MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter 2

Basic Design Controls

September 2016

Contents

Chapter 2

Basic Design Controls

2.1 INTRODUCTION

Roadway design is predicated on basic controls that establish the overall objective of the roadway facility and identify the basic purpose of the roadway project. Understanding the distinction between basic design controls and geometric design criteria is fundamental to executing a design approach that meets the desired outcomes of a project. **The design controls are attributes, values, or qualities that influence discrete geometric element dimensions or considerations. Design criteria are dimensions and values that meet design control needs, such as curve radius, cross section, and merge lengths.**

The performance-based design approach guides the design team to take the intended project outcome into account when establishing the design controls and associated design criteria on a project-by-project basis.

Chapter 2 of the *MDT Road Design Manual (RDM)* outlines the basic design controls for the criteria that impact roadway design. This includes a discussion on the functional classification system, speed, traffic volume controls, access control, sight distance, and the design exception process. *MDT Geometric Design Standards* present design criteria and references the design controls in Chapter 2 for more information on each design element *(1)*. Identifying the controls that impact the criteria can help the design team understand how the design decisions can impact the performance measures related to the overall project desired outcomes.

The design controls and associated criteria provide a platform for the design team to make thoughtful evaluations of the project needs and context. Design decisions may result in changing various design criteria to achieve the overall purpose of the project and/or more effectively serve the various users of the roadway. The design exception process is meant to help document the design decisions (changes to criteria based on project context) and provide a framework for balancing the importance of geometrics, safety, and operations, as well as considering tradeoffs. A performance-based design approach and the tools presented in this approach, provide an effective way to evaluate the performance measures, understand the tradeoffs of design decisions, and document the process.

2.1.1 Land Use and Terrain

Roadway topography and surrounding land use can affect basic design controls.

The roadway topography and surrounding land use can affect basic design controls, such as the design speed for the roadway. To determine the surrounding land use, the following descriptions are used:

1. **Urban Areas.** Those places within boundaries set by the responsible State and local officials or a place that has urbanized characteristics. Urban areas have three subcategories:
   a. **Urbanized Areas**. Those areas with a population greater than 50,000, as designated by the Bureau of the Census.
   b. **Small Urban Areas.** Those areas with a population greater than 5,000 and not within any Urbanized Areas.
   c. **Transitional Areas.** Those areas providing connections between urban and rural areas.
2. **Rural Areas.** Those places outside the boundaries of urban areas.

Topography that introduces horizontal and/or vertical constraints along a road segment, at more than one location, will establish the appropriate type of terrain for the design team to consider.

The topography of the land has an influence on the alignment of the roadway. To determine the type of terrain, the following descriptions are used:

1. **Level Terrain:** The available stopping sight distances are generally long or can be made to be so without construction difficulty or major expense.
2. **Rolling Terrain:** The natural slopes consistently fall below and rise above the roadway and occasional steep slopes offer some restriction to horizontal and vertical alignment.
3. **Mountainous Terrain:** Longitudinal and transverse changes in elevation are abrupt and extensive grading is frequently needed to obtain acceptable alignments.

2.2 HIGHWAY SYSTEMS

This section provides an overview of the highway systems within MDT. The functional classification system provides an overview of the types of roadway facilities that exist within MDT and the characteristics of the facilities. Other project context considerations are outlined to provide the design team with a fundamental understanding of how the functional classification may impact design controls and criteria. Additional information regarding the Federal-Aid System is provided in Section 2.2.3.

2.2.1 Functional Classification System

The functional classification of a highway is determined by the character of service it provides. Functional classification recognizes that the public highway network in Montana serves two basic and often conflicting functions: travel mobility and access to property. As shown in Exhibit 2-1, each type of highway or street may provide varying levels of access and mobility, depending upon its intended service. In the functional classification system, the overall objective is that the highway system, when viewed in its entirety, will yield an optimum balance between its access and mobility purposes.

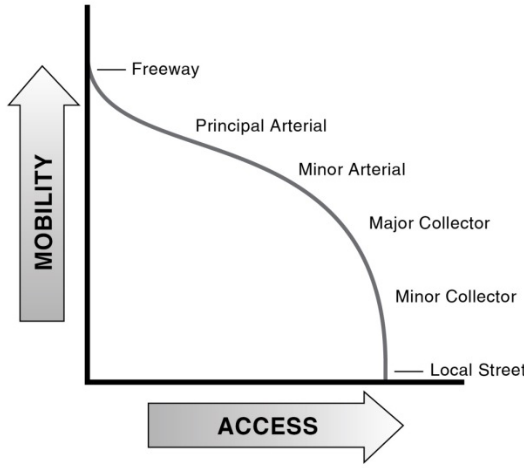


Exhibit 2-1
Functional Classification Mobility and Access

The overall objective is that the highway system will yield an optimum balance between its access and mobility purposes.

The functional classification system provides the guidelines for determining the geometric design of individual highways and streets. Once the function of the highway facility is defined, the design team can select an appropriate design speed, roadway width, roadside safety elements, amenities and other design values. The *RDM* is based upon this systematic concept to determining geometric design.

The functional classification map for State highways in Montana is provided at the following link on the Montana State Official Website.

MDT Functional Classification Map

For the purpose of the *RDM,* the functional classification for MDT facilities is consistent with the classifications described in the American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets (Green Book) (2).* The roadways that create the functional transportation system are different depending on whether it is in an urban or rural area. The following section provides a description for each functional class and the different characteristics for each type of area.

2.2.1.1 Freeways

Freeways, which include Interstate highways, are the highest level of arterial. These facilities are characterized by full control of access, high design speeds, and a high level of driver comfort and safety. For these reasons, freeways are considered a special type of highway within the functional classification system, and separate geometric design criteria have been developed for these facilities. Unless otherwise noted, Interstate System projects will be designed according to freeway design criteria.

2.2.1.2 Arterials

Arterials are characterized by a capacity to move relatively large volumes of traffic while also serving adjacent properties. The arterial system typically provides for higher travel speeds and serves longer trip movements. The arterial functional class is subdivided into principal and minor categories for rural and urban areas:

1. **Principal Arterials**. In both rural and urban areas, the principal arterials serve the highest traffic volumes and the greatest trip lengths. These facilities may be two or more lanes in each direction, with or without a median. In some cases, the level of geometric design is equivalent to that of freeways.
2. **Minor Arterials**. In rural areas, minor arterials will provide a mix of interstate and interregional travel service. In urban areas, minor arterials may carry local bus routes and provide intra-community connections. When compared to the principal arterial system, the minor arterials accommodate shorter trip lengths and lower traffic volumes, while providing more access to property.

2.2.1.3 Collectors

Collector routes are characterized by a roughly even distribution of their access and mobility functions. Traffic volumes will typically be somewhat lower than those of arterials. In rural areas, collectors serve intraregional needs and provide connections to the arterial system. In urban areas, collectors act as intermediate links between the arterial system and points of origin and destination. Urban collectors typically penetrate residential neighborhoods and commercial/industrial areas. Local bus routes will often include collector streets. Collectors are further described with the following subcategories.

1. **Major Collectors** serve traffic generators that are not served by the higher arterial system. This could include schools, freight distribution areas, parks or other agricultural areas. Major collectors link these types of areas to routes of higher classification, such as arterials.
2. **Minor Collectors** provide links to local traffic generators within rural and urban areas. These types of routes may be spaced consistently to accumulate traffic from local roads and bring developed areas to other collector roadways.

2.2.1.4 Local Roads and Streets

All public roads and streets not classified as freeways, arterials, or collectors are classified as local roads and streets. Local roads and streets are characterized by their many points of direct access to adjacent properties and their relatively minor value in accommodating mobility. Speeds and volumes are usually low and trip distances short. Through traffic is often deliberately discouraged.

2.2.2 Project Context and Functional Classification Considerations

There are additional project context and functional classification considerations that may impact the design controls and criteria. Understanding the project context can help the design team make appropriate design decisions that are consistent with the desired outcomes of a design project. The following subsections provide additional information on project context that the design team may consider.

Considerations for understanding the project context may include:

- **Rural or urban**
- **Project setting**
- **Roadway jurisdiction**
- **Existing or future constraints**
- **Overall roadway network**
- **Defining geometrics**
- **Current performance**

2.2.2.1 Future Land Use Needs

Understanding the anticipated land use needs in the vicinity of the roadway can help the design team consider the long-term vision and purpose for the roadway. For example, a roadway may have adjacent undeveloped land for the majority of its length, but the type of zoning may allow for more density and the need for access and multi-modal facilities (pedestrian, bicycle, and transit).

2.2.2.2 Coordination with Local Agencies

A project including local roadways or adjacent to a local community may consider how project context perspectives from local agencies can be integrated into the alternatives and design solutions. Local agencies may have developed separate categories or functional classes for local roadways that are different from the state functional classification system. The design team should consider how a roadway may function within a local community and coordinate with the local agencies to gain a full understanding of the roadway characteristics. As described in the *MDT Context Sensitive Solutions Guide (MDT CSS Guide)*, projects should involve local government and citizens to begin to ensure the needs of all interested parties are heard and considered throughout the project decision process. As described in that guide, a community-integrated approach can help guide future planning, funding and decision-making for the local and statewide transportation system, while meeting MDT's mission to emphasize quality, safety, cost effectiveness, economic vitality, and sensitivity to the environment *(3)*. This is also consistent with the performance-based approach described in Chapter 1, Section 1.2. Integrating stakeholders early in the project to help establish project context can help guide design decisions throughout the entire project.

2.2.2.3 Accommodating Other Modes of Travel

In some cases, the primary functional classification of a roadway should be considered along with other users of the roadway facility. Roadway facilities that accommodate several modes of travel, such as bicycles, pedestrians, railroads, and overweight/oversized vehicles, may require additional coordination and design considerations. Scenic byways also require special design consideration to serve the users and their needs.

