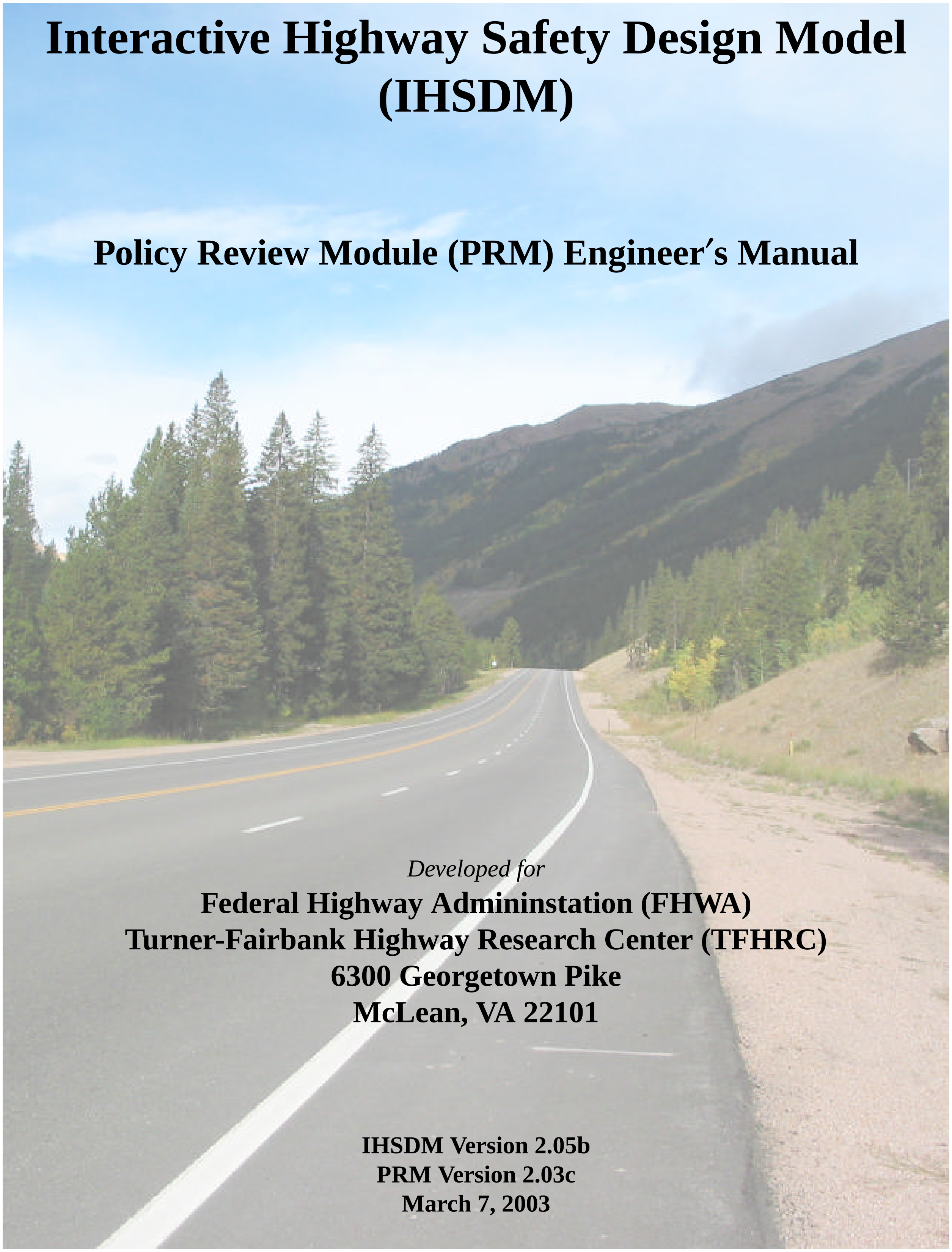
Interactive Highway Safety Design Model (IHSDM)

Policy Review Module (PRM) Engineer′s Manual



Developed for

Federal Highway Admininstation (FHWA)
Turner-Fairbank Highway Research Center (TFHRC)
6300 Georgetown Pike
McLean, VA 22101

IHSDM Version 2.05b
PRM Version 2.03c
March 7, 2003

Disclaimer

Limited Warranty and Limitations of Remedies

Notice

Table of Contents

List of Figures

List of Tables

1. Introduction

The Policy Review Module (PRM) Engineer's Manual is one component of the documentation supporting the Interactive Highway Safety Design Model (IHSDM). This introductory section: (1) provides a brief overview of IHSDM, (2) summarizes the capabilities and intended uses of the PRM, and (3) states the purpose and outlines the organization of the manual.

1.1 Overview of IHSDM

IHSDM is a suite of software analysis tools for evaluating safety and operational effects of geometric design in the highway project development process. The scope of the current release of IHSDM is two-lane rural highways.

IHSDM is intended as a supplementary tool to augment the design process. This tool is designed and intended to predict the functionality of proposed or existing designs by applying chosen design guidelines and generalized data to predict performance of the design. This tool is NOT a substitute for engineering judgment and does not create a standard, guideline or prescriptive requirement that can be argued to create any standard of care upon a designer, highway agency or other governmental body or employee. The use of this tool for any purpose other than to aid a qualified design engineer in the review of a set of plans is beyond the designed scope of this tool and is not endorsed by the Federal Highway Administration (FHWA).

The suite of IHSDM tools includes the following evaluation modules. Each module of IHSDM evaluates an existing or proposed geometric design from a different perspective and estimates measures describing one aspect of the expected safety and operational performance of the design.

- Policy Review Module (PRM) - The Policy Review Module checks a design relative to the range of values for critical dimensions recommended in AASHTO design policy.
- Crash Prediction Module (CPM) - The Crash Prediction Module provides estimates of expected crash frequency and severity.
- Design Consistency Module (DCM) - The Design Consistency Module estimates expected operating speeds and measures of operating-speed consistency.
- Intersection Review Module (IRM) - The Intersection Review Module leads users through a systematic review of intersection design elements relative to their likely safety and operational performance.
- Traffic Analysis Module (TAM) - The Traffic Analysis Module estimates measures of traffic operations used in highway capacity and quality of service evaluations.

Intended users of IHSDM results are geometric design decision makers in the highway design process, including project managers, planners, designers, and reviewers. The Federal Highway Administration's Flexibility in Highway Design document (Publication No. FHWA-PD-97-062) explains the context within which these decision makers operate:

> An important concept in highway design is that every project is unique. The setting and character of the area, the values of the community, the needs of the highway users, and the challenges and opportunities are unique factors that designers must consider in each highway project. Whether the design to be developed is for a modest safety improvement or 10 miles of new-location rural freeway, there are no patented solutions. For each potential project, designers are faced with the task of balancing the need for the improvement with the need to safely integrate the design into the surrounding natural and human environment.

The measures of expected safety and operational performance estimated by IHSDM are intended as inputs to the decision making process. The value added by IHSDM is in providing quantitative estimates of effects that previously could be considered only in more general, qualitative terms. The advantage of these quantitative estimates is that, when used appropriately by knowledgeable decision makers, they permit more informed decision-making.

The following general cautions should be considered in using IHSDM:

- Measures of expected safety and operational performance from IHSDM are only a subset of the large number of inputs that must be considered in making design decisions.
- Estimates from IHSDM are expected values, in the statistical sense, i.e., they represent the estimated average performance over a long time period and among a large number of sites with similar characteristics. Actual performance may vary over time and among sites. The estimates from IHSDM should not substitute for, but rather should supplement and complement local knowledge.
- While derived from the best available data using the best available methods, both the available data and methods have limitations. The engineer's manuals for each module document limitations that should be understood to apply appropriately the resulting estimates.

1.2 Overview of Policy Review Module

The basic functionality of the PRM is to automate the process of checking geometric design elements against relevant design policy documents. The PRM includes two basic components for each check: (1) electronic versions of "policy values," i.e., tables of recommended ranges of values for critical dimensions extracted from relevant AASHTO policy documents, and (2) a process for comparing "road values," i.e., the geometry of the highway being evaluated, against those "policy values."

The PRM tables of policy values and automated processes are based upon the following American Association of State Highway and Transportation Officials (AASHTO) documents: (1) *A Policy on Geometric Design of Highways and Streets* (1990, 1994, and 2001 editions), (2) *Roadside Design Guide* (1996 edition), and (3) Guide for the Development of Bicycle Facilities (1999 edition). The goal is to be faithful to these AASHTO documents in replicating the recommended range of values and in making appropriate comparisons between road values and policy values. The usage of terminology is also consistent with AASHTO definitions.

