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MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter Eight
BASIC DESIGN CONTROLS

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Chapter Eight
BASIC DESIGN CONTROLS

Roadway design is predicated on many basic controls which establish the overall objective of the highway facility and identify the basic purpose of the highway project. Chapter Eight presents these basic controls that impact roadway design. The Chapter includes a discussion on the functional classification system, the Federal-aid system, speed, traffic volume controls, access control, sight distance and the design exception process. The application of these items to a project will impact all elements of road design.

8.1 DEFINITIONS

8.1.1 Qualifying Words

Many qualifying words are used in road design and in this *Manual*. For consistency and uniformity in the application of various design criteria, the following definitions apply:

1. Shall, require, will, must. A mandatory condition. Designers are obligated to adhere to the criteria and applications presented in this context or to perform the evaluation indicated. For the application of geometric design criteria, this *Manual* limits the use of these words.

2. Should, recommend. An advisory condition. Designers are strongly encouraged to follow the criteria and guidance presented in this context, unless there is reasonable justification not to do so.

3. May, could, can, suggest, consider. A permissive condition. Designers are allowed to apply individual judgment and discretion to the criteria when presented in this context. The decision will be based on a case-by-case assessment.

4. Desirable, preferred. An indication that the designer should make every reasonable effort to meet the criteria and that he/she should only use a "lesser" design after due consideration of the "better" design.

5. Ideal. Indicating a standard of perfection (e.g., traffic capacity under "ideal" conditions).

6. Minimum, maximum, upper, lower (limits). Representative of generally accepted limits within the design community but not necessarily suggesting that these limits are inviolable. However, where the criteria presented in this context will not be met, the designer will in many cases need approval.

7. Practical, feasible, cost-effective, reasonable. Advising the designer that the decision to apply the design criteria should be based on a subjective analysis of the anticipated benefits and costs associated with the impacts of the decision. No formal analysis (e.g., cost-effectiveness analysis) is intended, unless otherwise stated.

8. Possible. Indicating that which can be accomplished. Because of its rather restrictive implication, this word will not be used in this *Manual* for the application of geometric design criteria.

9. Significant, major. Indicating that the consequences from a given action are obvious to most observers and, in many cases, can be readily measured.

10. Insignificant, minor. Indicating that the consequences from a given action are relatively small and not an important factor in the decision-making for geometric design.

11. Standard. Indicating a design value which cannot be violated without severe consequences. This suggestion is generally inconsistent with geometric design criteria. Therefore, "standard" will not be used in this *Manual* to apply to geometric design criteria.

12. Guideline. Indicating a design value which establishes an approximate threshold which should be met if considered practical.

13. Criteria. A term typically used to apply to design values, usually with no suggestion on the criticality of the design value. Because of its basically neutral implication, this *Manual* frequently uses "criteria" to refer to the design values presented.

14. Typical. Indicating a design practice which is most often used in application and which is likely to be the "best" treatment at a given site.

15. Target. If practical, criteria the designer should be striving to meet. However, not meeting these criteria will typically not require a justification.

16. Acceptable. Design criteria which do not meet desirable values, but yet is considered to be reasonable and safe for design purposes.

17. Policy. Indicating MDT practice which the Department generally expects the designer to follow, unless otherwise justified.

8.1.2 Acronyms

The following acronyms may be used in this *Manual*:

1. AASHTO. American Association of State Highway and Transportation Officials.
2. FHWA. Federal Highway Administration.
3. HCM. *Highway Capacity Manual*.
4. ITE. Institute of Transportation Engineers.
5. ISTEA. Intermodal Surface Transportation Efficiency Act of 1991.
6. MUTCD. *Manual on Uniform Traffic Control Devices*.
7. NCHRP. National Cooperative Highway Research Program.
8. NHS. National Highway System.
9. STP. Surface Transportation Program.
10. TEA-21. Transportation Equity Act for the 21st Century.
11. TRB. Transportation Research Board.
12. USDOT. United States Department of Transportation.

8.1.3 Project Scope of Work

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

1. New Construction. New construction is defined as horizontal and vertical alignment on 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% of the project length;

    b. reconstruction of the existing horizontal and vertical alignment for more than 25% of the project length; and/or

    c. the addition of through travel lanes.

3. Overlay and Widening. Overlay and widening is defined as work primarily intended to extend the service life of the existing facility by making cost-effective

improvements to upgrade the highway. It may include full-depth pavement reconstruction for up to 50% of the project length and may include horizontal and vertical alignment revisions for up to 25% of the project length. In addition, overlay and widening projects may include any number of the following spot improvements:

a. lane and shoulder widening;

b. converting an existing median to a two-way, left-turn lane (TWLTL);

c. adding a TWLTL;

d. adding a truck-climbing lane;

e. converting an uncurbed urban street into a curbed street;

f. geometric and/or roadside safety improvements;

g. drainage improvements;

h. intersection improvements (e.g., adding turn lanes, flattening turning radii, corner sight distance improvements, etc.).

i. flattening side slopes;

j. revising the location, spacing or design of existing approaches along the mainline.;

k. adding or removing parking lanes; and

l. adding sidewalks;

4. Pavement Projects. This category of projects encompasses a wide variety of surfacing treatments from preventative maintenance to major rehabilitation.

