earth measurements as a reliable proxy for field-based sight distance assessments (Quan et al., 2021; Yang, 2024), the approach was further evaluated through comparing real-world site plan documentation. Access was obtained to VDOT Chesterfield residency site plans, and documents were reviewed to find plans that included Case B1 intersections and noted sight distance measurements. These plans did not provide specific ISD values but simply indicated whether the minimum required ISD, as per VDOT standards, was met.

To test alignment with the method, virtual measurements were conducted for 10 intersections identified from the Chesterfield site plans using Google Earth. In all 10 cases, the measurements also indicated that the required ISD was met. This consistency provided some form of validation for the method by demonstrating alignment with documented design outcomes. The LiDAR method was also tested at these locations, but only 5 of the 10 intersections showed that the sight distance requirement was met, further indicating that the Google Earth method was better suited for this analysis.

ISD was measured using the built-in measure tool in Google Earth or Google Maps, depending on which platform provided clearer and more recent imagery. Each site was first examined using both Street View and aerial imagery to assess the presence and type of obstructions and to identify any visible grade changes.

Observer points were typically positioned 14.5 feet behind the edge of the traveled way, in accordance with guidance from the VDOT (2025b) RDM. This distance reflects a standard setback, assuming the stop bar is placed at a specified distance from the edge of the traveled way. When a stop bar was present, the observer point was instead placed 8 feet behind the stop bar, consistent with AASHTO (2018) guidelines. Laterally, DP was offset 4 feet from the centerline of the minor road.

From this observer location, the Google Earth Measure tool was used to draw sight lines toward the major road. For SDR, the line extended toward the centerline of the nearest far-side travel lane, whereas for SDL, it extended to the center of the nearest approach lane. Each line was extended until the line touched an obstruction, and the corresponding distance was recorded as the available sight distance in that direction. Sight distances were recorded up to a maximum of 1,100 feet, which covers the highest required ISD value specified in the VDOT (2025b) RDM. For any measurement exceeding this threshold, the value was recorded as 1,100 feet. Figure 13 presents a sample measurement for SDR conducted using Google Maps.

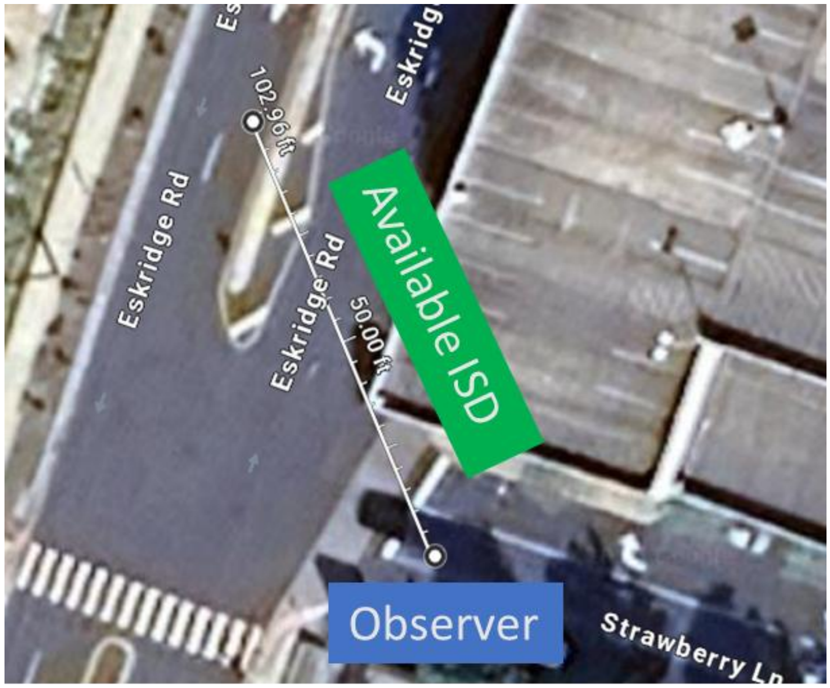


Figure 13. Example of ISD (Sight Distance to the Right) Measurement Using the Measure Tool in Google Maps©. Imagery copyright of 2025 Airbus, Maxar Technologies, Google Map 2025 data. ISD = intersection sight distance.

In measuring sight distance, a consistent and repeatable measurement criterion was essential to ensure consistency across locations. Because the analysis relied on Google Earth imagery and Google Maps Street View, which often vary in terms of date or time, only fixed obstructions that could consistently affect visibility were considered. These obstructions included buildings, fixed fences, distinct grade changes, and other permanent structures, such as retaining walls, as identified through Street View. Temporary elements such as vegetation, parked vehicles, and utility poles were excluded because of their variability, their inconsistent presence across imagery sources and dates, and the difficulty of accounting for them accurately when measuring in Planview.

To account for the potential influence of nonpermanent elements, a "Quality of Line of Sight" variable was introduced and scored on a scale from 1 to 3. A score of 1 indicated a clear view, whereas a score of 3 represented conditions that were consistently obstructed in Street View. This variable provided a standardized qualitative assessment of visibility conditions along the sight line, based on the frequency and extent of minor visual interferences not classified as fixed obstructions. Table 9 presents the methodology used to score this variable, and Figure 14 shows examples from Street View corresponding to each level of rating.

Table 9. Methodology for Quality of Line of Sight Scoring

Score	Description	Examples
1—Clear / Minimal Obstruction	• The sight triangle is mostly open with little to no obstruction. Visibility remains clear across all Google Street View images and seasons. • No noticeable vegetation, parked vehicles, or temporary items blocking the view.	Light grass, utility poles, small posts, sparse branches.

Score	Description	Examples
2—Partial / Seasonal Obstruction	• The view is partially blocked by vegetation or movable objects. • Visibility varies by season or imagery date—clear in some Google Street View images, obstructed in others.	Trees bare in winter but blocking sight in summer, bushes, cones, temporary signs, intermittently parked cars.
3—Consistent Obstruction	• The sight triangle is consistently obstructed across all Google Street View images, regardless of the season. • Caused by persistent vegetation or recurring temporary obstructions.	Evergreen trees, overgrown hedges, vehicles consistently parked in the line of sight.

(1) (2) (3)

Figure 14. Intersections with Quality of Line of Sight Scores from 1 (Clear/Minimal Obstruction) to 3 (Consistent Obstruction). Imagery copyright of 2025 Airbus, Maxar Technologies, and Google Map 2025 data.

Sampling Strategy

To ensure broad geographic representation of the intersection population, systematic random sampling was applied by selecting every third intersection from a spatially ordered list derived from OSM data. This method helped reduce the risk of geographic clustering or overrepresentation from any specific area. In addition, only intersections classified as urban under the U.S. Census Bureau (2020b) urban area criteria were included in the sample.

A mid-sample review showed that approximately 67% of the sampled intersections were T-intersections. To achieve a more balanced distribution between intersection types—because separate analyses were planned for T-intersections and four-leg intersections—additional four-leg intersections were intentionally added during the later sampling stages.
Sites were excluded from the sample if they met any of the following criteria:

- No or unclear aerial imagery or Street View coverage.
- Major changes in geometry or surroundings within the past 5 years.
- Private driveways or nonpublic entrances.
- Involved more than four legs or included offset or skewed approaches that deviated from conventional four-leg or T-shaped configurations.
- Did not have major road AADT and were not classified as “urban” by the Census Bureau classification.

The initial dataset consisted of 1,847 intersections from the OSM population. The total sample size used for analysis was 359 intersections. Although data for 420 intersections were collected overall, 61 intersections were excluded because the initial selection did not filter for urban classification or confirm the availability of AADT data on the major road. Table 10 presents the breakdown by intersection type and classification. Figures 15 and 16 show the geographic distribution of the sampled intersections.

Table 10. Sample Sizes by Intersection Types

Intersection Type	Total	≤ 25 mph	≥ 30 mph
T-intersection	184	132	52
Four-leg intersection	175	109	66
Total	359	241	118

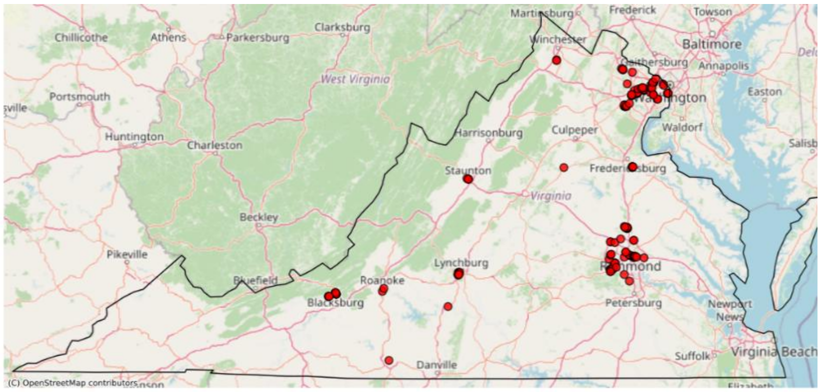


Figure 15. Screenshot of the Spatial Distribution of Sampled T-Intersections. Imagery copyright of the Commonwealth of Virginia, Maxar Technologies, and Microsoft.

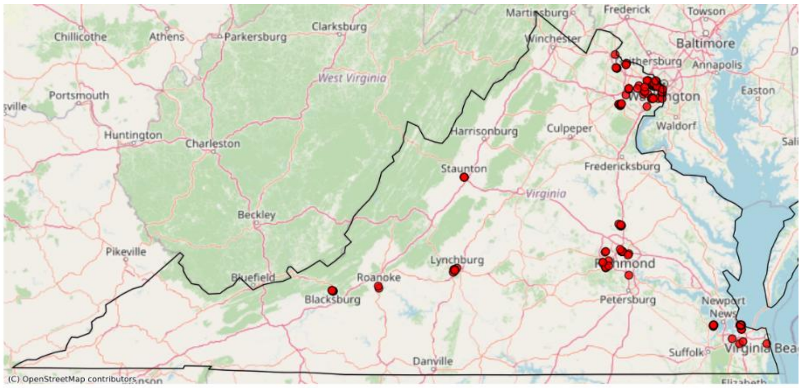


Figure 16. Screenshot of the Spatial Distribution of Sampled Four-Leg Intersections. Imagery copyright of the Commonwealth of Virginia, Maxar Technologies, and Microsoft.

Crash Analysis Approach

Data Sources

Table 11 summarizes the variables used in the analysis along with their respective data sources.

Table 11. Collected Data and Their Corresponding Sources

Data	Source
Available ISD (SDR/SDL)	Google Maps and Google Earth
Major Road AADT	VDOT (2024b)
Number of Lanes	Google Maps and Google Earth
Quality of Line of Sight (Score of 1 to 3)	Google Maps
Major Road Speed Limit	Google Maps
Presence of 18” Median	Google Maps
Crash Count	VDOT Crash Database (VDOT, 2025a)

AADT = average annual daily traffic; ISD = intersection sight distance; SDL = sight distance to the left; SDR = sight distance to the right.

Crash Data

Crash data were obtained from the VDOT Crash Database by applying a 250-foot buffer around each intersection point. Crashes were filtered to include only intersection-related types, specifically: Type 2 (Angle), Type 3 (Head-On), Type 4 (Sideswipe Same Direction), and Type 5 (Sideswipe Opposite Direction). Only crashes from the past 5 years (2020–2024) were included in the analysis. Each intersection was treated as a single site, allowing total crash counts for the specified types to be used in the analysis. Although attributing crash counts to specific approach types and associating them with the corresponding SDR or SDL values would have enabled treatment of each right or left turn movement as a separate site, it was very difficult to do based on the crash information available.

Variable Coding for Regression Analysis

Table 12 shows the list of variables used in the regression analysis. The AADT variable was log-transformed to normalize its distribution and reduce the influence of extreme values. Presence of a median was coded as a binary variable, with 1 indicating presence of median and 0 indicating absence of median. For four-leg intersections, two SDR and two SDL values were observed, one for each approach. Because each intersection was treated as a single site, the average SDR and average SDL were used for analysis.

Table 12. Variables and Their Data Types Used in Regression Analysis

Variable	Data Type
Available SDR (feet)	Continuous
Available SDL (feet)	Continuous
Number of Sight Distances Met	Discrete
Major Road AADT (vehicle/day)	Continuous (log-transformed)
Number of Lanes	Discrete
Quality of Line of Sight (Score of 1 to 3)	Categorical
Major Road Speed Limit (mph)	Discrete
Presence of 18” Median	Binary (0 = No, 1 = Yes)
Crash Count	Discrete

AADT = average annual daily traffic; SDL = sight distance to the left; SDR = sight distance to the right.

The number of sight distances met variable represented how many sight distance readings at each intersection met the required values set by VDOT (VDOT, 2025b). For example, a T-intersection includes two sight distances, SDR and SDL, so the variable could take values of 0, 1, or 2. For a four-leg intersection, four readings are possible, two for each approach, so the variable could range from 0 to 4.

Descriptive Statistics

Tables 13 and 14 present the summary statistics for the T-intersection group (N = 184) and the four-leg intersection group (N = 175), respectively. Figures 17 through 25 present corresponding distribution visualizations and correlation matrices. For both intersection groups, both crash count and AADT are right-skewed, indicating the presence of a few high values in otherwise lower distributions. Speed limit shows a strong peak at 25 mph, suggesting that the dataset represents a suitable sample of low-speed urban intersections. The log transformation of AADT helps reduce skewness and improves suitability for regression modeling.

T-intersections exhibit lower average crash counts (mean = 1.80) compared with four-leg intersections (mean = 3.85), with both showing strong positive skewness, indicating the presence of a few high-crash locations. Log AADT values are slightly lower for T-intersections (mean = 8.12) than for four-leg intersections (mean = 8.58), aligning with their typically lower traffic volumes. Presence of a median is more common at four-leg intersections (13.7%) than at T-intersections (4.3%). Speed limits are similar across both types, with a concentration around 25 mph, confirming that the dataset includes a substantial sample of urban low-speed intersections. Overall, four-leg intersections tend to have higher traffic volumes, more complex geometry, and greater crash frequency, highlighting the importance of analyzing the safety effects of ISD separately for each type.

Table 13. Summary Statistics for T-Intersection

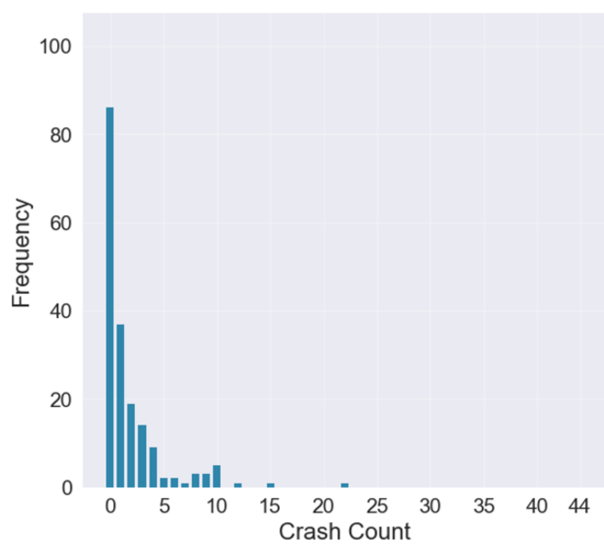
Variable	Mean	Median	Std Dev	Min	Max	Q1	Q3	Skewness	Kurtosis
Crash Count	1.80	1.00	3.09	0.00	22.00	0.00	2.00	3.03	12.21
Log AADT	8.12	8.41	1.46	4.39	11.34	7.17	9.15	– 0.45	– 0.34
Presence of Median	0.04	0.00	0.20	0.00	1.00	0.00	0.00	4.51	18.58
Number of ISD Met	1.56	2.00	0.71	0.00	2.00	1.00	2.00	– 1.32	0.27
Average SDR (feet)	615.38	575.00	341.95	67.00	1100.00	316.25	961.00	0.20	– 1.35
Average SDL (feet)	627.07	577.50	328.74	91.00	1100.00	340.00	992.50	0.27	– 1.31
Quality of LOS	2.03	2.00	0.55	1.00	3.00	2.00	2.00	0.42	0.65
Speed Limit (mph)	28.29	25.00	7.24	15.00	55.00	25.00	30.00	1.86	3.80
Number of Lanes	2.76	2.00	1.34	2.00	10.00	2.00	3.00	2.19	5.85

AADT = average annual daily traffic; ISD = intersection sight distance; LOS = line of sight; Max = maximum; Min = minimum; Q1 = first quartile; Q3 = third quartile; SDL = sight distance to the left; SDR = sight distance to the right; Std Dev = standard deviation.

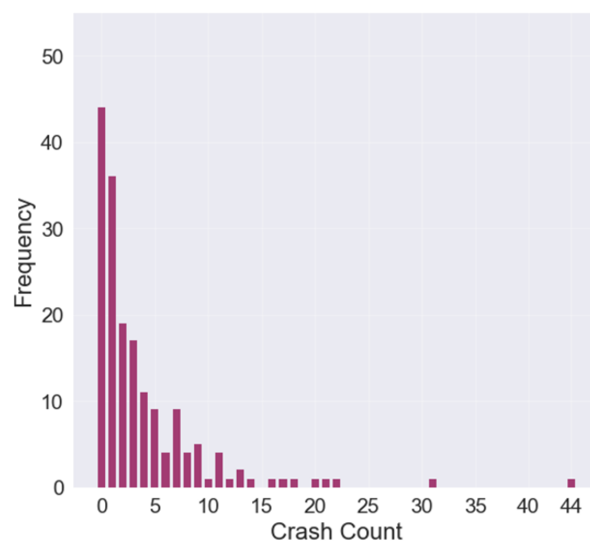
Table 14. Summary Statistics for Four-Leg Intersections

Variable	Mean	Median	Std Dev	Min	Max	Q1	Q3	Skewness	Kurtosis
Crash Count	3.85	2.00	5.71	0.00	44.00	0.50	5.00	3.42	16.83
Log AADT	8.58	8.80	1.03	5.67	11.29	7.78	9.21	– 0.55	– 0.05
Presence of Median	0.14	0.00	0.35	0.00	1.00	0.00	0.00	2.13	2.56
Number of ISD Met	3.22	4.00	1.12	0.00	4.00	3.00	4.00	– 1.30	0.61
Average SDR (feet)	672.07	720.00	295.55	118.50	1100.00	426.50	907.50	– 0.20	– 1.07
Average SDL (feet)	653.78	672.50	285.30	92.50	1100.00	430.00	875.00	– 0.06	– 1.10
Quality of LOS	1.91	2.00	0.44	1.00	3.00	1.75	2.00	0.18	0.10
Speed Limit (mph)	28.09	25.00	6.54	15.00	55.00	25.00	30.00	1.65	3.39
Number of Lanes	3.10	2.00	1.43	2.00	10.00	2.00	4.00	1.32	2.12

AADT = average annual daily traffic; ISD = intersection sight distance; LOS = line of sight; Max = maximum; Min = minimum; Q1 = first quartile; Q3 = third quartile; SDL = sight distance to the left; SDR = sight distance to the right; Std Dev = standard deviation.

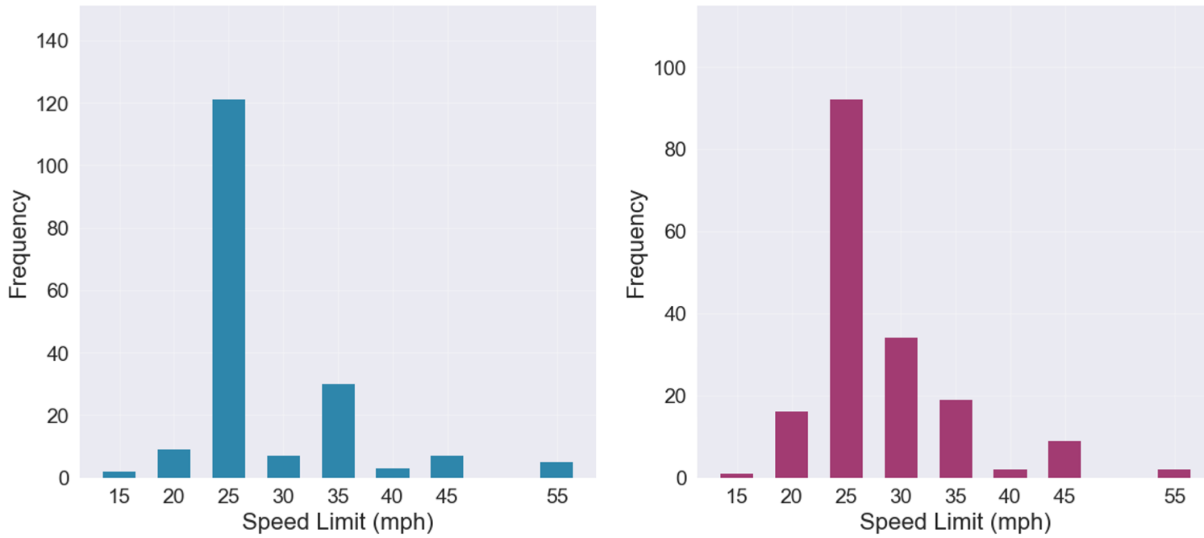


(a)



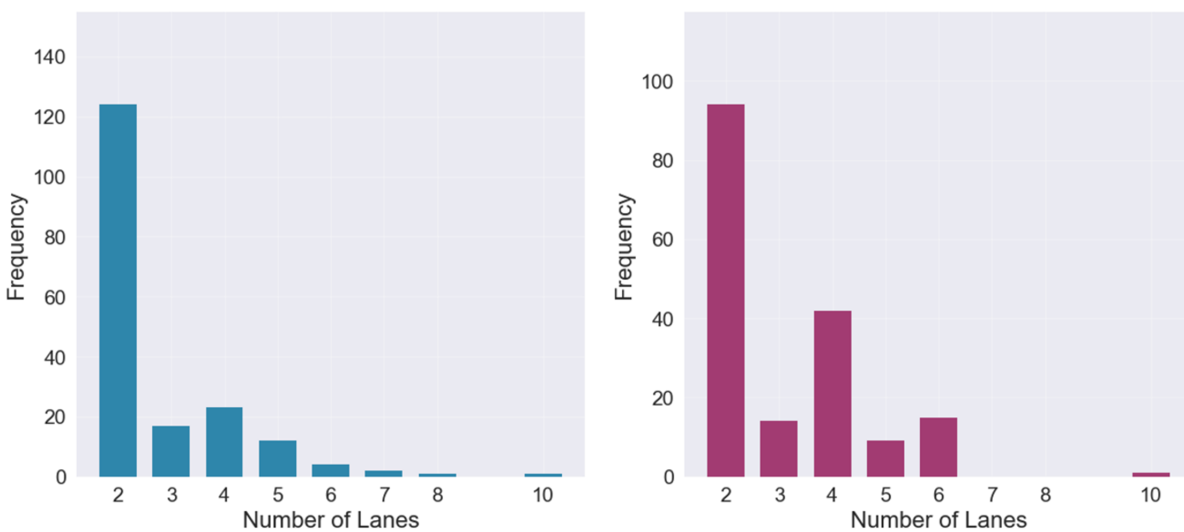
(b)

Figure 17. Distribution of Crash Count for (a) T-Intersections and (b) Four-Leg Intersections



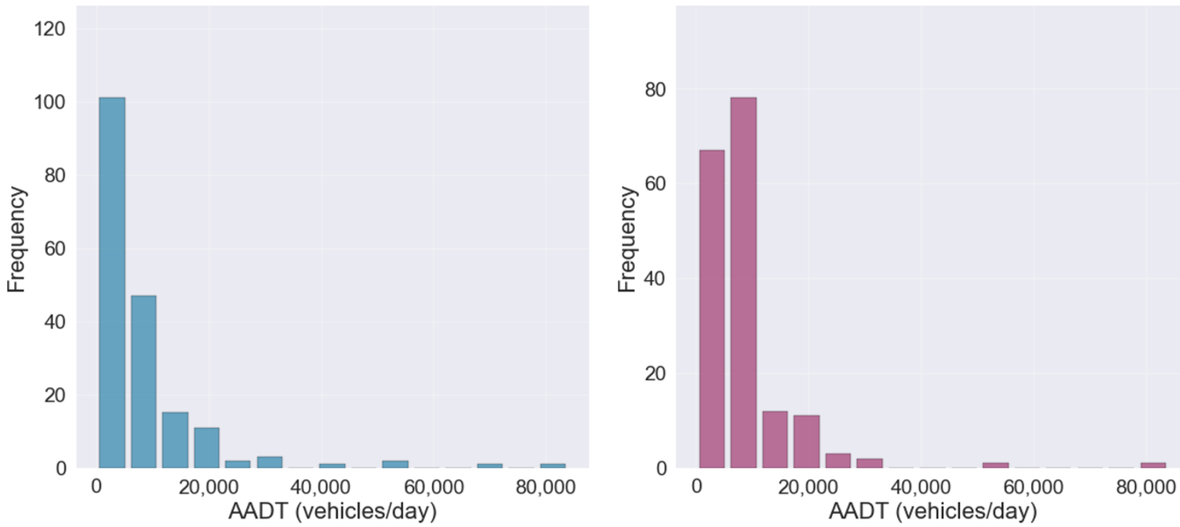
(a) **(b)**

Figure 18. Distribution of Speed Limit for (a) T-Intersections and (b) Four-Leg Intersections



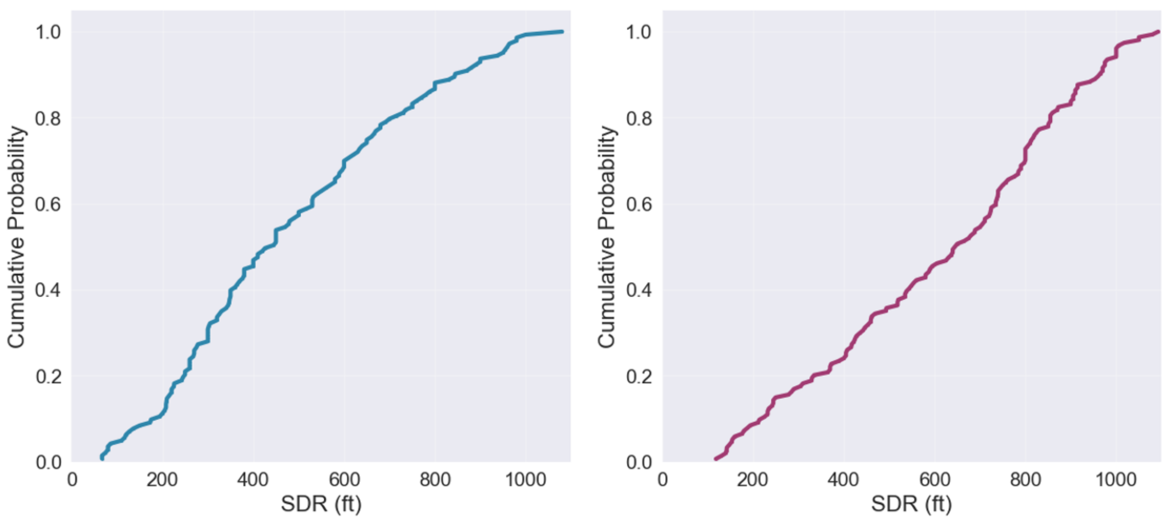
(a) **(b)**

Figure 19. Distribution of Number of Lanes for (a) T-Intersections and (b) Four-Leg Intersections



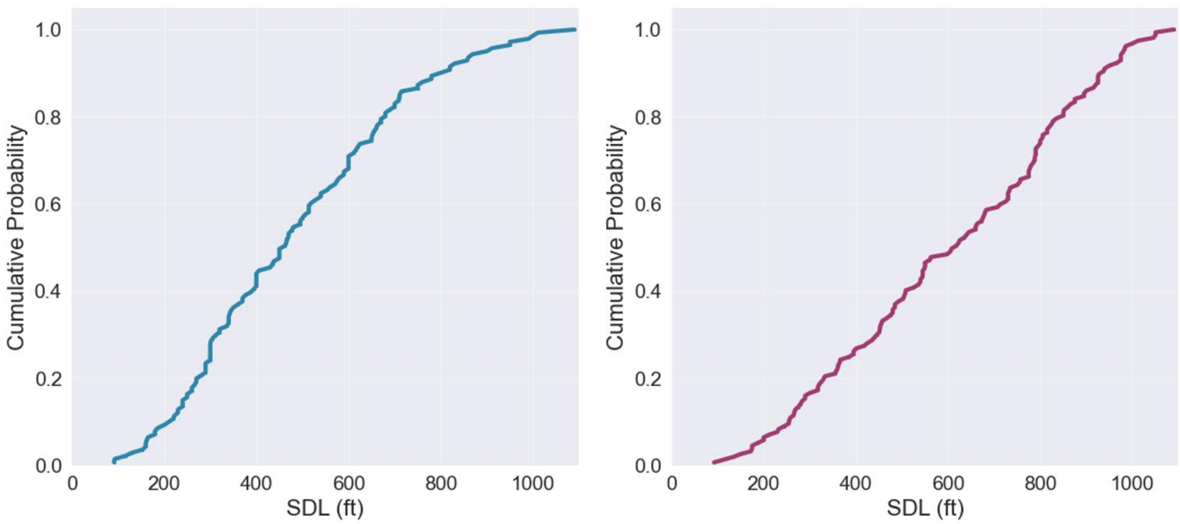
(a) (b)

Figure 20. Distribution of AADT for (a) T-Intersections and (b) Four-Leg Intersections. AADT = average annual daily traffic.