2.2.3 Federal-Aid System

The Federal-aid system consists of those routes within Montana which are eligible for the categorical Federal highway funds. MDT, working with the local governments and in cooperation with the Federal Highway Administration (FHWA), has designated the eligible routes. United States Code, Title 23, describes the applicable Federal criteria for establishing the Federal-aid system.

2.2.3.1 National Highway System

The National Highway System (NHS) is a system of those highways determined to have the greatest national importance to transportation, commerce and defense in the United States. It consists of the Interstate Highway System, logical additions to the Interstate system, selected other principal arterials, and other roadway facilities which meet the requirements of one of the subsystems within the NHS. A map of the NHS in Montana is shown at the following link on the Montana Official State Website:

MDT National Highway System Map

To properly manage the NHS, the FHWA has mandated that each State highway agency develop and implement several management systems for those roadway facilities on the NHS. These include management systems for pavements, bridges, traffic monitoring, congestion and safety.

2.2.3.2 Surface Transportation Program (Non-NHS Routes)

The primary system includes Non-NHS rural minor arterials. The secondary system includes Non-NHS rural major collectors. The urban system includes both minor arterials and major collectors within urban boundaries.

The Surface Transportation Program (STP) refers to all Non-NHS routes and is a block-grant program which provides Federal-aid funds for any public road not functionally classified as a minor rural collector, or a local road or street. The STP replaced a portion of the former Federal-aid primary system and replaced all of the former Federal-aid secondary and urban systems, and it includes some collector routes, which were not previously on any Federal-aid system. Collectively, these are called Federal-aid routes. In addition, bridge projects using STP funds are not restricted to Federal-aid routes, but may be used on any public road. Transit capital projects are also eligible under the STP program. The basic objective of the STP is to provide Federal funds for improvements to roadway facilities not considered to have significant national importance with a minimum of Federal requirements for funding eligibility.

The primary system includes Non-NHS rural minor arterials. The secondary system includes Non-NHS rural major collectors. The urban system includes both minor arterials and major collectors within urban boundaries. These systems are also included in the NHS map described above. Some MDT facilities may be distinguished differently than the systems described above. The design team should refer to the MDT Functional Classification Map to identify the appropriate roadway category that will guide the design criteria.

2.2.3.3 Bridge Replacement and Rehabilitation Program

The Bridge Replacement and Rehabilitation Program (BRRP) has its own separate identity within the Federal-aid program. BRRP funds are eligible for work on any bridge on a public road regardless of its functional classification.

2.2.3.4 National Network (for Trucks)

The Surface Transportation Assistance Act (STAA) of 1982 required that the U.S. Secretary of Transportation, in cooperation with the State highway agencies, designate a national network of highways that allow the passage of trucks of specified minimum dimensions and weight. The objective of the STAA is to promote uniformity throughout the nation for legal truck sizes and weights on a National Network. The National Network includes all Interstate highways and significant portions of the former Federal-aid primary system (before the 1991 Intermodal Surface Transportation Efficiency Act) built to accommodate large-truck travel. In addition, the STAA requires that "reasonable access" be provided along other routes for the STAA commercial vehicles from the National Network to terminals and to facilities for food, fuel, repair and rest. In addition, access should be provided for household goods carriers, to points of loading and unloading.

In Montana, the National Network includes the Interstate highway system and all primary routes that existed prior to the Intermodal Surface Transportation Efficiency Act (ISTEA). The WB-67 (a 73-foot tractor-trailer combination truck) is allowed on all public roads in the State without a permit. The WB-100 (a 105-foot triple semitrailer) is only allowed on the Interstate system and for reasonable access to the system. MDT has defined "reasonable access" as 1 mile from any interchange on the Interstate system.

2.2.3.5 Frontage Roads

Although frontage roads are not on the Federal-aid system, they are the State's responsibility. They are eligible for STP funds, as well as for Interstate Maintenance (IM) Program or National Highway (NH) funds if they are adjacent to an Interstate or NH route and are functionally classified as a major collector or above.

Frontage roads distribute and collect traffic and as such can be an essential element of a controlled access facility. Frontage roads enhance the safety of a controlled access facility by reducing the number of interchanges needed. They may also help to segregate lower speed local traffic from higher speed through traffic. They can also be used as an alternative system in case of freeway disruption.

2.3 PROJECT SCOPE

The project scope of work will reflect the basic intent of the roadway project and will determine the overall level of roadway improvement.

The project scope of work will reflect the basic intent of the roadway project and will determine the overall level of roadway improvement, to meet the purpose and need identified. Additional information can be found in the *Guidelines for Nomination and Development of Pavement Projects (4),* which is provided on the MDT Website at the following link:

Guidelines for Nomination and Development of Pavement Projects

1. **New Construction.** New construction is defined as horizontal and vertical alignment on a new location.
2. **Reconstruction**. Reconstruction is defined as work which includes one or more of the following:
    a. Full-depth pavement reconstruction for more than 50-percent of the project length;
    b. Intermittent reconstruction of the existing horizontal and vertical alignment for more than 25-percent of the project length; and/or
    c. Addition or removal of through travel lanes.
3. **Rehabilitation.** Rehabilitation is defined as work primarily intended to extend the service life of the existing roadway by making cost-effective improvements to upgrade the roadway. It may include full-depth pavement reconstruction for up to 50-percent of the project length and may include horizontal and vertical alignment revisions for up to 25-percent of the project length. Rehabilitation projects may be further categorized into major and minor rehabilitation projects.
    a. **Major Rehabilitation – with added capacity.** The intent of these projects is to rehabilitate the existing pavement structure through an engineered approach that considers the observed pavement distress, the in-place material, and roadway geometrics. Milling operations may be greater than 0.2 feet in depth and may expose base gravel, which can then be treated or modified. The work may include the addition of lanes or dualization of the existing highway (conversion from a two-lane highway to a divided multilane highway). New right-of-way and utility relocation may be required to improve geometrics, flatten slopes, or enhance safety. Other surfacing improvements shall follow the *Guidelines for Nomination and Development of Pavement Projects (4)*. The focus of this treatment is to extend the life of the pavement, improve ride quality, and/or add capacity. It may include rebuilding substandard horizontal or vertical curves, but the majority of the work shall be primarily on the existing alignment. It typically requires rebuilding less than 25-percent of the total project length. It may also include widening the lanes or shoulders. This work could also include base course improvement and removal of poor or contaminated material. Other improvements such as guardrail and/or other safety improvements as outlined in the *Guidelines for Nomination and Development of Pavement Projects* may be included.

b. **Major Rehabilitation – without added capacity.** The intent of these projects is to rehabilitate the existing pavement through an engineered approach that considers observed pavement distress, the in-place material, and roadway geometrics. Milling operations may be greater than 0.2 feet in depth and may expose base gravel, which can then be treated or modified. New right-of-way and utility relocation may be required to improve geometrics, flatten slopes, or enhance safety. Other surfacing improvements shall follow the *Guidelines for Nomination and Development of Pavement Projects (4)*.

   The focus of this treatment is to expand the life of the pavement and improve ride quality. It may include rebuilding substandard horizontal or vertical curves, but the majority of the work shall be on existing alignment. It typically requires rebuilding less than 25-percent of the total project length. It may include widening the lanes or shoulders without adding more through lanes. This work could also include base course improvement and removal of poor or contaminated material. Other improvements such as guardrail and other safety improvements as outlined in the *Guidelines for Nomination and Development of Pavement Projects* may be included (4).

c. **Minor Rehabilitation.** The intent of these projects is to rehabilitate the existing pavement surface through an engineered approach that considers the observed pavement distress and in-place materials. Milling operations will be less than or equal to 0.3 feet in depth without exposing base gravel. All slope work and other features are usually accomplished within existing right-of-way. Other surfacing improvements shall follow the *Guidelines for Nomination and Development of Pavement Projects (4)*.

   The objective of this treatment is to extend the life of the pavement structure by rehabilitating the wearing surface only. Other improvements such as slope flattening, guardrail and and/or other safety improvement as outlined in the *Guidelines for Nomination and Development of Pavement Projects* may be included *(4)*.

4. **Pavement Preservation.** Pavement Preservation is a type of preventative maintenance that includes such treatments as crack seal, seal and cover, milling less than or equal to 0.2 feet, and overlays less than or equal to 0.2 feet (the overlay thickness can be increased to a total of 0.22 feet inches, if an isolation lift is needed to address heavy crack sealing of the existing surfacing). For more complete information on pavement preservation projects, refer to the *Guidelines for Nomination and Development of Pavement Projects (4)*. Additional information on preservation projects including roadside safety treatments, such as guardrail treatments, is provided in Chapter 9.

   Scheduled maintenance is a type of preventative maintenance that is intended to extend the useful life of pavement through scheduled projects. This may include work on roadway surfaces in advance of various levels of observable deterioration.

5. **Other Projects**. This would include projects such as spot safety improvements, structure rehabilitation, sidewalks, and wetland mitigation.

2.3.1 Accessibility Considerations

To understand the accessibility needs, the design team should consider the land use area and the characteristics of the roadway.