Preventative maintenance includes such treatments as crack seal, seal and cover, milling $\leq$ 0.20’, and overlays $\leq$ 0.20’ (the overlay thickness can be increased to 0.22’ if an isolation lift is need to address heavy crack sealing in the existing surfacing). Rehabilitation includes treatments ranging from designed overlays to Cement-Treated Pulverized Base. The In addition to surfacing, the following items must be considered in the development of pavement projects:

a. Environmental document
b. Guardrail treatment

c. Safety
d. Geometrics
e. Capacity

The level of involvement with these items depends on the scope of the surfacing treatment. Geometrics and capacity are only considered for rehabilitation projects. For more complete information on pavement projects refer to the Joint Agreement between FHWA and MDT titled *Guidelines for Nomination and Development of Pavement Projects*.

8.1.4 Route Segment Plan

The purpose of the Route Segment Plan is to identify and define a consistent pavement width, which will be used when reconstruction or major widening are accomplished on a portion of the route segment. The Route Segment Plan is not intended to prescribe standards for overlay and minor widening projects. It is not intended to prescribe standards for roadway cross sections or construction elements other than the pavement width itself.

8.2 HIGHWAY SYSTEMS

8.2.1 Classification Systems

The *MDT Geometric Design Standards and Route Segment Plans* were approved by the Montana Transportation Commission in 1992. They have been adopted as the design standards for the highway system. These standards correlate to the highway funding categories. Figure 8.2A coordinates the funding classification to the functional classification system. Figure 12-1 of the *Road Design Manual* provides the functional classification of State highways in Montana.

Geometric Design Standards (Funding Classification)	Functional Classification System
NH Interstate	Principal Arterial (Freeways)
NH Non-Interstate	Principal Arterial
STP Primary	Minor Arterial
STP Secondary	Major Collector
Urban	Urban

FUNDING CLASSIFICATION VERSUS FUNCTIONAL CLASSIFICATION

Figure 8.2A

8.2.2 Functional Classification System

The functional classification concept is one of the most important determining factors in highway design. In this concept, highways are grouped by the character of service they provide. Functional classification recognizes that the public highway network in Montana serves two basic and often conflicting functions — travel mobility and access to property. Each highway or street will provide varying levels of access and mobility, depending upon its intended service. In the functional classification scheme, the overall objective is that the highway system, when viewed in its entirety, will yield an optimum balance between its access and mobility purposes. If this objective is achieved, the benefits to the traveling public will be maximized.

The functional classification system provides the guidelines for determining the geometric design of individual highways and streets. These guidelines equal or exceed the geometric design criteria that would be used based on the highway funding category. Once the function of the highway facility is defined, the designer can select an appropriate design speed, roadway width, roadside safety elements, amenities and other design values. The *Montana Road Design Manual* is based upon this systematic concept to determining geometric design.

The Rail, Transit and Planning Division has functionally classified all public roads and streets within Montana. For road design, it is necessary to identify the predicted functional class of the road or street for the selected design year (e.g., 20 years beyond the project completion date). The Rail, Transit and Planning Division will provide this information to the designer.

8.2.2.1 Arterials

Arterial highways are characterized by a capacity to quickly move relatively large volumes of traffic and an often restricted function to serve abutting properties. The arterial system typically provides for high travel speeds and the longest 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 provide the highest traffic volumes and the greatest trip lengths. Principal arterials can be further subdivided into the following classifications:

    a. Freeways. The freeway, which includes Interstate highways, is 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.

    b. (Other) Principal Arterials. These facilities may be 2 or more lanes with or without a median. In many cases, the level of geometric design is equivalent to that of freeways (e.g., 3.6 m lane widths are required on all principal arterials). Unless otherwise noted, all principal arterials will be designed according to principal arterial criteria, whether or not the facility is on the NHS.

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, but they provide more access to property.

8.2.2.2 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 intra-regional needs and provide connections to the arterial system. All cities and towns within a region will be connected. 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.

8.2.2.3 Local Roads and Streets

All public roads and streets not classified as 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.

8.2.3 Federal-Aid System

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

8.2.3.1 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 facilities which meet the requirements of one of the subsystems within the NHS.

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

8.2.3.2 Surface Transportation Program

The Surface Transportation Program (STP) 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 roads. In addition, bridge projects using STP funds are not restricted to Federal-aid roads 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 facilities not considered to have significant national importance with a minimum of Federal requirements for funding eligibility.

8.2.3.3 Bridge Replacement and Rehabilitation Program

Because of the nationwide emphasis on bridges, 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.

8.2.4 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 Network includes all Interstate highways and significant portions of the former Federal-aid primary system (before the 1991 ISTEA) 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 and, for household goods carriers, to points of loading and unloading.

In Montana, the National Network includes the Interstate highway system and all of the (former) Federal-aid primary system. The designer should note that the WB-67 (WB-20) is allowed on all public roads in the State. The WB-100 (WB-30) (triple semitrailer) is only allowed on the Interstate system and for reasonable access to the system. MDT has defined "reasonable access" as 1 mile (1.5 km) from any interchange.