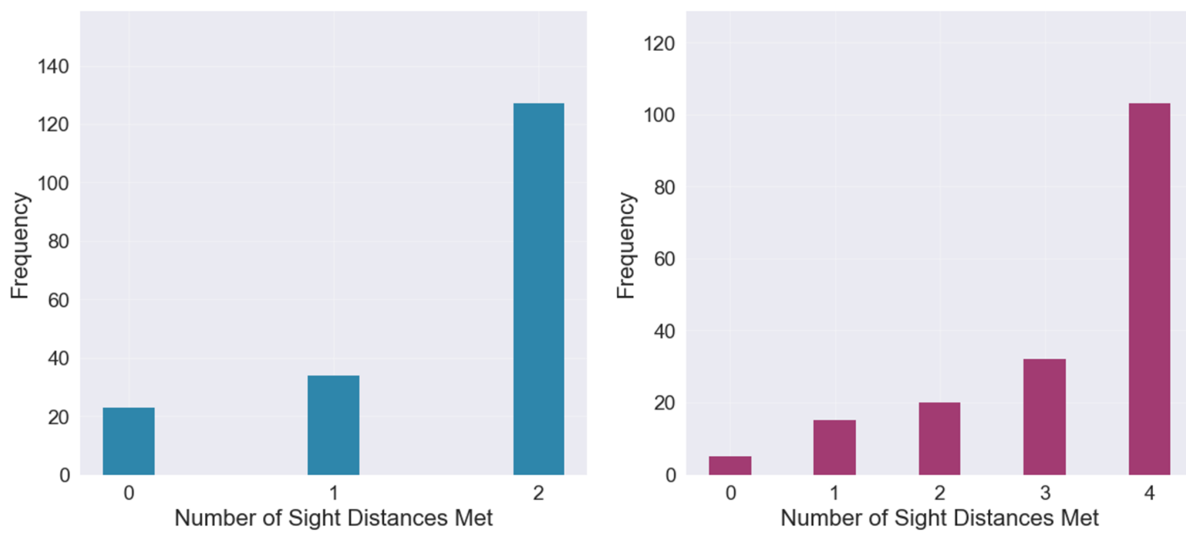
(a) (b)

Figure 21. Distribution of SDR for (a) T-Intersections and (b) Four-Leg Intersections. SDR = sight distance to the right.



(a) **(b)**

Figure 22. Distribution of SDL for (a) T-Intersections and (b) Four-Leg Intersections. SDL = sight distance to the left.



(a) **(b)**

Figure 23. Distribution of Number of Sight Distances Met for (a) T-Intersections and (b) Four-Leg Intersections

Figures 24 and 25 present the correlation matrices based on Pearson's correlation coefficients for T-intersections and four-leg intersections, respectively. For T-intersections, the number of sight distances met exhibits correlations with average SDR and average SDL (greater than 0.5), which is expected. Speed limit, number of lanes, and AADT demonstrate moderate correlations with each other (less than 0.5), which is also understandable because roadways with a higher number of lanes and greater traffic volumes typically have higher speed limits. For four-leg intersections, similar patterns emerge, although the correlation coefficients are higher. Average SDL and SDR show a strong correlation with each other, and speed limit and number of lanes also exhibit considerable correlation (0.659).

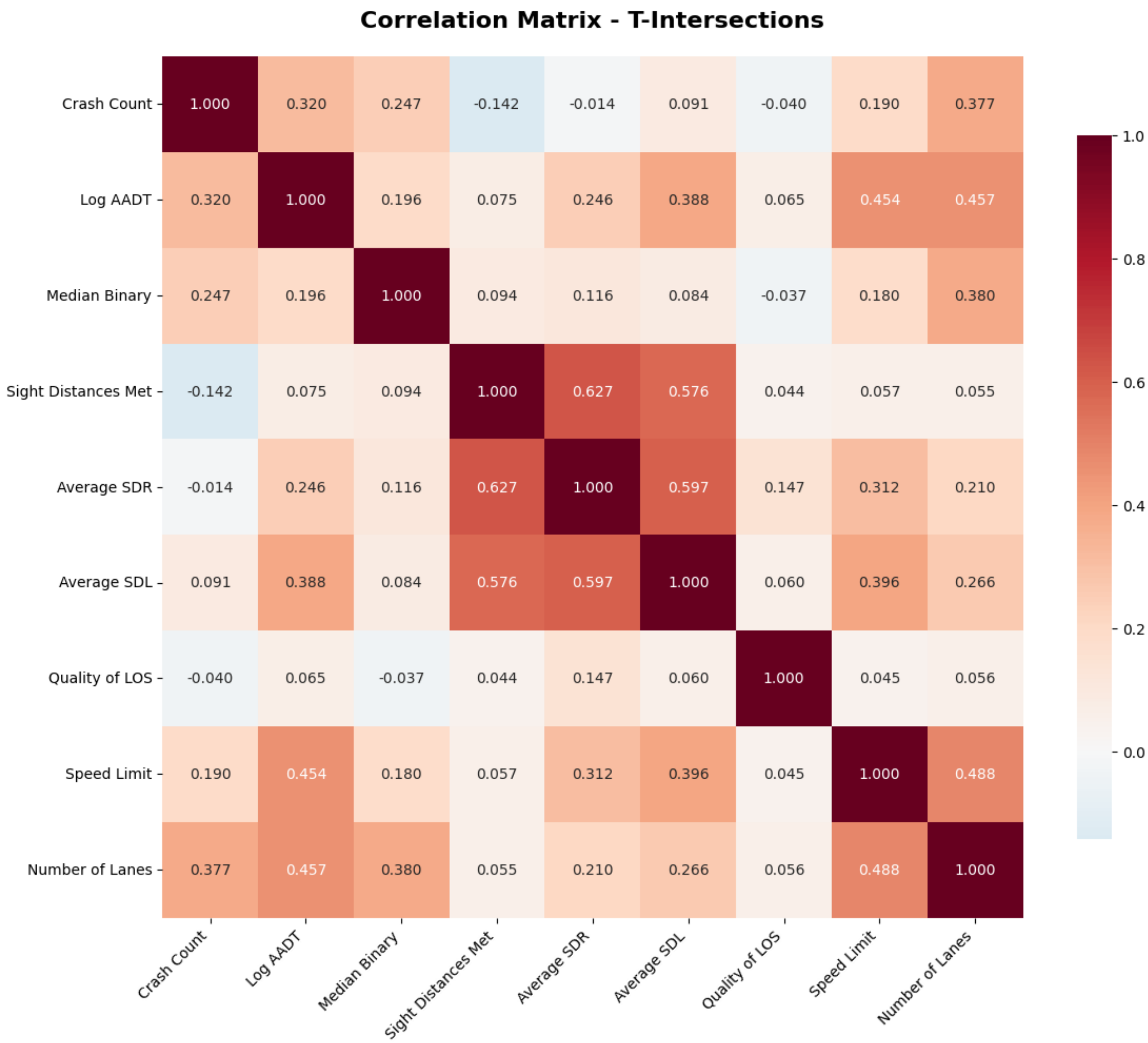


Figure 24. Correlation Matrix for T-Intersections Data. AADT = average annual daily traffic; LOS = line of sight; SDL = sight distance to the left; SDR = sight distance to the right.

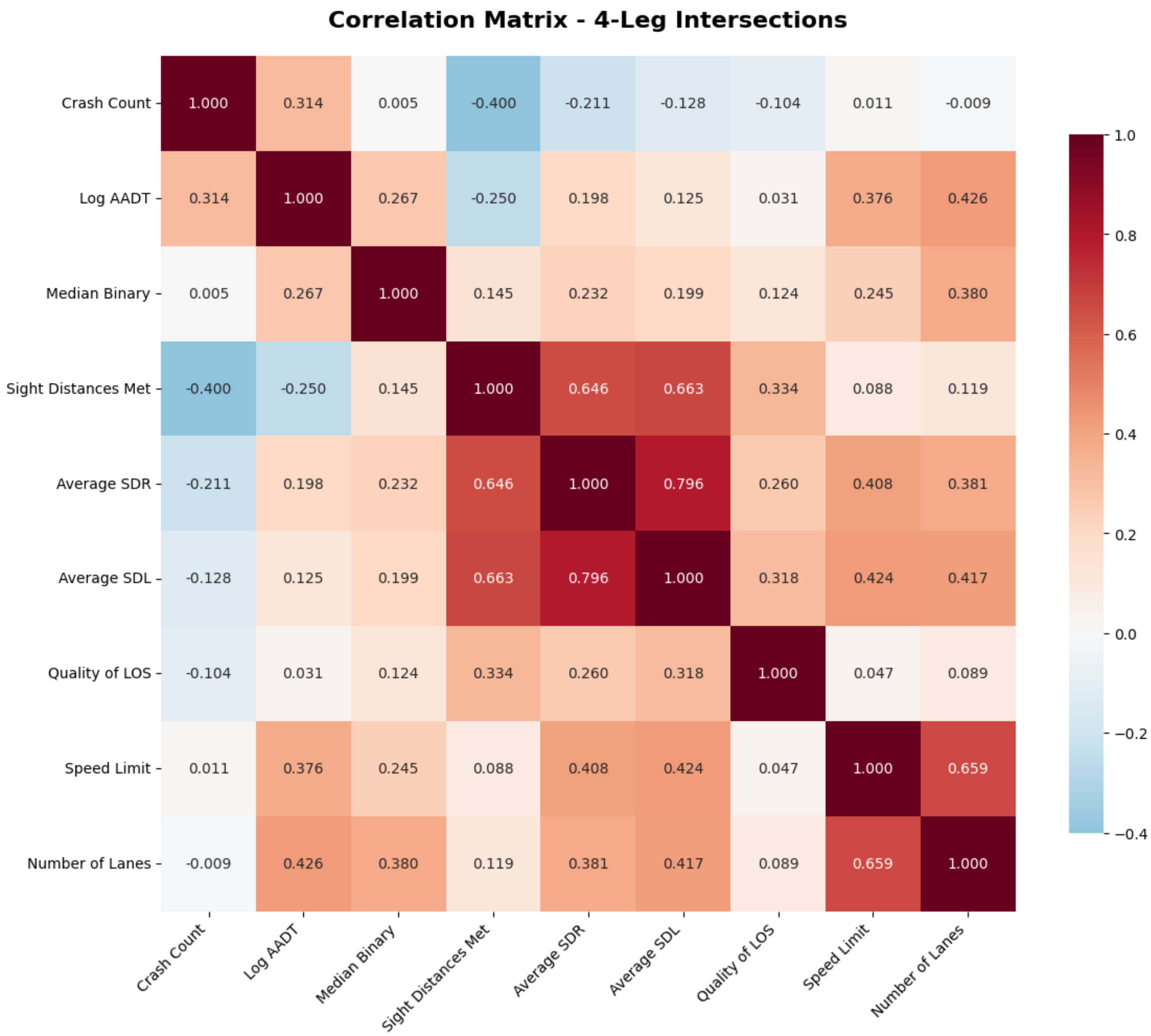


Figure 25. Correlation Matrix for Four-Leg Intersections Data. AADT = average annual daily traffic; LOS = line of sight; SDL = sight distance to the left; SDR = sight distance to the right

Model Selection

Because the dependent variable is crash count, both Poisson and Negative Binomial regression models were considered. However, as Table 15 shows, the data exhibited clear overdispersion, with the variance significantly greater than the mean. This result violates a key assumption of the Poisson model. In such cases, the Negative Binomial model is more suitable because it includes an additional dispersion parameter to account for this variability. A Zero-Inflated Negative Binomial model was also evaluated because of the high proportion of zero-crash intersections, but the model did not provide a better fit compared with the standard Negative Binomial model.

Table 15. Crash Count Dispersion Metrics

Intersection Type	Mean	Variance	Dispersion Ratio	Zero %
T-Intersections	1.8	9.5	5.3	46.7
Four-Leg Intersections	3.8	32.6	8.4	25.1
All Intersections	2.8	21.8	7.8	36.2

The analysis was conducted using two approaches: one based on the number of SDR and SDL requirements met at each intersection and the other using the actual SDR and SDL values. Although the analysis initially included all independent variables and interaction terms, quality of line of sight, speed limit, number of lanes, and SDL were consistently found to be statistically insignificant and removed in later iterations. Equations 2 and 3 present the general form of the negative binomial regression for T-intersections and four-leg intersections, respectively, with the number of crashes as the dependent variable.

The preferred models for T-intersections included SDR or number of sight distances met, AADT, and presence of a median as independent variables. The preferred model for four-leg intersections included SDR or number of sight distances met and AADT as the independent variables.

$$\ln(\text{Crashes}) = \beta_0 + \beta_1 \cdot \log(\text{AADT}) + \beta_2 \cdot (\text{SDR or number of sight distances met}) + \beta_3 \cdot \text{Median} \quad \text{(Eq. 2)}$$

$$\ln(\text{Crashes}) = \beta_0 + \beta_1 \cdot \log(\text{AADT}) + \beta_2 \cdot (\text{SDR or number of sight distances met}) \quad \text{(Eq. 3)}$$

Where:
$\ln(\text{Crashes})$ = natural log of the expected crash count.
β_0 = model intercept.
β_1 = model coefficient for log (AADT).
β_2 = model coefficient for SDR or number of sight distances met, depending on the model.
β_3 = model coefficient for presence of median.

RESULTS

Policy Document Review

Intersection Sight Distance Values

State Departments of Transportation

Among the state DOTs that own their secondaries, five of them—VDOT (2023), North Carolina DOT (2023), South Carolina DOT (2021), Delaware DOT (2019), and District of Columbia DOT (2023)—either directly reference the AASHTO (2018) *Green Book* or adopt the same values for ISD along the major road as those the *Green Book* specifies. When considering the state DOTs with the greatest number of lane miles, all policies either directly cite the *Green Book* for ISD requirements or specify their own values for sight distance based on time gap values, which align with the values the *Green Book* provides. Specifically, California DOT (2022) requires only SSD, corner sight distance, and decision sight distance. The corner sight distance values are derived using the same equation and parameters as Equation 1, resulting in values that are consistent with the ISD values specified in the *Green Book*.

Localities

Eleven of the 14 localities mention guidelines for ISD along the major road. Out of these 11 localities, 6—the City of Charlotte (2023), City of Scottsdale (2018), Carroll County (2007), City of Kirkland (2024), City of Virginia Beach (2022), and County of Henrico (2025)—provide values for ISD in their policies. The designated values are either equal to or within 5 feet of those provided by the AASHTO (2018) *Green Book*. The notable exceptions are that—

- The City of Kirkland (2024) recommends ISD values that are the same as those in the *Green Book*, but the minimum values given are equal to the SSD values in the *Green Book*.
- The City of Virginia Beach (2022) considers the functional classification of roads, leading to slightly different values from those in the *Green Book*.
- The County of Henrico (2025) considers road width instead of the number of lanes, but the values are ultimately within 5 feet of AASHTO *Green Book* standards.

Decision Point Location

DP refers to the location on the minor road where a driver evaluates whether it is safe to enter or cross the major road. According to the AASHTO (2018) *Green Book*, this point is typically assumed to be 14.5 feet from the edge of the major road’s traveled way, aligning with the approximate position of a driver’s eye in a stopped vehicle. Where feasible, increasing this distance to 18 feet is recommended to provide a greater buffer between the front of the vehicle and the roadway. These values reflect common stopping behavior, with field observations showing that drivers generally stop within 6.5 feet of the edge of the major road and that the eye-to-front bumper distance is typically 8 feet or less (AASHTO, 2018).

NCHRP Report 875 supports these assumptions. Eccles et al. (2018) found that in 83% of observed cases, drivers selected stopping positions closely matching the AASHTO-recommended location. However, the report also notes that the guidance is limited as to when it is practical to extend the distance to 18 feet, especially in constrained urban environments.

Morris et al. (2019) examined how stopping positions influence driver behavior on the major road. In a simulation study, they observed that when minor road drivers positioned themselves closer to the intersection than the standard stop bar, it encouraged main-road drivers to reduce their speed. This insight is relevant for urban settings, where traffic calming supports multimodal safety goals.

Eccles et al. (2018) reviewed 13 agency policies and found variation in defining DP: “[T]en specified longitudinal placement—most within AASHTO’s range, with one using the major-road right-of-way line and Oregon DOT using the crosswalk—while eight defined lateral placement (four at the lane center, two at a 4-ft or 5-ft centerline offset) and only one linked it to the stop bar" (Eccles et al., 2018). Building on this, this report's literature review examined how different state and local policies specify DP in greater detail. The subsequent section present the findings.

State Departments of Transportation

DP was found to be mostly within the guidelines specified by the AASHTO (2018) *Green Book* for state DOTs. Eleven of the 16 state DOTs specify a value (Table 16). The other five DOTs—West Virginia DOT (2021), District of Columbia DOT (2023), Texas DOT (2024), Missouri DOT (2021), and Michigan DOT (2022)—either directly quote or refer to the *Green Book* for standards. Policies vary, with some specifying a minimum value and others adopting different minimum values based on conditions. For example, Delaware DOT (2019) requires a minimum of 14.5 feet for minor subdivision entrances and 18 feet for major subdivision entrances. The minimum values given are in the range of 14.4 to 15 feet from the edge of the major roadway. Factors such as pedestrian crossings and design vehicle geometry may necessitate evaluating distances greater than the minimum 14.5 feet, as discussed by South Carolina DOT (2021).

Table 16. State DOT Guidelines on Decision Point Location

States	Decision Point Location
Virginia DOT (2023a)[a]	Minimum 14.5', where practical, should be determined by the location of stop bar and may exceed 18'
North Carolina DOT (2023)[a], Kansas DOT (2013), Illinois DOT (2025)	15'
South Carolina DOT (2023)[a], Minnesota DOT (2019)	14.5'
West Virginia DOT (2021)[a], District of Columbia DOT (2023), Texas DOT (2024), Missouri DOT (2021), Michigan DOT (2022)	AASHTO (2018) *Green Book*
Delaware DOT (2019)	Minimum 14.5' for minor subdivision entrances, 18' for major subdivision entrances
California DOT (2022)	Minimum 10' + shoulder width of major road (should not be less than 15')
Florida DOT (2024)	Min 14.5'
Georgia DOT (2025)	Greater of (a) 14.5' and 18' (desirable) and (b) 8' behind the final stop line marking
Ohio DOT (2025a)	Minimum 14.4', preferable 17.8'

DOTs = departments of transportation. [a] State DOTs owning the secondary system of roadways.

Most of the DOTs measure the DP location from the edge of the major road's traveled way. VDOT (2023b) and Georgia DOT (2025) consider the stop bar's location, indicating that the distance from the edge of the traveled way can exceed 18 feet during this evaluation. California DOT (2022) adopts a unique approach by including shoulder width in determining the DP's location from the edge of the major roadway. Florida DOT (2024) notes that DP may be adjusted based on a site-specific study of the driver's eye and vehicle stopping position.

Regarding the lateral position of DP on the minor road, nine agencies—North Carolina DOT (2023), South Carolina DOT (2021), Delaware DOT (2019), California DOT (2022), Illinois DOT (2025), Minnesota DOT (2019), Kansas DOT (2013), Florida DOT (2024), and

Ohio DOT (2025a)—either explicitly state that DP should be at the center of the lane or illustrate it at the lane's center in their sight triangle diagrams. Appendix B1 titled *Subdivision Street Design Guide* of the VDOT (2025b) RDM sets a different standard by placing DP 4 feet from the centerline or the left edge of the pavement of minor roadways for subdivision streets.

Localities

Seven of the 14 localities specify guidelines for the DP location (Table 17). The minimum distance of DP from the edge of the major roadway ranges from 10 to 15 feet, which is less than the 14.5 feet specified by the AASHTO (2018) *Green Book* and less than the distances observed for state DOTs. Some policies allow for DP to be positioned at a reduced distance of 10 feet under specific conditions. For instance, the City of Kirkland (2024) permits a reduction to 10 feet if both intersecting streets are neighborhood access roads, if one is a neighborhood access road and the other a collector, and if no angle-related crashes at the intersection occurred in the past 5 years. The City of Morgantown (2019) applies a 10-foot distance for DP in SSD cases. Some localities directly refer to either AASHTO standards or their respective DOT standards. For example, the City of Charlottesville (2023) recommends using the AASHTO *Green Book* for the design of local streets and Appendix B of the VDOT (2025b) RDM for roads requiring VDOT approval.

Table 17. Guidelines on Decision Point Location for Localities

Localities	Decision Point Location
City of Charlotte (2023)	10–14.5 feet
City of Scottsdale (2018)	14.5 feet
Carroll County (2007)	Minimum 15 feet, minimum 10 feet for single-use driveways that will access an existing county roadway
City of Kirkland (2024)	14.5 feet, may be reduced to 10 feet
City of Virginia Beach (2022), County of Henrico (2025)	14.5 feet
City of Morgantown (2019)	10 feet for stopping sight distance
City of Chicago (2007), City of Charlottesville (2023)	AASHTO (2018) *Green Book*
City of Charleston (2022)	South Carolina DOT *Road Design Manual*
New York City DOT (2025b), Los Angeles DOT (City of Los Angeles, 2020), Arlington County (2025), City of Newark (2023)	Not specified

AASHTO = American Association of State Highway and Transportation Officials; DOT = department of transportation.

Four of the localities outline the lateral position of DP on the minor road, where two localities—the City of Charlotte (2023) and Carroll County (2007)—place it at the center of the lane. The City of Virginia Beach (2022) denotes the position to be at 4 feet from the centerline, and the City of Scottsdale (2018) instructs placing DP at a distance of 5 feet measured to the nearest line or centerline.

Obstructions

The AASHTO (2018) *Green Book* states that any object elevated above the roadway surface that obstructs a driver's view should be removed or lowered when feasible. Obstructions within the sight triangle are generally defined by their height and sometimes width. Typically, both the driver's eye and potential obstacles are assumed to be approximately 3.5 feet high. Maximum allowable object heights within the sight triangle often range from 2 to 4 feet, with some guidance distinguishing between major obstructions and smaller elements that drivers can see around with slight adjustments in position.

Macdonald et al. (2006) examined how ISD standards intersect with urban elements, such as street trees and on-street parking. They found that parked vehicles are more likely to block sight lines than trees, yet municipalities often impose stricter limitations on trees. The study emphasized the challenges of applying AASHTO guidance in dense urban environments, where standards often assume suburban conditions and prioritize vehicle movement. In practice, achieving full sight distance as defined by AASHTO is often infeasible in compact settings. Simulations showed that drivers in urban environments were rarely able to see approaching vehicles at the full sight distance, particularly because of obstructions from parked cars.

The findings highlight the importance of flexible, context-sensitive definitions of obstructions that consider both the type and placement of objects rather than enforcing unrealistic clear zones in urban intersections. With relation to this, this research examines how state and local policies designate obstructions, and the following sections present the findings.

State Departments of Transportation

For the state DOTs that own their secondaries, all six DOTs conform to the AASHTO (2018) *Green Book* standards when specifying the driver's eye height and object height. Among those six DOTs, three of the policies explicitly state the value for both the driver's eye height and the object height, which is 3.5 feet above the roadway surface for passenger cars.

Similarly, all 10 state DOTs with the most lane miles adhere to the AASHTO (2018) *Green Book* standards for driver's eye height and object height. Eight of those DOTs specify the value (3.5 feet), whereas the other two DOTs—Texas DOT (2024) and Georgia DOT (2025)—directly refer to the *Green Book* for all ISD requirements.

State DOTs generally define obstructions as anything that blocks the line of sight within the sight triangle. The Illinois DOT (2025) provides a different viewpoint, stating that point obstacles, such as traffic signs and utility poles, are not considered sight obstructions because the drivers can slightly move to avoid these obstacles. Only the District of Columbia DOT (2023) gives additional criteria, defining an obstruction as any object within the sight triangle that exceeds 2 feet above the flow-line elevation of the adjacent street.

Four state DOTs, as indicated in Table 18, specify restrictions regarding trees, landscaping, and planting allowed in the vicinity of intersections. For those DOTs, street trees are not considered obstructions if they are more than 7 to 8.5 feet above the roadway surface. Similarly, the lower height restriction for landscaping and planting ranges from 2 to 2.5 feet above the roadway surface. Some policies impose this restriction within the limits of sight triangles, whereas others designate a specific horizontal boundary. For example, VDOT (2023a) imposes a height restriction on street trees and landscaping within a 30-foot distance from corners on all sides, measured from the end of curb return radii (i.e., the point at which the curved section of roadway near a corner meets the tangent section).