Projects should consider accessibility for all users. To understand the accessibility needs, the design team should consider the land use area, such as rural and urban and the characteristics of the roadway facility, such as the existing and future anticipated level of pedestrian and bicycle activity. For New Construction projects, the new roadway should include appropriate pedestrian and bicycle accommodations. For Rehabilitation projects, the accessibility considerations may be determined by whether the project includes major or minor rehabilitation. The design team may need to determine the level of impact to any existing pedestrian and bicycle facilities, or determine whether an existing roadway or intersection needs to be upgraded to provide additional pedestrian and bicycle features. For Pavement Preservation projects, accessibility considerations must be addressed where pedestrian facilities are added or existing pedestrian facilities are altered. The design team should reference the *Public Right-of-Way Accessibility Guidelines (PROWAG)* and the *Department of Justice/Department of Transportation Joint Technical Assistance on the Title II of the Americans with Disabilities Act Requirements to Provide Curb Ramps when Streets, Roads, or Highways are Altered through Resurfacing* for additional information on accessibility considerations *(5, 6)*. The Department of Justice Joint Technical Assistance is provided on the MDT Website at the following link:

Department of Justice/Department of Transportation Joint Technical Assistance on the Title II of the Americans with Disabilities Act Requirements to Provide Curb Ramps when Streets, Roads, or Highways are Altered through Resurfacing.

2.4 ROUTE SEGMENT PLAN

The Route Segment Plan is based on functional classification, traffic volumes, route continuity and is part of the *MDT Geometric Design Standards (1)*. The purpose is to identify and define a consistent pavement width to be used when reconstruction or major widening is conducted on a route segment. For NHS roadways, the standards provided in the AASHTO *Green Book* set the minimum standards. The MDT Route Segment Plan Map is provided at the following link on the MDT Website.

MDT Route Segment Plan Map

The MDT Roadway Width Decision Process can be found at the following link on the MDT Website.

MDT Roadway Width Decision Process (under construction)

Chapter 5 provides additional information regarding the roadway width decision process for MDT. Additional roadway width design information for various types of roadways can be found in the *AASHTO Green Book* and the *Guidelines for Nomination and Development of Pavement Projects (2, 4)*.

2.5 SPEED

Design speed is a selected speed used to determine the various geometric design features of the roadway. It should be appropriate with respect to topography, anticipated operating speeds, adjacent land use and functional classification of the roadway. The selected design speed for each project will establish criteria for several design elements, including horizontal and vertical curvature, superelevation, and sight distance. The speed relates to the driver's comfort and expectation, rather than the speed at which a vehicle will lose control. The following section discusses the selection of design speed, and the MDT *Geometric Design Standards* presents specific design speed criteria for various conditions *(1).*

Design speed should consider topography, anticipated operating speeds, adjacent land use and functional classification of the roadway.

The 85th-percentile speed is the speed at or below which 85-percent of vehicles travel on a given roadway. Nationally, the most common application of the value is its use as one of the factors for determining the posted, legal speed limit of a roadway section when not set by state statute. In most cases, field measurements for the 85th-percentile speed will be conducted during off-peak hours when drivers are free to select their desired speed.

When the posted speed limit is based on a traffic engineering study, the following are considered:

1. The 85th-percentile speed;
2. Pace, which is the 10 miles per hour (mph) range of speeds in which the highest number of speed observations are recorded;
3. Speed profile;
4. Montana Code *(7)*;
5. Type and density of roadside development;
6. Functional classification, land use and terrain;
7. Speeds on adjacent sections of the same roadway;
8. The crash experience for the previous three to five years, at least;
9. Road surface characteristics, shoulder condition, grade, alignment, and sight distance; and
10. Parking practices and pedestrian activity.

Additional guidance on selecting posted speed limits is provided by the Traffic and Safety Bureau.

2.5.1 Design Speed Selection

The selection of a design speed for a project should consider all of the following:

1. **Functional Classification**. In general, the higher class roadway facilities are designed with a higher design speed than the lower class facilities.
2. **Urban/Rural**. Design speeds in rural areas are generally higher than those in urban areas. This is consistent with the typically fewer constraints in rural areas (e.g., less development).

3. **Terrain.** Typically, the flatter the terrain, the higher the selected design speed will be. This is consistent with the typically higher construction costs associated with more rugged terrain. In certain situations, especially where a road follows a river through rugged terrain, the vertical alignment will be relatively level. However, the flat vertical alignment is achieved through the use of smaller radii horizontal curves. The utilization of flatter horizontal curves would result in extensive grading. For these situations, the lower design speed associated with more rugged terrain is appropriate.
4. **Driver Expectancy**. The selected design speed should be consistent with driver expectancy. The design team should consider the following when selecting a design speed:
   a. Avoid major changes in the design speed throughout the project limits and provide incremental speed reduction, where necessary;
   b. Avoid placing minimum radius horizontal curves at the end of long tangents;
   c. Consider the expected posted speed in the selection of the design speed, including an evaluation of 85th-percentile speed; and
   d. Balance the horizontal and vertical alignment (e.g., curvilinear alignment used with rolling grades).
5. **Project Context**. The selected design speed should be consistent with the project context, taking into account multimodal user considerations, adjacent land uses, roadway environment, and overall project setting.

For geometric design application, the relationship between the design elements and the selected design speed reflects the importance of addressing the safety and operational needs for the roadway. The value of a transportation facility in carrying goods and people is judged by its convenience and economy, which are directly related to its speed. The MDT *Geometric Design Standards* presents specific design speed criteria for various conditions *(1).*

2.6 TRAFFIC VOLUME CONTROLS

Traffic volume is a primary design control that can influence geometric element dimensions or considerations for a design project.

Traffic volume is a primary design control that can influence geometric element dimensions or considerations for a design project. The following traffic volume terminology is used throughout this discussion:

1. **Annual Average Daily Traffic (AADT).** The total yearly traffic volume in both directions of travel divided by the number of days in a year.
2. **Average Daily Traffic (ADT).** The total traffic volume in both directions of travel during a time period greater than one day but less than one year divided by the number of days in that time period.
3. **Capacity.** The maximum number of vehicles which reasonably can be expected to traverse a point or uniform roadway section during a given time period under prevailing roadway, traffic, and control conditions.
4. **Design Hourly Volume (DHV).** The one-hour vehicular volume in both directions of travel in the design year selected for roadway design. The DHV is typically the 30^{th} highest hourly volume during the design year.

5. **Equivalent Single-Axle Loads (ESALs).** The summation of equivalent 18,000 pound single-axle loads used to convert mixed traffic to design traffic for the design period.
6. **Level of Service (LOS).** A qualitative concept which has been developed to characterize a traveler's perception of quality of service. In the *Highway Capacity Manual (HCM)*, the qualitative grades for each level of service (A through F) have been assigned to quantitative measures for each highway element, including *(8):*
   a. freeway mainline;
   b. freeway mainline/ramp junctions;
   c. freeway weaving areas;
   d. interchange ramps;
   e. two-lane, two-way rural highways;
   f. multilane rural highways;
   g. signalized intersections;
   h. unsignalized intersections; and
   i. urban streets.

Appendix E presents guidelines for selecting the level of service for capacity analyses in road design.

2.6.1 Design Year Selection

2.6.1.1 Traffic Volumes

A roadway should be designed to accommodate the traffic volume expected to occur within the life of the roadway under reasonable maintenance. This involves projecting the traffic conditions for a selected future year. The following will apply:

1. **New Construction/Reconstruction Projects and Rehabilitation**. The roadway design will be based on a 20-year projection of traffic volumes. Life-cycle analysis for pavement types may exceed this period. For roads on the secondary system (refer to Section 2.2.3.2 for definition), the selection of certain geometric features is based on the current traffic volumes.
2. **Pavement Preservation**. For these projects, the pavement surfacing is typically non-engineered and is based on an 8-year minimum design forecast year. However, any traffic operations assessments will be based on a 20-year traffic projection.

The design team may consider interim design years and use a performance-based road design approach to understand the tradeoffs of the design year selection.

Future traffic volumes on MDT roadway facilities are provided by the MDT Data and Statistics Bureau. The design year is measured from the expected construction completion date. The design team should understand the tradeoffs for designing a roadway to accommodate traffic volumes for a specific design year. A performance-based design approach may define an intended project outcome that will provide benefits to the transportation system on an interim basis under the specific project context. This could result in a design year that is different than the typical 20-year projection.

2.6.1.2 Other Highway Elements

The following presents the recommended criteria for consideration of a design year for highway elements other than road design:

1. **Bridges/Underpasses**. The structural life of a bridge may be 75 years or more. For new bridges (including bridge replacements), the initial clear roadway width of the bridge or underpass will be based on the 20-year traffic volume projection beyond the construction completion date for flexible pavement designs and 30 years for concrete pavements. See the *MDT Structures Manual* for more information *(9).* Additional design standards for bridges are provided at the following link on the MDT Website:

   Bridge Design Standards

2. **Drainage Design.** Drainage appurtenances are designed to accommodate a flow rate based on a specific design year (or frequency of occurrence). The selected design year or frequency will be based on the functional class of the roadway and the specific drainage appurtenance (e.g., culvert). New drainage facilities are designed to have a structural life of 75 years. The MDT Hydraulics Section is responsible for determining the criteria for selecting a design year for drainage. Additional drainage design information is provided in Chapter 11.
3. **Pavement Design.** The pavement structure is designed to withstand the vehicular loads it will sustain during the design analysis period. The MDT Materials Bureau is responsible for determining criteria for selecting a design year for pavement design. Preventative maintenance overlays (pavement preservation projects) are utilized to extend the life of the riding surface and are not designed for a specific vehicular loading or analysis period.

2.6.2 Design Hourly Volumes

For most geometric design elements which are impacted by traffic volumes, the peaking characteristics are most significant. The roadway facility should be able to accommodate the design hourly volume at the selected level of service. This design hourly volume (DHV) will affect many design elements including the number of travel lanes, lane and shoulder widths and intersection geometrics. However, the performance-based design approach takes into account tradeoffs and the intended project outcome may focus on safety, accessibility or other performance measures other than capacity. Such a project may consider design hour volumes that are derived based on the overall project needs and context.