8.2.5 Frontage Roads

Although frontage roads are not on the Federal-Aid system, they are the State's responsibility. They are eligible for STP funds. They are also eligible for IM or NH funds if they are adjacent to an Interstate or NH route and functional 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 a backup system in case of freeway disruption.

8.3 SPEED

8.3.1 Definitions

1. Design Speed. Design speed is a selected speed used to determine the various geometric design features of the roadway. It should be logical 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 is not the speed at which a vehicle will lose control. Section 8.3.2 discusses the selection of design speed in general. Chapter Twelve presents specific design speed criteria for various conditions.

2. Low Speed. For geometric design purposes, low speed is defined as 45 mph (70 km/h) or less.

3. High Speed. For geometric design purposes, high speed is defined as greater than 45 mph (70 km/h).

4. Average Running Speed. Running speed is the average speed of a vehicle over a specified section of highway. It is equal to the distance traveled divided by the running time (the time the vehicle is in motion). The average running speed is the distance summation for all vehicles divided by the running time summation for all vehicles.

5. Average Travel Speed. Average travel speed is the distance summation for all vehicles divided by the total time summation for all vehicles, including stopped delays. (Note: Average running speed only includes the time the vehicle is in motion. Therefore, on uninterrupted flow facilities which are not congested, average running speed and average travel speed are equal.)

6. Operating Speed. Operating speed, as defined by AASHTO, is the highest overall speed at which a driver can safely travel a given highway under favorable weather conditions and prevailing traffic conditions while at no time exceeding the design speed. Therefore, for low-volume conditions, operating speed equals design speed. The designer should note that the term "operating speed" has little or no usage in geometric design.

7. 85th-Percentile Speed. The 85th-percentile speed is the speed below which 85 percent of vehicles travel on a given highway. The most common application of the value is its use as one of the factors, and usually the most important factor,

for determining the posted, legal speed limit of a highway section. 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.

8. Pace. Pace is defined as that 10 mph (15 km/h) range of speeds in which the highest number of observations are recorded.

9. Posted Speed Limit. The posted speed limit is based on a traffic engineering study considering:

    a. the 85th-percentile speed;

    b. pace, the 10 mph (15 km/h) range of speeds in which the highest number observations are recorded;

    c. speed profile;

    d. *Montana Code*;

    e. type and density of roadside development;

    f. functional classification and type of area;

    g. adjacent sections;

    h. the crash experience during at least the previous year;

    i. road surface characteristics, shoulder condition, grade, alignment and sight distance; and

    j. parking practices and pedestrian activity.

For additional guidance on selecting posted speed limits, see Chapter Forty of the *Montana Traffic Engineering Manual*.

8.3.2 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 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. 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 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 designer should consider the following when selecting a design speed:

   a. avoid major changes in the design speed throughout the project limits;

   b. where necessary, provide transitional design speeds between sections adjacent to the project;

   c. do not place minimum radius horizontal curves at the end of long tangents; and

   d. consider the expected posted speed in the selection of the design speed.

   e. balance the horizontal and vertical alignment (e.g. curvilinear alignment used with rolling grades).

   f. Evaluate the 85^{th} percentile speed

For geometric design application, the relationship between these design elements and the selected design speed reflects general cost-effective considerations. 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. See Chapter Twelve for specific design speed criteria.

8.4 TRAFFIC VOLUME CONTROLS

8.4.1 Definitions

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. The time period most often used for analysis is 15 minutes. "Capacity" corresponds to the upper boundary of LOS E.

4. Delay. The primary performance measure on interrupted flow facilities, especially at intersections. For intersections, average delay is measured and expressed in seconds per vehicle.

5. Density. The number of passenger car equivalents (PCE) occupying a given length of lane. It is usually expressed as vehicles per kilometer per lane.

6. Design Hourly Volume (DHV). The one-hour vehicular volume in both directions of travel in the design year selected for highway design. The DHV is typically the 30th highest hourly volume during the design year. Note that, for capacity analyses, the DHV is typically converted to an hourly flow rate based on the maximum 15 minute flow rate during the DHV.

7. Directional Design Hourly Volume (DDHV). The highest of two directional volumes which combine to form the DHV.

8. Directional Distribution (D). The distribution, by percent, of the traffic in each direction of travel during the DHV, ADT and/or AADT.

9. Equivalent Single-Axle Loads (ESAL's). The summation of equivalent 8165 kg single-axle loads used to convert mixed traffic to design traffic for the design period.

10. Heavy-Vehicle Adjustment Factor. A mix of vehicle types must be adjusted to an equivalent flow rate expressed in terms of passenger cars per hour per lane (see

Passenger Car Equivalent). The adjustment is made using the heavy-vehicle adjustment factor. The adjustment factor is based on the proportion of trucks, buses, and RVs in the traffic stream and on the length and severity of the upgrade or downgrade. Trucks and buses are treated identically. RVs are treated separately from trucks and buses. Data on heavy vehicles are compiled and reported by the MDT Data and Statistics Bureau.