Table 18. Obstruction Considerations for State DOTs

State DOTs	Street Trees, Landscaping, and Planting	
	Vertical	**Horizontal**
VDOT (2025b)[a]	Planting strips between 2 and 7 feet should be free of obstructions.	30 feet from corners on all sides, measured from the end of curb return radii.
District of Columbia DOT (2023)[a]	Street trees required by district are permitted if pruned up to 8 feet.	Within a 30- by 30-foot sight triangle (measured from center of travel lane to the center of the intersecting approach travel lane). Major roads require a 50- by 50-foot sight triangle.
Florida DOT (2024)	- Canopy of trees and trunked plants must be at least 5 feet above the sight line datum, i.e., 8.5 feet above the roadway. - Top of ground cover plants must be at least 1.5 feet below the sight line datum, i.e., a maximum of 2 feet above the roadway.	Within clear sight triangles.
Georgia DOT (2025)	Street trees should be pruned so that limbs are at least 7 feet above the grade.	Within medians and in pedestrian traffic areas.

DOTs = departments of transportation. [a] State DOTs owning the secondary system of roadways.

Localities

Among the localities studied, 8 of 14 adhere to the same standards for driver's eye height and object height as those established by the AASHTO (2018) *Green Book*. Seven of these localities—City of Charlotte (2023), City of Scottsdale (2018), Carroll County (2007), City of Charlottesville (2023), City of Virginia Beach (2022), and County of Henrico (2025)—explicitly state the values, and City of Chicago (2007) directly references the AASHTO *Green Book* for sight triangle considerations. The City of Morgantown (2019) sets the driver's eye height to 3.5 feet above the roadway surface but mentions that the standard is for SSD and mandates an object height (named as vehicle height) of 4.25 feet.

Six of the 14 localities provide guidelines for defining obstructions. Table 19 presents those localities (along with the City of Charlotte) and their observed standards. The lower limit of height restrictions for objects ranges from 2.5 to 3.5 feet above the roadway surface. In addition, three localities establish an upper height, beyond which objects are not considered obstructions, ranging from 6.7 to 8 feet above the roadway surface. These restrictions are applicable within the sight triangle, except for the Los Angeles DOT, which applies the height restriction for objects within 45 feet along the street edge from the point of intersection of the extended curb lines or street edges.

Table 19. Obstruction Considerations for Localities

Locality	Height of Obstruction	Street Trees, Planting, and Landscaping	
		Vertical Restriction	**Horizontal Restriction**
City of Charlotte (2023)	N.F.	N.F.	Trees are prohibited within 10 feet of traffic control devices (signals, signs, name marker) at intersections.

Locality	Height of Obstruction	Street Trees, Planting, and Landscaping	
		Vertical Restriction	Horizontal Restriction
City of Scottsdale (2018)	> 2.5 feet	- 8–13.5 feet (for canopies) above the curb height. - 2.5-foot height limit for vegetation - 3-foot height limit for shrubs.	For trees placed in sight distances and traffic safety triangles. Maximum mature trunk diameter is 8 inches.
City of Kirkland (2024)	3–8 feet	N.F.	N.F.
City of Virginia Beach (2022)	> 3.5 feet	Trees are not considered obstructions if they have a clearance of 14 feet on street side and 8 feet on sidewalk side.	For trees planted in crossing island.
City of Los Angeles (2020)	36–80 inches	Trees are not considered obstructions if they have a clearance of 14 feet on street side and 8 feet on sidewalk side.	For trees planted in crossing island.
City of Chicago (2007)	> 30 inches	N.F.	N.F.
County of Henrico (2025)	> 30 inches	30 inches to 8 feet for landscape plantings.	N.F.
City of Morgantown (2019)	3.5–8 feet	N.F.	N.F.

DOT = department of transportation; N.F. = not found.

Five localities—City of Charlotte (2023), City of Scottsdale (2018), City of Virginia Beach (2022), Los Angeles DOT (City of Los Angeles, 2020), and County of Henrico (2025)—have standards regarding the allowance of street trees, planting, or landscaping. The lower height limit is seen to be in the range of 2.5 to 3 feet above the roadway surface, and trees and landscaping objects are not considered obstructions if they are 8 to 14 feet above the roadway surface. The City of Virginia Beach and Los Angeles DOT clarify that trees need a clearance of 14 feet on the street side and 8 feet on the sidewalk side, applicable to trees planted in crossing islands. The City of Charlotte (2023) also instructs restricting trees within 10 feet of a traffic signal, sign, street name marker, or other traffic control device but notes that a line of trees should not inherently be considered as a sight distance impediment unless crash histories indicate otherwise. This policy further emphasizes that removing trees to improve sight distance should be considered only as a last resort.

Multimodal Considerations

Multimodal guidelines often include separate sight distance guidelines intended to govern the interactions between motorists and bicyclists or pedestrians. Notably, these guidelines are not tailored to a particular AASHTO case. That is, they apply equally whether the intersection in question is a two-way stop, a four-way stop, a signal-controlled junction, and so on. However, they *are* tailored to urban areas. The relationship between these multimodal guidelines and AASHTO guidelines is unclear.

According to VDOT’s (2025e) *Multimodal Design Standards for Mixed-Use Urban Centers*, only SSD is required on streets classified as P5 and P6 within an Urban Connected Network where speeds do not exceed 35 mph. However, ISD remains mandatory on all Multimodal Through Corridors. Multimodal centers are categorized by activity density—the combined number of jobs and residents per acre, with P6 Urban Cores exceeding 70 and P5 Urban Centers typically ranging between 36 and 70 (VDOT, 2025b).

The review on multimodal considerations for ISD, especially in urban areas, highlights the increasing need to account for the complex interactions between pedestrians, bicyclists, and motorists. The subsequent section will discuss findings related to multimodal considerations, including bicyclist and pedestrian standards, drawn from policies of state DOTs and localities mentioned in previous sections, as well as from other relevant policies identified that serve as useful cases.

Multimodal intersection design guidelines from Massachusetts DOT (2015) address cases where a detached bike lane runs behind parking spaces or other obstructions. Despite this somewhat limited scope of applicability, those cases are notable as instances of limiting on-street parking near intersections out of concern for sight distances. These guidelines recommend 40 to 60 feet of "approach clear space" to prevent right- and left-hook collisions. Given a vehicular turning speed of 10 to 20 mph and a bicyclist speed of 15 mph, that space is said to be sufficient for a motorist and a cyclist to (1) recognize a potential conflict, (2) decide who will yield, and (3) stop if necessary. In cases where motorists must cross a separated bike lane on the near side of the intersection (a case more similar to AASHTO Case B), 20 feet between the stop bar and the crosswalk is recommended. Because this space locates turning vehicles further than 14.5 feet from the edge of the near travel lane, the resulting AASHTO sight triangle would be much larger if the intersection were not signal controlled. However, this scenario is not addressed, possibly because most such intersections would in fact be signalized. NACTO's (2019) *Don't Give up at the Intersection* echoes the Massachusetts DOT requirements for protected bike lanes, recommending "the total clear sight distance should be at least 40 feet, measured from the front of the last parking space to the point where bikes become exposed to turning vehicles." NACTO also mentions that "the designer's challenge is to provide good lines of sight without encouraging higher speeds," representing a crucial shift in philosophy from the AASHTO guidelines (NACTO, 2019).

The Ohio DOT's (2025b) *Multimodal Design Guide* outlines sight distance requirements for different bike cases, distinct from those in AASHTO cases. The document emphasizes that approach clear space is crucial for providing necessary sight lines between motorists and bicyclists to facilitate yielding or stopping as required. The dimensions of the approach clear space are contingent on the effective turning radius and the target turning speed of vehicles. It suggests a range of values (20 to 70 feet) measured from the point of curvature of the motorists' effective turning radius for this approach clear space, considering both the effective vehicle turning radius and the target vehicular turning speed. The Texas DOT (2024) outlines approach clear space requirements for various biking scenarios, emphasizing that ISD standards typically ensure sufficient sight distances for cyclists using street-based facilities, such as shared and separated bike lanes. It specifies combining motorist and bicyclist SSD requirements for intersections of shared-use paths with roadways, referencing the AASHTO (2024) Bike Guide for further discussion. Similarly, the California DOT (2022) concurs, underscoring the importance of designing bicycle paths with adequate SSDs to allow cyclists to respond to unforeseen events safely.

Furthermore, on two-way streets featuring a left-side separated bike lane or side-path where motorists intend to make a left turn (similar to AASHTO Case B1), the operational dynamics of motorists seeking gaps in traffic pose unique challenges. These challenges cannot be solely addressed by improving sight distance because motorists are primarily focused on identifying gaps in oncoming motor vehicle traffic and may be less likely to scan for approaching bicyclists from behind. In addition, motorists may accelerate once they perceive a gap in traffic. In such cases, Ohio DOT (2025b) suggests deploying traffic control devices and ensuring adequate sight distance, including minimum SSD, even in constrained situations, or providing an adequate motorist yield zone in cases where implementing traffic control measures might not be feasible.

For calculating the departure sight triangle between passenger vehicles and bikeways, Ohio DOT (2025b) advises placing the DP location at a distance of 10 feet from the edge of the bikeway. In addition, it recommends adjusting the typical time gap for the appropriate sight distance from Equation 1 to accommodate the longer distance that motorists will traverse when assessing both bikeway conflicts and motorway conflicts from a single stopped location. Moreover, the sight distance for bicyclists should ideally be measured from a height of 3.83 feet above the ground to accommodate recumbent bicyclists.

The review found that some literature and policies suggest pedestrian sight distances may exceed SSD and even ISD. Easa (2016) presents a pedestrian crossing time model for two-way stop-controlled intersections that incorporates the width of the roadway, the "length of the crossing unit (e.g., wheelchair)," and observation-reaction time (e.g., in the case of older pedestrians). The model yields a "pedestrian crossing sight distance" that Easa (2016) notes generally exceeds ISD, especially as the horizontal curve on the major road becomes sharper. Similarly, the Town of Parker, Colorado, adds that available sight distance that is 10 or more times the posted speed limit will ensure that the distance for motorists to stop is adequate before reaching the crosswalk if necessary (Town of Parker, 2019).

Georgia DOT's (2021) *Pedestrian and Streetscape Guide* also calls out that the pedestrian crossing sight distance is longer than the vehicle SSDs, and in turn, is not satisfied by the minimum SSD and provides an equation where the pedestrian sight distance is calculated based on the startup and clearance time, crossing distance, and pedestrian walking speed. The policy addresses scenarios for vehicles and pedestrian considerations and indicates that where drivers must make complex decisions, the minimum SSD may not provide sufficient visibility distances for drivers to respond and perform appropriate maneuvers, and thus, decision sight distances should be used as recommended by AASHTO. The policy directs determining the sight triangle required as:

> Locate the point on the edge of the lane where the pedestrian would step into the vehicle travel lane. Draw a straight line representing the length of the minimum SSD and/or the decision sight distance and measure to a point in the center of the approaching travel lane(s). Lanes should be checked to ensure the "worst case" scenario is accounted for. Check that the area in the SSD and/or decision sight distance triangle is clear of objects that could obstruct the sight distance. Check that the measured stopping sight distance and/or decision sight distance is not obstructed by horizontal or vertical curves in the roadway. (Georgia DOT, 2021)

VDOT’s (2025f) *Complete Streets* further outlines provisions for on-street parallel parking, permitting it on collectors or local roadways with speed limits of 35 mph or less. However, parking within 20 feet of any intersection is prohibited to ensure adequate sight distance. In addition, a 20-foot clearance is required from the intersection curb return to the nearest edge of on-street parking, which increases to 30 feet if a traffic control device faces the parking channel. On-street parking must not obstruct necessary sight distance, and efforts should be made to place signal poles and control boxes behind sidewalks to minimize interference with sight lines. Corner radii also play a crucial role in pedestrian safety and vehicle maneuverability, as highlighted in VDOT’s (2025e) *Multimodal Design Standards*. In pedestrian-centric areas, smaller corner radii are favored to reduce crosswalk lengths and slow-turning vehicles. The presence of on-street parallel parking can facilitate smaller curb radii while accommodating larger vehicles.

Speed and Periphery

Although maintaining clear sightlines is essential for intersection safety, it is not the sole consideration. The *Global Street Design Guide* emphasizes the importance of fostering eye contact among users rather than relying exclusively on unobstructed sightlines for moving vehicles (Global Designing Cities Initiative [GDCI] and NACTO, 2018). It recommends basing sight distance calculations on target speeds rather than design speeds to encourage slower traffic. Both GDCI and NACTO (2018) and NACTO (2013) support the design of narrower intersections with additional street elements to naturally slow vehicles and enhance pedestrian safety. Lower speeds are particularly important because they expand drivers’ peripheral vision, improving awareness of pedestrians, cyclists, and other vulnerable road users. For this reason, compact intersections and daylighting are promoted as strategies to improve visibility and reduce speed-related risk.

The debate in the multimodal literature is ongoing regarding the treatment of street elements such as trees and utility poles. Although some NACTO guidelines suggest removing obstructions to achieve standard sight distances, others imply that intersection design should instead focus on improving the visibility of important objects without eliminating amenities. Dumbaugh and King (2018) interpret parts of NACTO’s guidance as supporting reconstruction of the intersection form, rather than simply clearing obstructions. Eccles et al. (2018) also raise the possibility that discrete roadside elements—such as poles, trees, and buildings—could assist drivers in judging the speed and distance of oncoming vehicles, although they note this topic warrants further research.

The design philosophy advocated by GDCI and NACTO (2018) represents a shift from conventional standards, such as those found in the AASHTO (2018) *Green Book*. Rather than opposing clear sightlines, the GDCI and NACTO guidelines argue for a broader definition of visibility, one that includes speed control as a core element. They caution that providing sight lines well beyond what is needed may unintentionally encourage speeding, thereby undermining safety goals.

Vehicle speed emerges as a central factor in intersection safety for all users. Modifying curb radii is one method to influence speed, as smaller radii reduce pedestrian crossing distances and restrict vehicle turning speeds. The Delaware DOT (2019) highlights that corner radii directly affect both pedestrian safety and vehicle behavior. Similarly, guidance from the Texas DOT (2024) and California DOT (2022) stresses minimizing curb radii as a way to reduce pedestrian-vehicle crashes. These agencies advocate for compact intersection designs that reduce turning speed and crossing length. FHWA (2016) recommends using an “effective” curb radius that accounts for features such as on-street parking or bike lanes to better control vehicle speed in multimodal environments.

Daylighting and Parking

Daylighting refers to the removal or prevention of visual obstructions near intersections and crosswalks to improve visibility and enhance safety, particularly for pedestrians and bicyclists. It is increasingly being considered as a design strategy to improve multimodal safety at urban intersections, especially where conventional ISD standards may not be met. Several cities have adopted daylighting initiatives as part of broader Vision Zero, a global strategy to eliminate traffic fatalities and severe injuries, or Complete Streets efforts. Hoboken, New Jersey, reported having zero traffic fatalities since 2018, citing daylighting as one contributing factor (Robbins, 2022). In San Francisco, crash reductions were observed at 80 intersections in the Tenderloin neighborhood after implementing daylighting treatments (Surico, 2023). Portland, Oregon, has announced plans to expand daylighting to 350 additional intersections, and California law now prohibits parking within 20 feet of any crosswalk. New York City has also mandated that 100 intersections be daylighted annually starting in 2025.

Daylighting is typically implemented through physical design treatments, such as curb extensions, street furniture, bikeshare stations, or signage that restricts parking close to intersections. Those measures aim to ensure that pedestrians and drivers have adequate visibility at crossing points, reducing the likelihood of collisions. Rather than representing a reduction in urban functionality, daylighting is viewed as a safety enhancement strategy that supports multimodal travel and reinforces visibility where traditional ISD requirements may not be fully attainable.

Flexibility Within Existing Standards

Flexibility in applying ISD standards varies across state and local agencies. Although some allow design waivers or exceptions when the minimum sight distance cannot be met, the process and thresholds differ. Generally, SSD is treated as a controlling criterion requiring a design exception, whereas ISD is not and may only require a waiver. VDOT and AASHTO encourage flexibility in applying standards, but the extent and application of this flexibility are often unclear. Another approach discussed in the literature is the use of a lower speed rather than the highest design speed to reduce sight distance requirements.

Overview of Flexibility in AASHTO and VDOT Guidance

VDOT and AASHTO emphasize context-sensitive design. Key documents such as VDOT’s (2023) IIM-LD-235, (2020a) IIM-LD-255.1, and (2025b) *Road Design Manual* encourage engineers to exercise judgment and adapt designs to the local context.

- VDOT's (2024a) IIM-LD-227.14 outlines procedures for requesting design waivers or exceptions when standard values cannot be met, provided the design remains protective of people and property.
- AASHTO (2018) allows field verification of actual sight lines in cases where the modeled ISD cannot be achieved and suggests mitigation strategies such as signage, signalization, or turn restrictions.
- AASHTO (2004) further clarifies that designers have flexibility in selecting design speed and vehicle type—key parameters that influence ISD values.
- AASHTO's (2001) guidelines for very low-volume roads allow reduced ISD when all intersection legs have AADT ≤ 400 vehicles per day and full ISD is impractical because of constraints. Some jurisdictions, such as Florida and Franklin, Tennessee, have adopted these reduced standards in official policy.

Despite these provisions, studies by the Institute of Transportation Engineers (2010) argue that AASHTO standards often lack sufficient technical detail or quantifiable relationships to guide decision-making when trade-offs between geometric elements are necessary.

Speed Reduction

A significant area of flexibility lies in the choice of design speed. Although the traditional approach has been to select the highest feasible design speed, more recent guidance recommends shifting toward a target speed based on street function, classification, and surrounding land use.

- The Institute of Transportation Engineers (2010) report on urban thoroughfare design encourages the use of target speed as the primary control variable for determining ISD. This change supports safer, context-responsive street designs in walkable areas.
- The National Academies (2009) notes that using a lower design speed often eliminates the need for a formal design exception by allowing shorter sight distances.

A New Jersey DOT study by Ewing and King (2002) offers practical insights on flexibility. It identified a national shift away from rigid highway design standards toward approaches that accommodate local context. The study compared minimum design speeds across states and found that New Jersey's 30-mph requirement was higher than Vermont's 25-mph and Idaho's 19-mph requirements. It recommended lowering main street design speeds to 20–25 mph to enable reduced geometric standards. The review of 81 design exception reports also revealed that although most projects involved community or environmental considerations, only a few included ISD-related deviations.

Types of Documents and Approval Processes

FHWA (2016) differentiates between design exceptions and design waivers based on whether the criterion in question is controlling:

- SSD is classified as a controlling criterion on most roadways. If SSD cannot be met, a formal design exception is required.

- ISD is considered noncontrolling. If ISD is not met, agencies typically process the deviation through a design waiver or variance, often requiring less documentation.

For nonfreeway National Highway System roads under 50 mph, only two criteria, structural capacity and design speed, are controlling. States may define their own internal documentation requirements for noncontrolling criteria depending on legal frameworks and risk management policies.

State Department of Transportation Flexibility

Most state DOT policies follow FHWA guidance by requiring a design exception when SSD is not met. ISD is not typically considered a controlling criterion and is encouraged where feasible. Some DOTs allow reduced ISD or rely solely on SSD in low-speed or physically constrained environments.

VDOT's (2025e) *Multimodal Design Standards for Mixed-Use Urban Centers* specifies that only SSD is required for P5 and P6 streets within Urban Connected Networks where speeds are 35 mph or lower. When ISD values cannot be met, even after applying adjustments for approach grades, a design waiver must be requested as outlined in IIM-LD-227 (VDOT, 2024a). A design exception is required when SSD is not met, whereas a design waiver is appropriate if SSD is met but ISD is not (VDOT, 2024b).

Most other state DOTs reviewed (Delaware, Texas, Illinois, Kansas, Missouri, Florida, North Carolina, Georgia, Ohio, District of Columbia, and Michigan) follow FHWA guidance that a design exception is needed when SSD is not met. Some states clarify that exceptions are only necessary for design speeds above 50 mph (North Carolina, Georgia, Ohio, and Michigan) or on National Highway System routes (District of Columbia). When ISD falls below recommended values but SSD is met, states often require a waiver or variance. For example, Georgia, Kansas, and Florida require a design variance in such cases.

Although most states encourage achieving ISD wherever practical, the main requirement is to meet SSD. Additional policy guidance includes the following:

- Illinois DOT (2025) notes that ISD is only a concern on major highways with horizontal curves, medians, or opposing left-turn movements.
- Minnesota DOT (2019) encourages ISD at intersections with public roads and high-volume driveways in new construction. For improvement projects, the benefits of enhancing sight distance should outweigh costs, considering crash history and expected performance gains.
- Ohio DOT (2025a) recommends that if ISD cannot be achieved because of physical constraints, SSD must still be provided.
- Florida DOT (2024) mandates ISD for roads with design speeds of 40 mph or more. For roads under 35 mph, the greatest feasible sight distance should be provided, with SSD as the minimum.

In cases where ISD cannot be achieved, some DOTs recommend mitigation strategies. Delaware DOT (2019) states that inadequate ISD may warrant left-turn lanes. Illinois DOT (2025) suggests offsetting opposing left-turn lanes to improve visibility and adding warning signs or other design treatments if obstructions cannot be removed. Ohio DOT (2025a) advises using advanced warning signs, flashers, or reduced speed zones. Although most states outline procedures for SSD-related exceptions, few provide detailed guidance on obtaining waivers for ISD. Kansas DOT (2013) and Florida DOT (2024) are among those offering such guidance.

Locality Flexibility

Few local policies address flexibility in ISD standards, but those that do emphasize meeting SSD and may allow limited leeway based on constraints:

- The City of Charlotte (2023) requires SSD in all cases. If ISD cannot be met, the maximum practical sight distance should be provided along with measures such as warning signs or reduced speed zones.
- The City of Kirkland (2024) allows SSD in place of ISD on low-speed streets with angle parking and no crash history, evaluated on a case-by-case basis.
- The City of Morgantown (2019) accepts SSD as the minimum required distance on local streets.
- Carroll County (2007) permits variance requests when ISD cannot be achieved. Requests must justify conditions and propose remedial actions to reach acceptable SSD.

Traditional Neighborhood Development

TND is defined as a compact, mixed-use neighborhood where residential, commercial, and civic buildings are within close proximity to each other. It is a planning concept based on traditional small towns and city neighborhoods. An attempt exists to control vehicle speeds through careful design of streets and streetscapes. Minimum design speeds for TNDs are 15 to 20 mph (FHWA, 2023b). The interest is growing in adapting sight distance requirements to better fit TNDs, which prioritize compact, walkable, mixed-use design and lower vehicle speeds. However, although some state DOTs and localities have started to address the unique needs of TNDs, the guidance specific to ISD is limited and inconsistent. Most policies reference general design principles, such as narrower streets, lower design speeds, and traffic calming, but only a few provide separate standards tailored to TND contexts. VDOT includes a dedicated section on Neotraditional Neighborhood Design in its *Road Design Manual* (VDOT, 2025b), encouraging proposals that emphasize features like street interconnectivity and curb extensions but mandates unobstructed sight triangles.

Separate documents dedicated to TNDs were found for North Carolina and Florida. In the case of North Carolina DOT, the minimum sight triangle required for stop conditions at street intersections is specified to be 70 by 10 feet, although this length may be adjusted for lower design speeds on lanes and streets (North Carolina DOT, 2000). Under AASHTO guidelines, the same triangle would measure 14.5 by 225 feet. In addition, the document prohibits trees and other objects within 30 feet of corners on all sides. However, it also states that on streets with design speeds of 20 mph or less, or on streets with on-street parking, small trees may be planted within 3 feet of the back of the curb along the centerline of the planting strip. Although the North Carolina DOT (2023) *Roadway Design Manual* adheres to AASHTO standards, North Carolina TND guidelines explicitly take precedence over North Carolina DOT standards. TND guidelines for the City of Franklin, Tennessee (2019), refer to sight distances specified in AASHTO's (2001) *Guidelines for Geometric Design of Very Low-Volume Roads (ADT ≤ 400)*.

Florida DOT (2011) guidelines allow parking within 20 feet of a crosswalk in TNDs by permitting a two-stage stop, which lets sight triangles be measured from a location other than the standard 14.5 feet. Although the typical minimum SSD for low-volume streets is 60 feet, the manual notes that reduced distances may be justified based on local experience and successful existing layouts.

Data Collection

Among all the reviewed state and local policies, detailed procedures for field measurement were found for four DOTs. The four policies used the traditional method of ISD measurement, with some modifications. Table 20 gives a brief overview of the equipment and procedure these policies use for measuring ISD.

Table 20. Data Collection Methodologies Specified by State and Local Policies

Source	Equipment and Technology
Kansas DOT (2013)	Target object created using traffic cone, roadway delineator, range pole, or other static, free-standing object.
Oregon DOT (2017)	Sighting rod, measuring wheel.
Caroll County (2007)	Sighting rod, target rod, measuring wheel (42 inches by 6 inches [top]).
Michigan DOT (2015)	Measuring wheel, chalk or lumber crayons, sighting board, target board, two-way communication system.

DOT = department of transportation.

Survey of Existing Practices

State Departments of Transportation

The survey had responses from 17 state DOTs, as shown in Table 5. At the beginning of the survey, the DOTs were asked to identify the document they use for ISD guidance and to upload or provide a link to it. Thirteen DOTs specified their documents and uploaded or provided links in the subsequent question, and the other four DOTs (Kentucky, Vermont, Arkansas, and Maryland) indicated that they refer to the AASHTO (2018) *Green Book*. The question that followed specifically asked the DOTs how they incorporated AASHTO standards into their ISD guidelines. Three DOTs (Indiana, Ohio, and Pennsylvania) stated that they primarily follow the AASHTO *Green Book*, albeit with modifications. The remaining 14 DOTs reported that they fully adhere to the AASHTO *Green Book* guidelines for ISD. None of the DOTs selected the option indicating that AASHTO standards are not considered.

The next section of the survey included questions regarding the dimensions of the sight triangle. The questions focused on whether the guidelines for the dimensions of sight triangles (ISD along the major road, DP location, and defining obstructions) differed from AASHTO guidelines. If differences were noted, the respondents were asked to explain how the values were derived or under what circumstances the guidelines varied.

Intersection Sight Distance Along the Major Road

Most (16) of the DOTs reported that their ISD values along the major road are equal to or within 5 feet of the values specified by the AASHTO (2018) *Green Book*, except the Indiana DOT, which indicated that their ISD values are less than those outlined in the AASHTO *Green Book*. Staff further explained that they apply the AASHTO *Green Book* with a time gap of 9 seconds for collectors and arterials.

Decision Point Location

Two DOTs (Connecticut and Ohio) indicated that their guidelines locate DP in the sight triangle differently than the AASHTO (2018) *Green Book*, which specifies a distance of 14.5 to 18 feet from the edge of the roadway. Respondents from those DOTs were asked to elaborate on their approaches. Connecticut DOT stated that they consistently use a distance of 15 feet, measured from the edge of the traveled way where restrictions limit offset. Ohio DOT mentioned that they currently utilize values of 14.4 and 17.8 feet but plan to update those values to align with AASHTO *Green Book* soon. Other DOTs reported no differences from AASHTO *Green Book* guidelines, except for the Missouri DOT, which provided no specific information. Overall, the deviation is minimal among DOTs in locating DP within the sight triangle.