Users have the option to edit the tables of AASHTO policy values to adapt them to a particular State highway agency's design manual. Users exercise this option through the IHSDM Administration Tool. Users may edit any or all of the values in any or all of the tables. The ability to edit policy tables has the following limitations: (1) users must operate within the set of existing tables; it is not possible to create additional tables, and (2) in editing a table, users are constrained by the number of columns and column headings, i.e., it is not possible to add columns or to change which data element the column defines. Additional details on using the IHSDM Administration Tool are found in the System Administrator's Manual. Details on editing policy tables are found in the Maintaining IHSDM Policies Manual.

Initial steps in using the PRM include specifying the type of project (new construction or reconstruction) and operations design vehicle (typical heavy truck or recreational vehicle) on the PRM Attributes Tab as well as the relevant policy and the geometry elements to be checked on the PRM Evaluation Tab. The "Choose or Change Policy" button of the PRM Evaluation Tab includes four standard options: AASHTO 1990 Policy (English), AASHTO 1994 Policy (Metric), AASHTO 2001 Policy (English), and AASHTO 2001 Policy (Metric). Additional policy options will appear if the user has edited and saved additional policies through the IHSDM Administration Tool. When specifying which checks to run on the PRM Evaluation tab, the user may either run only selected checks, run all checks in a certain category (e.g., cross-section, horizontal alignment, vertical alignment, or sight distance), or run all PRM checks.

The PRM begins each check by determining whether or not all design and control data necessary to complete the check are available in the IHSDM highway data file for the highway being evaluated. Users have the options of having the PRM either prompt them to input missing data in order to complete a selected check (by selecting Element Check: Missing through the General Tab of the Edit User Properties menu) or skip over the check and provide a message about the missing data in the PRM Analysis Report. When all data are available, the PRM compares road values against relevant policy values and reports the results.

PRM results are provided in an Analysis Report, which may be viewed in html browser, text editor, or word processor format. The user may change the default format (html browser) through the Reporting Tab of the Edit User Properties menu. The results for each check are summarized in one or more tables. For two checks (Stopping Sight Distance and Passing Sight Distance), graphical output is also provided. Users also have options for on-screen display of the tabular results and the sight distance graphs, through the Show Results and Display Sight Distance Graphs buttons, respectively, on the PRM Evaluation Tab. A final output option on the PRM Evaluation Tab is an analysis summary. The analysis summary condenses the results of all selected checks in a single table.

The intent of the PRM is the same as the intent of AASHTO policy documents, as stated in the Foreword to the 2001 edition of AASHTO's *A Policy on Geometric Design of Highways and Streets*, "to provide guidance to the designer by referencing a recommended range of values for critical dimensions." Caveats regarding intended and unintended uses of design policy also apply to the IHSDM PRM.

The relevance of the PRM is the same as the relevance of the policies upon which it is based. For example, the Foreword to AASHTO's 2001 *A Policy on Geometric Design of Highways and Streets* states it "is not intended as a policy for resurfacing, restoration, or rehabilitation (3R) projects." It is the user's responsibility to determine which policy is relevant to a particular design project and which elements of design should be checked. The IHSDM PRM evaluates user-specified elements against a user-specified policy. Therefore, output from the Module documenting a check of a given element against a given policy should not be interpreted as meaning the element needed to be checked or that the policy checked was the relevant policy.

PRM has potential application throughout the project development process. The following are examples of project development applications for the PRM:

- An analysis of existing highways to support design investigations and alternatives development is a task performed early in reconstruction projects.
- Quality control/quality assurance is an obvious use of the PRM, particularly for project managers and review agencies when comparing preliminary engineering to final design.
- Documentation of alternatives to support environmental studies and internal agency needs also is a use of the PRM.

- Preparation of design exception requests and documentation of design exceptions.

In all of these applications, other IHSDM modules (e.g., Crash Prediction, Design Consistency, and Traffic Analysis) might also be used to estimate the expected operational and safety performance of the highway. These performance measures can be used as input to decision-making and in documenting the basis for decisions.

1.3 Purpose of This Manual

The purpose of the Engineer's Manual is to provide sufficient information about the functionality and scope of the PRM that users can make appropriate judgments about whether and how to use it beneficially at any stage of a design project, and can make appropriate interpretations and applications of PRM outputs based upon an understanding of the PRM. The manual includes useful information about the data required to perform checks and describes the process used to perform the checks.

The manual is organized into the following sections:

- Section 2., *Input Data Requirements*
- Section 3., *Summary of PRM Checks*
- Section 4., *Cross Section Checks*
- Section 5., *Horizontal Alignment Checks*
- Section 6., *Vertical Alignment Checks*
- Section 7., *Sight Distance Checks*
- Section 8., *IHSDM Documentation*

2. Input Data Requirements

Each policy check has a set of input data requirements. Inputs may be defined either for the whole length of the highway or for specific station limits. There are three general classes of input data.

The first class of inputs includes the project and analysis attributes specified at the time the user creates an analysis or enters the PRM. This class of inputs includes: maximum superelevation used for the analysis, analysis year, analysis limits, type of project (new or reconstruction), and design vehicle. These data are set at the beginning of the analysis, and they are defined for the entire length of highway being checked.

The second class of inputs defines the highway alignment and is read from the IHSDM highway data file for the highway being evaluated. The user can modify these data through the IHSDM "Edit/View Highway Elements" interface but not while the analysis is running. Such inputs can be defined for specific station limits.

The third class of inputs defines road geometry elements other than alignment and may also be read from the IHSDM highway data file. This class of inputs includes: highway functional classification, highway terrain, design speed, design hour volume, number of through travel lanes, passing lane sections, and pavement type. The user can modify these data through the "Edit/View Highway Elements" interface. Additionally, this third class of inputs can be modified while the analysis is running if the "Element Check/All or Missing" option is chosen from the "Edit User Properties/General" menu. Such inputs can be defined for specific station limits.

3. Summary of PRM Checks

The two-lane rural highway version of the PRM contains 20 highway geometric design checks. Only 17 of these checks are available in the current release of IHSDM. Checks are organized into four categories: cross section, horizontal alignment, vertical alignment, and sight distance.

- Cross Section Checks
  - Through Traveled Way Width*
  - Auxiliary Lane Width
  - Shoulder Width*
  - Shoulder Type
  - Normal Cross Slope*
  - Normal Shoulder Slope
  - Cross Slope Rollover on Curves
  - Clear Zone Roadside Slope(not available in the current release of IHSDM)
  - Normal Ditch Design(not available in the current release of IHSDM)
  - Bridge Width*
- Horizontal Alignment Checks
  - Radius of Curve*
  - Superelevation*
  - Superelevation Transition Design(not available in the current release of IHSDM)
  - Length of Horizontal Curve
  - Compound Curve Ratio
- Vertical Alignment Checks
  - Vertical Tangent Grade*
  - Vertical Curvature*
- Sight Distance Checks
  - Stopping Sight Distance*
  - Passing Sight Distance
  - Decision Sight Distance

In the above list, asterisks denote elements included among the 13 controlling criteria established by FHWA in the Federal-Aid Policy Guide (Transmittal 23, dated June 17, 1998). PRM checks include 9 of the 13 controlling criteria. The controlling criteria that are not checked by the PRM are: design speed, structural capacity, vertical clearance, and horizontal clearance. The designation of elements as controlling criteria is relevant to projects covered by the Federal-Aid Policy Guide; this designation may not be relevant to other projects.

Section 4., *Cross Section Checks* through Section 7., *Sight Distance Checks* of the Engineers Manual describe the details of these components for each check. For each policy check, the engineer's manual provides the following information: overview of the check, input data requirements, the PRM process, boundary conditions and rounding, special conditions, and output. The inputs required to perform a check are listed in the input data requirements section.

The PRM process section identifies the source of the policy values against which designs are checked and describes how the comparison between road and policy values is made. Policy tolerance values and rounding are detailed in the boundary conditions and rounding section. The special conditions section contains information about policy values for special cases addressed in AASHTO policies and describes how the PRM handles anomalies in the policy. Lastly, the output section describes the format of the output tables, detail about the road and policy values for a specific check, and a listing of output comments and a description of the situations they represent.

4. Cross Section Checks

This section describes each individual PRM cross-section element check. Included is an overview of the check, input data requirements, the PRM process, boundary and rounding conditions, special conditions, and output. Notes are made to illustrate the differences between the 1994 and 2001 editions of the AASHTO *A Policy on Geometric Design of Highways and Streets* (AASHTO policy). Discussions of the 1994 AASHTO policy (in metric units) also apply to the 1990 AASHTO policy (in English units). The AASHTO *Guide for Development of Bicycle Facilities* and *Roadside Design Guide* are also cited where appropriate.