11. Level of Service (LOS). A qualitative concept which has been developed to characterize acceptable degrees of congestion as perceived by motorists. In the *Highway Capacity Manual*, the qualitative descriptions of each level of service (A through F) have been converted into quantitative measures for the capacity analysis for each highway element, including:

    a. freeway mainline;
    b. freeway mainline/ramp junctions;
    c. freeway weaving areas;
    d. interchange ramps;
    e. 2-lane, 2-way rural highways;
    f. multi-lane rural highways;
    g. signalized intersections;
    h. unsignalized intersections; and
    i. urban and suburban arterials.

    Chapter Twelve presents guidelines for selecting the level of service for capacity analyses in road design.

12. Passenger Car Equivalent (PCE). Compared to passenger cars, heavy vehicles (trucks, buses, RVs) are slower moving and greater in length and create longer and more frequent gaps of excessive lengths in the traffic stream. PCE represents an equivalent number of passenger cars that would use the same amount of capacity as a heavy vehicle under prevailing roadway and traffic conditions and is determined by applying an adjustment factor in the analysis (see Heavy-Vehicle Adjustment Factor). This allows capacity to be estimated based on a consistent measure of flow in terms of passenger cars per hour per lane.

13. Peak-Hour Factor (PHF). A ratio of the volume occurring during the peak hour to the maximum rate of flow during a given time period within the peak hour (typically, 15 minutes). PHF may be expressed as follows:

$$\text{PHF} = \frac{\text{Peak Hour Volume}}{4\ (\text{Peak 15-minute Volume})}$$

14. Rate of Flow. The equivalent hourly rate at which vehicles pass over a given point or section on a lane or roadway on which the volume is collected over a time interval less than one hour.

15. Service Flow Rate. The maximum hourly vehicular volume which can pass through a highway element at the selected level of service.

8.4.2 Design Year Selection

8.4.2.1 Traffic Volumes

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

1. New Construction/Reconstruction Projects. The roadway design will be based on a 20 year projection of traffic volume. Life-cycle analysis for pavement types may exceed this period. For roads on the secondary system the selection of certain geometric features is based on the current traffic volumes.

2. Overlay and Widening Projects. When capacity and level of service are assessed, the analysis will be based on a 20 year projection of traffic. However, it is acceptable to base the design year on the design analysis period used for pavement design, with 8 years as a minimum design forecast year.

The design year is measured from the expected construction completion date. Future traffic volumes on State highways are provided by the MDT Data and Statistics Bureau.

8.4.2.2 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 50 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.

2. Right-of-Way/Grading. The designer should consider potential future right-of-way needs for a year considerably beyond that used for roadway design.

3. 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 facility 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.

4. Pavement Design. The pavement structure is designed to withstand the vehicular loads it will sustain during the design analysis period without falling below a selected terminal pavement serviceability. 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. They are not designed for a specific vehicular loading or analysis period.

8.4.3 Design Hourly Volume Selection

For most geometric design elements which are impacted by traffic volumes, the peaking characteristics are most significant. The highway facility should be able to accommodate the design hourly volume (adjusted for the peak-hour factor) 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.

The 30^{th} highest hourly volume in the selected design year will typically be used to determine the DHV for design purposes.

For design analysis of intersections, the DHV of the intersecting roadways should be compared with the existing 30^{th} highest hourly volume. An expected percent growth should be identified. If a modeled DHV is not available, existing traffic volumes should be analyzed with respect to the ability to absorb the expected growth.

8.4.4 Capacity Analyses

8.4.4.1 Objective

Design the highway mainline or intersection to accommodate the selected design hourly volume (DHV) at the selected level of service (LOS). This may involve adjusting the various highway factors which affect capacity until a design is found that will accommodate the DHV. The detailed calculations, factors and methodologies are presented in the *Highway Capacity Manual* (HCM). During the analysis, the design service volume (or flow rate) of the facility is calculated. Capacity assumes a LOS E; the design service volume is the maximum volume of traffic that a highway of designed dimensions is able to serve without the degree of congestion falling below a preselected level. This is always higher than LOS E.

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. These measures are presented in Figure 8.4A. 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 highway mainline:

1. Select the design year.

2. Determine the DHV.

3. Select the target level of service, see Figure 8.4B.

4. Identify and document the proposed highway 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:

    a. determine the maximum flow rate under ideal conditions;

    b. identify the adjustments for prevailing roadway, traffic and control conditions; and

    c. calculate the service flow rate for the selected level of service.

6. Compare the calculated service flow rate to the DHV. If the DHV is less than or equal to the service flow rate, the proposed design will meet the objectives of the capacity analysis. If the DHV exceeds the service flow rate, the proposed design will be inadequate. The various elements in the capacity analysis will help the designer assess where excess or deficient design parameters exist.

The default values in the HCM will apply unless reliable local data is available (e.g., for the peak-hour factor). Use the criteria presented in Figure 8.4B when selecting the level of service for the facility.

8.4.4.2 Responsibility

The MDT Traffic Engineering Section is responsible for performing all capacity analyses required for the project.