Six DOTs (Kentucky, Illinois, Maryland, District of Columbia, Pennsylvania, and Connecticut) noted that the DP position can be adjusted based on site-specific conditions. When asked about the factors influencing these adjustments, as Figure 26 shows, most cited geometric characteristics, and one mentioned crash history at the site. Among the three DOTs that selected the “other” option, Pennsylvania specified that horse-drawn vehicles at low-volume driveways can necessitate adjustments to the DP location. Kentucky referenced AADT as a consideration, and Connecticut indicated that adjustments might occur “where restrictions limit offset,” allowing DP to be measured from the edge of the traveled way instead of the roadway.

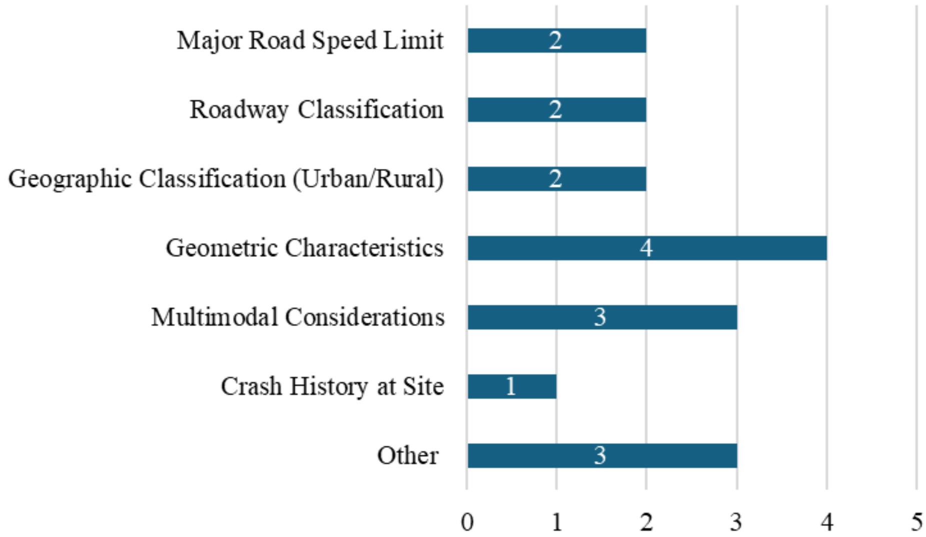


Figure 26. Factors State Departments of Transportation Consider while Allowing Adjustment in the Decision Point Location

Defining Obstructions

State DOTs have varied approaches when defining obstructions within the sight triangle. Most DOTs define obstruction as anything that blocks the line of sight within the sight triangle (Figure 27). In addition, some also specify a maximum height of objects within the sight triangle.

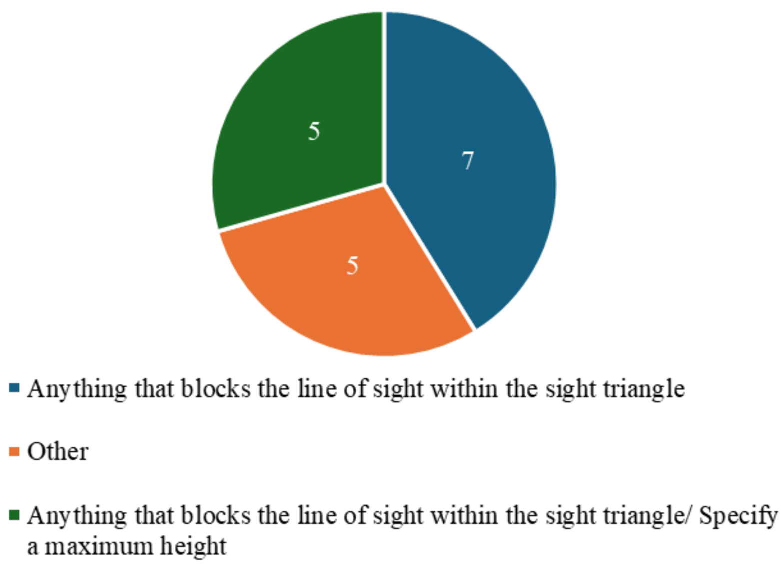


Figure 27. Definition of Obstructions by State Departments of Transportation

Several states also specify allowable object heights within the sight triangle. Most commonly, states use thresholds of 30 or 3.5 inches above ground, beyond which objects are considered obstructions. For example, Michigan defines objects above 30 inches as obstructions, whereas Indiana applies 3.5 inches.

Some DOTs provide additional guidance on exceptions. For instance, Michigan and Delaware state that narrow objects such as tree trunks, signposts, or fire hydrants are not considered visual barriers if they do not materially impair the driver's view. Connecticut mandates the removal of any objects that obstruct the sight triangle when feasible, and Kentucky explicitly includes traffic control devices as potential obstructions if they impair sight distance.

Table 21 includes the details state DOTs provided regarding their guidelines on parking restrictions at intersections where on-street parking is permitted. These restrictions vary by state. For example, New Jersey, Ohio, the District of Columbia, and Pennsylvania restrict parking at distances of 20 to 25 feet from crosswalks or within 30 to 50 feet from traffic signals or stop signs. Some states impose restrictions on specific parking spaces near intersections, and others restrict parking entirely within the sight triangle or within a certain distance from the edge of the curb return radii.

Table 21. Parking Restrictions by State Departments of Transportation

State	Parking Restrictions
Michigan	1 to 2 parking spaces of width are omitted near an intersection.
Illinois	Restrict parking in sight triangle.
New Jersey	Within 25 feet of the nearest crosswalk or sideline of a street or intersecting highway; within 50 feet of a stop sign.
Ohio	20 feet from a crosswalk or 30 feet from the intersection.
District of Columbia	Parking setbacks are approximately 25 feet from crosswalks.
Pennsylvania	Within 20 feet of a crosswalk or within 30 feet of a stop sign or signal; local authorities may impose restrictions with department of transportation approval.
Delaware	In subdivisions, within 40 feet from the edge of the radius return; 60 feet at subdivision entrances.

Multimodal Considerations

The DOTs were asked if they provide guidance on multimodal considerations related to ISD. If they do, they were prompted to answer further questions on the topic. Five DOTs (Ohio, the District of Columbia, Kentucky, Illinois, and Pennsylvania) indicated differences in ISD guidelines between multimodal and conventional guidelines. The Ohio DOT incorporates its guidance into the *Multimodal Design Guide* (Ohio DOT, 2025b). Meanwhile, the District of Columbia DOT is in the process of updating its *Bike Facilities Design Manual* to include guidance on multimodal considerations (District of Columbia DOT, 2020). The Kentucky DOT noted that mitigation measures, such as improved curb radii and curb extensions, are implemented to reduce pedestrian exposure and increase visibility. The Pennsylvania DOT highlighted that carriage-drawn and freight vehicles require different sight distances than passenger vehicles. Overall, approximately one-third of the surveyed DOTs provided specific guidance for multimodal features, and the remaining two-thirds did not.

Those DOTs were further asked whether they address sight distances for bicyclists and pedestrians and if they have approach clear space requirements at intersections. Illinois, Ohio, the District of Columbia, and Pennsylvania responded affirmatively. The Illinois DOT was the only one to indicate conditions requiring larger sight distances to account for added conflicts due to bikeways and pedestrians at intersections featuring bike lanes. They explained that they consider crossing distances and times for cyclists and pedestrians, as well as skew angles and features that might obscure visibility.

Four DOTs (Illinois, Pennsylvania, District of Columbia, and Ohio) reported having requirements for approach clear spaces at intersections. Ohio suggested referring to their *Multimodal Design Guide* (Ohio DOT, 2025b), and the District of Columbia DOT noted that they are updating their *Bike Facilities Design Manual* to include requirements for approaching clear spaces at intersections (District of Columbia DOT, 2020). Pennsylvania emphasized that intersection crossings should be designed to enhance safety and minimize delays for bicyclists, seeking to minimize conflict points.

With regard to daylighting, four state DOTs (South Dakota, Indiana, Illinois, and the District of Columbia) reported either implementing daylighting practices or planning to do so in the future. Most states carry out such practices informally, without explicitly labeling them as "daylighting." South Dakota DOT stated that they conduct these assessments as a common practice, although they may not term it as daylighting. Illinois DOT implements it on a case-by-case basis through site visits. Only the District of Columbia DOT mentioned guidelines prohibiting parking within 25 feet of a crosswalk.

Traditional Neighborhood Developments

This section included questions about whether states had observed an increase in TNDs, whether they had separate design guidance for TNDs, whether their ISD guidelines for TNDs differed from conventional guidelines, and whether the DOT was involved in the approval process for these developments concerning ISD standards. Only Michigan, Indiana, Vermont, and North Carolina reported an increase in TNDs within their states.

In addition, only Delaware indicated that they have separate design guidance for TNDs, although they did not upload it, stating it was unavailable at the time. The Delaware DOT was the only agency that reported differences in ISD guidelines for TNDs compared with conventional guidelines. They explained that in subdivisions, shrubbery and visual barriers are prohibited within the triangular areas formed by two curb lines and a line connecting points 30 feet from the intersection. These areas, referred to as sight triangle easements, must be designated on record plans. The Delaware DOT has full authority to maintain these easements to ensure proper sight distance. Table 22 shows the DOTs' involvement with approval regarding these types of developments:

Table 22. State DOT Involvement with Approvals Related to Traditional Neighborhood Developments

State DOT	Involvement
Vermont, North Carolina	Always
Michigan, Indiana, New Jersey, Kentucky, Delaware	Sometimes
Arizona, Ohio	Never
South Dakota, Arkansas, Connecticut, Maryland, Illinois, District of Columbia, Missouri, Pennsylvania	Unknown

DOT = department of transportation.

Design Flexibilities

The research team sought to understand the level of involvement that various DOTs have in approving design plans for developments. All DOTs reported some degree of involvement in this process. Most indicated that they review proposed developments only if they fall within their jurisdiction, mostly if they are situated on a state-maintained system or involve access to a state-maintained highway. If these criteria are not met, the responsibility for review typically falls to the local jurisdiction. Connecticut provided additional context, noting that even if a development is not on a state roadway, the DOT may still review it if it exceeds certain thresholds, such as being more than 100,000 square feet, having more than 200 parking spaces, or depending on a specific threshold of peak-hour trips.

In terms of specific involvement, Pennsylvania and the District of Columbia indicated that their DOTs handle all reviews independently. In contrast, states such as South Dakota, Vermont, Arkansas, Maryland, Illinois, and Missouri require joint reviews with local authorities. Several states—including Michigan, Connecticut, North Carolina, Kentucky, Indiana, Arizona, New Jersey, Ohio, and Delaware—stated that the need for DOT involvement depends on the location of the development.

Respondents were also asked about the documentation required when proposed developments do not meet necessary ISD standards. The types of documentation required vary by state. Indiana, Vermont, Connecticut, Arizona, Illinois, and Missouri require a design exception, whereas Arkansas requires a variance, and the District of Columbia requires a waiver. In addition, several states—including Michigan, South Dakota, Kentucky, North Carolina, Maryland, New Jersey, Ohio, Pennsylvania, and Delaware—mentioned other types of documentation. Within this "other" category, Delaware specified the need for a design deviation, and Maryland highlighted the requirement for an AASHTO review and milestone report.

States generally appear to be less stringent regarding documentation when ISD standards are not met. Concerns typically arise only when SSD for the major road is also insufficient. According to New Jersey, Ohio, and Pennsylvania, no documentation is required if SSD is met. Michigan further clarified that ISD guidance is not considered a hard standard, meaning that no requirement exists for design exceptions, design variances, or waivers when the guidance is not met. Instead, when ISD is insufficient, mitigations or adjustments are implemented, such as removing obstacles, trimming trees, or, in unusual cases, installing traffic signals. South Dakota added that it is uncertain whether these adjustments are formally documented through waivers or exceptions. Instead, they may be addressed through other methods, such as signage. Connecticut specified that design exceptions are reserved for official projects only, and for developments, they may allow ISD to be met based on the posted speed limit. In contrast, Kentucky noted that if ISD standards are not met, a permit could be denied until the standards are satisfied. They indicated that although they would impose the same flexibility as in their internal processes, they do not formally document design exceptions outside their internal permit logs.

When approving design modification requests, state DOTs consider several factors. Figure 28 illustrates the factors selected by those DOTs during their evaluations. The primary considerations include geometric characteristics, speed limits, crash history at the site, and multimodal considerations. In addition, approximately one-half of the DOTs take into account context sensitivity as a relevant factor in their decision-making process.

When asked if state DOTs kept a record of design modification requests, only New Jersey reported keeping a database of design modification requests. All the other DOTs either responded "no" or "unknown." New Jersey DOT also added that the number was unknown.

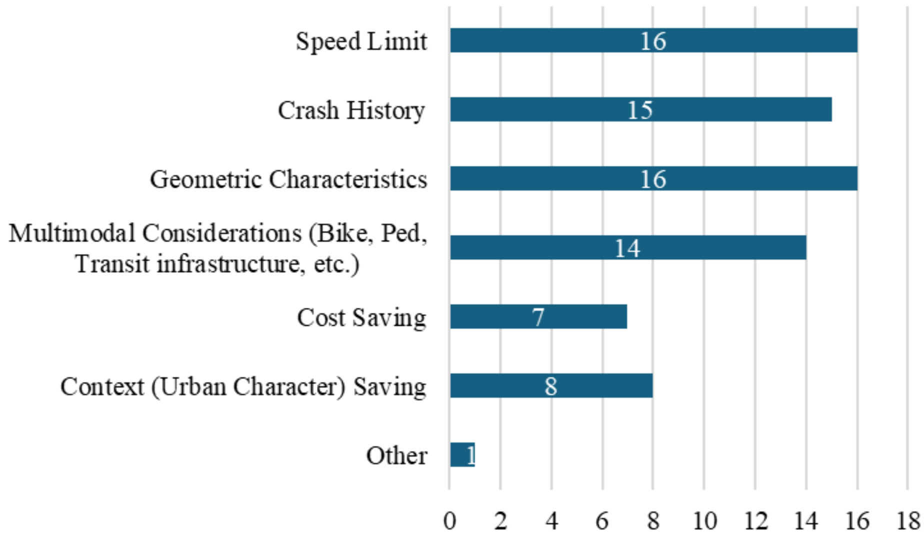


Figure 28. Factors State Departments of Transportation Consider when Evaluating Design Modification Requests

Virginia Localities

A total of 38 responses were obtained from 34 localities, as shown in Table 11. Because the survey was sent to multiple contacts within the same localities, it was not surprising that four localities provided two responses. For three of those four localities, one response was complete and one was incomplete, so only the complete response was used. For one locality, both responses were incomplete, so the one with more survey progress was included in the analysis. Then, for the 30 localities that provided just a single response, most (27) were complete, with three being incomplete. The result was that the survey analysis was based on 34 responses representing 34 localities, with 30 responses being complete and 4 being incomplete.

The survey began by asking if localities had an official document containing ISD guidelines. Some of the following questions were tailored based on the responses to this question. Nine localities reported having such a document, whereas 25 said they did not (Figure 29). Those nine respondents were asked to either provide a link to or upload the document, and all complied except for the Town of Wytheville. Of the nine, two—the Town of Culpeper and Town of Strasburg—fully follow the VDOT (2025b) RDM for ISD guidelines. Chesapeake and the City of Norfolk have established their own guidelines. Harrisonburg, the City of Manassas, the City of Hopewell, and Henrico County stated that they follow the VDOT RDM but with modifications.

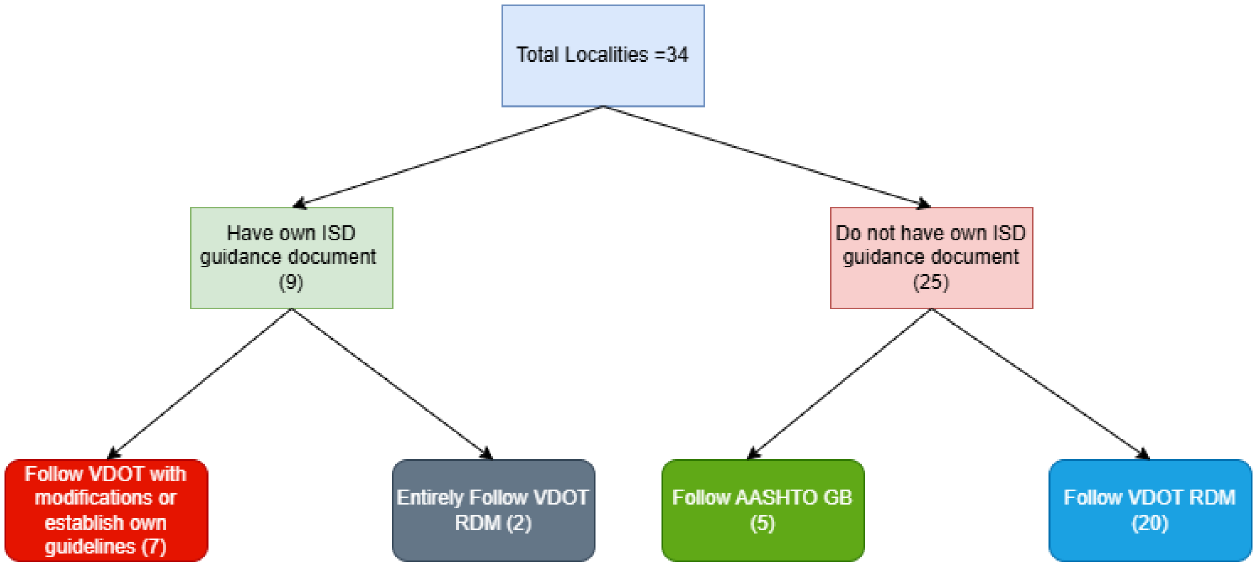


Figure 29. Survey Responses on ISD Guidance Document. AASHTO = American Association of State Highway and Transportation Officials; GB = *Green Book*; ISD = intersection sight distance; RDM = *Road Design Manual*.

Among the remaining 25 localities, 5 (Roanoke, City of Winchester, City of Petersburg, City of Alexandria, and City of Lexington) stated that they refer to AASHTO (2018) *Green Book* for ISD guidelines, and the other 20 localities said they refer to VDOT (2025b) RDM.

Based on this initial question, localities were asked slightly different questions on the same topics, including ISD along major roads, DP locations, obstructions, and multimodal considerations, as shown in Appendix B. Localities that had their own documents and that did not fully follow VDOT (2025b) RDM were asked more detailed questions about their standards. In contrast, those that did not have their own guidelines or fully followed VDOT RDM or AASHTO (2018) *Green Book* were asked fewer questions, focusing on whether they had cases where their guidelines deviated from VDOT or AASHTO standards.

Intersection Sight Distance Along the Major Road

For the localities that have an ISD guideline document, among the seven localities with their own ISD guidelines (not fully following VDOT), four (Harrisonburg, Chesapeake, Henrico County, and City of Norfolk) reported that their guidelines differ from VDOT's, and two (the City of Manassas and Hopewell) said theirs were the same. The key points are:

- Harrisonburg requires sight distance for all entrances as the posted speed limit of the uncontrolled road * 10 feet, resulting in generally lower distances than in the VDOT (2025b) RDM.
- In Chesapeake, ISD values for two-lane roads match VDOT, but other classifications differ—sometimes higher, sometimes lower. Chesapeake's manual lacks specific right- and left-turn sight distances.
- Henrico County makes no distinction between left or right turns and uses the total width of the major roadway to determine sight distance.

- In Norfolk, as a built-out urban city, ISD reviews are case-by-case, primarily focused on minor development projects.

For the localities that follow the VDOT (2025b) RDM, Blacksburg was the only locality to report having a reduced ISD requirement along the major road, differing from VDOT standards, although no further details were provided. Eight other localities had no such cases, and 11 reported unknowns.

For the five localities following the AASHTO (2018) *Green Book*, two (the City of Winchester and City of Alexandria) reported having reduced ISD requirements compared with AASHTO along major roads. Roanoke said “no,” and the remaining two responses were incomplete.

- The City of Winchester cited old roadways with less sight distance.
- The City of Alexandria, because of its urban environment, relies more on SSD than ISD.

Decision Point Location

Among the seven localities with an ISD guideline document, three (Henrico County, Chesapeake, and Harrisonburg) indicated that they had differences from the VDOT (2025b) RDM’s guidelines regarding the decision point location. Three (the City of Norfolk, City of Manassas, and City of Hopewell) stated they did not have any such cases, and one response was left blank (incomplete). The differences can be explained in the following points:

- Harrisonburg stated that DP is measured 6 feet from the centerline and 10 to 12 feet from the travel lane. Note that the city does not have roads with speed limits higher than 45 mph.
- Chesapeake said that the 4-foot value offset on the minor roadway is taken to be the center point of that travel lane.
- Henrico County said that they make no mention of DP distance and use 14.5 feet only, rather than the range of 14.5 to 18 feet.

All localities in the survey were asked if they allowed adjustments to the decision point location. Less than one-third (13 localities) said “yes” (Figure 30).

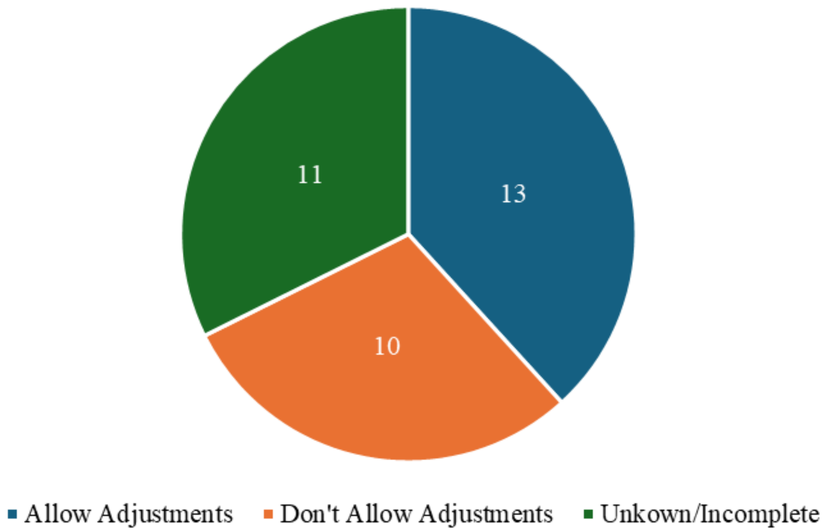


Figure 30. Virginia Localities' Responses on Whether They Allow Adjustment in the Decision Point Location

Figure 31 shows the count of factors localities consider when allowing adjustments to the DP location. Geometric characteristics were the most frequently cited factor, followed by major road speed limit and crash history at the site as the other key considerations.

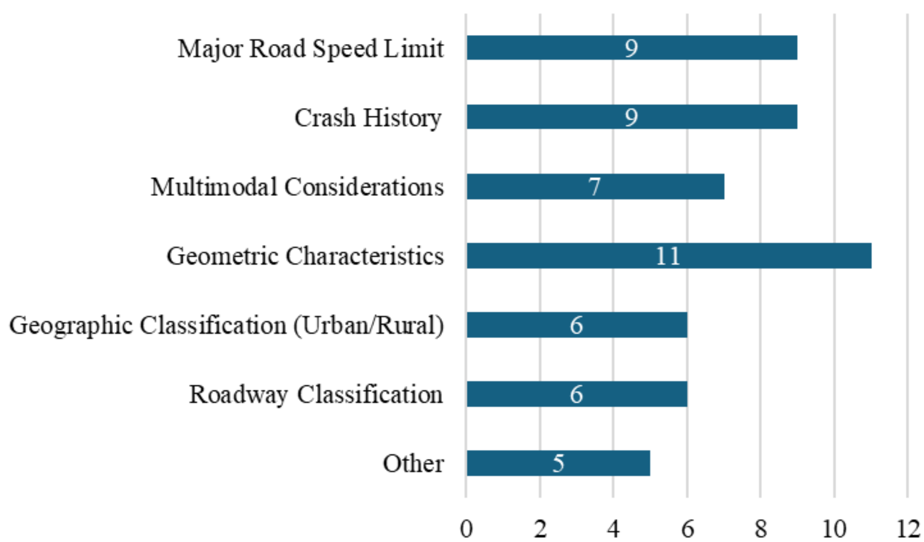


Figure 31. Factors Localities Consider while Allowing Adjustment in the Decision Point Location

In the "Other" option, respondents provided the following details:

- Harrisonburg—Adjustments are approved when traffic calming infrastructure lowers the effective speed, allowing modifications to sight distance requirements.
- City of Manassas—Adjustments are determined by the city engineer.
- Leesburg—Decisions are made on a case-by-case basis, often considering the best available entrance or using SSD.
- City of Winchester—Adjustments are allowed in areas with old roadways and buildings constructed many years ago.

- City of Buena Vista—Adjustments are based on subjective determinations, reviewed case by case.

Obstructions

Among the seven localities having an ISD guideline document, three (the City of Manassas, Chesapeake, and Henrico County) reported that their obstruction guidelines differ from VDOT's. Three others (Harrisonburg, the City of Hopewell, and the City of Norfolk) stated that their guidelines were the same. One locality's response was incomplete.

- In the City of Manassas, the engineering director determines the obstruction guidelines.
- Chesapeake defines obstructions as anything that blocks the line of sight within the sight triangle and enforces a height restriction of 3.5 feet.
- Henrico County defines obstructions as anything that blocks the line of sight within the sight triangle, with a height restriction ranging from 30 inches to 8 feet.

Four localities (Harrisonburg, Henrico County, City of Norfolk, and Chesapeake) reported having parking restrictions at intersections where on-street parking is allowed. Three localities provided further details:

- Harrisonburg reported that parking is restricted 20 feet from the tangent point of public road intersections and 5 feet from private roads and entrances.
- In Henrico County, parking restrictions apply only at roundabouts, with no further details provided.
- City of Norfolk code prohibits parking within 20 feet of a corner.

For the localities that follow the VDOT (2025b) RDM entirely, only the Town of Marion reported having obstruction guidelines that differed from the VDOT RDM. They indicated that guidelines might differ for light poles, street signs, and streets between buildings. Eleven localities said they had no differences, and the rest provided unknown or incomplete responses.

Among the localities that follow the AASHTO (2018) *Green Book*, three localities (Roanoke, City of Winchester, and City of Alexandria) reported that they had no conditions where their obstruction guidelines differed from the AASHTO *Green Book*. The remaining responses were unknown or incomplete. All localities were asked if they were aware of instances where compliance with ISD standards led to the removal or modification of urban elements like street trees, on-street parking, or utilities. Many said "yes" (Figure 32).