The following cross section checks are included in this section (those denoted with * are controlling criteria):

- Through Traveled Way Width*
- Auxiliary Lane Width
- Shoulder Width*
- Shoulder Type
- Normal Cross Slope*
- Normal Shoulder Slope
- Cross Slope Rollover Curves
- Clear Zone Roadside Slope(not available in the current release of IHSDM)
- Normal Ditch Design(not available in the current release of IHSDM)
- Bridge Width*

Table 1., *Summary of Input Data Requirements for Cross Section Checks* is a summary of the input data required to perform each cross section check.

Table 1. Summary of Input Data Requirements for Cross Section Checks

Cross Section Check/Input Data	Through Traveled Way Width	Auxiliary Lane Width	Shoulder Width	Shoulder Type	Normal Cross Slope	Normal Shoulder Slope	Cross Slope Rollover Curves	Clear Zone Roadside Slope	Normal Ditch Design	Bridge Width
Type of Project/Study	*		*							*
Functional Classification	*	*	*	*	*			*		*
Highway Terrain	*		*							
Design Speed	*		*					*		*
Design Vehicle	*									
Traffic Volume	*		*					*		*
Horizontal Alignment Data	*						*	*		
Pavement Type					*					
Through Lane Cross Slope					*		*			
Bridge Width										*
Number of Through Lanes										*
Bridge Characteristics										*
Superelevation							*			
Curve Widening	*		*							
Through Lane Width	*	*	*		*					*
Auxiliary Lane Data		*	*					*		
Use as a Bike Facility			*	*						*
Shoulder Width			*	*		*		*		*
Shoulder Type/Category			*	*		*				*
Shoulder Cross Slope						*	*			
Roadside Slope & Ditch Data								*	*	

4.1 Through Traveled Way Width

AASHTO policy defines traveled way as "The portion of the highway for the movement of vehicles, exclusive of shoulders." The PRM refers to through traveled way width, which is evaluated in this check. This check also considers pavement widening on horizontal curves. A separate check evaluates auxiliary lane width.

On a two-lane rural highway, the through traveled way width of the highway is the sum of the lane widths of the two lanes. The traveled way is usually assumed to be symmetrical around the centerline of the alignment, but in IHSDM the user can define it otherwise. Lane width is among the 13 controlling criteria.

4.1.1 Input Data Requirements

To check through traveled way width, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Type of project/study (new construction or reconstruction)
- Design vehicle (SU, Bus, A-Bus, WB-12, WB-15, WB-18, WB-19, WB-20, WB-29, WB-35, MH, P/B, MH/B, P, P/T)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)
- Functional classification (local, collector, or arterial)
- Highway terrain (level, rolling or mountainous)
- Design speed
- Traffic volume (design-year average daily traffic (ADT) and/or design hour volume [applies only to 1990 and 1994 AASHTO policies])
- Through lane width
- Curve widening

4.1.2 The PRM Process

According to AASHTO policy, through traveled way width may vary from tangent to horizontal curve because the through traveled way on curves may be widened to accommodate vehicle offtracking. The PRM process evaluates both through traveled way width on tangent sections and through traveled way width, with the additional consideration of pavement widening, on horizontal curves.

4.1.2.1 Through Traveled Way Width on Tangent Sections

The PRM determines the road values for through traveled way width on tangent sections from the through lane widths specified in the IHSDM highway data file for the highway being evaluated. The through traveled way width on tangent sections is the sum of the through lane widths. These road values for through traveled way width are then compared to the relevant policy values, which are determined as outlined below.

AASHTO policy values for through traveled way width vary according to the highway functional classification and the design traffic volumes. Based on these two parameters, the PRM references Tables V-6, VI-4, and VII-2 in the 1994 AASHTO policy [Exhibits 5-5, 6-5, and 7-3 in the 2001 AASHTO policy] to determine the policy value for the traveled way width on a tangent section.

4.1.2.2 Through Traveled Way Width on Horizontal Curves

The IHSDM highway data file includes separate specification of curve widening, which is an increment of pavement width on curves in addition to through traveled way width on tangent sections. The PRM calculates the sum of the through traveled way and curve widening on the horizontal curves. These road values are then compared to the relevant policy values, which are determined as outlined below.

AASHTO policy values for through traveled way width on horizontal curves are determined by adding the through traveled way width policy value (determined above) to the policy value for pavement widening on horizontal curves. The PRM references Figure III-23 (a, b, and c) and Table III-22 in the 1994 AASHTO policy [Exhibits 3-51 and 3-52 in the 2001 AASHTO policy] to determine the widening values for two-lane rural highways. In cases where the road values fall between criteria in the policy tables, the PRM rounds the radius to the next highest value in the table. For values of widening less than 0.6 m [2 ft], the PRM uses a policy value of 0 m [0 ft], based upon the AASHTO recommendation that a minimum widening of 0.6 m [2 ft] be used and lower values be disregarded.

4.1.3 Boundary Conditions and Rounding

The road and policy values in the through traveled way width output table are rounded to the nearest 0.01 m [0.01 ft].

4.1.4 Special Conditions

If the project is a reconstruction project, a special condition applies per AASHTO policy. Footnotes in the AASHTO tables/exhibits indicate that on highways being reconstructed, an existing 6.6 m [22 ft] traveled way width, i.e., 3.3 m [11 ft] lane widths, may be retained where alignment and safety records are satisfactory.

Tables V-6, VI-4, and VII-2 in the 1994 AASHTO policy [Exhibits 5-5, 6-5, and 7-3 in 2001 AASHTO policy] all contain arithmetic overlaps in the column headings for design ADT. These occur for ADT values of 1,500 vehicles/day, resulting in the potential for roads with exactly 1,500 vehicles/day having more than one policy value. To resolve this anomaly, the PRM converts the category of 1,500 to 2,000 vehicles/day to 1,501 to 2,000 vehicles/day.

In addition, Table VII-2 in the 1994 AASHTO policy does not include a column of policy values for ADT greater than 2,000 vehicles/day. The "DHV over 200" column may account for this (it would assume a peak hour volume of 10 percent of ADT), but it is not clear. For cases in which a user specifies a DHV of less than 200 vehicles/hr but a design year ADT of greater than 2,000 vehicles/day, the PRM will select the policy value from the last column for "DHV over 200" in Table VII-2.

4.1.5 Output

Results of the "Through Traveled Way Width" check are summarized in a single table of the PRM Analysis Report. In the table, rows represent a highway segment in which the through traveled way width is uniform. Since the "Through Traveled Way Width" check also evaluates widening on curves, a new segment (and, therefore, a new row in the table) is defined at the beginning and end of each horizontal curve as well as at the beginning of each change in width. The table includes the following columns:

- Stations-Start and End: the station limits of a highway segment with uniform through traveled way width.
- Traveled Way Width and Widening-Road and Policy:
  - The road value is the through traveled way width for the highway segment defined by the start and end stations. The two components of width are shown separately, i.e., Traveled Way Width + Widening on Curves. The sum of these two widths is the total through traveled way width.

  - The policy value is the recommended minimum width referenced in the selected policy for the specified design controls. The two components of width are shown separately, i.e., Traveled Way Width + Widening on Curves.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 2., *Summary of Comment Values for Through Traveled Way Width Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 2. Summary of Comment Values for Through Traveled Way Width Check

Comment	Description of the Situation
Road value is within controlling criteria	The total of through traveled way width and widening is greater than or equal to the policy value for through traveled way width.
Road value varies from controlling criteria	The total of through traveled way width and widening for the highway is less than the recommended minimum value for through traveled way width referenced in policy (Except for the situation described below).
Road value varies from controlling criteria; may be acceptable for reconstruction if the crash history at this location is satisfactory.	The project is a re-construction project and the total of through traveled way width and widening for the highway is less than the recommended minimum value for through traveled way width referenced in policy but equal to or larger than the width AASHTO policy indicates may remain on reconstructed highways where alignment and safety records are satisfactory.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up tables.

4.2 Auxiliary Lane Width

An auxiliary lane is a full lane added to the traveled way for use over a short, specified length of highway. The following types of auxiliary lanes may be checked in the PRM: climbing, passing, right-turn and left-turn lanes.

A climbing lane is provided as an extra lane on the upgrade side of the highway, where the combination of passenger car and truck volumes degrades traffic operations. Passing sections may be either three-lane or four-lane sections that provide for an additional lane in either one or both directions of travel. Passing lanes are provided on two-lane roads to achieve the desired frequency of safe passing zones or to lessen the interference between the traffic flow and low-speed heavy vehicles. Right and left turn lanes are provided to accommodate speed changes and vehicle maneuvers at intersections and other access openings.