2.6.3 Traffic Operations Analysis

The objective of conducting traffic operations analysis is to design the roadway mainline or intersection to accommodate the selected design hourly volume (DHV) at the selected level of service (LOS). LOS Criteria for various types of roadway facilities is provided in Appendix E. The detailed calculations, highway factors and methodologies are presented in the *Highway Capacity Manual* (*HCM*) *(8).* During the analysis, the design service volume (or flow rate) of the facility is calculated.

The MDT Traffic and Safety Bureau is responsible for performing all capacity analyses required for the project.

For various types of highway facilities, the *HCM* documents the measures of effectiveness that should be used in capacity analyses to determine level of service. For each facility type, the *HCM* provides the analytical tools necessary to calculate the numerical value of its respective measure of effectiveness.

The following presents the simplified procedure for conducting a capacity analysis for the roadway mainline:

1. Select the design year.
2. Determine the DHV.
3. Select the target level of service.
4. Identify and document the proposed roadway geometric design (lane width, clearance to obstructions, number and width of approach lanes at intersections, etc.).
5. Using the *HCM*, analyze the capacity of the highway element for the proposed design.
6. Compare the calculated service flow rate to the DHV.

Coordinate with the MDT Traffic and Safety Bureau for additional information on level of service criteria.

The default values in the *HCM* will apply unless reliable local data is available. The level of service targets for various roadway facilities are provided in Appendix E.

2.7 ACCESS CONTROL

The density and number of access points along a roadway segment can impact mobility and safety. Access control considerations for private and public access can affect the road design process and design elements. Private access control consists of approaches, such as a driveway, between private landowners and public MDT facilities. Public access control (MDT facilities, and/or local agencies' roads) relates to intersection spacing along MDT facilities. The following sections provide an overview of these types of access control.

2.7.1 Private Access Control

Private access control is defined as the condition where the public authority fully or partially controls the right of abutting owners to have access to and from the public roadway. Private access control may be exercised by statute, zoning, right-of-way purchases, approach controls and permits, turning and parking regulations or geometric design (e.g., approach spacing).

Additional access control information is provided in the *MDT Approach Manual for Landowners and Developers*, located at the following link on the MDT Website.

MDT Approach Manual for Landowners and Developers

The following provides definitions for the three basic types of access control:

1. **Full Control (Access Controlled).** Full control of access is achieved by giving priority to through traffic by providing access only at grade separation interchanges with selected public roads. No at-grade crossings or approaches are allowed. The freeway is the common term used for this type of highway. Full control of access maximizes the capacity, safety, and vehicular speeds on the freeway.
2. **Limited Access Control.** Limited access control is an intermediate level between full control and regulated access. Priority is given to through traffic, but a few at-grade intersections and approaches may be allowed. Limited access control on a specific highway is established by passage of an Access Control Resolution by the Transportation Commission. The proper selection and spacing of at-grade intersections and service connections will provide a balance between the mobility, safety and access service of the highway.
3. **Regulated Access.** All highways warrant some degree of access control by permit or by design. Access is regulated through the granting of revocable permits for the construction and maintenance of approaches. If access points to other public roads and approaches are properly spaced and designed, the adverse effects on highway capacity and safety will be minimized. These points should be located where they can best suit the traffic and land use characteristics of the highway under design. Their design should enable vehicles to enter and exit safely with a minimum of interference to through traffic.

Limited access control and regulated access is exercised by MDT on the State highway system (see the *MDT Approach Manual for Landowners and Developers* described above) and by the local jurisdiction on other facilities to determine where private interests may have access to and from the public road system.

2.7.2 Public Access

Coordinate with the Traffic and Safety Bureau and Right-of-Way Bureau for additional information on intersections and access spacing.

To provide a safe and efficient transportation system, MDT maintains public access control procedures and criteria to govern roadway approaches, access control, spacing standards, medians and restriction of turning movements in compliance with statewide planning goals. Local agencies will collaborate with MDT when considering new public intersections to provide appropriate intersection spacing.

2.8 SIGHT DISTANCE

Designing a roadway with adequate sight distance allows vehicles to travel safely and efficiently and perform necessary driving maneuvers. This section provides an overview of the various types of sight distance evaluated in road design. Descriptions and criteria tables for each type of sight distance are provided in this section. Detailed equations and examples for calculating sight distance are provided in Appendix K. The discussions in this chapter relate to design elements discussed in other *RDM* chapters; therefore, references for additional design considerations are provided throughout the following subsections. The following types of sight distance will be discussed:

1. Stopping Sight Distance
    a. Horizontal Sight Distance
    b. Vertical Sight Distance
2. Intersection Sight Distance
3. Passing Sight Distance
4. Decision Sight Distance

Graphical sight distance representations should be reviewed to further understand if the calculated criteria are consistent with project context.

The following sections provide sight distance equations and criteria tables to assist the design team in evaluating this design element during a project. As the design team evaluates the sight distance criteria, graphical representation of sight lines and distances for existing conditions and future conditions should be reviewed to further understand if the calculated criteria are consistent with project context and local conditions.

2.8.1 Stopping Sight Distance

Stopping sight distance (SSD) is the sum of the distance traveled during a driver's perception/reaction or brake reaction time and the distance traveled while braking to a stop, as shown in Equation 2.8-1. SSD is a controlling criterion that should be carefully evaluated during a design project. The *MDT Geometric Design Standards* provide additional information on the SSD criteria for MDT roadway facilities *(1).*

$$SSD = Brake\ Reaction\ Distance + Braking\ Distance$$

Equation 2.8-1

SSD is affected by the grade of the roadway. Vehicles traveling downhill will require more SSD than a vehicle traveling uphill on a roadway. Equation 2.8-2 provides stopping sight distances for passenger cars on a level grade and Exhibit 2-2 that summarizes the SSD for passenger cars on level grade. When applying the SSD values, the height of eye is assumed to be 3.5 feet, and the height of object 2.0 feet.

$$SSD_{Level} = 1.47Vt + 1.075\left(\frac{V^2}{a}\right)$$

Equation 2.8-2

where:

SSD =	stopping sight distance, ft
V =	design speed, mph
t =	brake reaction time, 2.5 s
a =	deceleration rate, 11.2 ft/s^2

Exhibit 2-2
Stopping Sight Distance on Level Roadways

Design Speed (V) (mph)	Brake Reaction Distance 1.47Vt (ft)	Braking Distance $1.075(V^2/a)$ (ft)	Calculated SSD (ft)	SSD Rounded for Design (ft)
15	55.1	21.6	76.7	80
20	73.5	38.4	111.9	115
25	91.9	60.0	151.9	155
30	110.3	86.4	196.7	200
35	128.6	117.6	246.2	250
40	147.0	153.6	300.6	305
45	165.4	194.4	359.8	360
50	183.8	240.0	423.8	425
55	202.1	290.3	492.4	495
60	220.5	345.5	566.0	570
65	238.9	405.5	644.4	645
70	257.3	470.3	727.6	730
75	275.6	539.9	815.5	820
80	294.0	614.3	908.3	910

Brake Reaction Time (t) = 2.5 s; Deceleration Rate (a) = 11.2 ft/s^2

Equation 2.8-3 provides stopping sight distances for passenger cars on grades and Exhibit 2-3 that summarizes the SSD for passenger cars on various grades.

Equation 2.8-3

$$SSD_{Downgrades} = 1.47Vt + \frac{V^2}{30\left[\left(\frac{a}{32.2}\right) - G\right]}$$

$$SSD_{Upgrades} = 1.47Vt + \frac{V^2}{30\left[\left(\frac{a}{32.2}\right) + G\right]}$$

where:

- *SSD* = stopping sight distance, ft
- *V* = design speed, mph
- *t* = brake reaction time, 2.5 s
- *a* = deceleration rate, 11.2 ft/s^2
- *G* = gradient, ft/ft

Exhibit 2-3
Stopping Sight Distance on Grades

Note: Refer to Equation 2.8-3 for calculating stopping sight distances for upgrades or downgrades other than those shown in Exhibit 2-3. Interpolation between the values shown is not appropriate. Additional equations and examples are also shown in Appendix K.

Design Speed (V) (mph)	Stopping Sight Distances (ft)					
	Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%
15	80	82	85	75	74	73
20	116	120	126	109	107	104
25	158	165	173	147	143	140
30	205	215	227	190	184	179
35	257	271	287	237	229	222
40	315	333	354	289	278	269
45	378	400	427	344	331	320
50	446	474	507	405	388	375
55	520	553	593	469	450	433
60	598	638	686	538	515	495
65	682	728	785	612	584	561
70	771	825	891	690	658	631
75	866	927	1003	772	736	704
80	965	1035	1121	859	817	782