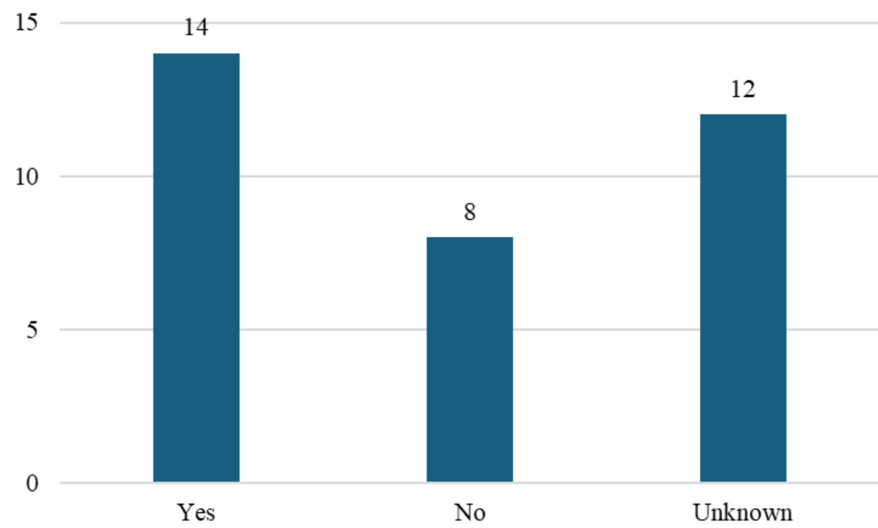


Figure 32. Virginia Localities' Responses on Whether Intersection Sight Distance Compliance Has Led to Removal of Urban Elements

The major elements were street trees and parking. Some localities added that actions were taken only when somebody expressed safety concerns. The details from those who said "yes" are summarized as follows:

- Harrisonburg, Leesburg, the City of Winchester, the Town of Smithfield, Manassas Park, and Henrico County reported removing street trees and non-street parking because of ISD concerns.
- The City of Colonial Heights, City of Norfolk, and Town of Culpeper removed street trees or landscaping.
- The Town of Vienna, Chesapeake, the Town of Strasburg reported restricting on-street parking.
- Lynchburg and Chesapeake reported taking actions only when a safety concern or a request is received.

Multimodal Considerations

Localities with their own ISD documents were asked only about multimodal considerations. Limited information was obtained. The City of Manassas was the only locality that provided guidance on multimodal considerations related to ISD, but further questions on bicycle and pedestrian sight distances and approach clear spaces revealed no guidance. The city also reported no differences between multimodal and conventional ISD guidelines.

With regard to daylighting, only Harrisonburg and the City of Hopewell reported either implementing or planning to implement daylighting practices. Four other localities were unaware of such practices, and the rest had unknown or incomplete responses.

- Harrisonburg has added physical curb bump outs at some intersections, especially where pedestrian traffic is heavy, and works with developers to include these bump outs in new road designs. They also plan to incorporate a Complete Streets Design Guide into their standards and have applied for Virginia Highway Safety Improvement Program funding to add more curb bump outs in safety projects. An existing example is along South Main Street near downtown.

- The City of Hopewell reported that daylighting is being considered in their city-specific design manual, which is currently under development.

Traditional Neighborhood Developments

In this section, initial questions were asked about whether localities had developments classified as TNDs. If respondents said "yes," they were asked additional questions about whether they had seen an increase in these developments during the past 10 years, whether they were aware of cases where these developments failed to meet ISD requirements, and if the ISD guidelines for TNDs differed from conventional ISD guidelines. Fourteen localities reported having TNDs, and these localities were asked those further questions (Figure 33). Ten localities reported no such developments, and the remaining 10 localities had unknown or incomplete responses.

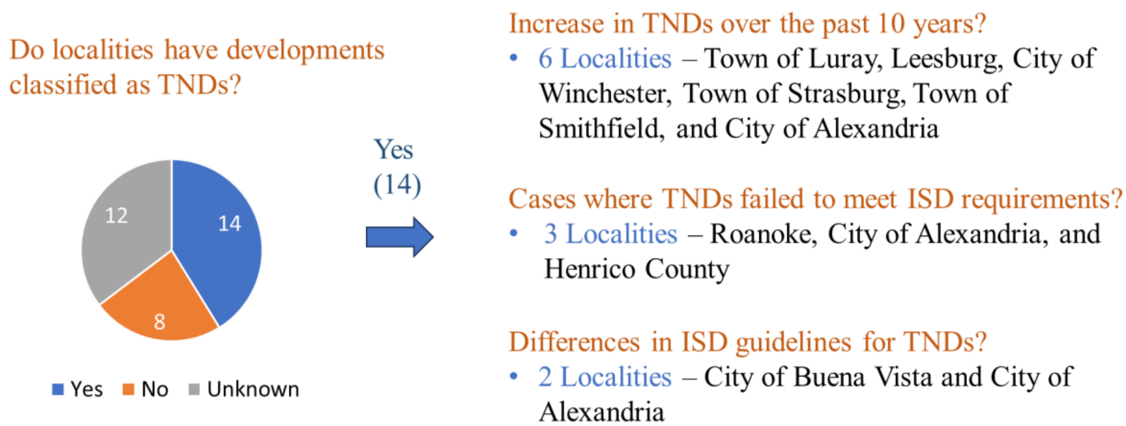


Figure 33. Virginia Locality Survey Responses on TNDs. The 14 localities that answered "yes" are the Town of Culpeper, Town of Luray, Leesburg, Roanoke, City of Winchester, City of Manassas, Town of Strasburg, Martinsville, City of Buena Vista, Town of Smithfield, City of Alexandria, Town of Marion, Henrico County, and City of Staunton. TNDs = traditional neighborhood developments.

Among the 14 localities, 6 reported an increase in TNDs during the past 10 years. Three localities reported cases where TNDs failed to meet ISD requirements. The City of Buena Vista and City of Alexandria noted differences in ISD guidelines for TNDs compared with conventional guidelines. Buena Vista explained that its historic street grid effectively functions as a TND, requiring flexibility with sight distance requirements. The City of Alexandria stated that its city code prohibits any building or vertical obstruction within the sight triangle, specifically within 30 feet of the intersection.

Locality Involvement with Development Site Plan Approvals

In this section, localities were first asked whether they were involved in development site plan approvals. For those that responded "yes," further questions were asked about the documentation required when ISD-related design modifications were necessary and the factors considered during the evaluation of those requests. Thirty localities indicated they were involved in the development site plan approval process, and four (the Town of Bluefield, Town of Wytheville, City of Lexington, and Town of Bridgewater) had incomplete responses. This result indicates a high level of involvement by localities in site plan approvals compared with DOTs, which is expected.

Design Flexibilities

When asked about the type of documentation (design exception, waiver, variance, or other) required when ISD standards are not met, localities provided varied responses (Table 23).

Table 23. Documentation Virginia Localities Require when Intersection Sight Distance Standards Cannot Be Met

Documentation	Count	Locality
Other	14	Leesburg, Roanoke, City of Winchester, Town of Christiansburg, Berryville, Chesapeake, Town of Strasburg, City of Buena Vista, City of Bristol, Town of Smithfield, Town of Vienna, City of Alexandria, Town of Marion, Town of Farmville
Design Waiver	7	Town of Culpeper, City of Colonial Heights, Lynchburg, City of Manassas, Martinsville, Henrico County, Town of Purcellville
Design Variance	3	Blacksburg, City of Norfolk, City of Staunton
Design Exception	2	Harrisonburg, City of Salem
Design Exception, Design Variance	1	City of Petersburg
Design Exception, Design Variance, Other	1	City of Hopewell
Design Waiver, Design Exception, Design Variance	1	Town of Luray
Design Waiver, Design Exception, Design Variance, Other	1	Manassas Park

Many localities strictly enforce ISD standards, offering no process for design modifications. Some allow modifications depending on factors like street classification, whether obstructions are movable, or if no other viable options exist. Some localities defer to VDOT requirements for guidance. For instance, Berryville and Vienna have no history of granting waivers or variances because ISD standards are always met. Localities like Chesapeake and Manassas Park require full compliance with ISD standards, with no waivers allowed in Chesapeake for safety reasons. On the other hand, localities like Luray and Lynchburg allow design waivers or exceptions based on the severity of the impact or the situation, such as whether the street is a dead-end or the obstruction is immovable. Leesburg reviews cases individually with applicants to find alternatives when ISD cannot be met. Buena Vista takes a subjective approach, assessing sight distances without always adhering to ISD standards, focusing more on practical adequacy than strict compliance. Table 24 provides the detailed responses.

Table 24. Details on Design Modifications on ISD for Virginia Localities

Locality	Details
Town of Luray	Design Waiver—when the impact is minor; Design Exception—when the impact is moderate, one primary street, and one secondary street; Design Variance—when the impact is significant and involves two primary streets.
City of Colonial Heights	Waiver is required if the obstruction is not movable.
Leesburg	Evaluated case by case, approved by the chief engineer when no other options exist. If ISD cannot be met, the site is reviewed for the best entrance location, and historic sites require at least stopping sight distance standards.
City of Winchester	Reviews process of site plan if ISD not met.
Town of Christiansburg	Not a common occurrence, so the town does not have an official process for exceptions.
Lynchburg	Requires design waiver, depending on the situation, such as a dead-end street.
Berryville	Town has no history of granting waivers or variances.
City of Hopewell	Any design exceptions have to be submitted to and approved by the Department of Public Works director or his designee.
Chesapeake	ISD is always a requirement for safety, and no waivers are granted.
Town of Strasburg	Does not permit standards unless approved by VDOT.
City of Buena Vista	Makes subjective determinations on adequacy of sight distances and does not always reference ISD standards.
City of Bristol	Generally, requests revisions of plans to meet standards unless any exceptions exist.
Town of Smithfield	Must meet guidelines.
Town of Vienna	Requires new developments to meet ISD standards and has not run into situations where it was not met.
City of Alexandria	Carries out a zoning modification.
City of Salem	Exceptions allowed in areas where existing conditions do not allow for the minimum standards to be met.
City of Norfolk	Design variance when all accommodations have been exhausted.
Manassas Park	All developers have to comply with ISD standards.
City of Staunton	Design variance allowed based on the VDOT *Road Design Manual*.

ISD = intersection sight distance.

The localities were asked to select all the factors they consider when evaluating design modification requests. Figure 34 shows the count of all the factors selected. Localities consider several key factors in these decisions. Speed limit is the most cited factor, with 15 mentions, followed by functional classification, with 14. Crash history and geometric characteristics both appear 13 times, emphasizing safety. Multimodal considerations were mentioned nine times, and context and other factors had five and six mentions, respectively. Cost savings were cited only three times. These results show that localities prioritize safety and functionality in design modification decisions, with speed limits, road classification, crash history, and geometry being key factors. Cost savings, although considered, play a lesser role in these evaluations.

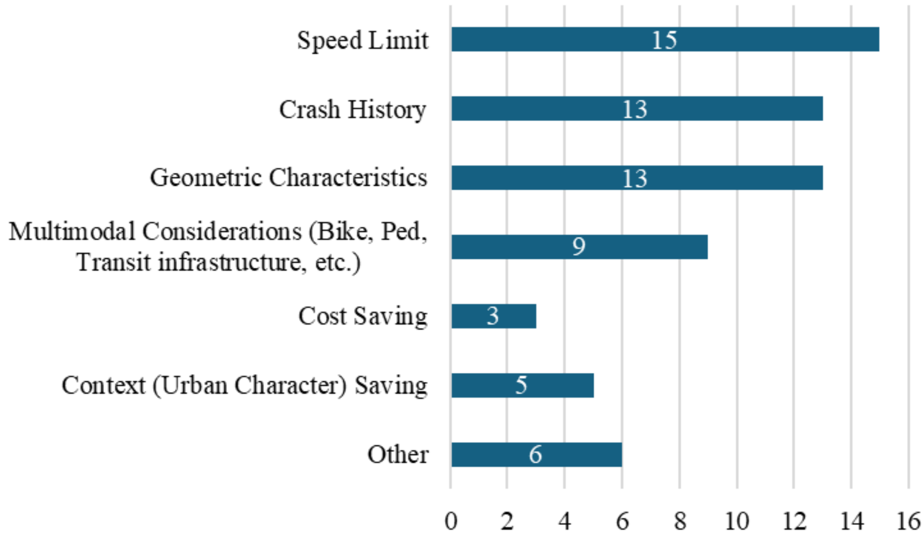


Figure 34. Factors Virginia Localities Consider when Evaluating Design Modification Requests

Only four localities—Leesburg, the City of Manassas, the Town of Strasburg, and Manassas Park—reported keeping records of design modification requests related to ISD. Leesburg and the City of Manassas each stated that they receive approximately two design modification requests per year. The Town of Strasburg reported receiving fewer than one request annually, and Manassas Park indicated it receives about one request per year or fewer.

Intersection Sight Distance Records

Only two localities said that they maintain a database of ISD at intersections: Leesburg and Harrisonburg.

Safety Issues at Intersections Where Intersection Sight Distance Is Not Met

The respondents were asked if they were aware of safety issues at intersections where the ISD was not met, and eight of the localities (the City of Winchester, Town of Christiansburg, Lynchburg, Harrisonburg, Berryville, City of Buena Vista, City of Bristol, and Manassas Park) said "yes." These localities report various safety issues at intersections where ISD is not met. Some act by installing all-way stops or restricting parking, and others note that older intersections need upgrades. Many face challenges from built structures, geometric constraints, and overgrown vegetation obstructing sightlines. One response that the project team found interesting was Berryville's, where it was said that they had safety issues regardless of whether ISD was met. The following summarizes the details each respondent gave:

- The City of Winchester takes actions such as making intersections all-way stops or restricting parking.
- The Town of Christiansburg has older intersections that need improvement.
- Lynchburg has geometric issues with retaining walls and building edges.
- Harrisonburg has locations throughout the city where sight distance is unattainable because of either built environment (walls, buildings, and so on) or geometric constraints.

- Berryville has safety issues regardless of whether ISD is provided.
- The City of Buena Vista has a lot of property maintenance issues regarding trees, shrubs, and so on interfering with sight distances but has not addressed them yet.
- The City of Bristol has seen instances where rolling terrain obstructs the line of sight.
- Manassas Park is working on improving ISD at intersections through the Virginia Highway Safety Improvement Program.

Additional Thoughts Provided by Respondents

At the end of the locality survey, participants were asked to reflect on how ISD requirements affect the safety and character of urban streets. The responses highlighted a range of perspectives shaped by differences in community size, history, and built form. In older and historic areas, respondents emphasized the difficulty of retrofitting existing streets to meet modern ISD standards, often favoring lower speed limits as a practical alternative. Others noted that strict ISD enforcement can conflict with efforts to preserve urban character or accommodate landscaping. In addition, localities called for clearer guidance and better tracking mechanisms for ISD compliance. The following summarizes these locality-specific insights in detail.

- Historic and Built Environments:
  - The City of Winchester indicated that it has many streets that were constructed before ISD considerations were in place.
  - The City of Manassas specified that it is difficult to upgrade historic downtown fabric to modern ISD standards, but all roads operate at low speeds (25 mph or less).
  - The Town of Strasburg stated that the old structures on King Street have a zero-foot lot line setback, which significantly contributes to the town's character and complicates sight distance improvements.
  - Berryville requires ISD standards for new developments but noted that its small, congested business district has adapted to existing conditions.
- Alternatives to Infrastructure Changes:
  - Harrisonburg stated that lowering vehicle speeds is often more feasible than removing buildings or infrastructure to improve ISD in built environments.
  - Leesburg is considering limbing up street trees in urban areas and seeking more VDOT guidance on signal warrants, parking in mixed-use communities, and exception approvals.
- Design Challenges:
  - The City of Bristol noted that undulating terrain, retaining walls, fencing, and landscaping present obstacles to achieving good sight lines.
  - Manassas Park indicated that ISD requirements are critical but may affect urban character by forcing changes to landscaping and street design aesthetics.
- Monitoring and Review Practices:
  - The City of Hopewell monitors ISD through new development reviews but lacks a citywide tracking mechanism and relies on citizen feedback.
  - The City of Buena Vista needs more ISD-related training materials to better review development proposals.

Follow-up Responses

Follow-up emails were sent to selected Virginia localities to gather further details in cases where they:

- Indicated maintaining records of design modifications.
- Reported tracking ISD compliance.
- Mentioned TNDs that did not meet ISD.
- Cited other sight distance-related concerns.

Nine localities were contacted, and the three that responded provided this information:

- Harrisonburg—
  - Clarified that although site plans for new or redeveloped entrances are permanently stored on the city's servers, they are not compiled or maintained specifically for ISD tracking.
  - Maintains a maintenance log of requests from staff or citizens regarding ISD issues and provided a spreadsheet with around 20 such locations.
- City of Manassas Park—
  - Reported no formal design modification requests.
  - Mentioned a few possible locations of concern but clarified that ISD was likely still met.
- Winchester—
  - Explained that sight distance issues are usually resolved by converting intersections into all-way stops.
  - Clarified that no dedicated ISD recordkeeping system exists, and prior responses may have been misinterpreted.

In summary, although some localities initially indicated keeping ISD records, the follow-up responses revealed that records were not systematically maintained, and a few responses stemmed from misinterpretations of the original survey questions.

Residency Survey

A total of 24 nonduplicative responses were received. The research team received 29 responses, but a residency had provided more than one response in some cases, so the response that was either complete or provided more information was generally chosen. Of the 24 responses used for analysis, 18 had answers for every question, and 6 were incomplete.

The first section of the survey asked whether the residencies were involved in the approval process for development site plans. If they responded "yes," they were further asked whether ISD was part of the evaluation criteria (Figure 35). Those who answered "yes" were then asked if ISD values were included in the plans. If ISD values were not provided, they were asked how ISD compliance with VDOT standards would be determined. In addition, those who confirmed ISD involvement were asked if they maintained records of ISD values, whether these records indicated compliance with ISD standards at intersections, and if the ISD data covered only VDOT-maintained roads or extended to roads managed by local authorities. If residencies were not involved in the approval process, they were asked which entities were responsible.

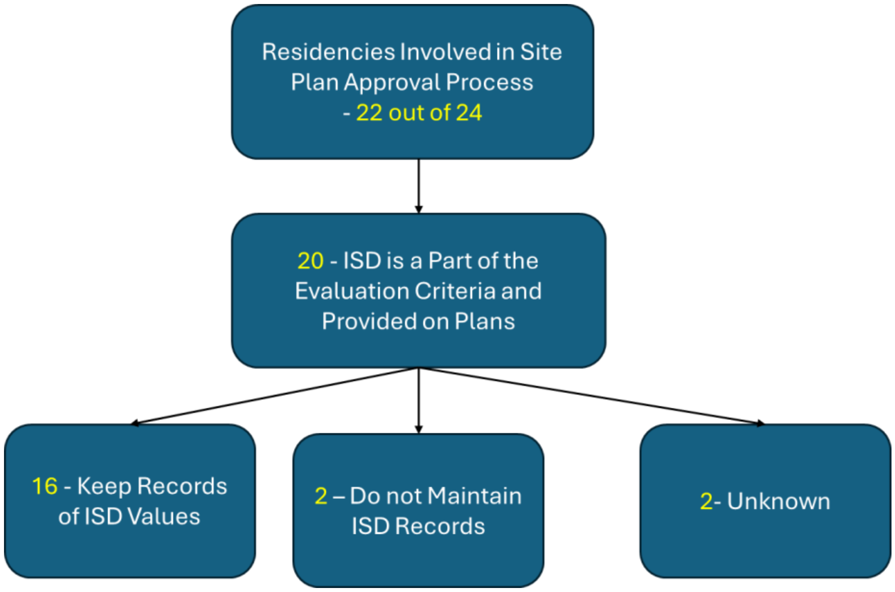


Figure 35. VDOT Residency Responses on ISD Consideration in Site Plan Reviews. Residencies that keep ISD records are Wytheville (Bristol District), Edinburg (Staunton District), Bedford (Salem District), Chesterfield (Richmond District), Martinsville (Salem District), Petersburg (Richmond District), Charlottesville (Culpeper District), Warrenton (Culpeper District), Appomattox (Lynchburg District), Abingdon (Bristol District), Wise (Bristol District), Lexington (Staunton District), South Hill (Richmond District), Salem (Salem District), Harrisonburg (Staunton District), and Christiansburg (Salem District). ISD = intersection sight distance.

Out of 24 residencies, 22 confirmed their involvement in the development site plan approval process, and 2 others—Northern Neck (Fredericksburg District) and Franklin (Hampton Roads District)—gave incomplete responses. This result indicates that most residencies are involved in the approval process. Those who responded "yes" were asked additional questions. Of the 22 involved residencies, 20 confirmed that ISD was part of the evaluation criteria, as Figure 35 shows. Two—Northern Virginia Engineering and Williamsburg (Hampton Roads District)—reported "unknown." All 20 also stated that ISD values were provided on the plans. Among them, 16 residencies said they kept records of ISD values. Two residencies—Saluda (Fredericksburg District) and Farmville (Lynchburg District)—reported "unknown," and two others—Halifax (Lynchburg District) and Accomack (Hampton Roads District)—said they did not maintain such records.

Among the 16 residencies that maintained ISD records, all confirmed that the records indicated whether intersections met ISD standards. Twelve of these residencies stated that the ISD data were available solely for VDOT-maintained roads, and the remaining four (Martinsville, Petersburg, Wise, and South Hill) said the data were available for both VDOT and locality-managed roads.

Northern Virginia Engineering noted that other entities review sight distance because they were unsure whether ISD was a component of the criteria evaluated.

Design Modification Requests

In this section, residencies were asked who was responsible for initiating the design waiver, exception, and variance process in cases for which ISD standards were not met. Table 25 presents the options the residencies selected.

Table 25. Responses on Who Initiates the Design Modification Process when Intersection Sight Distance Is Not Met

Entity that Initiates Design Modification Process	Residencies
Developer	Bedford, Chesterfield, Martinsville, Appomattox, Abingdon, Harrisonburg Residency, Christiansburg
Developer, Locality	Petersburg, Lexington
VDOT District	Wytheville, Northern Virginia
VDOT Residency, Developer	Halifax, Charlottesville, Warrenton, Saluda, Wise, Farmville, Accomac, Salem
VDOT Residence, Developer, Locality	South Hill
VDOT Residency, VDOT District	Edinburg

Twenty of the residencies confirmed that they maintain records of ISD-related design modification requests. Northern Virginia stated that they do not, and the responses from Williamsburg, Northern Neck, and Franklin County were incomplete. For those that did not maintain records, they were asked which entity keeps these records. However, limited responses were received, with Northern Virginia being the only one to reply, indicating they did not know.

Intersection Sight Distance Records for Older Developments and Downtown Districts

Only three residencies (Petersburg, Abingdon, and Harrisonburg) indicated that they maintain ISD records for older developments or downtown districts (Figure 36). Most said either they did not or reported unknown.

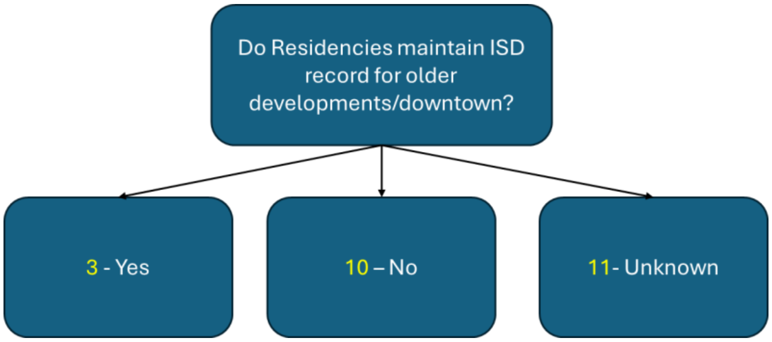


Figure 36. Residency Responses on Maintaining ISD Records for Developments and Downtown Districts. ISD = intersection sight distance.

Several residencies reported being aware of instances in which VDOT ISD standards were not met for older developments or downtown districts within their jurisdiction, as the first column in Table 19 notes. Three residencies said they were not aware of such cases, and the rest reported unknown. Those residencies that reported being aware of cases in which ISD standards were not met were then asked how ISD was determined in those instances. They were given the options to choose between field measurement, visual inspection, or other methods. Table 26 displays those responses.

Table 26. Residencies with Cases in Older Developments and Downtown Districts where VDOT Intersection Sight Distance Is Not Met

Residency	**Method of Determination**
Martinsville, Petersburg, Charlottesville, Abingdon, Harrisonburg	Field Measurement
Edinburg, Bedford, Northern Virginia, Warrenton, Christiansburg	Field Measurement, Visual Inspection
Wise	Visual Inspection
Halifax, Saluda	Other

For those who selected the "other" option, Halifax explained that the intersections in question were not new, so they had never actually measured them. The Saluda residency mentioned that they determined ISD through a survey.

Safety Issues at Intersections Where Intersection Sight Distance Standards Are Not Met

Less than one-half of the residencies surveyed indicated that they were aware of safety issues at intersections where VDOT ISD standards were not met (Figure 37).

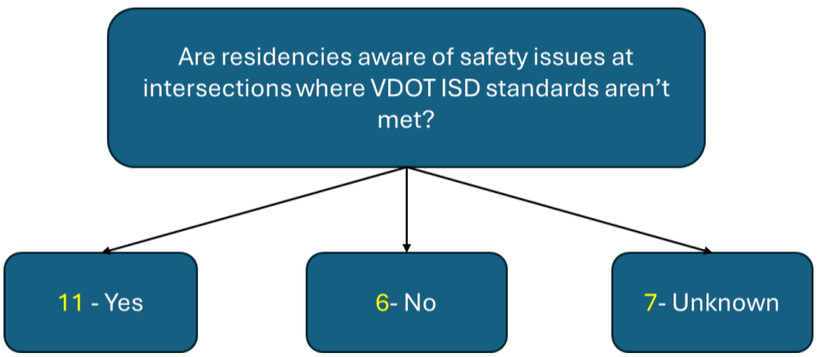


Figure 37. Residencies Noting Safety Issues at Intersections Not Meeting VDOT ISD Requirements. Residencies that answered "no" are Warrenton, Abingdon, Lexington, Farmville, Accomack, and Harrisonburg. Residencies that answered "yes" are Wytheville, Halifax, Edinburg, Chesterfield, Martinsville, Petersburg, Northern Virginia, Charlottesville, Wise, and Christiansburg. ISD = intersection sight distance.

Additional Thoughts from Respondents

At the end of the survey, respondents were asked to reflect on how ISD requirements affect urban street safety and character. Their responses varied based on the urban or rural context of their locality. The following summarizes key themes and insights.

- Limited Urban Presence—Minimal ISD Concerns:
  - Halifax, Farmville, and Accomack reported limited urban areas. ISD is less critical because of low-speed environments and local municipalities handling street maintenance.
  - Lexington indicated that urban areas are city-maintained. VDOT involvement occurs only through specific programs.
- Urban Challenges—ISD is Critical:

- Northern Virginia mentioned that designers often move stop bars to reduce crosswalk distance, unintentionally compromising sight distance.
  - Wise emphasized that ISD and SSD are vital for both drivers and pedestrians. Seasonal factors (e.g., landscaping and parked cars) can reduce visibility, requiring periodic field reviews.
  - Edinburg stated that ISD is treated as a core safety component. Although nonstandard intersections exist, exceptions are rarely granted.
  - Abingdon reinforced that ISD is a necessary safety requirement.
- Parking and Legacy Road Design Issues:
  - Warrenton reported that parking often inhibits sight at older intersections. Although these areas are low speed, visibility issues persist.
  - Saluda concluded that developers may need to alter preexisting buildings to accommodate ISD standards.
  - Petersburg, as a rural-focused residency, noted that local administrative projects without state or federal funds are outside VDOT review.
- Other Notes:
  - Harrisonburg indicated that ISD waivers are typically not granted unless mitigated by devices like four-way stops or signals.
  - Salem stated that ISD documentation exists in plans and design waivers, although it is not tracked in a centralized database.