4.2.1 Input Data Requirements

To check auxiliary lane width, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Functional classification (local, collector, or arterial)
- Through lane width
- Auxiliary lane data (number, type, width)

4.2.2 The PRM Process

The PRM determines the road values for auxiliary lane width from the IHSDM highway data file for the highway being evaluated. These road values are compared to the relevant policy values, which are determined as outlined below.

In the 1994 AASHTO policy, the recommended minimum auxiliary lane width referenced by policy depends on the type of lane and, in some cases, the functional classification. The policy recommends that a climbing lane on a collector or local road should be at least as wide as the narrowest through lane (p. 250). A climbing lane on an arterial should be at least 3.6 m (p. 453). The passing lane should be at least as wide as the through lane (p. 265). Right- and left-turn lanes should be at least 3.0 m [10 ft] and as wide as the narrowest through lane (p. 780).

In the 2001 AASHTO policy, the recommended minimum auxiliary lane width referenced by policy depends on the type of lane. The policy recommends that the climbing lane should be at least as wide as the narrowest through lane for all classification of highways (p. 251). A passing lane should be at least as wide as the narrowest through lane (p. 256). Right- and left-turn lanes should be at least 3.0 m [10 ft] and as wide as the narrowest through lane (p. 718).

4.2.3 Boundary Conditions and Rounding

The road and policy values in the auxiliary lane width output table are rounded to the nearest 0.01 m [0.01 ft].

4.2.4 Special Conditions

The 2001 AASHTO Policy (p. 453) indicates climbing lanes on arterials "should be the same width as the through lanes." In PRM, this statement is interpreted to mean that climbing lanes should be at least as wide as the policy value for through lane width.

4.2.5 Output

Results of the check are summarized in a single table of the PRM Analysis Report. In the table, each row represents a segment of uniform auxiliary lane width. The table includes the following columns:

- Stations-Start and End: the station limits of a segment of uniform auxiliary lane width.
- Direction of Travel: The side of the road (left or right) facing in the direction of increasing stations.
- Auxiliary Lane Width-Road and Policy:
    - The road value is the auxiliary lane width for the highway segment defined by the start and end stations.
    - The policy value is the recommended minimum auxiliary lane width referenced in the selected policy for the specified design controls.

- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 3., *Summary of Comment Statements for Auxiliary Lane Width Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 3. Summary of Comment Statements for Auxiliary Lane Width Check

Comment	Description of the Situation
Road value is within recommended values	The road value is greater than or equal to the recommended minimum auxiliary lane width referenced by policy.
Road value varies from recommended values	The road value is less than the recommended minimum auxiliary lane width referenced by policy.
No data: (comment specific to missing data element)	Required data are missing.

4.3 Shoulder Width

Shoulder width is defined as the portion of the highway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of sub-base, base, and surface courses. Shoulder width is among the 13 controlling criteria. A shoulder can be further defined as either graded or usable (see Figure IV-2 in the1994 AASHTO policy or Exhibit 4-5 in the 2001 AASHTO policy). The graded width of shoulder is measured from the edge of the traveled way to the intersection of the shoulder slope and fore slope planes. The usable width of shoulder is the actual width that can be used when a driver makes an emergency or parking stop.

4.3.1 Input Data Requirements

To check shoulder width, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Type of project/study (new construction or reconstruction)
- Functional classification (local, collector, or arterial)
- Highway terrain (level, rolling or mountainous)
- Design speed
- Traffic volume (design-year average daily traffic (ADT) or design-hour volume [applies only to 1994 policy])
- Through lane width
- Shoulder width
- Shoulder category (usable, graded)
- Shoulder type (turf, gravel, paved or composite)
- Use as a bike facility

4.3.2 The PRM Process

PRM determines the shoulder width(s) from the IHSDM highway data file for the highway being evaluated. These road values are then compared to the relevant policy values, which are determined as outlined below.

On the basis of the functional classification of the highway, the PRM determines the relevant policy values from the recommended minimum shoulder widths referenced by the 1994 AASHTO policy in Tables V-6, VI-4, and VII-2 and by the 2001 AASHTO policy in Exhibits 5-5, 6-5, and 7-3 in 2001Green Book. Depending on the design volume, these values range from 0.6 m [2 ft] to 2.4 m [8 ft]. These tables refer to the outside shoulders on undivided facilities.

When bicycles are anticipated to use the facility, the 1999 AASHTO *Guide for the Development of Bicycle Facilities* suggests using paved shoulder widths of at least 1.2 m [4 ft]. The recommendation is 1.5 m [5 ft] when curb, guardrail, or other roadside barriers are present.

4.3.3 Boundary Conditions and Rounding

The road and policy values in the shoulder width output table are rounded to the nearest 0.01 m [0.01 ft].

4.3.4 Special Conditions

For local roads with a design speed greater than 60 km/h [35 mi/h] and an ADT in the range of 400 to 1500, both 1994 and 2001 AASHTO policies include provisions for reducing the recommended minimum shoulder widths as long as a minimum highway width of 9 m [30 ft] is maintained. Similarly, for collector roads with a design speed greater than 50 km/h [30 mi/h] and an ADT in the range of 400 to 1500, both 1994 and 2001 AASHTO policies include provisions for reducing the recommended minimum shoulder widths as long as a minimum highway width of 9 m [30 ft] is maintained.

Tables V-6, VI-4, and VII-2 in the 1994 AASHTO policy and Exhibits 5-5, 6-5, and 7-3 in 2001 AASHTO policy contain arithmetic overlaps in the column headings for design ADT. These occur for ADT values of 1,500, resulting in the potential for roads with exactly 1,500 vehicles per day having more than one policy value. To resolve this anomaly, the PRM converts the category of 1,500 to 2,000 vehicles per day to 1,501 to 2,000 vehicles per day.

In addition, Table VII-2 in the 1994 AASHTO policy does not include a column of policy values for ADT greater than 2,000 vehicles per day. The "DHV over 200" column may account for this (it would assume a peak hour volume of 10 percent of ADT), but it is not clear. For cases in which a user specifies a DHV of less than 200 vehicles/hr but a design year ADT of greater than 2,000 vehicles/day, the PRM will select the policy value from the last column for "DHV over 200" in Table VII-2.

4.3.5 Output

Results of the check are summarized in a single table of the PRM Analysis Report. In the table, each row represents a segment of uniform shoulder width. The table includes the following columns:

- Stations-Start and End: the station limits of a highway segment with uniform shoulder width.
- Direction of Travel: The side of the road (left or right) facing in the direction of increasing stations.

- Shoulder Width-Road and Policy:
  - The road value is the shoulder width for the highway segment defined by the start and end stations.
  - The policy value is the recommended minimum shoulder width referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 4., *Summary of Comment Statements for Shoulder Width Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 4. Summary of Comment Statements for Shoulder Width Check

Comment	Description of the Situation
Road value is within controlling criteria	The shoulder width is greater than or equal to the recommended minimum shoulder width referenced in policy or, under special conditions, the total highway width is greater than 9 m [30 ft].
Road value varies from controlling criteria	The shoulder width is less than the policy value for shoulder width.
No data: (comment specific to missing data element)	Required data are missing.

4.4 Shoulder Type

Shoulders may be surfaced for either full or partial width to provide a better all-weather load support. There are several materials used to surface shoulders, including gravel, crushed rock, bituminous surface treatments, and various forms of asphalt or concrete pavements.

The AASHTO *A Policy on Geometric Design of Highways and Streets* and the AASHTO *Guide for the Development of Bicycle Facilities* address shoulder conditions. There are two conditions covered by AASHTO: paved or unpaved. This section of the PRM incorporates policy guidelines for type of shoulder. The required inputs and process are described below.

4.4.1 Input Data Requirements

To check shoulder type, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Functional classification (local, collector, or arterial)
- Shoulder width
- Shoulder type (turf, gravel, paved or composite)
- Use as a bike facility

4.4.2 The PRM Process

PRM determines shoulder type from the IHSDM highway data file for the highway being evaluated. These road values are then compared to the relevant policy values, which are determined as outlined below.

The 1994 and 2001 AASHTO policies do not recommend shoulder types for local or collector roads. The PRM, therefore, assumes that any shoulder type is acceptable for a local or collector road. For arterials, the AASHTO policies suggest using paved shoulders. When bicycles must be accommodated on the shoulder, the 1999 AASHTO *Guide for the Development of Bicycle Facilities* recommends a paved shoulder.

4.4.3 Boundary Conditions and Rounding

Shoulder type is entered as turf, gravel, paved, or composite.

4.4.4 Special Conditions

If the shoulder type is composite, the PRM assumes that half the width is "paved" and half is "turf." Therefore, if the shoulder type for the highway segment being evaluated is composite in a situation where AASHTO recommends paved shoulders, the PRM reports that the segment is within recommended values if the shoulder width is greater than or equal to twice the required width of the paved shoulder. If the composite shoulder is less than twice the required width of the paved shoulder, then the PRM reports that the segment varies from recommended values.