Brake Reaction Time (t) = 2.5 s; Deceleration Rate (a) = 11.2 ft/s^2

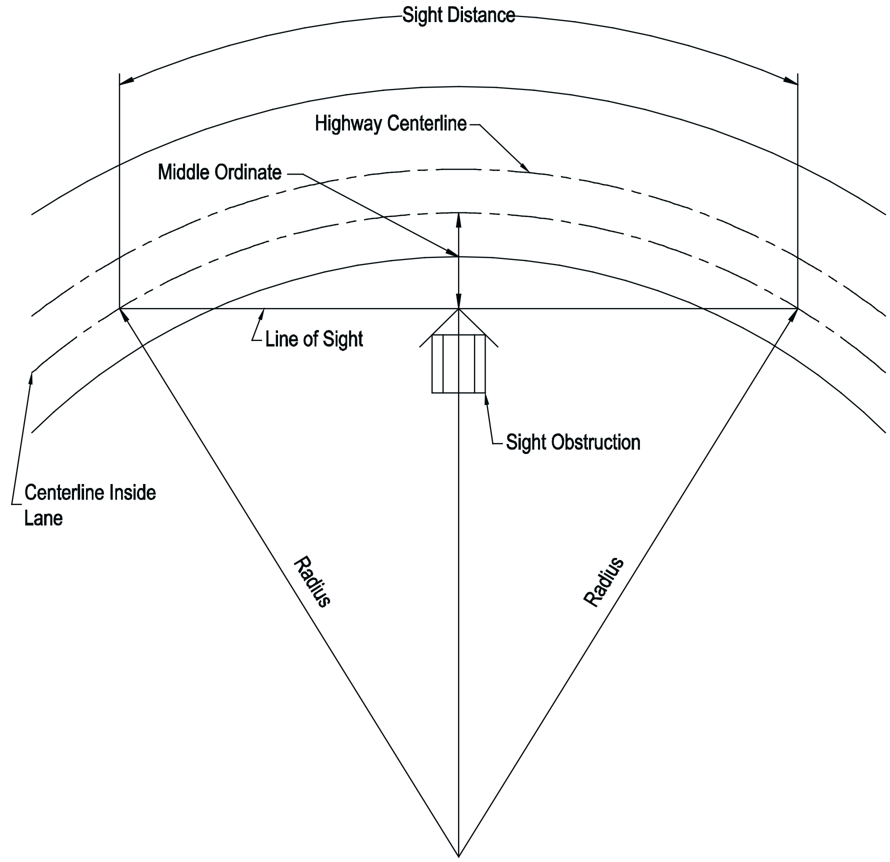
2.8.1.1 Horizontal Stopping Sight Distance

Sight obstructions on the inside of a horizontal curve are defined as obstacles which interfere with the line of sight on a continuous basis. These may include walls, cut slopes, wooded areas, buildings, and high farm crops. In general, point obstacles such as traffic signs and utility poles are not considered sight obstructions on the inside of horizontal curves. The design team must examine each curve individually to determine whether it is necessary to remove an obstruction or to adjust the horizontal alignment to obtain the required sight distance.

The design team must examine each curve individually to determine the need to remove an obstruction or to adjust the horizontal alignment.

Exhibit 2-4 illustrates the components for determining horizontal sight distance.

**Exhibit 2-4
Diagram Illustrating Components for Determining Horizontal Sight Distance**



Application

For application, the height of eye is 3.5 feet and the height of object is 2.0 feet. Both the eye and object are assumed to be in the center of the inside travel lane. In the elevation view, the line-of-sight intercept with the obstruction is at the midpoint of the sightline and 2.75 feet above the road surface at the center of the inside lane, for constant gradients.

2.8.1.1.1 Longitudinal Barriers

The design team should check the line of sight over a barrier along a horizontal curve and attempt to locate the barrier such that it does not block the line of sight.

Longitudinal barriers (e.g., bridge rails, guardrail, and concrete median barrier) can cause sight distance restrictions at horizontal curves, because barriers are placed relatively close to the traveled way (often 10 feet or less) and because their height is greater than 2 feet. The design team should check the line of sight over a barrier along a horizontal curve and attempt to locate the barrier such that it does not block the line of sight. The following should also be considered:

1. **Superelevation.** A superelevated roadway will elevate the driver eye and improve the line of sight over the barrier.
2. **Vertical Curves.** The line of sight over a barrier may be improved for a driver on a sag vertical curve and lessened on a crest vertical curve.

3. **Barrier Height.** The higher the barrier, the more obstructive it will be to the line of sight.
4. **Object Height.** Because of the typical heights of barriers, there may be many sites where the barrier blocks visibility to lower objects but does not block the view of taller objects. This observation provides some perspective to the potential safety problem at the site.

Each barrier location on a horizontal curve will require an individual analysis to determine its impacts on the line of sight. The design team must determine the elevation of the driver eye, the elevation of the object (2 feet above the pavement surface) and the elevation of the barrier where the line of sight intercepts the barrier run. If the barrier does block the line of sight to a 2-foot object, the design team should consider relocating the barrier or revising the horizontal alignment.

Additional horizontal curve information is provided in Chapter 3.

2.8.1.2 Vertical Curve Sight Distance

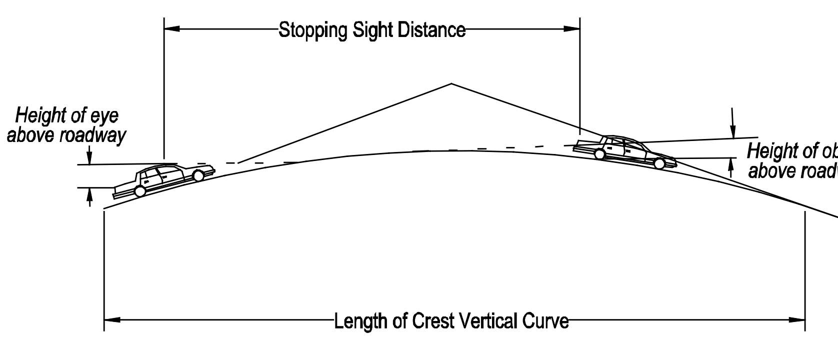
Additional SSD should be provided at intersections, if practical, especially if turn lanes are not provided.

One of the design controls for vertical curves is the provision of adequate sight distances for vehicles traveling through sag and crest vertical curves at the designated design speed. It is recommended that all vertical curves are designed to provide at least the stopping sight distances shown in Exhibit 2-2 and additional stopping sight distance should be provided when practical. The following information provides equations and example exhibits for designing sag and crest vertical curves with adequate sight distance.

2.8.1.2.1 Crest Vertical Curves

Determining the minimum length of a crest vertical curve using stopping sight distance criteria typically results in a curve that is satisfactory from a safety, comfort, and appearance standpoint. Exhibit 2-5 illustrates the design elements used in determining the length of a crest vertical curve to provide adequate sight distance. The assumed height of eye is 3.5 feet and height of object is 2.0 feet.

Exhibit 2-5 Design Elements Considered for Crest Vertical Curves to Provide Sight Distance

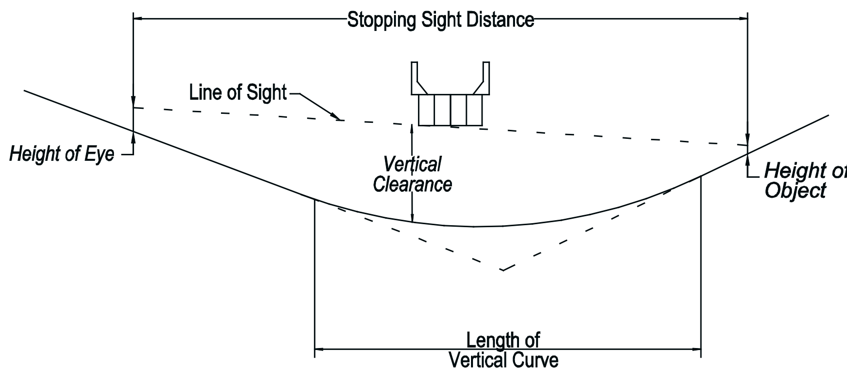


2.8.1.3 Sag Vertical Curves

Sag vertical curves are designed to allow the vehicular headlights to illuminate the roadway surface (i.e., the height of object is 0 feet) for a given sight distance. The length of the sag vertical curve will depend upon the difference between the two tangent grades for the specific curve and depend upon the selected sight distance and headlight height. The principal control in the design of sag vertical curves is to ensure that, at a minimum, stopping sight distance (SSD) is available for headlight illumination throughout the curve. The design assumes that there is a 1-degree upward divergence of the light beam from the longitudinal axis of the headlights.

Stopping sight distance for sag vertical curves at an undercrossing should also be considered. Sight distance on a roadway through a grade separation should be at least as long as the minimum stopping sight distance and where practical, even longer. Exhibit 2-6 illustrates the design components of designing a sag vertical curve at an undercrossing. The assumed height of eye is 8 feet for a truck driver and height of object is 2 feet for the taillights of a vehicle.

Exhibit 2-6
Sight Distance at an Undercrossing



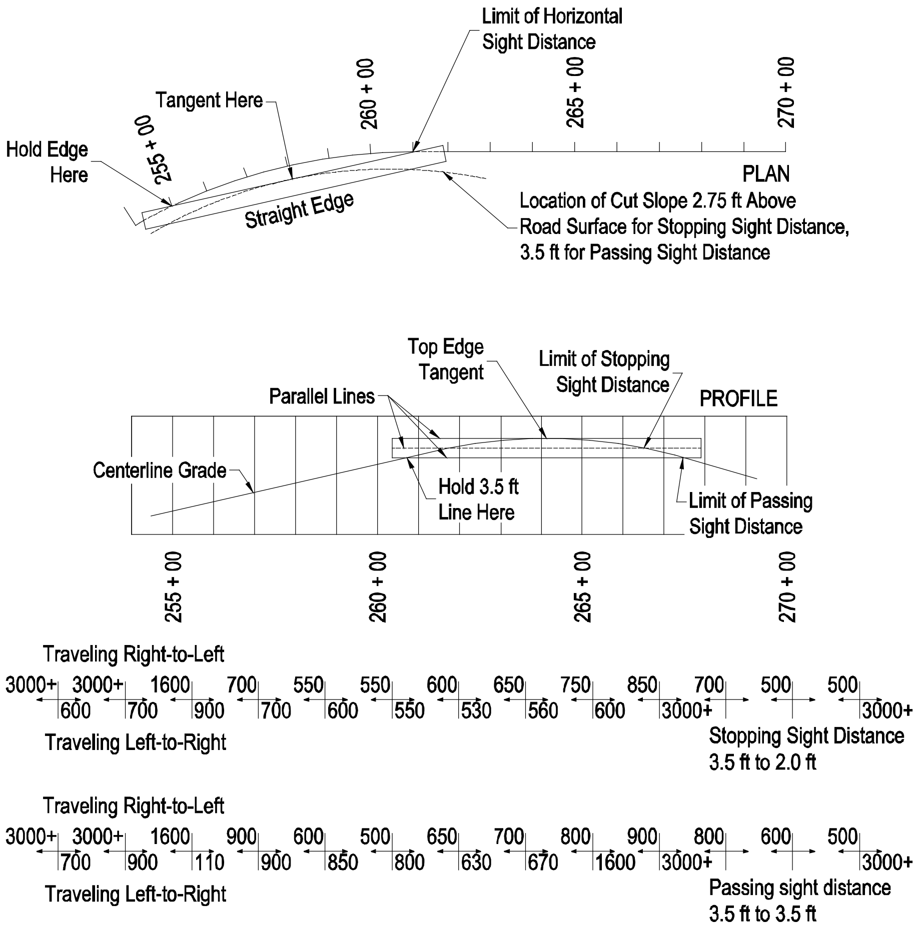
Additional sag vertical curve information is provided in Chapter 4.