TYPE OF FACILITY	MEASURE OF EFFECTIVENESS
Freeways	
Basic freeway segments	Density (pce/km/ln)
Weaving areas	Density (pce/km/ln)
Ramp junctions	Flow rates (pce/h)
Multilane highways	Density (pce/km/ln) Free-flow speed (km/h)
Two-lane highways	Time delay (%)
Signalized Intersections	Average stopped delay (s/veh)
Unsignalized intersections	Average total delay (s/veh)
Arterials	Average travel speed (km/h)

MEASURES OF EFFECTIVENESS FOR LEVEL OF SERVICE

Figure 8.4A

TYPE OF FACILITY	LEVEL-OF-SERVICE CRITERIA	
Freeways (NHS — Interstate)	Rural: B	Urban: B
Principal Arterials (NHS — Non-Interstate)	Level/Rolling: B	Mountainous: C
Minor Arterials (Non-NHS — Primary)	Level/Rolling: B	Mountainous: C
Rural Collector Roads (Non-NHS — Secondary)	Desirable: B	Minimum: C
Urban Principle Arterials (NHS — Non-Interstate) 2-Lane and Multi-Lane	Desirable: B	Minimum: C
Urban Minor Arterials (Non-NHS) 2-Lane and Multi-Lane	Desirable: B	Minimum: C
Urban Collector Streets (Non-NHS)	Desirable: C	Minimum: D

LEVEL-OF-SERVICE CRITERIA

Figure 8.4B

8.5 ACCESS CONTROL (Definitions)

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 highway. 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).

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 the Department on the State highway system (see the *MDT Approach Standards for Montana Highways*) and by the local jurisdiction on other facilities to determine where private interests may have access to and from the public road system.

8.6 SIGHT DISTANCE

8.6.1 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. To calculate SSD on level grade, the following formula is used:

SSD = Brake Reaction Distance + Braking Distance, (Figure 8.6A)

US Customary

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

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

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

Metric

$$SSD_{Level} = 0.278Vt + 0.039\left(\frac{V^2}{a}\right)$$

$$SSD_{Downgrades} = 0.278Vt + \frac{V^2}{254\left(\left(\frac{a}{9.8}\right) - G\right)}$$

$$SSD_{Upgrades} = 0.278Vt + \frac{V^2}{254\left(\left(\frac{a}{9.8}\right) + G\right)}$$

where: SSD = stopping sight distance, ft. (m)

V = Design Speed
t = brake reaction time, 2.5 s
a = Deceleration Rate ft/s^2 , 11.2 ft/s^2 (a=3.4m/s^2)
G = Gradient ±

Figure 8.6A provides stopping sight distances for passenger cars on level grade. The designer should always attempt to meet the desirable values. Only use the minimum values where the desirable values are impractical due to natural features or existing development. When applying the SSD values, the height of eye is assumed to be 3.5 ft, (1.080 m) and the height of object 2.0 ft. (0.600 m).

Design Speed (V) (mph)	Brake Reaction Distance 1.47Vt (ft)	Braking Dist $1.075(V^2/a)$ (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 seconds
Deceleration Rate (a)= 11.2 ft/s^2

Stopping Sight Distances
(Level)

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 seconds
Deceleration Rate (a)= 11.2 ft/s^2

STOPPING SIGHT DISTANCE
(Level Grades)
Figure 8.6A (**US Customary)**

Design Speed (V) (kph)	Brake Reaction Distance 0.278Vt (m)	Braking Dist $0.039(V^2/a)$ (m)	Calculated SSD (m)	SSD Rounded for design (m)
20	13.9	4.6	18.5	20
30	20.9	10.3	31.2	35
40	27.8	18.4	46.2	50
50	34.8	28.7	63.5	65
60	41.7	41.3	83.0	85
70	48.7	56.2	104.9	105
80	55.6	73.4	129.0	130
90	62.6	92.9	155.5	160
100	69.5	114.7	184.2	185
110	76.5	138.8	215.3	220
120	83.4	165.2	248.6	250
130	90.4	193.8	284.2	285

Brake Reaction Time (t)= 2.5 seconds
Deceleration Rate (a)= 3.4 m/s^2

Stopping Sight Distances
(Level)

Design Speed (V) (kph)	Stopping sight distances (m)					
	Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%
20	20	20	20	19	18	18
30	32	35	35	31	30	29
40	50	50	53	45	44	43
50	66	70	74	61	59	58
60	87	92	97	80	77	75
70	110	116	124	100	97	93
80	136	144	154	123	118	114
90	164	174	187	140	141	136
100	194	207	223	174	167	160
110	227	243	262	203	194	186
120	263	281	304	234	223	214
130	302	323	350	267	254	243

Brake Reaction Time (t)= 2.5 seconds
Deceleration Rate (a)= 3.4 m/s^2

Stopping Sight Distances
(Grades)
Figure 8.6A (Metric)

8.6.2 Passing Sight Distance

8.6.2.1 Theoretical Discussion

Passing sight distance considerations are limited to 2-lane, 2-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 2-lane highways is determined from the sum of four distances as illustrated in Figure 8.6B. Figure 8.6C and the following provides the basic assumptions used to develop passing sight distance values for design:

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, and the passing vehicle is accelerating at the rate shown in Figure 8.6C.