If no shoulder is present, the check is not performed, and the PRM generates a message to that effect in the analysis report.

4.4.5 Output

Results of the check are summarized in a single table of the PRM Analysis Report. In the table, each row represents a segment of uniform shoulder type. The table includes the following columns:

- Stations-Start and End: the station limits of a highway segment with uniform shoulder type.
- Direction of Travel: The side of the road (left or right) facing in the direction of increasing stations.
- Shoulder Width-Road and Policy:
    - The road value is the shoulder type for the highway segment defined by the start and end stations.
    - The policy value is the recommended shoulder type referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 5., *Summary of Comment Statements for Shoulder Type Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 5. Summary of Comment Statements for Shoulder Type Check

Comment	Description of the Situation
Road value is within recommended values	The shoulder type for the highway segment being evaluated is the same as the shoulder type referenced in the policy.
Road value is within recommended values; composite width is greater than twice the recommended paved width	The road has a composite shoulder where a paved shoulder is recommended and the composite shoulder width is at least twice the minimum recommended paved width.
Road value varies from recommended values	The shoulder type is not the same as the shoulder type referenced in the policy, or (in the case of the road having a composite shoulder where a paved shoulder is required) the composite shoulder width is less than twice the minimum recommended paved width.
No data: (comment specific to missing data element)	Required data are missing.

4.5 Normal Cross Slope

The normal cross slope is the lateral grade or slope of the traveled way on tangent alignment. Cross slope is among the 13 controlling criteria. The downward cross slope may be a plane or rounded section or a combination. With a plane section, there is a cross slope break at the crown line and constant slopes on either side. A rounded section is usually parabolic, with a rounded surface at the crown line and increasing cross slope toward the edge of traveled way. Two-lane traveled ways on tangents or on flat curves have a crown at the centerline and slope downward toward both edges. The PRM can check only plane sections.

4.5.1 Input Data Requirements

4.5.1 Input Data Requirements To check normal cross slope, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Functional classification (local, collector, or arterial)
- Through lane width
- Pavement type (high, intermediate, low) [intermediate applies to 1994 policy]
- Through lane cross slope

4.5.2 The PRM Process

The PRM determines the normal cross slope from the IHSDM highway data file for the highway being evaluated. These road values are then compared to the relevant policy values, which are determined as outlined below.

AASHTO policy values depend on the functional classification and, for local and collector roads, on the pavement type of the highway. Policy values range from 1.5 to 6 percent. For two-lane rural highways, recommended ranges of values are referenced for local roads in Table V-5 of the 1994 AASHTO policy [p. 387 of the 2001 AASHTO policy], for collector roads on p. 464 of the 1994 AASHTO policy [p. 425 of the 2001 AASHTO policy], and for arterials on p. 487 of the 1994 AASHTO policy [pp. 450-451 of the 2001 AASHTO policy].

The 1994 AASHTO policy defines pavement types as follows:

- High-type pavements are those that retain smooth riding qualities and good nonskid properties in all weather under heavy traffic volumes and loadings with little maintenance.
- Intermediate-type pavements are those designed to retain smooth riding qualities and good nonskid properties in all weather, but under lighter loads and lesser traffic volumes.
- Low-type pavements are those with treated earth surfaces and those with loose aggregate surfaces.

The 2001 AASHTO policy eliminated intermediate pavement types. Thus, policy values for normal cross slope are based on high- or low-type pavements.

4.5.3 Boundary Conditions and Rounding

The road and policy values in the normal cross slope output tables are rounded to the nearest 0.01 percent.

4.5.4 Special Conditions

AASHTO policy indicates that the cross slope on high-type pavements in areas of intense rainfall may be increased to 2.5 percent (see p. 331 of the 1994 AASHTO policy or p. 314 of the 2001 AASHTO policy). If the road value for normal cross slope on a high-type pavement is greater than 2 percent but less than or equal to 2.5 percent, the PRM reports that the road value varies from controlling criteria but may be acceptable in areas of intense rainfall.

4.5.5 Output

Results of the check are summarized in a single table of the PRM Analysis Report. In the table, each row represents a segment of uniform normal cross slope. The table includes the following columns:

- Stations-Start and End: the station limits of a highway segment with uniform normal cross slope.
- Direction of Travel: The side of the road (left or right) facing in the direction of increasing stations.
- Normal Cross Slope-Road and Policy:
  - The road value is the normal cross slope for the highway segment defined by the start and end stations.
  - The policy value is the recommended range of values referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 6., *Summary of Comment Statements for Normal Cross Slope Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 6. Summary of Comment Statements for Normal Cross Slope Check

Comment	Description of the Situation
Road value is within controlling criteria	The normal cross slope is within the recommended range of values for normal cross slope referenced in policy.
Road value varies from controlling criteria	The normal cross slope is outside the recommended range of values for normal cross slope referenced in policy. (Except for the situation described below.)
Road value varies from controlling criteria; may be acceptable in areas of intense rainfall	The pavement is high-type and the cross slope is greater than 2 percent and less than or equal to 2.5 percent, which AASHTO policy indicates may be acceptable in areas of intense rainfall.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of policy look up tables.

4.6 Normal Shoulder Slope

Normal shoulder slope is defined as the downward slope of the shoulder away from the traveled way. The shoulder should be sloped sufficiently to drain surface water, but not to the extent that vehicle use would be restricted. Shoulder slope values vary according to the type of shoulder material and whether the shoulder is located on horizontal tangent or curve. This PRM check evaluates only normal shoulder slope. A separate check evaluates cross slope rollover on horizontal curves.

4.6.1 Input Data Requirements

To check normal shoulder slope, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Shoulder width
- Shoulder type (turf, gravel, paved or composite)
- Shoulder cross slope

4.6.2 The PRM Process

The PRM determines the normal shoulder slope from the IHSDM highway data file for the highway being evaluated. These road values are then compared to the relevant policy values, which are determined as outlined below.

AASHTO policy values for shoulder slope vary according to the type of material (see pp. 339-340 of the 1994 AASHTO policy and pp. 319-321 of the 2001 AASHTO policy). The recommended range of values referenced by policy for undivided rural highways is from 2 to 6 percent for paved shoulders; 4 to 6 percent for gravel or crushed rock shoulders; and 6 to 8 percent for turf shoulders. No recommended range of values is referenced specifically for composite shoulders.

4.6.3 Boundary Conditions and Rounding

Road and policy values for normal shoulder slope are rounded to the nearest 0.01 percent.

4.6.4 Special Conditions

No special conditions are identified for normal shoulder slope. If no shoulder is present, the check is not performed, and the PRM generates a message to that effect in the analysis report.

4.6.5 Output

Results of the check are summarized in a single table of the PRM Analysis Report. In the table, each row represents a highway segment over which a normal shoulder slope is specified. The table includes the following columns:

- Stations-Start and End: the station limits of a highway segment with a uniform normal shoulder slope.
- Direction of Travel: The side of the road (left or right) facing in the direction of increasing stations.
- Normal Shoulder Slope-Road and Policy:
  - The road value is the normal shoulder slope for the highway segment defined by the start and end stations.
  - The policy value is the recommended range of values referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 7., *Summary of Comment Statements for Normal Shoulder Slope Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 7. Summary of Comment Statements for Normal Shoulder Slope Check

Comment	Description of the Situation
Road value is within recommended values	The normal shoulder slope is within the recommended range of values referenced in policy.
Road value varies from recommended values	The normal shoulder slope is outside the recommended range of values referenced in policy for normal shoulder slope.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are outside of the range of the policy look up tables.

4.7 Cross Slope Rollover on Curves

Design of the cross section on horizontal curves often incorporates the use of adverse shoulder slopes on the outside of the curve. This practice minimizes earthwork and provides for drainage of the shoulder outside rather than across the traveled way. The cross slope rollover on horizontal curves is defined as the algebraic difference in the cross slopes of the shoulder and traveled way. AASHTO policy references a recommended range of values for the algebraic difference, in recognition of potential operational problems for vehicles that leave the curve on the outside and encroach on the shoulder sloped away from their intended path.

4.7.1 Input Data Requirements

To check cross slope rollover on curves, the following data must be inputs by the PRM user:

- Analysis limits (Start Station and End Station)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)
- Through lane cross slope
- Shoulder cross slope

4.7.2 The PRM Process

To obtain the road value for cross slope rollover on each horizontal curve, the PRM locates the midpoint of the horizontal curve and differentiates between positive and negative (or adverse) slopes. The PRM then computes the algebraic difference in slopes between the traveled way and the shoulder to determine the cross slope rollover. For each horizontal curve, the computed road value is compared to the relevant policy value, which is determined as outlined below.