2.8.1.4 Horizontal and Vertical Combinations

Sight distance should be considered early in the design process when the horizontal and vertical alignments are still able to be adjusted relatively easily. By evaluating the sight distance graphically on the design plans and recording the sight distance at frequent intervals, the design team can review the overall layout and produce a more balanced design. This may require minor adjustments to the plan and profile. A method for scaling sight distance on a design plan is shown in Exhibit 2-7. This exhibit shows the sight distance that may be recorded on the design plans.

The view of the roadway may change, therefore it is recommended that sight distance be measured and recorded for both directions of travel at each station on the design plans. This includes both horizontal and vertical sight distances being measured and the shorter of the lengths being recorded. Horizontal sight distance on the inside of a curve may be limited by obstructions, such as buildings, landscaping, cut sections or other topographic features. Horizontal sight distance is measured with a straight edge, as shown in Exhibit 2-7, and graphically shows the cut slope obstruction. Vertical sight distance may be scaled from a plotted profile, which is also shown in Exhibit 2-7.

Exhibit 2-7
Example of Scaling Sight Distance Method



Example Sight Distance Record

Exhibit 2-7 was developed from the AASHTO Green Book, Figure 3-2. This resource document provides additional information for the design team to reference, if needed *(2)*.

2.8.2 Intersection Sight Distance

For an at-grade intersection to operate properly, adequate sight distance should be available. Intersection sight distance (ISD) is a design element that should be evaluated during a design project to ensure the design meets MDT standards. Appendix F provides additional information on the SSD criteria for MDT roadway facilities.

The design team should provide sufficient sight distance for a driver to perceive potential conflicts and to perform the actions needed to negotiate the intersection

The design team should provide appropriate sight distance for a driver to perceive potential conflicts and to perform the actions needed to negotiate the intersection safely. The additional costs and impacts of removing sight obstructions are often justified. If it is impractical to remove an obstruction blocking the sight distance, the design team should consider providing traffic control devices or design applications (e.g., warning signs or turn lanes) which may not otherwise be considered.

In general, ISD refers to the corner sight distance available in intersection quadrants which allows a driver approaching an intersection to observe the actions of vehicles on the crossing leg(s). ISD evaluations involve establishing the needed sight triangle in each quadrant by determining the legs of the triangle on the two crossing roadways. The necessary clear sight triangle is based on the type of traffic control at the intersection and on the design speeds of the two roadways.

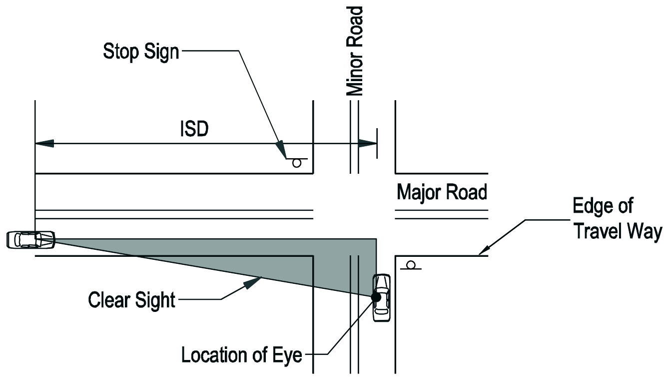
MDT uses gap acceptance as its basic methodology in the design of intersection sight distance. Additional information on gap acceptance is provided in the *AASHTO Green Book (2).*

There are specific design considerations, criteria and equations for each of the following types of traffic control:

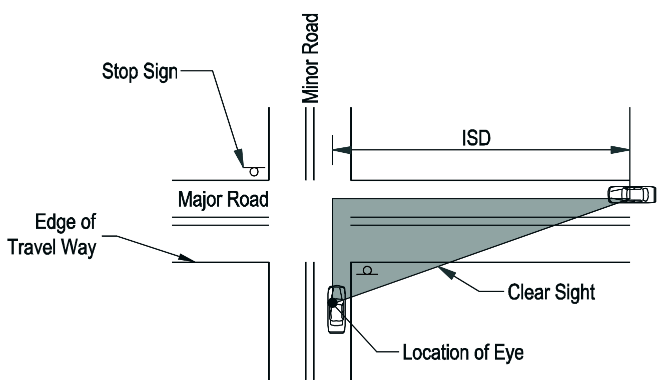
- **No Traffic Control (AASHTO Case A).** Intersections between low-volume and low-speed roads/streets may have no traffic control. At these intersections, appropriate corner sight distance should be available to allow approaching vehicles to adjust their speed to avoid a collision.
- **Stop Controlled/Traffic Signal Controlled** (AASHTO Case B and D). Where traffic on the minor road of an intersection is controlled by stop signs, the driver of the vehicle on the minor road must have appropriate sight distance for a safe departure from the stopped position assuming that the approaching vehicle comes into view as the stopped vehicle begins its departure. If a signalized intersection implements two-way flashing operations or right turns are permitted on red, the stop-controlled criteria may apply for intersection sight distance.

  MDT uses gap acceptance as the conceptual basis for its ISD criteria at stop-controlled and traffic-signal controlled intersections. The intersection sight distance is obtained by providing clear sight triangles both to the right and left. An example of this is shown in Exhibit 2-8.
- **Yield Control (AASHTO Case C).** At intersections controlled by a yield sign (except roundabouts, which are described below), drivers on the minor road will typically slow down as they approach the major road; make a stop/continue decision; and either brake to a stop or continue their crossing or turning maneuver onto the major road.
- **All-Way-Stop (AASHTO Case E).** At intersections with all-way stop control, provide appropriate sight distance so that the first stopped vehicle on each approach is visible to all other approaches.

Exhibit 2-8
Sight Lines for ISD at Stop Controlled and Traffic Signal Control



Clear Sight Triangle For Viewing



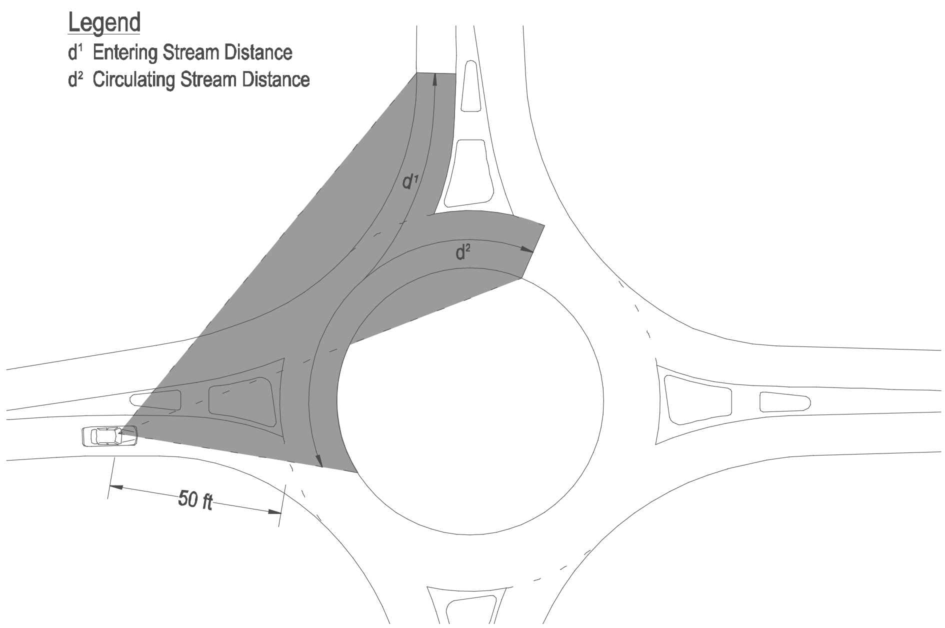
Clear Sight Triangle For Viewing

- **Stopped Vehicle Turning Left (AASHTO Case F).** At all intersections, regardless of the type of traffic control, the design team should consider the sight distance needs for a stopped vehicle turning left from the major road. The driver must see straight ahead for an appropriate distance to turn left and clear the opposing travel lanes before an approaching vehicle reaches the intersection. In general, if the major roadway has been designed to meet the stopping sight distance criteria, intersection sight distance will only be an issue where the major road is on a horizontal curve, where there is a median, or where there are opposing vehicles making left turns at the intersection.
- **Channelized Right-Turn.** When designing a channelized right-turn lane at an intersection, the sight distance for the approaching vehicles and sight distances for the pedestrians approaching the intersection should

be considered. Sight lines should be clear of obstructions and provide sufficient visibility for various users.