The average speed of the passing vehicle is assumed to be 15 km/h greater than the overtaken vehicle. Use Equation 8.6-2 to determine d_1:

US Customary

$$d_1 = 1.47 t_1 \left(v - m + \frac{a t_1}{2} \right)$$

Metric

$$d_1 = \frac{t_1}{3.6} \left(v - m + \frac{a t_1}{2} \right)$$

(Equation 8.6-2)

where:
- t_1 = time of initial maneuver, s
- a = average acceleration, mph/s (km/h/s)
- v = average speed of passing vehicle, mph (km/h)
- m = difference in speed of passed vehicle and passing vehicle, mph (km/h)

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. Assumed times for when the passing vehicle occupies the left lane are shown in Figure 8.6C. Use Equation 8.6-3 to determine d_2:

US Customary

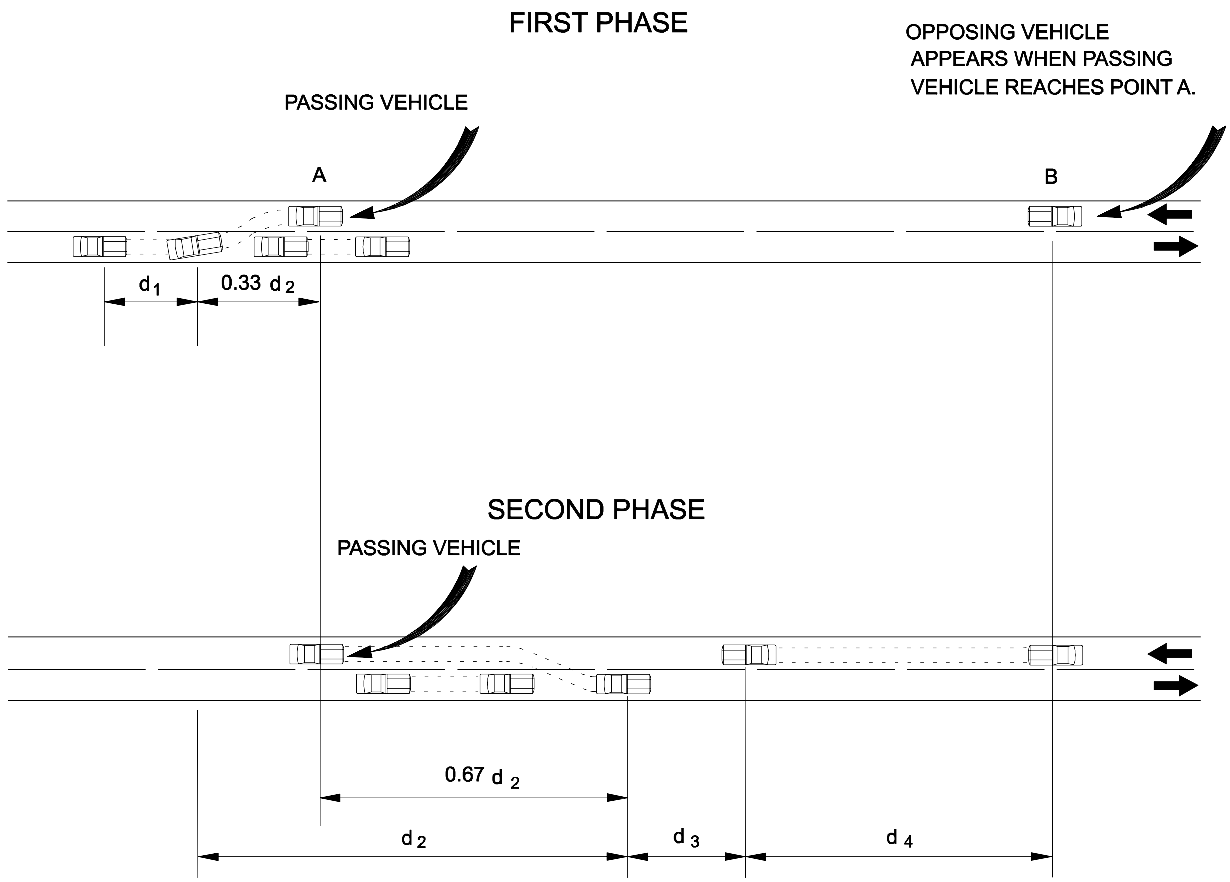
$$d_2 = 1.47 v t_2$$

Metric

$$d_2 = \frac{v t_2}{3.6}$$

(Equation 8.6-3)

where:
- t_2 = time passing vehicle occupies the left lane, s
- v = average speed of passing vehicle, mph (km/h)



ELEMENTS OF PASSING DISTANCE
(2-Lane Highways)

Figure 8.6B

US Customary

Design Speed (mph)	Assumed Speeds		Minimum PSD for Design (ft)
	Passed Vehicle (mph)	Passing Vehicle (mph)	
30	26	36	1090
35	30	40	1280
40	34	44	1470
45	37	47	1625
50	41	51	1835
55	44	54	1885
60	47	57	2135
65	50	60	2285
70	54	64	2480
75	56	66	2580