For the high side of the highway on curves, the recommended range of values referenced in AASHTO policy for cross slope rollover is between 0 and 8 percent. On the low side of the curve, the travel way cross slope should be equal to or less than the shoulder cross slope. As such, the algebraic difference in slope should equal or exceed 0 percent. (Refer to Figure IV-3 in the 1994 AASHTO policy or Exhibit 4-2 in the 2001 AASHTO policy for cross slope rollover sections.)

4.7.3 Boundary Conditions and Rounding

Values for cross slope rollover are rounded to the nearest 0.01 percent.

4.7.4 Special Conditions

No special conditions are identified for cross slope rollover. If no shoulder is present, the check is not performed, and the PRM generates a message to that effect in the analysis report.

4.7.5 Output

Results of the check are summarized in a single table of the PRM Analysis Report. In the table, each row represents the cross slope rollover for a horizontal curve. The table includes the following columns:

- Stations-Start and End: the station limits of a horizontal curve.
- Direction of Travel: The side of the road (left or right) facing in the direction of increasing stations.
- Cross Slope Rollover-Road and Policy:
  - The road value is the maximum cross slope rollover on the horizontal curve.
  - The policy value is the recommended range of values referenced in the selected policy.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 8., *Summary of Comment Statements for Cross Slope Rollover Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.

- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 8. Summary of Comment Statements for Cross Slope Rollover Check

Comment	Description of the Situation
Road value is within recommended values	The cross slope rollover on the curve is within the recommended range of values for cross slope rollover referenced in policy.
Road value varies from recommended values	The cross slope rollover on the curve is outside the recommended range of values for cross slope rollover referenced in policy.
No data: (comment specific to missing data element)	Required data are missing.

4.8 Clear Zone and Roadside Slope (not available in the current release of IHSDM)

Clear zone requirements and roadside slope requirements are directly related to each other. Therefore, it is appropriate to evaluate them together.

In AASHTO policy, the term "clear zone" is used to designate the unobstructed, relatively flat area provided beyond the edge of traveled way for the recovery of errant vehicles. The clear zone includes shoulders and auxiliary lanes. Clear zone requirements are based on traffic volumes, design speed and roadside geometry.

The roadside geometry may consist of the shoulder and any one or all of the following:

- A fill slope. The grade of a fill slope is considered negative. That is, elevation decreases as the distance from the edge of traveled way increases.
- A cut slope. The grade of a cut slope is considered positive. That is, elevation increases as the distance from the edge of traveled way increases.
- A roadside channel (or ditch) where the slope changes from negative to positive.

AASHTO recommends that the recovery area should be clear of all unyielding objects such as trees, sign supports, utility poles, above ground drainage structures and any other fixed objects. The PRM assumes it is not practical for users to provide sufficient data to determine the attributes (height, size, type of material, etc.) of potential obstructions located within the clear zone but that may be practical to provide roadside geometry data.

4.8.1 Input Data Requirements

To check clear zone and roadside slope, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)
- Functional classification (local, collector, or arterial)
- Design speed
- Traffic volume (design-year average daily traffic (ADT))

- Auxiliary lanes (number, type, width)
- Shoulder width
- Roadside slope data (fore slope, direction/side of road, width)

4.8.2 The PRM Process

For roadside slope, the PRM checks only the first slope adjacent to the highway against the recommended range of values. In the IHSDM, this slope is called fore slope, and it could have either a negative or positive slope. The intersection of fore slopes and back slopes (where the fore slope is negative and the back slope is positive) is checked under "Normal Ditch Design."

With respect to clear zone, given the practical limitations of the data, the PRM only determines the recommended clear zone dimensions referenced by policy. The designer should then review the roadside for unshielded hazards located within the recommended clear zone.

The 1994 AASHTO policy references a recommended minimum clear zone distance of 3 m [10 ft] for local roads and for collector roads with a design speed of 60 km/h [35 mi/h] or below. The 2001 AASHTO policy references recommended minimum clear zone distances of 2 to 3 m [7 to 10 ft] for local roads and of 3 m [10 ft] or more for collector roads with design speeds of 70 km/h [40 mi/h] or less. For other cases, these AASHTO policies reference the 1996 AASHTO *Roadside Design Guide*.

For collector roads with a design speed greater than 60 km/hr [35 mph] and for arterials, the PRM uses Table 3.1 of the 1996 AASHTO *Roadside Design Guide* to determine the recommended range of values for clear zone. Finally, the PRM uses Table 3.2 of the 1996 AASHTO *Roadside Design Guide* to adjust the recommended clear zone distance on horizontal curves.

The 1996 AASHTO *Roadside Design Guide* recommends a fill slope be flatter than 1:4 at the outside edge of the shoulder and a cut slope be flatter than 1:3 without a barrier. For fill slopes between 1:3 and 1:4, it recommends that the clear zone not end on the slope and that a clear runout area at the base of the slope is desirable.

4.8.3 Boundary Conditions and Rounding

The road and policy values in the clear zone output tables are rounded to the nearest 0.01m [0.01ft] of clear zone. Roadside slopes are rounded to the nearest 0.01 percent.

4.8.4 Special Conditions

Table 3.1 of the 1996 AASHTO *Roadside Design Guide* contains arithmetic overlaps and gaps that require interpretation. First, the following ADT categories have been implemented in the PRM to eliminate an overlap at 1500, as follows: under 750, 750 to 1500, 1501 to 6000 and greater than 6000.

Second, where a range of recommended clear zone values is provided, the maximum value in the range is used in the PRM. For example, for a design speed of 60 km/h, a fill slope of 1:6 or flatter, and an ADT in the range of 750 to 1500, the recommended range of clear zone distances is 3.0-3.5 m. The PRM uses 3.5 m as the policy value.

Third, there are arithmetic gaps in the slope categories. There are four slope ranges and two discrete slope values in the table. The slope ranges are (-1:6 or flatter) and (-1:5 to -1:4) for fill slopes, and (1:4 to 1:5) and (1:6 or flatter) for cut slopes and the discrete values are -1:3 for fill slopes and 1:3 for cut slopes. For the slope values between the two adjacent slope ranges/values the slope would be rounded to the next steeper (flatter) range/value if it were a fill (cut). If the highway value is out of the ranges available in the table, rounding is not performed. Instead, the result is reported as a "No Policy" case.

Fourth, in the design speed category, the highway design speed is rounded up to the nearest 10 km/h. Again, if the highway value is out of the ranges available in the table there should not be rounding. Instead, it should be reported as a "No Policy" case.

4.8.5 Output

Results of the check are summarized in two tables of the PRM Analysis Report: one for clear zone, and one for roadside slope. In the tables, each row represents a highway segment with uniform clear zone or roadside slope.

The table for clear zone includes the following columns:

- Stations-Start and End: the station limits of the highway segment with uniform clear zone.
- Direction of Travel: The side of the road (left or right) facing in the direction of increasing stations.
- Clear Zone-Only the relevant policy value is reported for clear zone. The value reported is the recommended minimum clear zone distance referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the policy value for the highway segment. Table 9., *Summary of Comment Statements for Clear Zone Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 9. Summary of Comment Statements for Clear Zone Check

Comment	Description of the Situation
Recommended clear zone	The recommended minimum clear zone distance referenced in policy for the specified design controls.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up tables.

The table for roadside slope includes the following columns:

- Stations-Start and End: the station limits of the highway segment with uniform roadside slope.
- Direction of Travel: The side of the road (left or right) facing in the direction of increasing stations.
- Roadside Slope-Road and Policy:
  - The road value is the roadside slope of the highway segment defined by the start and end stations.
  - The policy value is the recommended maximum slope referenced in the selected policy for the specified design controls.

- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 10., *Summary of Comment Statements for Roadside Slope Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 10. Summary of Comment Statements for Roadside Slope Check

Comment	Description of the Situation
Road value is within recommended values	All roadside slopes within the clear zone are within recommended policy values for roadside slope.
Road value varies from recommended values	One or more of the roadside slopes within the clear zone is/are steeper than the policy values for roadside slope.
Road value may vary from recommended values; may be acceptable if clear runout area is provided at bottom of the slope	A fill slope is greater than 1:4 but less than 1:3.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up tables.

4.9 Normal Ditch Design (not available in the current release of IHSDM)

A roadside ditch is defined as an open channel usually paralleling the highway embankment and within the limits of the right-of-way. The primary function of the ditch is to collect and convey storm water runoff from the highway right-of-way.