- **Roundabouts.** Intersection sight distance should be evaluated at the entries of a roundabout. At roundabouts, the sight triangle should follow the curvature of the roadway, and thus distances should be measured not as straight lines but as distances along the vehicular path. *NCHRP Report 672: Roundabouts An Information Guide, Second Edition* describes the method for evaluating intersection sight distance at roundabouts, *(10).* Exhibit 2-9 presents a diagram showing the method for determining intersection sight distance.

Exhibit 2-9 Intersection Sight Distance at Roundabouts



2.8.2.1 Measures to Improve Intersection Sight Distance

The available ISD should be checked using the above noted parameters. If the ISD values from the above sections are provided, no further investigation is needed. If the line of sight is restricted by either bridge railing, guardrail, other obstructions, or the horizontal and vertical alignment of the main road, and the ISD value is not available, evaluate one or more of the following modifications, or a combination, to achieve the intersection sight distance:

1. Remove the obstructions that are restricting the sight distance,
2. Relocate the intersecting road farther from the end of the bridge, if a bridge is present,
3. Widen the structure on the side where the railing is restricting the line of sight, if a bridge is present,
4. Flare the approach guardrail,
5. Revise the grades on the main road and/or the intersecting road,
6. Close the intersecting road,

7. Make the intersecting road one-way away from the main road, and/or
8. Review other measures that may be practical at a particular location.

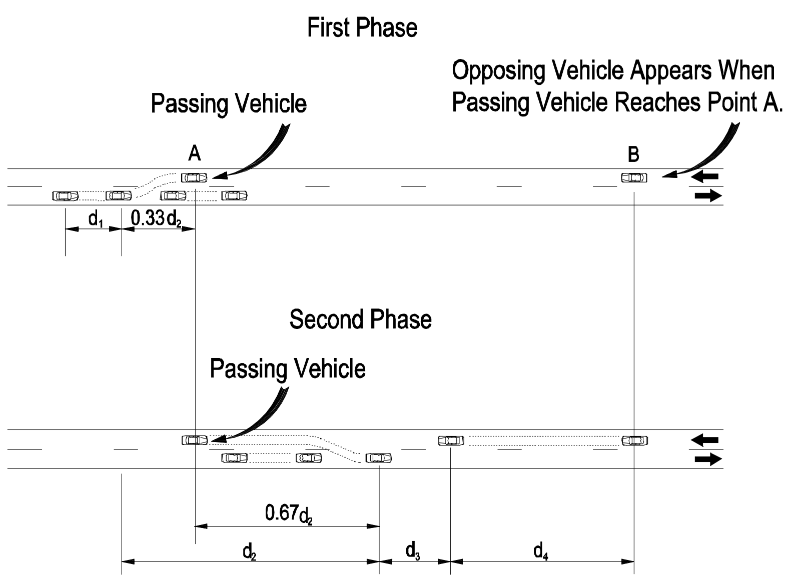
Appendix F provides additional design details and equations for intersection sight distance for each type of control, along with the summary tables and evaluation procedures.

2.8.3 Passing Sight Distance

Passing sight distance considerations are limited to two-lane, two-way highways. On these facilities, vehicles may overtake slower moving vehicles, and the passing maneuver must be accomplished on a lane used by opposing traffic.

The minimum passing sight distance for two-lane highways is determined from the sum of four distances as illustrated in Exhibit 2-10.

Exhibit 2-10
Elements of Passing Distance (Two-Lane Highways)



The following discussion provides the basic assumptions used to develop passing sight distance values for design:

Providing passing sight distance will make a crest curve flatter.

1. **Initial Maneuver Distance (d_1).** This is the distance traveled during the perception and reaction time and during the initial acceleration to the point of encroachment on the left lane. For the initial maneuver, the overtaken vehicle is assumed to be traveling at a uniform speed.
2. **Distance of Passing Vehicle in Left Lane (d_2).** This is the distance traveled by the passing vehicle while it occupies the left lane.
3. **Clearance Distance (d_3).** This is the distance between the passing vehicle at the end of its maneuver and the opposing vehicle.
4. **Opposing Vehicle Distance (d_4).** This is the distance traveled by an opposing vehicle during the time the passing vehicle occupies the left lane. The opposing vehicle appears after approximately one-third of the passing maneuver (d_2) has been accomplished. The opposing vehicle is assumed to be traveling at the same speed as the passing vehicle.

Exhibit 2-11 provides the minimum passing sight distance for design on two-lane, two-way highways.

Exhibit 2-11
Minimum Passing Sight Distance (Two-Lane Highways)

Design Speed (mph)	Assumed Speeds: Passed Vehicle (mph)	Assumed Speeds: Passing Vehicle (mph)	Minimum PSD for Design (ft)
20	8	20	400
25	13	25	450
30	18	30	500
35	23	35	550
40	28	40	600
45	33	45	700
50	38	50	800
55	43	55	900
60	48	60	1000
65	53	65	1100
70	58	70	1200
75	63	75	1300
80	68	80	1400

On rural reconstruction projects of two-lane highways, the design team should attempt to provide passing sight distance over as much of the highway length as practical. It will generally not be cost effective to make improvements to the horizontal and vertical alignment solely to increase the available passing sight distance. When determining the percent of passing sight distance, consider the following factors:

1. traffic volumes,
2. truck volumes, and
3. safety.

Passing sight distance is measured from a 3.5-foot height of eye to a 3.5 feet high object. The 3.5 feet height of object allows 0.8 feet of the top of a typical passenger car to be seen by the opposing driver.

2.8.3.1 Passing Lanes

The Traffic and Safety Bureau is responsible for conducting the study to justify the need for passing lanes.

Passing lanes are defined as added lanes provided in one or both directions of travel on a two-lane, two-way highway to improve passing opportunities. They may present a relatively low-cost improvement for traffic operations by breaking up traffic platoons and reducing delay on roadways with inadequate passing opportunities. Truck-climbing lanes are one type of passing lane used on steep grades to provide passenger cars with an opportunity to pass slow-moving trucks. The Traffic and Safety Bureau can provide additional information and criteria for the design of truck-climbing lanes.

Passing lanes other than truck-climbing lanes may be necessary on two-lane roadways where the desired level of service cannot be obtained. Passing lanes also may be determined to be necessary based on an engineering study that includes judgment, operational experience, and a capacity analysis. The use of a passing lane will be determined on a case-by-case basis. The Traffic and Safety Bureau is responsible for conducting the study to justify the need for passing lanes. For more information on passing lane guidance, see the FHWA publication *Low Cost Methods for Improving Traffic Operations on Two-Lane Roads*, Report No. FHWA-IP-87-2 *(11)*.

The FHWA publication also presents approximate adjustments which may be made to the highway capacity methodology in the *Highway Capacity Manual* to estimate the level-of-service benefits from adding passing lanes to two-way roadway facilities *(8, 11).*

As described in Section 2.8.1.4, scaling and recording sight distances on plans can also be beneficial for evaluating passing sight distances on two-lane highways. For two-lane highways, passing sight distance and stopping sight distance should be measured and recorded to allow for appropriate design decisions with the horizontal and vertical alignments. These records may be used to determine the markings of no-passing zones on two-lane highways, in accordance with criteria given in the *Manual on Uniform Traffic Control Devices (MUTCD) (12).* No-passing zones should be verified to fit field conditions.

2.8.4 Decision Sight Distance

While stopping sight distances are usually sufficient for typical drivers to navigate the roadway effectively, there are some situations when greater distances may be needed to allow drivers to make complex or sudden decisions. Decision sight distance may be considered in a location where the driver may be faced with multiple objects, pedestrians, design features, complex traffic control or complex surrounding land use, unique topographic conditions, and signage for multiple destinations. In these situations, drivers may need additional time and distance to react and make appropriate decisions.

Decision sight distance is the distance required for a driver to detect information that is difficult to perceive, to recognize the condition or its potential threat, to select an appropriate speed and path, and to initiate and complete complex maneuvers *(2)*. Decision sight distance provides drivers with additional length to maneuver their vehicles, compared to stopping sight distance. Exhibit 2-12 provides decision sight distances for each avoidance maneuver at various design speeds.

**Exhibit 2-12
Decision Sight
Distance**

Design Speed (V) (mph)	Decision Sight Distances (ft) Avoidance Maneuver				
	A	B	C	D	E
30	220	490	450	535	620
35	275	590	525	625	720
40	330	690	600	715	825
45	395	800	675	800	930
50	465	910	750	890	1030
55	535	1030	865	980	1135
60	610	1150	990	1125	1280
65	695	1275	1050	1220	1365
70	780	1410	1105	1275	1445
75	875	1545	1180	1365	1545
80	970	1685	1260	1455	1650

Avoidance Maneuver A: Stop on rural road (t = 3.0 s)
Avoidance Maneuver B: Stop on urban road (t = 9.1 s)
Avoidance Maneuver C: Speed/path/direction change on rural road (t varies between 10.2 and 11.2 s)
Avoidance Maneuver D: Speed/path/direction change on suburban road (t varies between 12.1 and 12.9 s)
Avoidance Maneuver E: Speed/path/direction change on urban road (t varies between 14.0 and 14.5 s)

Drivers performing evasive maneuvers may involve less risk and be preferable to stopping.

Drivers performing evasive maneuvers may involve less risk and be preferable to stopping. For the avoidance maneuvers shown in Exhibit 2-12, the pre-maneuver time (t) is greater than the braking reaction time for stopping sight distance to allow the driver additional time to detect and recognize the roadway or traffic situation, identify alternative maneuvers and initiate a response at critical locations on the roadway. The decision sight distance is dependent on the area type, such as rural or urban, and the type of maneuvers required to negotiate the given situation.