These perspectives highlight that although ISD concerns may be reduced in rural or low-speed urban settings, ISD remains a crucial factor in ensuring roadway safety—especially in densely built, high-activity areas.

Follow-up Responses

To gather more detailed information, follow-up emails were sent to 20 Virginia residencies that either indicated they kept ISD records, documented design modifications, or reported ISD records for older developments. Follow-up responses were received from the 11 residencies listed in Table 27.

Table 27. Residencies that Responded to Follow-up Requests

Residency
Abingdon
Accomack
Chesterfield
Christiansburg
Farmville
Halifax
Harrisonburg Residency
Lexington
Salem
South Hill
Wise

The follow-up responses revealed that most residencies do not formally maintain ISD. Although some noted that ISD information may be available in individual plan sets, it is not centrally compiled or tracked. A few provided locations where sight distance may be limited, often citing rural or low-speed settings as mitigating factors. Overall, the responses indicate varied practices and limited documentation across the residencies. The following presents the key insights.

- General Recordkeeping Insight: Most residencies clarified that they do not formally document ISD-related data or design modifications. Some noted that records may exist within individual plan sets but are not stored in any centralized format.
- Provided Lists of Potential Concern Areas: Some residencies—Accomack, Christiansburg, Halifax, and Harrisonburg—shared a list of locations or corridors where ISD may not be fully met.
- Rural Context and Limited Issues: Several residencies—Abingdon, Farmville, Halifax, and Christiansburg—explained that their districts are primarily rural, so ISD issues are infrequent. Accomack added that some visibility challenges arise seasonally because of agricultural conditions.
- Policies on ISD Waivers:
    - Harrisonburg emphasized that they do not grant ISD waivers unless mitigated by traffic control devices. Full compliance is typically required.
    - Christiansburg indicated that they accept reduced ISD if SSD is met.
- Notable Observations: Wise highlighted that older VDOT roads with limited ISD due to terrain and geometry do not necessarily pose crash risks because of naturally reduced vehicle speeds and low traffic volumes. In urban parts of the district, on-street parking and existing traffic signals help offset ISD limitations.

Safety Analysis

T-Intersections

For T-intersections, the regression was conducted using both the full dataset and speed-stratified subsets (≤ 25 mph and ≥ 30 mph). Initially, the analysis was performed using the number of sight distances met as an independent variable. To further examine the nuance of SDR and SDL effects, the models were run again using continuous SDR and SDL values. Table 28 presents the preferred model for the full dataset using the number of sight distances met variable, followed by the speed-segmented models. Table 29 shows the output for low-speed intersections, and Table 30 shows the results for high-speed intersections.

Table 28. Model Results for T-Intersection Using Number of Sight Distances Met (Full Data) (N = 184)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 3.5091	0.7005	– 5.0094	0	– 4.8820	– 2.1361	***
log_aadt	0.5590	0.0815	6.8591	0	0.3992	0.7187	***
median_binary	1.1103	0.4062	2.7334	0.0063	0.3142	1.9064	**
num_of_sight_ distances_met	– 0.5241	0.1337	– 3.9205	0.0001	– 0.7861	– 0.2621	***

AADT = average annual daily traffic; VIF = variance inflation factor. Fit statistics: log likelihood = -300.54; Akaike information criterion = 611.08; Bayesian information criterion = 627.51; McFadden’s pseudo $R^2 = 0.076$; dispersion parameter = 1.23; VIF (num_of_sight_distances_met) = 1.012; VIF (log_aadt) = 1.043; VIF (median_binary) = 1.047; CI = 95% confidence interval. Significance: **$p \leq 0.01$; ***$p \leq 0.001$.

Table 29. Model Results for T-Intersection Using Number of Sight Distances Met (Speed Limit <= 25 mph) (N = 132)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 3.8041	0.8508	– 4.4712	0	– 5.4716	– 2.1365	***
log_aadt	0.5759	0.0995	5.7858	0	0.3808	0.7710	***
median_binary	1.8896	0.6374	2.9644	0.0030	0.6403	3.1390	**
num_of_sight_ distances_met	– 0.4791	0.1646	– 2.9112	0.0036	– 0.8017	– 0.1566	**

AADT = average annual daily traffic; VIF = variance inflation factor. Fit statistics: log likelihood = -184.45; Akaike information criterion = 378.91; Bayesian information criterion = 392.48; McFadden's pseudo $R^2 = 0.076$; dispersion parameter = 1.19; VIF (num_of_sight_distances_met) = 1.010; VIF (log_aadt) = 1.009; VIF (median_binary) = 1.019; CI = 95% confidence interval. Significance: **$p \leq 0.01$; ***$p \leq 0.001$.

Table 30. Model Results for T-Intersection Using Number of Sight Distances Met (Speed Limit >= 30 mph) (N = 52)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 2.4281	2.1811	– 1.1132	0.2656	– 6.703	1.8468	-
log_aadt	0.4728	0.2531	1.8683	0.0617	– 0.0232	0.9688	-
median_binary	0.3648	0.554	0.6585	0.5102	– 0.7211	1.4507	-
num_of_sight_ distances_met	– 0.6062	0.2592	– 2.339	0.0193	– 1.1142	– 0.0982	*

AADT = average annual daily traffic; VIF = variance inflation factor. Fit statistics: log likelihood = -113.3; Akaike information criterion = 236.6; Bayesian information criterion = 248.41; McFadden's pseudo $R^2 = 0.082$; dispersion parameter = 1.28; VIF (num_of_sight_distances_met) = 1.216; VIF (log_aadt) = 1.343; VIF (median_binary) = 1.116; CI = 95% confidence interval. Significance: - = not significant at $p \leq 0.05$; * $p \leq 0.05$.

The variables number of sight distances met, presence of median, and log (AADT) were statistically significant for both the full dataset and the low-speed model (≤ 25 mph). The number of sight distances met was also marginally significant in the high-speed model (≥ 30 mph). Across all models, the number of sight distances met variable showed a negative relationship with crash count, suggesting that T-intersections with fewer approaches and with sufficient sight distances are associated with a higher number of crashes—an effect that was more pronounced in low-speed intersections. For high-speed intersections, the conclusion is less definitive because of the smaller sample size and the marginal statistical significance.

The models showed consistent and acceptable levels of model fit, with McFadden R^2 values ranging from 0.076 to 0.082 and dispersion parameters between 1.19 and 1.28, indicating mild overdispersion appropriate for negative binomial modeling. Variance inflation factors were well below 5 for all predictors, suggesting no multicollinearity concerns and stable coefficient estimates across the models.

To gain a deeper understanding of the effect of different approaches' ISD on crash occurrence, another regression using actual SDR and SDL values instead of the number of sight distances met variable was run. Table 31 presents the preferred model for the full dataset using the actual SDR variable, followed by the speed-segmented models. Table 32 shows output for low-speed intersections, and Table 33 shows the results for high-speed intersections.

Table 31. Model Results for T-Intersection (Full Data) Using Sight Distance Right (N = 184)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 4.0304	0.6921	– 5.8235	0	– 5.3869	– 2.6739	***
log_aadt	0.5926	0.0844	7.0198	0	0.4271	0.758	***
median_binary	0.8662	0.4081	2.1223	0.0338	0.0663	1.666	*
avg_sdr	– 0.00085	0.0003	– 2.8364	0.0046	– 0.0014	– 0.0003	**

AADT = average annual daily traffic; avg sd = average sight distance; VIF = variance inflation factor. Fit statistics: log likelihood = -304.03; Akaike information criterion = 618.05; Bayesian information criterion = 634.48; McFadden's pseudo R^2 = 0.065; dispersion parameter = 1.23; VIF (avg_sdr) = 1.070; VIF (log_aadt) = 1.098; VIF (median_binary) = 1.045; CI = 95% confidence interval. Significance: *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

Table 32. Model Results for T-Intersections Using Sight Distance Right (Speed Limit <= 25 mph) (N = 132)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 4.0122	0.8298	– 4.8351	0	– 5.6385	– 2.3858	***
log_aadt	0.5762	0.0996	5.7877	0	0.3811	0.7713	***
median_binary	1.5262	0.6346	2.405	0.0162	0.2824	2.7699	*
avg_sdr	– 0.00091	0.0004	– 2.3663	0.018	– 0.0017	– 0.0002	*

AADT = average annual daily traffic; avg sd = average sight distance right; VIF = variance inflation factor. Fit statistics: log likelihood = -185.79; Akaike information criterion = 381.58; Bayesian information criterion = 395.14; McFadden's pseudo R^2 = 0.071; dispersion parameter = 1.17; VIF (avg_sdr) = 1.001; VIF (log_aadt) = 1.010; VIF (median_binary) = 1.009; CI = 95% confidence interval. Significance: *$p \leq 0.05$; ***$p \leq 0.001$.

Table 33. Model Results for T-Intersections Using Sight Distance Right (Speed Limit >= 30 mph) (N = 52)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 1.5833	2.2309	– 0.7097	0.4779	– 5.9557	2.7892	-
log_aadt	0.3331	0.2664	1.2503	0.2112	– 0.1891	0.8553	-
median_binary	0.3736	0.5536	0.6748	0.4998	– 0.7115	1.4587	-
avg_sdr	– 0.0006	0.0006	– 1.0011	0.3168	– 0.0018	0.0006	-

AADT = average annual daily traffic; avg sdr = average sight distance right; VIF = variance inflation factor. Fit statistics: log likelihood = -115.46; Akaike information criterion = 240.92; Bayesian information criterion = 250.68; McFadden's pseudo R^2 = 0.011; dispersion parameter = 1.11; VIF (avg_sdr) = 1.470; VIF (log_aadt) = 1.593; VIF (median_binary) = 1.114; CI = 95% confidence interval. Significance: - = not significant at $p \leq 0.05$.

From the model results in Tables 31 to 33, SDR, presence of median, and log (AADT) were statistically significant for both the full model and the low-speed model (≤ 25 mph), whereas none of the variables were statistically significant in the high-speed model. The coefficient estimate for SDR for the low-speed model was larger than that of the full model, suggesting a stronger effect in these environments. For high-speed roads (≥ 30 mph), none of the variables were statistically significant. The models showed acceptable fit, with the McFadden R^2 between 0.011 and 0.071 and the dispersion parameter ranging from 1.11 to 1.23. Variance inflation factor values for all predictors remained well below the threshold of 5, indicating no multicollinearity concerns.

From the preferred models, CMFs were developed (under a baseline no median condition) for SDR and number of sight distances met at intersection, defined as the ratio of expected crashes under a given condition to the expected crashes under a baseline condition. The baseline SDR value (CMF = 1) was chosen as 300 feet because it closely represents the average of the minimum and maximum SDR values—specified in *Appendix F: Access Management Design Standards for Entrances and Intersections* (VDOT, 2021) and found in the VDOT (2025b) RDM for posted speed limits of 20 and 25 mph. The baseline condition for number of sight distances met was chosen to be 2 for T-intersections and 4 for four-leg intersections.

Equation 4 presents CMF for SDR or the number of sight distances met, and Equation 5 shows CMF for the presence of median.

$$CMF = \exp(\beta \times \Delta x) \quad \text{(Eq. 4)}$$

Where:
CMF = crash modification factor.
β = regression coefficient.
Δx = change in SDR (feet) or in number of sight distances met.

$$CMF = \exp(\beta \times 1) \quad \text{(Eq. 5)}$$

Where:
CMF = crash modification factor for presence of median (value = 2.38 for full-data and 4.6 for low-speed intersections).
β = regression coefficient for presence of median.

Figures 38 and 39 show the CMF plots for the full dataset and low-speed dataset at T-intersections, based on changes in SDR. The plots display CMF values at 100-foot SDR intervals. As the plots show, increasing SDR from lower values (e.g., 100 to 300 feet) results in greater crash reduction compared with similar increases at higher sight distances (e.g., above 300 feet). For the same increase in SDR, the safety benefits are more substantial when starting from a lower SDR. The average crash reduction associated with each 100-foot increase in sight distance up to 600 feet is approximately 9.24% for the low-speed model, whereas the full model shows a slightly lower average reduction of 8.62%. Similarly, Figure 40 shows the CMF plot for low-speed dataset based on the number of sight distances met at an intersection per VDOT threshold. The Implementation and Benefits section explains the benefits in more detail.

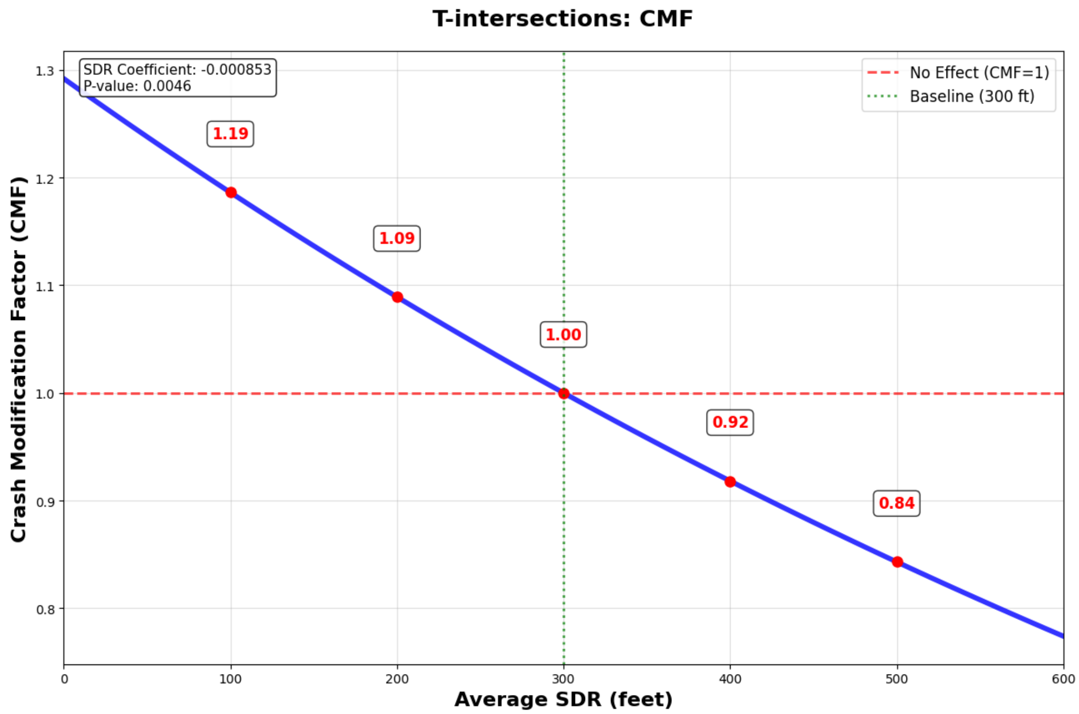


Figure 38. CMF Plot for T-Intersection (Full Data) Based on SDR. CMF = crash modification factor; SDR = sight distance to the right.

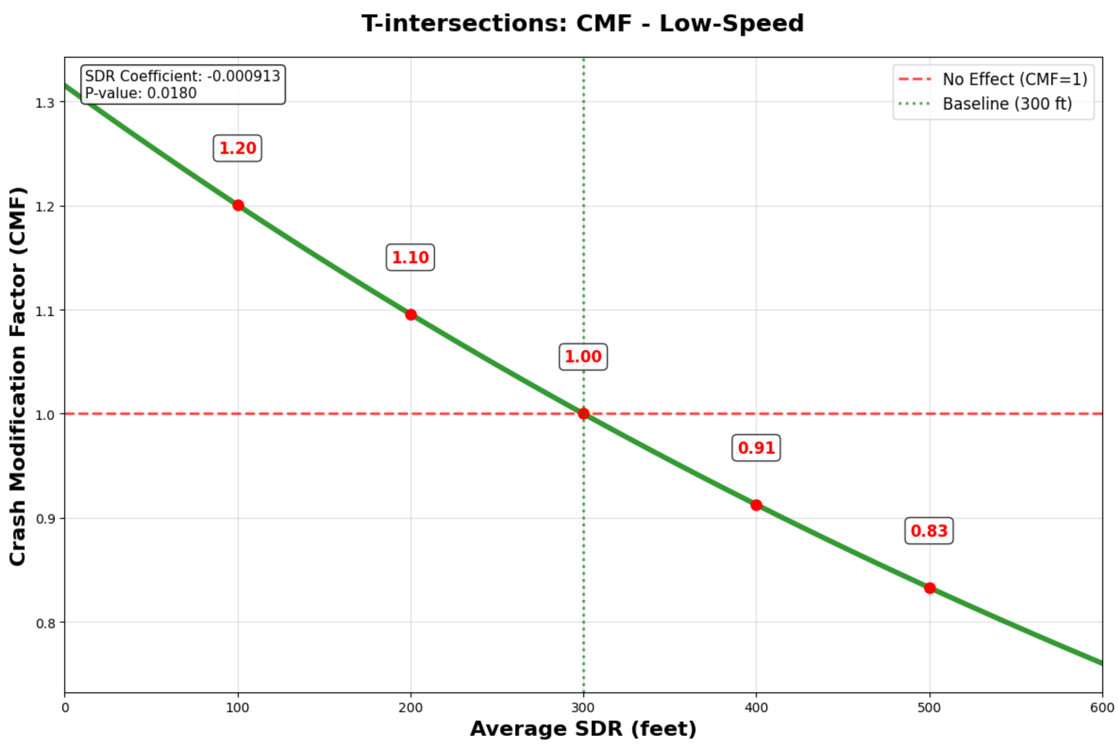


Figure 39. CMF Plot for T-Intersection (Speed Limit <= 25 mph) Based on SDR. CMF = crash modification factor; SDR = sight distance to the right.

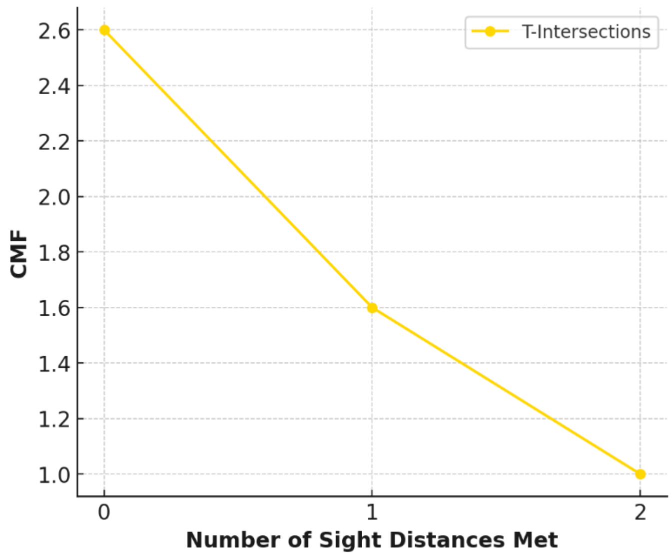


Figure 40. CMF Plot for T-Intersection (Speed Limit <= 25 mph) Based on Number of Sight Distances Met. CMF = crash modification factor.

Four-Leg Intersections

Similar to T-intersections, the regression was conducted for four-leg intersections using both the full dataset and speed-stratified subsets (≤ 25 mph and ≥ 30 mph). The analysis was performed twice: once using the number of sight distances met as an independent variable and again using the actual SDR and SDL values. Table 34 presents the preferred model for the full dataset using the number of sight distances met variable, followed by the speed-segmented models. Table 35 shows the output for low-speed intersections, and Table 36 shows the results for high-speed intersections.

Table 34. Model Results for Four-Leg Intersections Using Number of Sight Distances Met (Full Data)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 3.0610	0.9303	– 3.2903	0.0010	– 4.8844	– 1.2376	**
log_aadt	0.6015	0.0969	6.2024	0	0.4114	0.7915	***
num_of_sight_ distances_met	– 0.3142	0.0768	– 4.0879	0.0004	– 0.4648	– 0.1635	***

AADT = average annual daily traffic; VIF = variance inflation factor. Fit statistics: log likelihood = -397.97; Akaike information criterion = 803.95; Bayesian information criterion = 816.61; McFadden’s pseudo R^2 = 0.069; dispersion parameter = 0.93; VIF (num_of_sight_distances_met) = 1.067; VIF (log_aadt) = 1.067; CI = 95% confidence interval. Significance: **p ≤ 0.01; ***p ≤ 0.001.

Table 35. Model Results for Four-Leg Intersections Using Number of Sight Distances Met (Speed Limit ≤ 25 mph)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 3.1828	1.1893	– 2.6760	0.0074	– 5.5139	– 0.8516	**
log_aadt	0.6542	0.1247	5.2445	0	0.4097	0.8987	***
num_of_sight_ distances_met	– 0.4020	0.0980	– 4.1020	0	– 0.5941	– 0.2099	***

AADT = average annual daily traffic; VIF = variance inflation factor. Fit statistics: log likelihood = -235.86; Akaike information criterion = 479.71; Bayesian information criterion = 490.48; McFadden’s pseudo R^2 = 0.113; dispersion parameter = 0.77; VIF (num_of_sight_distances_met) = 1.184; VIF (log_aadt) = 1.184; CI = 95% confidence interval. Significance: **p ≤ 0.01; ***p ≤ 0.001.

Table 36. Model Results for Four-Leg Intersections Using Number of Sight Distances Met (Speed Limit ≥ 30 mph)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 5.4167	2.2642	– 2.3923	0.0167	– 9.8544	– 0.9789	*
log_aadt	0.6990	0.2339	2.9876	0.0028	0.2404	1.1576	**
num_of_sight_ distances_met	0.0709	0.14203	0.4997	0.6172	– 0.2074	0.3493	-

AADT = average annual daily traffic; VIF = variance inflation factor. Fit statistics: log likelihood = -156.55; Akaike information criterion = 321.10; Bayesian information criterion = 329.86; McFadden's pseudo $R^2 = 0.024$; dispersion parameter = 0.95; VIF (num_of_sight_distances_met) = 1.019; VIF (log_aadt) = 1.019; CI = 95% confidence interval. Significance: - = not significant at $p \leq 0.05$; *$p \leq 0.05$; **$p \leq 0.01$.

Similar results were observed for four-leg intersections, consistent with the findings for T-intersections. The variables log_aadt and number of sight distances met were both statistically significant in the full model and the low-speed model. However, in the high-speed model, only log_aadt was significant. The number of sight distances met was negatively correlated with crash count in both the full and low-speed models, with a larger coefficient magnitude in the low-speed model—indicating a stronger effect in lower speed environments. Unlike T-intersections, the presence of a median did not have a statistically significant effect on crash occurrence in four-leg intersections.

The preferred models for four-leg intersections showed reasonably good fit, particularly in the low-speed subset (≤ 25 mph), which had the highest McFadden R^2 (0.113). The full and high-speed (≥ 30 mph) models showed modest fit (McFadden $R^2 = 0.069$ and 0.024, respectively), with acceptable dispersion values ($\alpha = 0.93$ and 0.95). All variance inflation factor values for predictors were close to 1.0, indicating no multicollinearity concerns.

The regression was then repeated using actual SDR and SDL values instead of the number of sight distances met variable. Table 37 presents the preferred model for the full dataset using the average SDR variable, followed by the speed-segmented models. Table 38 shows the output for low-speed intersections, and Table 39 shows the results for high-speed intersections.

Table 37. Model Results for Four-Leg Intersections Using Sight Distance Right (Full Data)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 4.767	0.8440	– 5.647	0	– 6.4215	– 3.1127	***
log_aadt	0.7756	0.0979	7.920	0	0.5836	0.9675	***
avg_sdr	– 0.0011	0.0003	– 3.9181	0	– 0.001	– 0.0005	***

AADT = average annual daily traffic; avg sdr = average sight distance right; VIF = variance inflation factor. Fit statistics: log likelihood = -424.29; Akaike information criterion = 856.58; Bayesian information criterion = 869.24; McFadden's pseudo $R^2 = 0.008$; dispersion parameter = 2.74; VIF (avg_sdr) = 1.041; VIF (log_aadt) = 1.041; CI = 95% confidence interval. Significance: ***$p < 0.001$.

Table 38. Model Results for Four-Leg Intersections Using Sight Distance Right (Speed Limit ≤ 25 mph)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 5.2229	1.0203	– 5.1185	0	– 7.2228	– 3.2230	***
log_aadt	0.8593	0.1180	7.280	0	0.6285	1.0906	***
avg_sdr	– 0.0015	0.0003	– 3.9871	0	– 0.0022	– 0.001	***

AADT = average annual daily traffic; avg sdr = average sight distance right; VIF = variance inflation factor. Fit statistics: log likelihood = -251.8205; Akaike information criterion = 511.6411; Bayesian information criterion = 522.4064; McFadden's pseudo $R^2 = 0.0529$; dispersion parameter = 2.3201; VIF (avg_sdr) = 1.001; VIF (log_aadt) = 1.001; CI = 95% confidence interval. Significance: ***$p \leq 0.001$.

Table 39. Model Results for Four-Leg Intersections Using Sight Distance Right (Speed Limit ≥ 30 mph)

Variable	Coefficient	Std_Error	z_value	P_value	CI_Lower	CI_Upper	Significance
Intercept	– 5.1868	2.1338	– 2.4308	0.0150	– 9.3690	– 1.0046	*
log_aadt	0.6324	0.2333	2.7098	0.0067	0.1750	1.0898	**
avg_sdr	0.0007	0.0006	1.2083	0.2269	– 0.0004	0.0019	-

AADT = average annual daily traffic; avg sdr = average sight distance right; VIF = variance inflation factor. Fit statistics: log likelihood = -165.392; Akaike information criterion = 338.7841; Bayesian information criterion = 347.5427; McFadden's pseudo R^2 = -0.0311; dispersion parameter = 2.6079; VIF (avg_sdr) = 1.015; VIF (log_aadt) = 1.015; CI = 95% confidence interval. Significance: - = not significant at $p \leq 0.05$; *$p \leq 0.05$; **$p \leq 0.01$.

Similar to the findings of the models using number of sight distances met, the variable for SDR and log_aadt were both statistically significant in the full model and the low-speed model, whereas only log_aadt was significant in the high-speed model. SDR was negatively associated with crash count in both the full and low-speed models, with a larger coefficient of magnitude in the low-speed model. This result indicates that lower SDR contributes to higher crash occurrence, especially on low-speed roadways. Model fit was generally weaker in this group compared with the other models for four-leg intersection using number of sight distances met. Dispersion parameters ranged from 2.32 to 2.74, suggesting moderate overdispersion. No multicollinearity issues were detected because all variance inflation factors were approximately 1.0.

CMFs for four-leg intersections for average SDR and number of sight distances met were computed from the preferred model in a similar manner as for T-intersections, using the same baseline assumptions. Figures 41, 42, and 43 present the resulting plots.