A roadside ditch is formed by the intersection of the fore slope and the back slope. Two ditch types are checked by the PRM: a Vee-type ditch (described as channels with abrupt slope changes in the 1996 AASHTO *Roadside Design Guide*), and a trapezoidal ditch ((described as channels with gradual slope changes in the 1996 AASHTO *Roadside Design Guide*). The PRM check deals with the design of roadside ditches as they relate to the location and shape necessary to avoid creating a potential conflict with errant vehicles. The hydrological characteristics of the roadside ditch are not considered.

A PRM check of the roadside ditch is only useful to the user if it is run in conjunction with the PRM check of the clear zone. For example, if the user evaluates a particular ditch design and the program determines that it varies from the recommended range of values referenced in policy, then this may or may not be an issue depending on whether or not the ditch is located within the clear zone. Therefore, the PRM reports, "If the ditch is located within the clear zone, then the road value varies from the recommended range of values."

4.9.1 Input Data Requirements

To check normal ditch design, the following data must be input by the PRM user:

- Analysis limits (Start Station and End Station)
- Ditch data (fore slope, back slope, width, bottom shape and bottom type)

4.9.2 The PRM Process

On the basis of the type of roadside ditch being evaluated (Vee-type or trapezoidal) and size of the ditch, the PRM references the appropriate figures in the 1996 AASHTO *Roadside Design Guide* to determine if the ditch design is within recommended values referenced in the policy.

The PRM references figures in the 1996 AASHTO *Roadside Design Guide* depending on the size and type of ditch:

- Use Figure 3.5 if the ditch is:
  - A "true" Vee ditch,
  - A rounded Vee or trapezoidal ditch with a bottom width less than 2.4 m [8 ft], or
  - A "true" trapezoidal channel with a width less than 1.2 m [4 ft].
- Use Figure 3.6 if the ditch is:
  - A rounded Vee or trapezoidal ditch with a bottom width equal to or more than 2.4 m [8 ft], or
  - A "true" trapezoidal channel with a width equal to or more than 1.2 m [4 ft].

4.9.3 Special Conditions

The 1996 AASHTO *Roadside Design Guide* policy requires the user to determine the bottom width of a rounded ditch. The policy does not define and does not describe how to measure the width of a rounded ditch. Therefore, for the purpose of the PRM, the width of a rounded ditch will be measured as the horizontal distance between the end of the fore slope and the beginning of the back slope, i.e., the diameter of a rounded ditch.

4.9.4 Output

Results of the check are summarized in a single table of the PRM Analysis Report. In the table, each row represents the highway segment with a uniform normal ditch design. The table includes the following columns:

- Stations-Start and End: the station limits of a highway segment with a uniform normal ditch design.
- Direction of Travel: The side of the road (left or right) facing in the direction of increasing stations.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 11., *Summary of Comment Statements for Normal Ditch Design Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 11. Summary of Comment Statements for Normal Ditch Design Check

Comment	Description of the Situation
Road value is within recommended values	The normal ditch design falls within the recommended range of values for preferred channel cross section referenced in policy.
If the ditch is within the clear zone, road value varies from recommended values	The normal ditch design falls outside of the recommended range of values for preferred channel cross section referenced in policy.
Comment specific to missing data element	Required data are missing.

4.10 Bridge Width

Bridge width is defined as the clear highway width on a structure including the traveled way and shoulder. Bridge width is among the 13 controlling criteria. Bridge width is measured from face of curb to face of curb or from base of parapet to base of parapet. Bridge width does not include sidewalk or other pedestrian facilities not available for the use of vehicular traffic.

4.10.1 Input Data Requirements

To check bridge width, the following data must be input by the PRM user:

- Analysis limits (Start Station and End Station)
- Type of project/study (new construction or reconstruction)
- Functional classification (local, collector, or arterial)
- Design speed
- Traffic volume (design-year average daily traffic (ADT) or design hour volume)
- Through lane width
- Shoulder width
- Use as a bike facility
- Bridge width
- Bridge characteristics (type of bridge project, bridge length)

4.10.2 The PRM Process

The PRM determines bridge width from the IHSDM highway data file for the highway segment being evaluated. On the basis of the highway functional classification, the PRM references the appropriate tables in the 1994 and 2001 AASHTO policy, and performs the appropriate checks as defined in the policy. The PRM also considers the intended use as a bicycle facility in evaluating bridge width.

The 1994 and 2001 AASHTO policy values are determined as follows:

- For bridges on undivided two-lane local roads:
  - If it is new or reconstructed: Table V-7 in the 1994 AASHTO policy and Exhibit 5-6 in the 2001 AASHTO policy
  - If it is an existing bridge that remains in place: Table V-8 in the 1994 AASHTO policy and Exhibit 5-7 in the 2001 AASHTO policy

- For bridges on undivided two-lane collector roads:
  - If it is new or reconstructed: Table VI-5 in the 1994 AASHTO policy and Exhibit 6-6 in the 2001 AASHTO policy
  - If it is an existing bridge that remains in place: Table VI-6 in the 1994 AASHTO policy and Exhibit 6-7 in the 2001 AASHTO policy
- For bridges on arterials:
  - If it is new or reconstructed:
    - If the length of the bridge is less than or equal to 60 m [200 ft], the recommended minimum width referenced in policy is the full highway width. This is the sum of the traveled way plus shoulders. (See p. 487 in the 1994 AASHTO policy and p. 451 in the 2001 AASHTO policy.)
    - If the length of the bridge is more than 60 m [200 ft], the recommended minimum clear highway width referenced in policy is the width of traveled way plus 1.2 m [4 ft] on each side (or a total of 2.4 m [8 ft] for a two-lane road). (See p. 487 in the 1994 AASHTO policy and p. 451 in the 2001 AASHTO policy.)
- If it is an existing bridge that remains in place then the recommended range of values for clear highway width on the structure is greater than or equal to the width of traveled way plus 0.6 m [2 ft] on each side (or a total of 1.2 m [4 ft] for a two-lane road). (See p. 487 in the 1994 AASHTO policy and p. 451 in the 2001 AASHTO policy.)

If the highway is intended for bicycle use, the 1999 AASHTO *Guide for the Development of Bicycle Facilities* recommended range of values for bridge width is greater than or equal to the width of the traveled way plus 1.5 m [5 ft] on each side or the highway (or a total of 3.0 m [10 ft] in the undivided highway case).

4.10.3 Boundary Conditions and Rounding

The road and policy values are rounded to the nearest 0.01 m [0.01 ft].

4.10.4 Special Conditions

Table V-7 in the 1994 AASHTO policy and Exhibit 5-7 in the 2001 AASHTO policy contain arithmetic overlaps in the categorization of an ADT of 1,500 vehicles/day. In PRM, the following categories have been used for these tables: 0 to 49, 50 to 250, 251 to 1500, 1,501 to 2,000, and over 2,000.

Tables V-6, VI-5 and VI-6 in the 1994 AASHTO policy, and Exhibits 5-6, 6-6 and 6-7 in the 2001 AASHTO policy, contain arithmetic overlaps in the categorization of ADT (design volume). For these Tables and Exhibits, the PRM assumes the following categories: under 400, 400 to 1500, 1501 to 2000, and over 2000.

Because 1994 and 2001 AASHTO policies provide no specific criteria for bridges to remain in place on local and collector roads with total lengths greater than 30 m [100 ft], the PRM cannot check such cases. A "No Policy" message is output for this condition. The 2001 AASHTO policy for new or reconstructed collector and local road bridges in excess of 30 m [100 ft] in length recommends a minimum traveled way width plus 1 m [3 ft] for the bridge width.

4.10.5 Output

Results of the check are summarized in a single table of the PRM Analysis Report. In the table, each row represents a bridge. The table includes the following columns:

- Stations-Start and End: the station limits of the highway segment constituting a bridge.
- Bridge Width-Road and Policy:
  - The road value is the bridge width within the highway segment defined by the start and end stations.
  - The policy value is the recommended minimum bridge width referenced in the selected policy for the design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 12., *Summary of Comment Statements for Bridge Width Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 12. Summary of Comment Statements for Bridge Width Check

Comment	Description of the Situation
Road value is within controlling criteria	The bridge width is greater than or equal to the policy value for bridge width.
Road value varies from controlling criteria	The bridge width is less than the policy value for bridge width.
No data: (comment specific to missing data element)	Required data are missing.
No policy applies, structure should be analyzed individually, taking into consideration the clear width provided, traffic volume, remaining life of bridge, pedestrian volume, snow storage, design speed, accident record, and pertinent factors.	The bridge is an existing structure to remain in place on a local or collector road of length 30 m [100 ft] or greater.