Metric

Design Speed (km/h)	Assumed Speeds		Minimum PSD for Design (m)
	Passed Vehicle (km/h)	Passing Vehicle (km/h)	
50	44	59	350
60	51	66	400
70	59	74	490
80	65	80	550
90	73	88	615
100	79	94	675
110	85	100	750

MINIMUM PASSING SIGHT DISTANCE
(2-Lane Highways)
Figure 8.6C

3. Clearance Distance (d_3). This is the distance between the passing vehicle at the end of its maneuver and the opposing vehicle. Based on various studies, this clearance distance at the end of the passing maneuver is assumed to be between 100' (37 m) and 250' (75 m).

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. As shown in Figure 8.6B, 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. Therefore, d_4 = 0.67 d_2.

8.6.2.2 Application

Figure 8.6C provides the minimum passing sight distance for design on 2-lane, 2-way highways. These distances allow the passing vehicle to safely complete the passing maneuver. These values should not be confused with the values presented in the *MUTCD* for the placement of no-passing zone stripes, which are based on different operational assumptions (i.e., distance for the passing vehicle to abort the passing maneuver). The designer should also realize that the highway capacity adjustment in the *Highway Capacity Manual* for 2-lane, 2-way highways is based on the *MUTCD* criteria for marking no-passing zones. It is not based on the percent of passing sight distance from the AASHTO *A Policy on Geometric Design of Highways and Streets* and shown in Figure 8.6C.

On rural reconstruction projects, the designer should attempt to provide passing sight distance over as much of the highway length as practical. It will generally not be cost effective, however, to make significant 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' (1.08 m) height of eye to a 3.5' (1.08 m) height of object. The 3.5' (1.08 m) height of object allows 0.8' (225 mm) of a typical passenger car to be seen by the opposing driver:

8.6.3 Passing Lanes

Passing lanes are defined as a short added lane provided in one or both directions of travel on a 2-lane, 2-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 facilities 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 criteria for and design of truck-climbing lanes are discussed in Chapters Twenty-six and Thirty of the *Traffic Engineering Manual*.

Passing lanes other than truck-climbing lanes may be necessary on 2-lane facilities 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 Engineering Section 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. The Report discusses the following for passing lanes:

1. their location and configuration,
2. their length and spacing,
3. geometrics,
4. signing and pavement marking, and
5. operational and safety effectiveness.

The Report also presents approximate adjustments which may be made to the highway capacity methodology in Chapter Eight of the *Highway Capacity Manual* to estimate the level-of-service benefits from adding passing lanes to 2-way facilities.

8.7 FHWA INVOLVEMENT

FHWA will be involved in project development as follows:

1. Preliminary Field Review. FHWA should be invited to preliminary field reviews. The Highways Engineer, or designee, will sign all reports regardless of the system except where the Bridge Bureau or the Traffic & Safety Bureau is the lead. FHWA will receive copies of all Preliminary Field Review reports.

2. Scope of Work Reports. FHWA will be included in the distribution for concurrence and recommendations on all Scope of Work reports for projects on the National Highway System (NHS) that meet the following criteria:

   a. All projects on the non-Interstate NHS costing $3 million or more

   b. All reconstruction projects on the Interstate system costing $1 million or more, and all pavement preservation and rehabilitation projects on the Interstate system costing $3 million or more.

   FHWA will receive copies of the Scope of Work reports for lower cost projects on the NHS and all projects in the Surface Transportation Program.

3. Design Exceptions. FHWA will sign design exceptions for all Federal-aid projects on the NHS that meet the criteria in 2. a. & b. MDT will approve design exceptions internally on other projects with a copy sent to FHWA for informational purposes.

4. Plan Reviews. FHWA will receive all NHS road plans, estimates and special provisions, as well as any other plans with unusual or innovative features for Plan-in-Hands. For STP projects, FHWA will receive a copy of the cover letter indicating the date and location of the Plan-in-Hand.

5. Plan-in-Hand Reports. The Preconstruction Engineer, or designee, will sign all Plan-in-Hand reports except where the Bridge Bureau is the lead. FHWA will only receive Plan-in-Hand reports for NHS projects.

6. PS&E Approval. FHWA will give formal PS&E approval for all NHS projects. PS&E approval for STP projects will be done internally.

7. Concurrence in Award. FHWA will concur in award on all NHS contracts.

8.8 ADHERENCE TO GEOMETRIC DESIGN CRITERIA

The *Montana Road Design Manual* presents numerous criteria on road design for application on individual road design projects. In general, the designer is responsible for making every reasonable effort to meet these criteria in the project design. However, this will not always be practical. This Section discusses the Department's procedures for identifying, justifying and processing exceptions to the geometric design criteria in the *Road Design Manual*.