2.9 DESIGN EXCEPTIONS

The *RDM* presents numerous criteria on road design elements for application on individual road design projects. In general, the design team is responsible for making every reasonable effort to meet these criteria in the project design. However, this will not always be practical or appropriate. In addition, the performance-based design approach will guide the design team to take the project context and the intended project outcome into account when establishing the design controls and associated design criteria on a project-by-project basis. The design decisions can be documented through design exceptions. This section discusses MDT's procedures for identifying, justifying and processing exceptions to the geometric design criteria in the *RDM*.

Design exceptions are an effective way to document design decisions that occur throughout a project to meet desired outcomes and serve various users.

Design exception processes represent a means for the design team to implement design features that do not fall within the designated design criteria established by MDT. Historically, design exceptions yielded projects that took the form of Resurfacing, Restoration, and Rehabilitation (3R) projects, as states began to face the challenges of redesigning existing roadway facilities within an environment of increasing constraints. In essence, it is a form of documentation that shows the analysis and engineering judgment performed to design a roadway to fit the surrounding environment and local context.

As roadway networks become more built-out and the surrounding land uses make certain roadway improvements impractical, design exceptions will become increasingly embraced as a process with which to implement customized and flexible designs to better meet the needs of a constrained environment.

2.9.1 Design Elements

Information regarding the design elements can be found in the relevant chapters of the *RDM*, and the geometric design criteria for MDT design projects are summarized in the *MDT Geometric Design Standards (1)*.

The following describes the MDT standards for which design exceptions are required. The *Guidelines for Nomination of Pavement Projects (4)* provides additional information for design exceptions related to various types of projects.

Design exception requirements vary based on project work type; see the *Guidelines for Nomination of Pavement Projects (4).*

1. **Minimum design speed.** Design speed applies to all types of roadways in rural and urban areas.
2. **Minimum lane and shoulder widths**. This applies to variation in lane and/or shoulder widths for the following:
    a. Through travel lanes
    b. Auxiliary lanes
    c. Ramps
3. **Cross slopes on travel lanes**. This applies to travel lanes (through lanes, as well as auxiliary lanes) only, and does not apply to shoulders. The appropriate cross slope must be used, as defined by MDT criteria for the given surfacing type and whether the section is curbed or not.
4. **Side slopes**. This applies to all side slopes, including surfacing inslopes, as well as cut/fill slopes. If the proposed slope is steeper than the

Non-preferred ditch section includes narrowing, steepening, or creating a non-traversable ditch.

maximum specified by MDT criteria, a design exception is required. Additionally, MDT includes flat-bottom ditches in rural cut sections. While variations to the width and/or slope of this flat-bottom ditch do not specifically require a design exception, any modification that results in a non-preferred ditch section may require a design exception.

5. **Horizontal alignment elements**. This applies to the following elements of a horizontal alignment:
    a. Minimum radii. If the proposed curve radius is less than the minimum specified by MDT criteria, a design exception is required. This also applies to deflection angles without curves that exceed MDT criteria.
    b. Spiral curve selection. If a circular curve is proposed where a spiral curve is required per MDT criteria, a design exception is required.
    c. Minimum stopping sight distance. The sight line through the middle ordinate is typically the controlling criteria for sight distance at horizontal curves, particularly when the inside of the curve is in a cut section. If the stopping sight distance provided by the horizontal curve is less than the minimum specified by MDT criteria, a design exception is required.
6. **Superelevation rates.** Any variation from the appropriate superelevation rate for the proposed curve radius, as defined by MDT criteria, requires a design exception.
7. **Vertical alignment elements.** This applies to the following elements of a vertical alignment:
    a. Stopping sight distance. If the stopping sight distance provided by a crest or sag vertical curve is less than the minimum specified by MDT criteria, a design exception is required. Sight distance provided on sag vertical curves is based on headlight illumination in all cases, and based on line of sight when checking overhead sight obstructions.
    b. Grades. A design exception is required for grades that exceed MDT maximum grade criteria. If a proposed grade is flatter than the minimum specified by MDT criteria, a design exception is not needed, though drainage should be a major design consideration in this case.
8. **Vertical clearances**. Any proposed vertical clearance that does not meet minimum MDT criteria requires a design exception.
9. **Roadside clear zones.** This applies to obstructions that lie within the clear zone. An obstruction is anything harmful to an errant vehicle, such as, but not limited to, bridge piers, critical side slopes, non-preferred ditch sections, non-traversable culvert ends, sign bridges, or any body of water of sufficient depth. If the proposed roadway clear zone does not meet the width specified by MDT criteria, a design exception is required.
10. **Intersection sight distance.** All intersections, including private, public, and farm field approaches that do not meet the necessary intersection sight distance, as identified in Section 2.8.2, require a design exception.

11. **Structural capacity.** Any structures that do not meet minimum structural capacity, as identified in the *MDT Bridge Manual*, require a design exception.

2.9.2 Considerations

Design exceptions should be developed by considering geometric design, operations, and safety for the project segment, consistent with the corridor goals. Mitigating features and countermeasures should be considered in the analysis. The objective is to produce a design that is geometrically feasible, operates effectively, and provides a safe environment for various modes of travel.

2.9.2.1 Design

The geometric design of a roadway is limited by environmental constraints, including natural terrain and availability of right-of-way. A design exception may be submitted with the objective of preventing unnecessary changes to the local environment or to accommodate inflexible geographic constraints.

2.9.2.2 Operations

Roadways should be designed to accommodate existing and future demands of various modes of travel, including motor vehicles, pedestrians, bicyclists, and heavy vehicles. An operational analysis should show that the design exception will accommodate various users and enable the roadway to operate effectively. The *Highway Capacity Manual (HCM)* provides methodologies to analyze the operational needs for various users *(8)*.

2.9.2.3 Safety

The design exception should maintain or improve the safety conditions for various roadway users. In addition to the standard safety analyses using historical crash data, the *Highway Safety Manual (HSM)* can offer additional insights to improve roadway safety *(13)*.

The *HSM* provides science-based guidance for conducting roadway safety analysis. This includes conducting roadway network screening using the performance measures contained in Part B of *HSM* as well as evaluating countermeasures and potential safety effects of roadway geometry using the information in Parts C and D of the *HSM*. The information in Parts C and D are particularly useful for evaluating the potential safety performance (e.g., number and severity of crashes) for alternative roadway cross sections and alignments. In contexts where the *HSM* is applicable, the *HSM* provides a means to quantitatively evaluate safety and compare the potential tradeoffs of different design decisions *(13)*. In addition, FHWA maintains a Crash Modification Factors (CMF) Clearinghouse that provides an online, searchable database with the findings regarding the safety effects of specific design features and treatments *(14)*.

The *HSM* is not applicable to every context, and therefore the design team needs to pay close attention to when the methodologies do and do not apply. The *HSM* contains specific guidance regarding the different roadway contexts to which the information is applicable. Similarly, the information in the CMF

Clearinghouse is not universally applicable to every context and some of the information in the database should be considered preliminary results that are not suitable for application in-practice, but instead considered as an area of needed research. The CMF Clearinghouse provides a star rating for each CMF to help the design team differentiate between the CMFs sufficiently reliable to be used in practice versus those that require additional research *(14)*.

MDT's *Safety Information Management System (SIMS)* is a database and analysis system that allows users to screen the roadway network and complete reviews of specific locations using HSM tools and methodologies. In addition, MDT uses Safety Performance Functions (SPF), which reflects the relationship between traffic exposure measured in Annual Average Daily Traffic (AADT), and crash count for a unit of road section measured in crashes per mile per year. The SPF models provide an estimate of the normal or expected crash frequency and severity for a range of AADT among similar roadway facilities.

Development of the SPF lends itself well to the conceptual formulation of the Level of Service of Safety (LOSS). The concept of level of service uses quantitative measures and qualitative descriptions that characterize safety of a roadway segment in reference to its expected frequency and severity. If the level of safety predicted by the SPF will represent a normal or expected number of crashes at a specific level of AADT, then the degree of deviation from the norm can be stratified to represent specific levels of safety.

LOSS reflects how the roadway segment is performing in regard to its expected crash frequency and severity at a specific level of ADT. If a safety problem is present, LOSS will only describe its magnitude from a frequency and severity standpoint. The nature of the problem is determined through diagnostic analysis using direct diagnostics and pattern recognition techniques.

2.9.3 Process/Application

A design exception submitted to MDT will be reviewed by MDT and may also be reviewed by the Federal Highway Administration (FHWA). The submittal documentation will not differ based on the reviewing agency.

The MDT design exception process applies to all capital improvement projects under the jurisdiction of MDT, as well as improvements along MDT roadway facilities by private developers. The projects with design elements that do not comply with the MDT design standards will require a design exception submittal.

Design exceptions will be submitted to FHWA for all Projects of Division Interest (PoDI). PoDI are those projects that have an elevated risk, contain elements of higher risk, or present a meaningful opportunity for FHWA involvement to enhance the meeting of program or project objectives. Design exceptions for PoDI require FHWA approval. Design exceptions will be submitted internally to MDT for all other projects.

2.9.4 Documentation Format

The type and detail of the documentation needed to justify a design exception will be determined on a case-by-case basis depending on the type of project and type of design exception being requested. The template for documenting a design exception is available on the MDT Website at the following link:

MDT Design Exception Template

Comprehensive documentation, including design, mitigation measures, operations and safety considerations, allows the design exception reviewers to have a clear understanding of the project context and justification for the exception to the design criteria. FHWA memorandum, *Revisions to Controlling Criteria for Design and Documentation for Design Exceptions* and FHWA document, *Mitigation Strategies for Design Exceptions* provide additional information *(15, 16)*.

2.10 REFERENCES

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