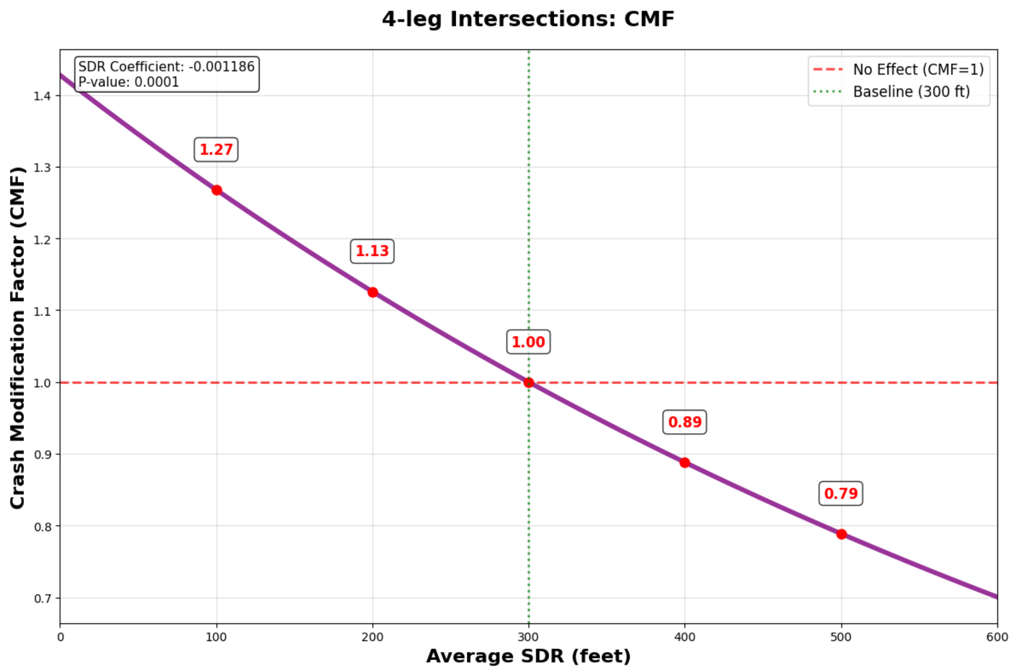


Figure 41. CMF Plot for Four-Leg Intersections (Full Data) Based on SDR. CMF = crash modification factor; SDR = sight distance to the right.

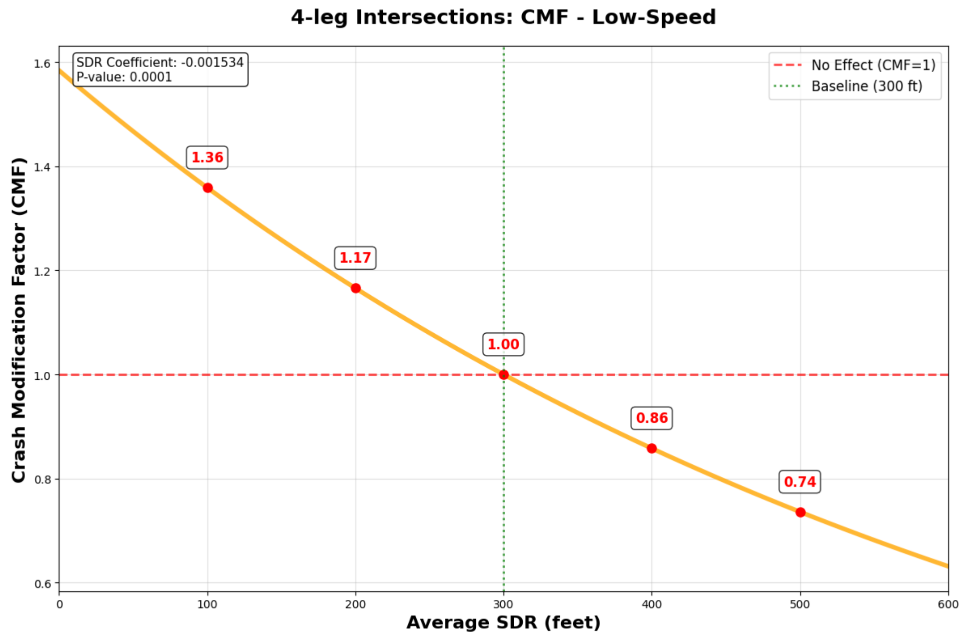


Figure 42. CMF Plot for Four-Leg Intersections (Speed Limit <= 25 mph) Based on SDR. CMF = crash modification factor; SDR = sight distance to the right.

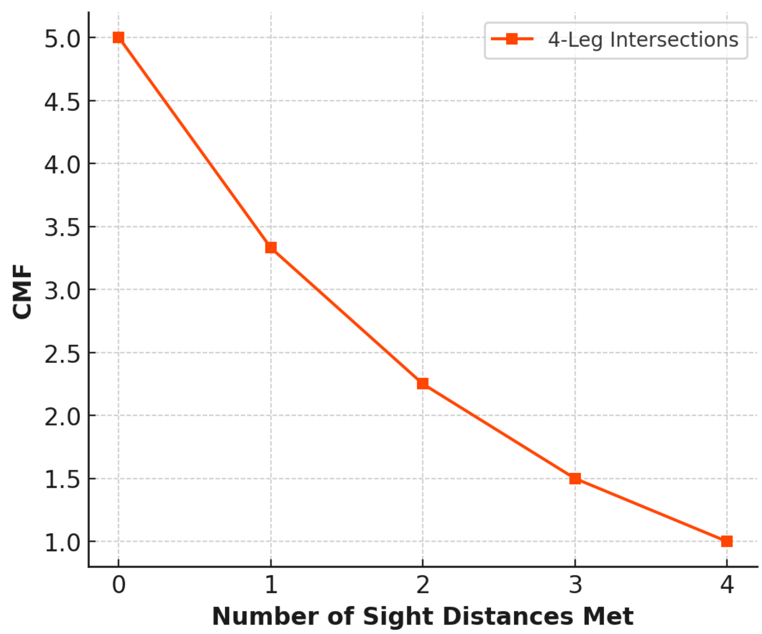


Figure 43. CMF Plot for Four-Leg Intersections (Speed Limit <= 25 mph) Based on Number of Sight Distances Met. CMF = crash modification factor.

The effect of increasing SDR is greater at lower SDR values, as shown in the plot. On average, each 100-foot increase in SDR up to 600 feet results in a 15.89% crash reduction in the low-speed model (Figure 42) and a 12.11% crash reduction in the full dataset model (Figure 41).

Because the ISD data collection method accounted only for permanent obstructions, field measurements at select intersections were performed to verify accuracy. Field verification at 10 intersections showed that this method of considering only permanent obstructions overestimated

SDR by an average of 32%. To assess the effect, SDR values were uniformly reduced by this percentage, and the analysis was rerun. The results showed similar trends, with limited sight distance still significantly associated with higher crash frequency, particularly near or below VDOT's minimum thresholds. These findings indicate that the analysis is based on conservative sight distance estimates, and the true safety effects may be even greater under actual field conditions.

DISCUSSION

Although AASHTO standards form the baseline for most agencies, their application is far from uniform. Jurisdictions vary in how they define DP, interpret obstruction height, and adapt ISD standards for multimodal or urban contexts. Flexibility often exists in the form of waivers or exceptions, but guidance on how to apply these flexibilities remains sparse and inconsistently defined. The survey reinforced these observations. Among the 17 state DOTs surveyed, nearly all follow AASHTO guidance, but approximately one-third allow some form of adjustment in defining sight triangles based on site-specific conditions. Approximately 30% reported having separate ISD guidance for multimodal needs, and only 18% included specific sight distance requirements for bicyclists and pedestrians. ISD is generally treated as less stringent, whereas SSD is enforced more strictly. Around one-half of the agencies surveyed reported having provisions for design modifications, and only one had a strict mandate for meeting ISD. Recordkeeping related to ISD waivers or exceptions is minimal or absent in most agencies. Many DOTs also noted limited involvement in low-speed environments, stating they review developments only if on state-maintained roads and depending on the project's location and scale.

At the local level in Virginia, nearly 75% of jurisdictions follow VDOT or AASHTO guidance without having their own ISD standards, and only approximately 20% apply modified values or context-specific adjustments. Few localities define sight triangles differently or address multimodal needs explicitly, with only one reporting dedicated guidance for pedestrian and bicycle considerations. Localities are more involved, with 88% participating in development review, and generally enforce ISD more strictly, especially in new developments. For existing and older developments, particularly those built before ISD standards were established, enforcement is less strict. In these cases, limited ISD is often tolerated unless complaints arise, at which point agencies may take corrective actions, such as converting intersections to all-way stops or restricting on-street parking. Less than one-half of the localities allow formal design modifications when ISD is not met, and many lack clear provisions to address such situations. Although many localities underscored the importance of ISD for safety, some noted that strict enforcement can conflict with goals related to urban character. Several also cited limited resources, staffing constraints, and a lack of detailed guidance as key barriers to effective ISD evaluation across varied contexts.

Residency responses echoed similar themes. ISD is considered in the review process in approximately 90% of the residencies, and 70% said they maintain some form of ISD record. However, follow-up responses revealed that documentation is often informal or inconsistently maintained. Approximately 60% of residency responses indicated having encountered intersections, often in downtown or legacy districts, where ISD was not met, and one-half reported safety concerns in such areas. Some residencies noted that localities handle urban areas, but several emphasized that ISD is vital and raised safety concerns.

The crash analysis supported the safety concerns raised by localities and residencies. Based on a sample of 184 T-intersections and 175 four-leg intersections in Virginia, meeting VDOT's ISD requirements was statistically linked to fewer crashes at low-speed locations, reinforcing the importance of maintaining minimum sight distances even in constrained urban settings. SDR was significantly and negatively associated with crash frequency, particularly at intersections with posted speeds of 25 mph or lower. For these low-speed intersections, increasing SDR by 100 feet was associated with an average crash reduction of approximately 9.24% at T-intersections and 15.89% at four-leg intersections. This result highlights the importance of visibility for left-turning vehicles at low-speed locations where conflict points are greater.

Both the number of sight distances met and SDR were significant in the full and low-speed models, highlighting their role in urban safety. The number of sight distances met, based on VDOT's thresholds, was also a significant predictor of crash frequency, suggesting measurable safety benefits of compliance. In contrast, results were not significant for higher speed intersections, likely because of limited sample size and reduced statistical power in that subset. Although the analysis clearly shows that adequate ISD improves safety in low-speed urban environments, no established metrics exist to weigh these safety benefits against the potential effects on other critical aspects of urban design, such as walkability, multimodal access, and compact development with active streetscapes.

CONCLUSIONS

- *Most agencies follow AASHTO or VDOT ISD standards, but many allow adjustments based on site-specific factors.* Roughly one-third of state DOTs and approximately 20% of Virginia localities apply modifications or allow flexibility in ISD application. A small share use different DP definitions or obstruction criteria.

- *Multimodal considerations are rarely reflected in formal ISD standards.* Only around 30% of state DOTs and one Virginia locality reported ISD guidance that accounts for pedestrians or bicyclists, indicating limited integration of multimodal needs in existing policies.

- *Documentation and enforcement of ISD are inconsistent across agencies.* Although approximately one-half of agencies require documentation when ISD is not met, few maintain formal records. Several VDOT residencies and localities noted that ISD is considered during development review, but recordkeeping is often informal or inconsistent.

- *Clearer guidance is needed to help agencies apply ISD flexibly while supporting safety and documentation.* Surveys and analysis highlight the need for more consistent provisions, especially when ISD cannot be met, and better recordkeeping practices to support informed decision-making.

- *Safety concerns are frequently reported where ISD is not met.* Roughly 60% of VDOT residencies and 25% of localities reported safety issues at locations lacking minimum ISD. Common agency responses include installation of all-way stops or on-street parking restrictions.

- *Crash analysis shows SDR is significantly associated with crash frequency on low-speed roads.* In intersections with speeds of 25 mph or lower, a 100-foot increase in SDR was linked with an average crash reduction of 8.5% at T-intersections and 13% at four-leg intersections. SDL was not statistically significant.

- *Meeting VDOT's ISD standards is associated with lower crash rates.* The number of sight distances that met VDOT thresholds was a significant predictor of crash frequency in both full and low-speed models, reinforcing the value of verifying ISD compliance during design and review.

RECOMMENDATIONS

1. *VDOT's Location and Design Division should continue to apply the ISD values in Tables 2 through 5 in Appendix F of the* Road Design Manual*, particularly for urban low-speed intersections (i.e., posted speed limits of 25 mph and below).* The study found that reduced sight distance—especially SDR—and failure to meet the ISD standards in the VDOT (2025b) RDM were statistically associated with higher crash counts at urban low-speed intersections. This recommendation does not preclude site-specific modifications because design exception or waiver requests must still be submitted in accordance with VDOT (2024a) IIM-LD-27, *Design Exceptions/Design Waivers*.

2. *With the support of an appropriate research advisory committee, the Virginia Transportation Research Council (VTRC) should initiate a project to develop a mobile LiDAR data collection tool.* This recommendation would involve developing a research needs statement for a research advisory committee presentation that proposes a pilot project to collect mobile LiDAR data in an urban environment within a VDOT district. The objective of this pilot would be to establish a scalable ISD measurement tool capable of analyzing multiple scenarios and producing more accurate ISD data.

IMPLEMENTATON AND BENEFITS

Researchers and the technical review panel (listed in the Acknowledgments) for the project collaborate to craft a plan to implement the study recommendations and to determine the benefits of doing so. This process is to ensure that the implementation plan is developed and approved with the participation and support of those involved with VDOT operations. The implementation plan and the accompanying benefits are provided here.

Implementation

Two action items must be completed to implement the recommendations. The first one is complete, and the second one will be completed by December 31, 2026.

Regarding Recommendation 1, VDOT's Location and Design Division will continue to apply the ISD values in Tables 2 through 5 in Appendix F of the Road Design Manual. These standards will remain the foundation for project reviews, while existing protocols for site-specific design modification requests will continue to be followed.

Regarding Recommendation 2, VTRC will identify and work with a champion from a VDOT division or district to develop a research needs statement. The statement will be presented at the Transportation Planning Research Advisory Committee or at the Traffic, Operations, and Safety Research Advisory Committee meeting, or both, as appropriate. The focus of the research needs statement will be a pilot mobile LiDAR collection effort in an urban environment. The purpose is to provide VDOT with a scalable and accurate tool to virtually collect ISD data, account for observer and obstruction positions, and generate reliable measures across diverse intersection scenarios. This tool will allow for consistent evaluations statewide and improve the ability to identify and prioritize intersections with visibility-related safety risks.

Benefits

The benefits of implementing the recommendations are provided in two subsections: (1) crash cost benefits based on Recommendation 1 and (2) efficiently screening sites for further review based on Recommendation 2.

Crash Cost Benefits

This section presents the quantifiable benefits derived from the safety analyses. The first section estimates crash cost savings based on the number of sight distances met relative to VDOT (2025b) *Road Design Manual* thresholds. For context, T-intersections have one SDR and one SDL, whereas four-leg intersections have two SDRs and two SDLs. The number of sight distances met represents how many of them are satisfied at each intersection. The second analysis presents benefits with respect to actual sight distance values, showing how deviations from VDOT-specified values would translate into additional crash costs. The numbers provided in both analyses are more applicable to urban low-speed intersections with posted speed limit of 25 mph and lower.

Number of Sight Distances Met per Intersection

Tables 40 and 41 show the additional crash costs when sight distances are reduced from the baseline condition, where all are met. CMFs in these tables are derived from the regression analysis (Figures 40 and 43), and the baseline average annual crashes per site were estimated using the model. Assuming conservatively that all crashes are property damage only crashes valued at $13,743 (Cole, 2022), the costs per site and the additional annual costs per site were then calculated. The "additional annual cost per site" values represent the incremental crash cost associated with each sight distance not being met compared with the baseline condition. For example, not meeting one sight distance compared with a baseline of meeting all sight distances results in an additional annual cost of approximately $1,683 per site for T-intersections and $3,100 per site for four-leg intersections.

Table 40. Benefits Based on Analysis for T-Intersections (Number of Sight Distances Met)

Sight Distances Met	CMF[a]	Crash % Change	Avg Crashes per Site per Year	Annual Cost per Site ($)[b]	Additional Annual Cost per Site ($)[c]
2	1.000	0.00	0.199	2737.82	0.00
1	1.615	61.46	0.322	4420.53	1682.72
0	2.607	160.70	0.519	7137.49	4399.67

CMF = crash modification factor. [a] Refer to the Results section for CMF and average crashes derivation; [b] Annual cost per site = average crashes/site/year * $13,743 (unit cost for property damage only crashes (Cole, 2022)); [c] Additional annual cost per site = annual cost per site for given condition, annual cost per site for baseline condition.

Table 41. Benefits Based on Analysis for Four-Leg Intersections (Number of Sight Distances Met)

Sight Distances Met	CMF[a]	Crash % Change	Avg Crashes per Site per Year	Annual Cost per Site ($)[b]	Additional Annual Cost per Site ($)[c]
4	1.000	0.00	0.456	6264.87	0.00
3	1.495	49.48	0.681	9364.79	3099.93
2	2.234	123.45	1.019	13998.60	7733.73
1	3.340	234.01	1.523	20925.30	14660.40
0	4.993	399.28	2.276	31279.30	25014.50

CMF = crash modification factor. [a] Refer to the Results section for CMF and average crashes derivation; [b]Annual cost per site = average crashes/site/year * $13,743 (unit cost for property damage only crashes (Cole, 2022)); [c] Additional annual cost per site = annual cost per site for given condition, annual cost per site for baseline condition.

SDR Values per Approach

In this approach, crash costs were calculated using actual SDR values rather than the number of sight distances met. Only SDR was included because SDL was not a statistically significant predictor in the preferred models. Tables 42 and 43 present the resulting costs by SDR value. Assuming a baseline condition of 300 feet SDR (the average of the minimum and maximum SDR values from the VDOT (2025b) *Road Design Manual* for speeds of 25 mph and below), the average crashes per site were estimated from the model. Changes in SDR in 100-foot increments above and below the baseline were then applied using CMFs (Figures 39 and 42), and the resulting additional crashes were converted to costs. Assuming conservatively that all crashes are property damage only crashes valued at $13,743 (Cole, 2022), the additional crash costs associated with each increment or decrement from baseline are shown in the final columns of Tables 42 and 43. For example, reducing SDR from 300 to 200 feet results in an additional annual cost of approximately $451 per site for T-intersections and $2,563 per site for four-leg intersections.

Table 42. Benefits Based on SDR Values for T-Intersections

SDR (feet)	CMF[a]	Crash % Change	Avg Crashes per Site per Year	Annual Cost per Site ($)[b]	Additional Annual Cost per Site ($)[c]
100	1.200	20.00	0.381	5238.08	872.49
200	1.100	10.00	0.350	4816.82	451.23
300	1.000	0.00	0.318	4365.59	0.00
400	0.910	– 9.00	0.289	3975.68	– 389.91
500	0.830	– 17.00	0.264	3625.36	– 740.23

CMF = crash modification factor; SDR = sight distance to the right. [a] Refer to the Results section for CMF and average crashes derivation; [b] Annual cost per site = average crashes/site/year * $13,743 (unit cost for property damage only crashes (Cole, 2022)); [c] Additional annual cost per site = annual cost per site for given condition, annual cost per site for baseline condition.

Table 43. Benefits Based on SDR Values for Four-Leg Intersections

SDR (feet)	CMF[a]	Crash % Change	Avg Crashes per Site per Year	Annual Cost per Site ($)[b]	Additional Annual Cost per Site ($)[c]
100	1.360	36.00	1.492	20503.81	5427.48
200	1.170	17.00	1.284	17639.31	2562.98
300	1.000	0.00	1.097	15076.33	0.00
400	0.860	– 14.00	0.943	12965.65	– 2110.69
500	0.740	– 26.00	0.812	11156.49	– 3919.85

CMF = crash modification factor; SDR = sight distance to the right. [a] Refer to the Results section for CMF and average crashes derivation; [b] Annual cost per site = average crashes/site/year * $13,743 (unit cost for property damage only crashes (Cole, 2022)); [c] Additional annual cost per site = annual cost per site for given condition, annual cost per site for baseline condition.

Statewide Crashes

Conversion of the per-intersection values (Tables 40 and 41) or the per-approach values (Tables 42 and 43) to a statewide benefit depends on how frequently localities or VDOT may be asked to reduce ISD requirements in the future. If this question never arises, then the monetary benefits are zero. If the question is asked every year for each of the 1,847 OpenStreetMap intersections for which data were sought in this study, then the monetary benefits would be quite large.

Recall that for roughly one-half (34) of those localities that responded to the survey, 6 have seen an increase in TNDs during the past decade. If the past is a good predictor of the future, and if the 34 localities are representative of all 133 localities statewide, then one can envision approximately 2 dozen (e.g., 6/34*133 ≈ 24) locations during the next 10 years where TNDs will be proposed. For a given TND, multiple intersections can exist where a proposal is made not to meet ISD requirements. If two such intersections exist for each TND where such a proposal is made, and if a fairly conservative value is chosen (such as the $3,100 from Table 41 or the $1,683 from Table 40, for a mean of $2,400), then on an annual basis maintaining ISD at these 48 intersections in 2 dozen TNDs would save $115,200, or slightly more than $1.1 million during a 10-year period.

Efficiently Screening Sites for Further Review

A mobile LiDAR-based ISD measurement tool would provide VDOT with a consistent and automated method for efficiently evaluating intersection visibility. By integrating high-resolution point cloud data with GIS tools, the system could simulate driver eye height, identify obstructions with high accuracy, and capture urban features such as buildings, trees, signs, and parked vehicles. Most importantly, it would calculate both available and recommended ISD values with precision, replacing manual field measurements that are often inconsistent and resource intensive. In this study, for example, a contractor conducted 5 field measurements and 10 virtual measurements at a total cost of $4,670.50. A LiDAR-based tool could produce similar results at scale with significantly lower costs, particularly for repetitive measurements and scenario analyses, while also improving consistency and reducing reliance on labor-intensive field work. In addition, the tool could estimate occlusion rates, generate standardized results across different intersection types, and produce 3D visualizations. With these capabilities, VDOT would be able to systematically screen intersections and identify high-risk sites more efficiently and accurately.

ACKNOWLEDGMENTS

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APPENDIX A: STATE DOT SURVEY QUESTIONS

Appendix A shows the survey distributed to state DOTs. Some modifications were made from the original survey for report formatting purposes.

The Virginia Department of Transportation is conducting a study evaluating the effectiveness (in terms of safety) of intersection sight distance (ISD) guidance provided in the AASHTO *Green Book*. One project task is to survey other DOTs for insights into current practices and prescribed guidance. The survey is brief and should take no longer than 5 minutes to complete. Your participation is very much appreciated!

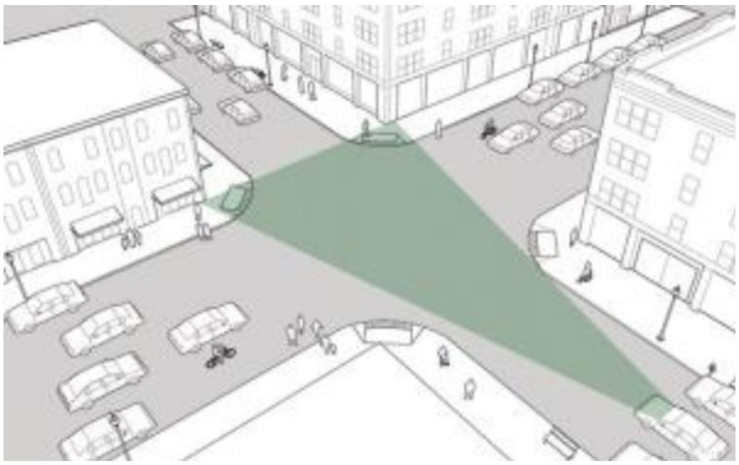


Figure A1. (NACTO, 2013)

Q1. Please provide your contact information.
- Name
- DOT
- Email

Q2. What document does your DOT use to provide ISD guidance? Please indicate the name and the latest version (year) of this document.
- Name of the document
- Date
- If possible, please provide a link to access the document, or upload it. Select the appropriate option below.
- Provide a link
- Upload the document
- Not available at this time

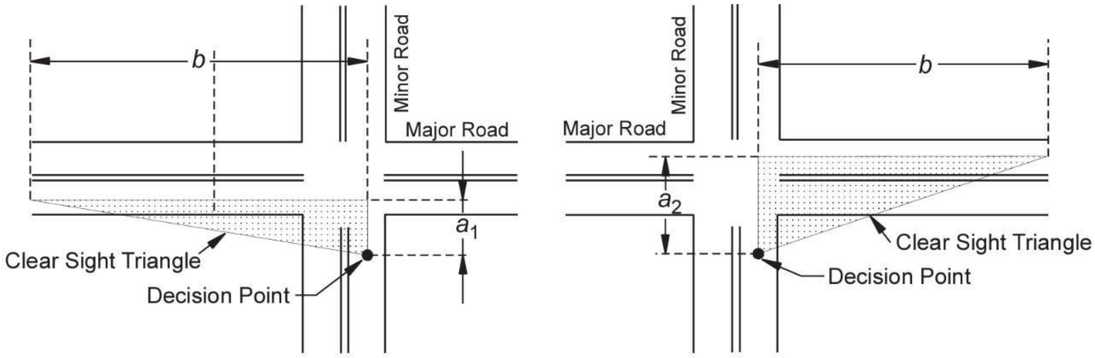
Q3. Please provide the link in the box below.

Q4. Please upload the document.

Q5. To what extent has your DOT incorporated AASHTO standards (AASHTO *Green Book* (GB)) into your ISD guidelines?
- Entirely follow AASHTO GB for ISD guidelines
- Follow AASHTO GB primarily, but with modifications, AASHTO standards are not considered.

Sight Triangles

The following section contains questions on the sight triangle for AASHTO GB Case B1 intersections (stop controlled minor road and uncontrolled major road). These intersections require the largest ISD. Please refer to the figure for the various elements of sight triangle.



Departure Sight Triangle for Viewing Traffic Approaching the Minor Road from the Left

Departure Sight Triangle for Viewing Traffic Approaching the Minor Road from the Right

Departure Sight Triangles (Stop-Controlled)

Figure A2. (AASHTO, 2018)

Distance 'b' = Intersection sight distance along the major road **Decision Point =** Position of stopped driver on the minor road

The table below shows the ISD values for Case B1 intersections from AASHTO GB 2018 depending upon the design speed of the major road.

Design Speed (mph)	Design Intersection Sight Distance for Passenger Cars (ft)*
	Case B1
15	170
20	225
25	280
30	335
35	390
40	445
45	500
50	555
55	610
60	665
65	720
70	775
75	830
80	885

Figure A3. (AASHTO, 2018). *Intersection sight distance shown is for a stopped passenger car to turn left onto a two-lane highway with no median and grades 3% or less. For other conditions, the time gap must be adjusted and required sight distance recalculated.

Q6. How do your design ISD values for Case B1 intersections compare to these values?
- The values are the same or within 5 feet
- The values are higher by more than 5 feet
- The values are lower by more than 5 feet
- Unknown

Q7. Please briefly explain how you derive the ISD values.