8.8.1 <u>Department Intent</u>

The general intent of the Montana Department of Transportation is that all road design criteria in this *Manual* should be met and, wherever practical, the proposed design should exceed the minimum criteria. Where a range of values is presented, the designer should make every reasonable effort to provide a design which equals or exceeds the upper value. This is intended to ensure that the Department will provide a highway system that meets the transportation needs of the State and provides a reasonable level of safety, comfort and convenience for the traveling public. However, recognizing that this will not always be practical, the Department has established a process to identify, evaluate and approve exceptions to geometric design criteria.

8.8.2 <u>Design Exceptions</u>

8.8.2.1 General

This Section presents those design elements which require a design exception when the proposed design does not meet the applicable criteria. The "controlling" design criteria are highway elements that are judged to be the most critical indicators of a highway's overall safety and serviceability.

Because the 10 km/h incremental value for design speeds does not directly equate to the 10 mph increment, situations may arise where the metric value is less than the US Customary value. FHWA has determined that designs which were acceptable under the metric system will not be considered substandard under the US Customary system if the differences are strictly the result of hard conversion. Consequently, for these situations no design exception is required.

Design exceptions are not required for substandard design elements for preventative maintenance projects. However these elements must be documented in the scope of Work Report. For major and minor rehabilitation projects design exceptions are required for specific elements under certain conditions. Refer to the *Guidelines for Nomination and Development of Pavement Projects* for more detailed information.

8.8.2.2 Design Elements

The designer must seek a MDT/FHWA design exception when the proposed design includes any of the following elements which do not meet MDT criteria:

1. design speeds;
2. horizontal alignment elements:
   a. minimum radii,
   b. warrants for spiral curves, and
   c. sight distance at curves based on desirable SSD*;
3. vertical alignment elements:
   a. crest and sag vertical curves based on desirable SSD*,
   b. maximum grades, and
   c. vertical clearances;
4. lane and shoulder widths for:
   a. through travel lanes,
   b. auxiliary lanes, and
   c. ramps;
5. bridge widths;
6. superelevation rates;
7. cross slopes on travel lanes;
8. cut and fill slopes;
9. roadside clear zones, including the adjustment for horizontal curves;
10. horizontal clearances to obstructions on curbed facilities (obstructions with 2’ (0.5 m) of curb);
11. intersection sight distances.

8.8.2.3 Design Element Documentation

The following design elements do not require design exceptions. However, they must be documented in the Scope of Work Report.

1. Superelevation transition lengths

2. Unshielded obstacles within the clear zone and shielded obstacles outside the clear zone

3. A minimum 2’ (0.6 m) offset between the face of the roadside barrier and the edge of the traveled way

4. Guardrail details (e.g. post spacing)

5. Raised medians less than 20’ (6 m) wide

8.8.3 <u>Project Application</u>

8.8.3.1 MDT

The MDT design exception process applies to all capital improvement projects under the jurisdiction of the Department with the following exceptions:

1. State and Federally-funded pavement preservation projects,

2. projects on routes where the intent is to maintain the existing level of development (black routes),

3. projects on off-system roads, and/or

4. safety projects.

For all of the projects listed above, except the State-funded pavement preservation projects, the elements that do not comply with the MDT design criteria will be described in the Scope of Work report. The discussion should provide limited documentation for the justification of the design exceptions.

8.8.3.2 FHWA

As noted in Section 8.7, requests for design exceptions will be submitted to FHWA for all projects on the NHS that meet the criteria for oversight (All projects on the non-

Interstate NHS costing $3 million or more, all reconstruction projects on the Interstate system costing $1 million or more, and all pavement preservation and rehabilitation projects on the Interstate system costing $3 million or more). The request for design exceptions will be submitted internally to MDT for all projects in the STP. The MDT criteria will be utilized by both entities in the evaluation of the design elements.

8.8.4 Documentation

The type and detail of the documentation needed to justify a design exception will be determined on a case-by-case basis. The following lists potential items which may be addressed in the documentation for a specific design exception:

1. crash data,
2. environmental impacts,
3. right-of-way impacts,
4. construction costs, and
5. serviceability impacts (e.g., traffic level of service).

8.8.5 Procedures

The following procedure will be used to process a proposed design exception:

1. Project Design Manager. The Project Design Manager will assemble the package for the design exception request. The package will be submitted to the Highways Engineer through the Road Design Engineer.

2. Highways Engineer. The Highways Engineer will review the design exception package and, if in agreement, will sign the request. This will complete the internal MDT process. In rare cases where the Highways Engineer believes necessary, the design exception request may be submitted to the Chief Engineer for action.

   If FHWA approval is needed, the Highways Engineer will submit the package to the FHWA Division Office.

3. FHWA. On applicable projects, the FHWA will review the design exception request and, if in agreement, will sign the request and return the package to the Highways Engineer.

4. Design Exception Denial. If the Highways Engineer and/or FHWA has denied the design exception request, the Project Design Manager will use the following steps:

   a. The Project Design Manager will first try to meet MDT criteria.

   b. If the MDT design criteria cannot be met, the Project Design Manager will develop alternatives and submit documentation to the Road Design Engineer.

   c. The Road Design Engineer will meet with the Highways Engineer and the Project Design Manager, discuss the issues and decide if a new design exception submittal is needed or if the issue can be resolved.