Sight Triangles (Decision Point)

AASHTO GB 2018 locates the decision point at a distance of 14.5' from the edge of the major road and suggests increasing this to 18' wherever practical.

Figure A4. (FHWA, 2016)

Q8. Is your guideline different from this in terms of either the distance or the point where it is measured from?
- Yes
- No
- Unknown

Q9. Please explain how you locate the decision point in the sight triangle.

Q10. Do your guidelines have cases where the position of decision point in the sight triangle may be adjusted based on site specific conditions?
- Yes
- No
- Unknown

Q11. What factors allow the adjustment in the location of decision point in such cases? (Select all that apply.)
- Major road speed limit
- Roadway classification
- Geographic classification (urban/rural)
- Crash history at site
- Geometric characteristics
- Multimodal considerations (Bicycle, pedestrian, transit infrastructure, etc.)
- Other (Please explain in the box below.)

Sight Triangles (Obstructions)

AASHTO GB 2018 defines sight obstructions as anything that obstructs the line of the sight (assuming driver's eye and object height to be 3.5' above the roadway surface).

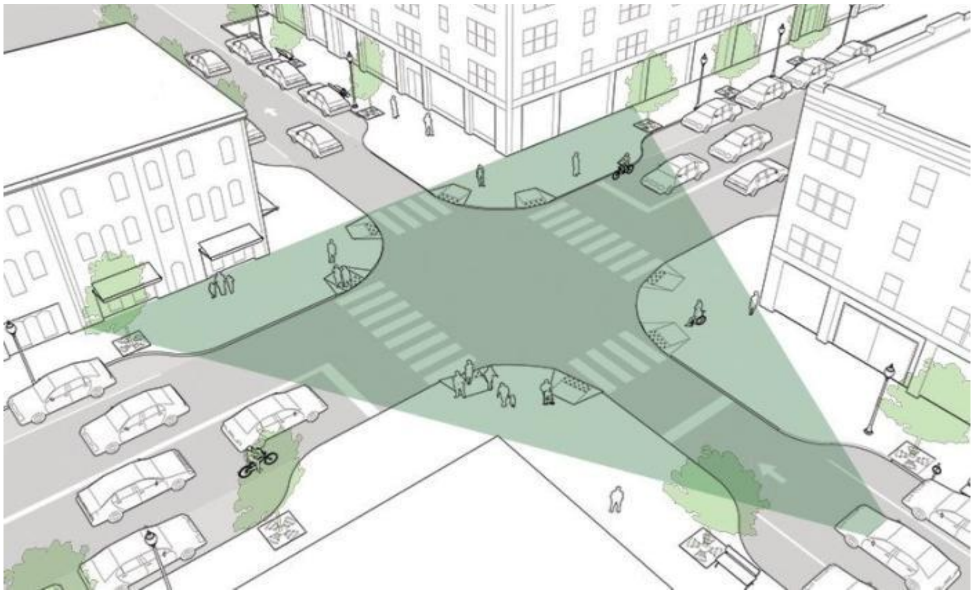


Figure A5. (NACTO, 2013)

How do your guidelines define sight obstructions (or restrict objects within the sight triangle)? (Select all that apply and add details in the boxes if applicable.)

- Specify a maximum height for objects within the sight triangle
- Specify a maximum diameter/width
- Define obstruction as anything that blocks the line of sight within the sight triangle

Q12. Does your guideline entail parking restrictions within a designated distance from intersections where on-street parking is permitted? If so, please explain the restrictions briefly.
- Yes (Please provide details in the box below.)

Multimodal Guidelines

Multimodal intersection design aims to safely accommodate not only motor vehicles but also bicycles, pedestrians, and public transit. These guidelines often include separate sight distance requirements intended to govern the interactions between motorists and bicyclists or pedestrians. The following section contains questions on sight distance requirements from a multimodal perspective.

Figure A6. (VDOT, 2024c)

Q13. Does your DOT provide guidance on multimodal considerations (e.g., bicyclists, pedestrians) with relation to ISD?
- Yes
- No
- Unknown

Q14. Do you have differences in ISD guidelines between the multimodal design guidelines and the conventional ISD guidelines?

Q15. Do your guidelines address bicyclist sight distance and/or pedestrian sight distance requirements?
- Yes
- No
- Unknown

At intersections featuring bike lanes, there may be situations where greater sight distances are necessary to assess potential conflicts between bikeways and motorways from a single point.

Figure A7. (VDOT, 2025g)

Q16. Do your guidelines address any cases where longer sight distances involving bicyclists and/or pedestrians are required, compared to the conventional ISD guidelines?
- Yes (Please provide details in the box below.)
- Approach clear spaces at an intersection provide the necessary sight lines between motorists and bicyclists to yield (or stop) as appropriate.

Q17. Do your guidelines have requirement for approach clear spaces at intersections?
- Yes (Please provide brief details in the box below.)
- Multimodal Guidelines
- Daylighting refers to the removal of sight obstacles around an intersection or crosswalk for the purpose of making it safer for multimodal travel. Several jurisdictions have started daylighting efforts throughout the nation.

Q18. Has your DOT implemented daylighting practices or plan to do so in the future?
- Yes - Implemented in the past (If possible, provide details in the box below.)
- Yes - Plan to do so (If possible, provide details in the box below.)
- Unknown

Traditional Neighborhood Developments (TNDs)

The following section contains questions on ISD guidelines in the context of Traditional Neighborhood Developments (TNDs), which may also be referred to as *new urbanism* or *neo-traditional developments*. They are characterized by dense building layout and narrow setbacks.

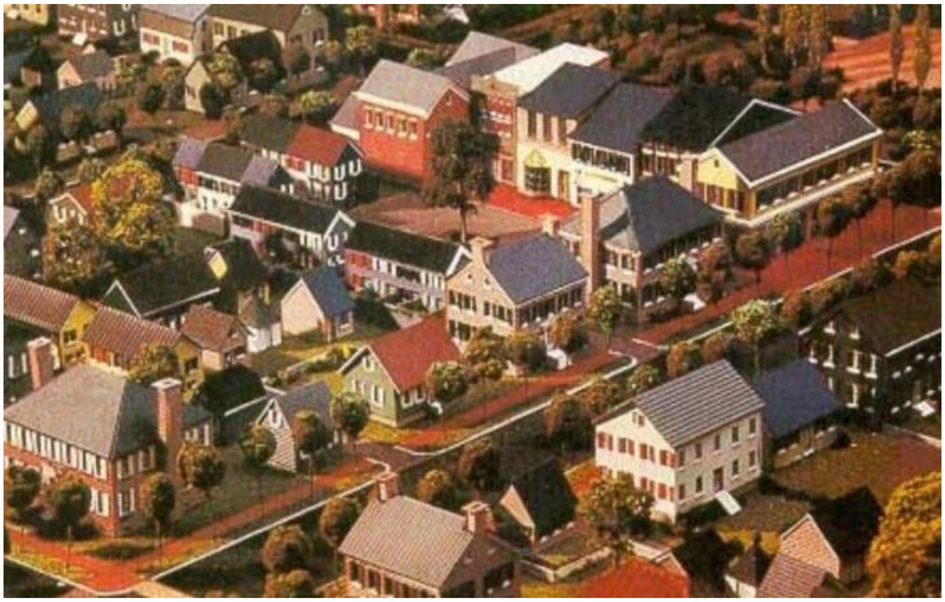


Figure A8. (Palani, 2023)

Q19. Has there been an increase in TNDs in your state?
- Yes
- No
- Unknown

Q20. Do you have a separate design guidance pertaining to TNDs?
- Yes
- No
- Unknown

If possible, please provide a link to access the document, or upload it.
- Provide a link
- Upload document
- Not available at this time

Q21. Please upload the document here.

Q22. Please provide a link to the document below.

Q23. Do your ISD guidelines for TNDs differ from your conventional ISD guidelines? If yes, please explain how they differ.

Q24. Does your DOT get involved with the approval process for these developments with relation to ISD standards?
- Always
- Sometimes
- Never
- Unknown

Design Flexibilities

This section contains questions on design modification requests in cases where ISD requirements are not met.

Q25. When a design plan for a development is submitted, who reviews it?

- DOT
- Both DOT and locality
- Locality
- Depends on the location (If possible, please provide details in the box below.)

Q26. What form of documentation is required when the ISD standards are not met? (Select all that apply.)

- Design waiver
- Design exception
- Design variance
- Other (Please mention it in the box below.)

Q27. Please briefly explain the process.

- Is there a difference between these types of processes? If yes, please explain the differences briefly.

Q28. What factors do you take into consideration while approving or denying requests on ISD-related design modifications? (Select all that apply.)

- Functional classification
- Speed limit
- Crash history at site
- Geometric characteristics
- Multimodal considerations (bike, pedestrian, transit infrastructure, etc.)
- Cost saving
- Context saving (preserving the urban character)
- Other (Please mention in the box below.)

Q29. Do you keep a database of the design modification requests (design exceptions/waivers/variances) related to ISD?

- Yes
- No
- Unknown

Q30. Approximately, what is the average number of such design modification requests received per year?

- We are also seeking to study ISD practices at the local level.

Q31. If possible, could you suggest a few localities in your state and their contacts (email/phone) for us to follow up with?

APPENDIX B: VIRGINIA LOCALITY SURVEY QUESTIONS

Appendix B shows the survey distributed to Virginia localities. The references shown in Appendix B have been updated from the original survey to be consistent with the references used in this report.

The Virginia Department of Transportation is conducting a study evaluating the effectiveness (in terms of safety) of intersection sight distance (ISD) guidance provided in VDOT's *Road Design Manual* (RDM). VDOT primarily follows the AASHTO *Green Book* (GB) for ISD guidelines, with certain additional requirements. One project task is to survey Virginia localities for insights into current practices and prescribed guidance. The survey is brief and should take no longer than 10 minutes to complete. Your participation is very much appreciated!

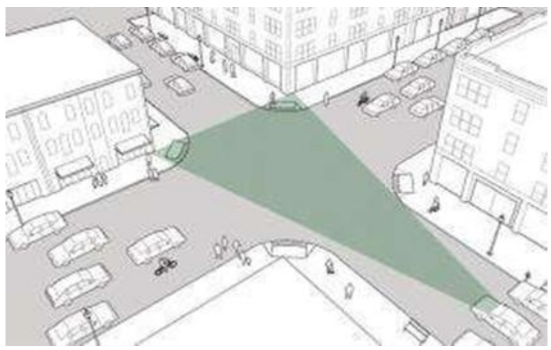


Figure B1. (NACTO, 2013)

Q1. Please provide your contact information.
- Name
- Locality
- Email

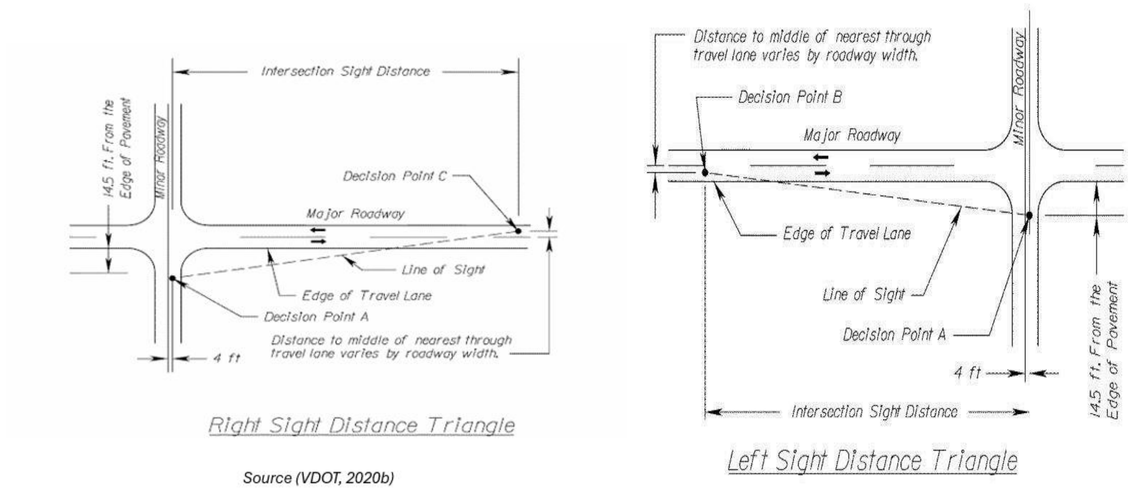
Q2. Does your locality have an official document containing ISD guidelines?
- Yes
- No

Q3. If possible, please provide a link to access the document, or upload it.
- Provide a link
- Upload the document
- Not available at this time

Q4. How has your locality incorporated VDOT RDM into your ISD guidelines?
- Entirely follow VDOT RDM
- Follow VDOT RDM primarily, but with modifications
- Establish own set of guidelines

Sight Triangles

The following section contains questions on the sight triangle for AASHTO GB Case B1 intersections (stop controlled minor road and uncontrolled major road). These intersections require the largest ISD. Please refer to the figure for the various elements of sight triangle.



Source (VDOT, 2020b)

Figure B2. (VDOT, 2020b)

Q5. The table below shows the ISD values for Case B1 intersections from VDOT RDM 2024 depending upon the design speed of the major road.

SDR = Sight Distance Right (For a vehicle making a left turn)
SDL = Sight Distance Left (For a vehicle making a right or left turn)

Height of Eye 3.5'									**Height of Object 3.5'**			
Design Speed (mph)**		**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**
SDL=SDR: 2 Lane Major Road	**In Feet**	225	280	335	390	445	500	555	610	665	720	775
SDR: 4 Lane Major Road (Undivided) or 3 Lane		250	315	375	440	500	565	625	690	750	815	875
SDL: 4 Lane Major Road (Undivided) or 3 Lane		240	295	355	415	475	530	590	650	710	765	825
SDR: 4 Lane Major Road (Divided – 18' Median)		275	340	410	480	545	615	680	750	820	885	955
SDL: 4 Lane Major Road (Divided – 18' Median)		240	295	355	415	475	530	590	650	710	765	825
SDR: 5 Lane Major Road (continuous two-way turn-lane)		265	335	400	465	530	600	665	730	800	860	930
SDL: 5 Lane Major Road (continuous two-way turn-lane)		250	315	375	440	500	565	625	690	750	815	875
SDR: 6 Lane Major Road (Divided – 18' Median)		290	360	430	505	575	645	720	790	860	935	1005
SDL: 6 Lane Major Road (Divided – 18' Median)		250	315	375	440	500	565	625	690	750	815	875
SDL: (Where left turns are physically restricted)		210	260	310	365	415	465	515	566	620	670	725

TABLE 2-5 INTERSECTION SIGHT DISTANCE

Source (VDOT, 2021)

Figure B3. (VDOT, 2021)

Q6. How do your ISD requirements for Case B1 intersections compare to VDOT’s guidelines?
- They are the same
- They are different
- Unknown

Q7. Please briefly explain the differences.

Sight Triangles (Decision Point)

VDOT RDM locates the decision point at a distance of 4’ from the centerline or left edge of the pavement of the minor roadway and 14.5’ - 18’ from the edge of the travel lane of the major roadway. Also, where practical, the decision point should be determined by the location of stop bar and may exceed 18’ from the edge of the travel lane.

Figure B4. (FHWA, 2016)

Q8. Is your guideline different from this?
- Yes
- No
- Unknown

Q9. Please explain how you locate the decision point in the sight triangle.

Q10. Do your guidelines allow adjustment of the decision point in the sight triangle based on site specific conditions?
- Yes
- No
- Unknown

Q11. What factors allow the adjustment?
- Major road speed limit
- Roadway classification
- Geographic classification (urban/rural)
- Crash history at site
- Geometric characteristics
- Multimodal considerations
- Other

Sight Triangles (Obstructions)

When defining obstructions in the sight triangle, VDOT RDM 2023 requires planting strips between 2-7 feet wide to be free of obstructions within 30 feet of corners, measured from the end of curb return radii, assuming a driver's eye and object height of 3.5 feet above the roadway surface.

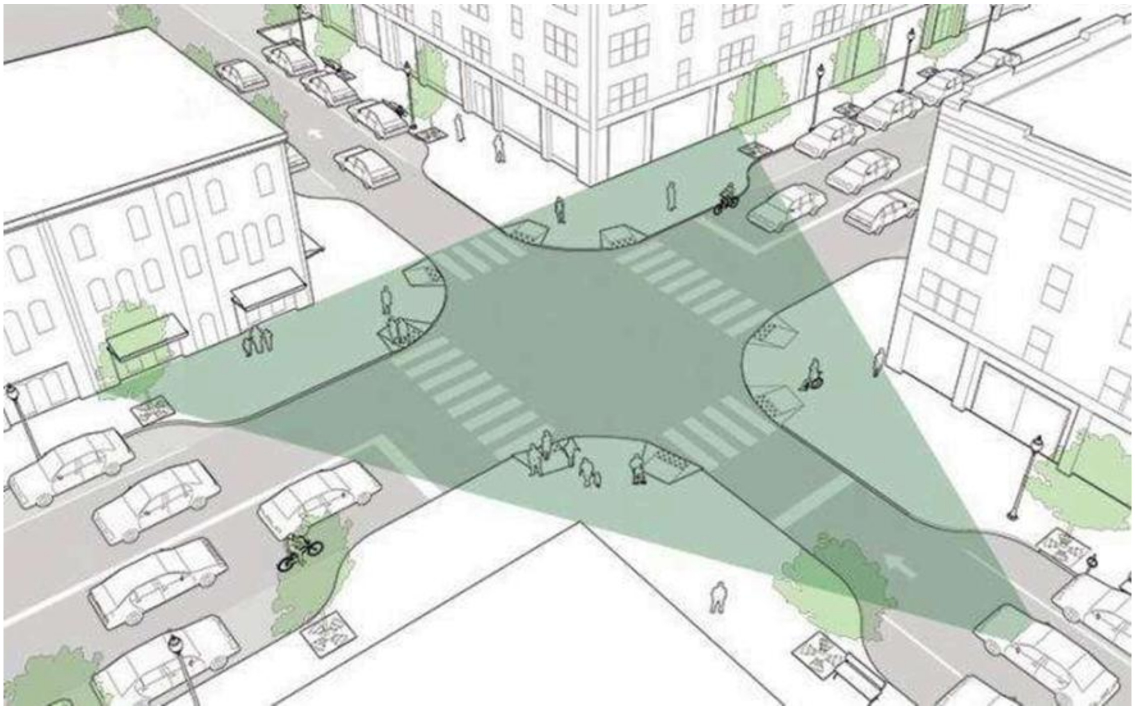


Figure B5. (NACTO, 2013)

Q12. Are your guidelines different from this?
- Yes
- No
- Unknown

Q13. How do your guidelines define sight obstructions?
- Specify a maximum height
- Specify a maximum diameter/width
- Define obstruction as anything that blocks the line of sight
- Other

Q14. Does your guideline entail parking restrictions near intersections?
- Yes (please provide details)
- No
- Unknown

Q15. Are you aware of instances where compliance with ISD standards has led to the removal or modification of urban elements (trees, parking, utilities, transit)?
- Yes (please provide details)
- No
- Unknown

Multimodal Guidelines

Multimodal intersection design aims to safely accommodate not only motor vehicles but also bicycles, pedestrians, and public transit. These guidelines often include separate sight distance requirements.

(Source: VDOT, 2024c)

Figure B6. (VDOT, 2024c)

Q 16. Does your locality provide guidance on multimodal considerations?
- Yes
- No
- Unknown

Q17. In your locality's guidance, are there differences in ISD guidelines between multimodal and conventional designs?
- Yes (please provide details)
- No
- Unknown

Q18. At intersections featuring bike lanes, do your guidelines address cases where longer sight distances are required?
- Yes (please provide details)
- No
- Unknown

Q19. Do your guidelines require approach clear spaces at intersections?
- Yes (please provide details)
- No
- Unknown

Q20. Has your locality implemented daylighting practices, or plan to?
- Yes - Implemented in the past

- Yes - Plan to do so
- No
- Unknown

Q21. Which guidance document do you refer to for ISD guidelines?
- VDOT RDM
- AASHTO GB
- Other (please specify)

Traditional Neighborhood Developments (TNDs)

These are characterized by dense building layout and narrow setbacks.

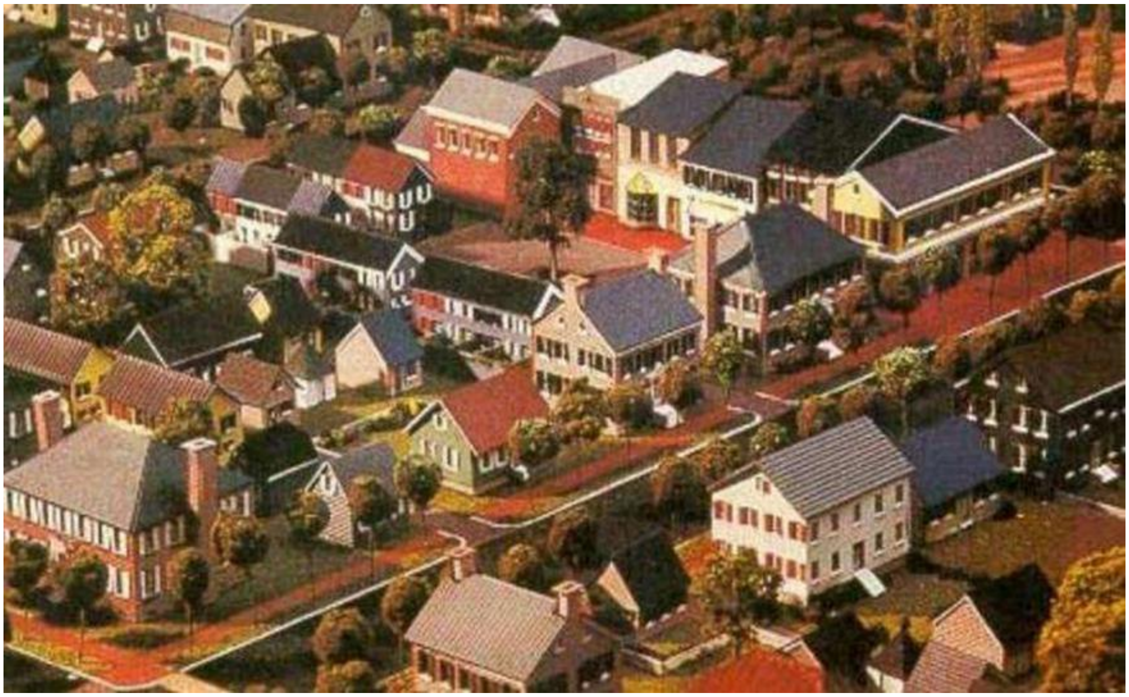


Figure B7. (Palani, 2023)

Q 22. Does your locality have developments classified as TNDs?
- Yes
- No
- Unknown

Q23. Have you noticed an increase in TNDs in the last 10 years?
- Yes
- No
- Unknown

Q24. Are you aware of cases where TNDs have failed to meet ISD requirements?
- Yes
- No
- Unknown

Q25. Do ISD guidelines for TNDs differ from conventional ISD guidelines?
- Yes (please explain)

- No
- Unknown

Q26. Design Flexibilities

This section contains questions on design modification requests when ISD requirements are not met.

Q 27. Does your locality get involved with development site plan approvals?
- Yes
- No
- Unknown

Q28. What form of documentation is required when ISD standards are not met?
- Design waiver
- Design exception
- Design variance
- Other

Q29. What factors are considered while approving or denying ISD design modifications?
- Functional classification
- Speed limit
- Crash history
- Geometric characteristics
- Multimodal considerations
- Cost saving
- Context saving
- Other

Q29. Do you keep a database of design modification requests?
- Yes
- No
- Unknown

Q30. Approximately, what is the average number of such requests per year?

Q31. Does your locality maintain a database of ISD at intersections?
- Yes
- No
- Unknown

Q32. Are you aware of safety issues at intersections where ISD standards are not met?
- Yes (please provide details)
- No
- Unknown

Q33. End of Survey – Concluding Thoughts

Please feel free to share any additional thoughts on the impact of ISD requirements on urban street safety and character.

APPENDIX C: VDOT RESIDENCY SURVEY

Appendix C shows the survey distributed to VDOT residencies.

VDOT’s Research Council is involved in a research study focused on safety implications of intersection sight distance. More specifically, the study is attempting to determine the safety record of low-speed urban/suburban intersections that don’t meet VDOT (or AASHTO) ISD standards. This brief survey should take no longer than 5 minutes to complete. We appreciate your help with this effort!

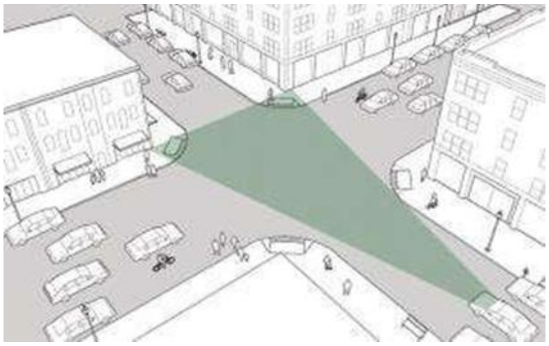


Figure C1. (NACTO, 2013)

Q1. Please provide your contact information.
- Name
- VDOT District
- Residency

Q2. Is your residency involved in the approval process for development site plans?
- Yes
- No

Q3. Is Intersection Sight Distance (ISD) a component of the criteria evaluated?
- Yes
- No
- Unknown

Q4. When a developer submits a plan for review, are ISD values provided on plans?
- Yes
- No
- Unknown

Q5. Do you maintain records of ISD values on plans that are submitted?
- Yes
- No
- Unknown

Q6. Do these records indicate whether or not intersections meet ISD standards?
- Yes
- No
- Unknown

Q7. Is the ISD data available solely for roads under VDOT’s maintenance, or does it extend to roads managed by local authorities as well?

- Solely VDOT-owned roads
- Roads managed by localities
- Both VDOT and locality managed roads

Q8. How is ISD determined to be in compliance with VDOT standards?

Q9. What entities are involved in the development site plan approval process?

Q10. In cases where ISD standards are not met, who is responsible for initiating the ISD-related design waiver/exception/variance process?
- VDOT Residency
- Developer
- Locality
- VDOT District

Q11. Does your residency maintain records of ISD-related design waiver/exception/variance?
- Yes
- No

Q12. What entity maintains ISD-related design waiver/exception/variance records?

Q13. For older development/downtown districts, does your residency maintain ISD records?
- Yes
- No
- Unknown

Figure C2. Image: Downtown Charlottesville (Google Maps, 2023)

Q14. For older developments/downtown districts in your jurisdiction, are you aware of cases where VDOT ISD standards are not met?
- Yes
- No
- Unknown

Q15. For those cases where VDOT ISD standards are not met, how was ISD determined?
- Field measurement
- Visual inspection
- Other (please specify)

Q16. Are you aware of safety issues at intersections where VDOT ISD standards are not met?
- Yes
- No
- Unknown

Q17. End of Survey – Concluding Thoughts

Please feel free to share your thoughts on the impact of ISD requirements on urban street safety and character.