5. Horizontal Alignment Checks

This section describes each horizontal alignment element check. Included in the discussion is a definition of the check, the input data requirements, the PRM check process, boundary and rounding conditions, special conditions, and the output generated by the PRM for each check. Notes are made to illustrate the differences between the 1994 and 2001 editions of the AASHTO *A Policy on Geometric Design of Highways and Streets* (AASHTO policy). Discussions of the 1994 AASHTO policy (in metric units) also apply to the 1990 AASHTO policy (in English units). The following horizontal alignment checks are included in this section (those denoted with * are controlling criteria):

- Radius of Curve*
- Superelevation*
- Superelevation Transition Design(not available in the current release of IHSDM)
- Length of Horizontal Curve

- Compound Curve Ratio

Table 13., *Summary of Input Data Requirements for Horizontal Alignment Checks* summarizes the input data required to perform each horizontal alignment check.

Table 13. Summary of Input Data Requirements for Horizontal Alignment Checks

Horizontal Alignment Check/Input Data	Radius of Curve	Superelevation	Superelevation Transition	Length of Horizontal Curve	Compound Curve Ratio
Functional Classification	*	*		*	
Design Speed	*	*	*	*	
Maximum Superelevation	*	*	*		
Horizontal Alignment Data	*	*	*	*	*
Surface Type	*	*			
Through Lane Cross Slope		*	*		
Superelevation	*	*	*		
Through Lane Width			*		*

5.1 Radius of Curve

Radius of curve is a basic design parameter for horizontal curves. Radius of curve is among the 13 controlling criteria. AASHTO design policy references a recommended minimum radius of curve for a given design speed and maximum superelevation rate (e) so as not to exceed a maximum side friction factor (f). The maximum side friction factor is a function of design speed. One set of factors is provided for rural highways, urban freeways, and high-speed urban streets; IHSDM uses this set. Another set is provided for low-speed urban streets, which is not used by IHSDM. AASHTO also provides guidance on the selection of a maximum superelevation rate (4, 6, 8, 10, or 12 percent). The recommended minimum radius of curve for a given design speed corresponds with the use of the maximum superelevation rates. The PRM checks the radius of curve for a given design speed relative to the recommended minimum radii referenced in AASHTO Policy. Other checks evaluate the superelevation rate and superelevation transition from tangent alignment into the curve.

5.1.1 Input Data Requirements

To check radius of curve, the following data must be input by the PRM user:

- Analysis limits (Start Station and End Station)
- Maximum superelevation for the analysis (4, 6, 8, 10, and 12 percent)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)
- Functional classification (local, collector, or arterial)
- Design speed
- Surface type (paved, aggregate)

- Superelevation of each curve (derived from cross slope)

5.1.2 The PRM Process

Using the maximum superelevation, design speed, and the curve radius from the IHSDM highway data file, the PRM compares the road value to the recommended minimum radius referenced in Table III-6 of the 1994 AASHTO policy or Exhibit 3-14 of the 2001 AASHTO policy. The radius of a given horizontal curve is reported to fall within controlling criteria for the specified design speed if it is greater than or equal to the recommended minimum radius referenced in AASHTO policy.

The PRM also calculates an "effective design speed" for each horizontal curve. Effective design speed, V(eff), is determined using the following equations:

V(eff) = (127*R[e+f])1/2 ;where e = superelevation rate and f = side friction (metric)

V(eff) = (15*R[e+f])1/2 ; where e = superelevation rate and f = side friction (U.S.)

V(eff) is the maximum speed for the radius [R] and superelevation [e] of a given curve such that the resultant side friction factor does not exceed the maximum side friction factor for that speed as specified in Table III-6 in the 1994 AASHTO policy or Exhibit 3-14 in the 2001 AASHTO policy. If the IHSDM highway data file contains superelevation for the curve, then that rate is used; if the file does not contain superelevation for the curve, then the maximum superelevation specified for the analysis is used to calculate effective design speed.

The PRM also evaluates the maximum superelevation specified for the analysis. The PRM reports whether the maximum superelevation falls within or outside the range of recommended values referenced in policy, which are determined as follows. For rural local roads, the PRM references page 421 of the 1994 AASHTO policy [page 387 of the 2001 AASHTO policy]; the range of recommended values for maximum superelevation is from 6 to 10 percent for paved surfaces, and from 6 to 12 percent for aggregate surface roads. For rural collector roads, the PRM references page 464 of the 1994 AASHTO policy [page 428 of the 2001 AASHTO policy]. For rural arterials, the PRM references page 486 of the 1994 AASHTO policy [page 450 of the 2001 AASHTO policy]. For rural collectors and arterials, the range of recommended values referenced in policy is 6 to 12 percent.

5.1.3 Boundary Conditions and Rounding

All curve radii values are rounded to the nearest 0.01 m [0.01 ft].

5.1.4 Special Conditions

Three special cases are addressed in this section: compound curves, back-to-back spiral curves, and horizontal points of intersection (PIs).

For compound curves, the PRM checks separately the radius of each of the simple circular curves in the compound curve set.

For back-to-back spiral curves, there is no section of alignment that is defined as a simple circular curve. The PRM checks the value of radius at the common point of the two spirals (SS). At this point, there is a local, effective minimum radius. This local radius is checked against the recommended minimum radius referenced in policy.

Horizontal points of intersection without curves, i.e., horizontal deflections, are not evaluated by this check. So, PRM output provides no notice or mention of this condition.

5.1.5 Output

Results of the check are summarized in two tables of the PRM Analysis Report: one for radius of curve, and one for maximum superelevation.

In the table for the radius of curve check, each row represents a horizontal curve. The table includes the following columns:

- Stations-Start and End: the station limits of the horizontal curve.
- Radius of Curve-Road and Policy:
  - The road value is the radius of the curve within the highway segment defined by the start and end stations.
  - The policy value is the recommended minimum radius referenced in the selected policy for the specified design controls.
- Effective Design Speed
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 14., *Summary of Comment Statements for Radius of Curve Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 14. Summary of Comment Statements for Radius of Curve Check

Comment	Description of the Situation
Road value is within controlling criteria	The road value of radius of curve is greater than or equal to the recommended minimum radius of curve referenced in policy.
Road value varies from controlling criteria.	The road value for radius of curve is less than the recommended minimum radius of curve referenced in policy.
No data: (comment specific to missing data element)	Required data are missing.

The table for maximum superelevation includes a single row for the analysis limits. The table includes the following columns:

- Stations-Start and End: the analysis limits.
- e_{max} Bounds-Road and Policy:
  - The road value is the maximum superelevation specified for the analysis.
  - The policy values are the recommended range of maximum superelevation referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 15., *Summary of Comment Statements for Maximum Superelevation Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 15. Summary of Comment Statements for Maximum Superelevation Check

Comment	Description of the Situation
Road value is within controlling criteria	The maximum superelevation specified for the analysis is within the range of recommended values referenced in policy.
Road value varies from controlling criteria.	The maximum superelevation specified for the analysis is outside the range of recommended values referenced in policy.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up table.

5.2 Superelevation

Superelevation refers to the banking of the plane of the highway section through the horizontal curve to counterbalance the lateral forces developed by the vehicle as it proceeds at speed through the curve. Superelevation is among the 13 controlling criteria.

AASHTO policy references a range of recommended maximum superelevation. These maximum superelevation rates are used for the sharpest curve (i.e., minimum radius of curve) referenced for a given design speed. For curves with radii larger than the minimum, AASHTO references a recommended design superelevation rate less than the maximum rate.

This check compares the superelevation rate of a given horizontal curve relative to the values referenced in AASHTO for design superelevation rates. Another check evaluates the superelevation transition between approach and departure tangents and the horizontal curve.

5.2.1 Input Data Requirements

To check superelevation, the following data must be input by the PRM user:

- Analysis limits (Start Station and End Station)
- Maximum superelevation for the analysis (4, 6, 8, 10, and 12 percent)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)
- Functional classification (local, collector, or arterial)
- Design speed
- Surface type (paved, aggregate)
- Superelevation of each curve (derived from cross slope)

5.2.2 The PRM Process

The PRM determines the full superelevation of each curve from the cross slope data specified in the IHSDM highway data file for the highway being evaluated. Prior to checking superelevation, the PRM must first establish whether the radius of curve is within controlling criteria, i.e., greater than or equal to the recommended minimum radius referenced in policy. AASHTO policy tables for design superelevation reference recommended values only for radii greater than or equal to the recommended minimum radius; therefore, the superelevation check can be performed only for curves with radii within controlling criteria. If the radius of a curve is less than the minimum radius referenced in policy, there are no design superelevation policy values to reference and, therefore, the superelevation check cannot be performed.

Using the maximum superelevation and the curve radius, the PRM checks to make sure that the road value for radius is greater than or equal to the recommended minimum radius referenced in Table III-6 of the 1994 AASHTO policy [Exhibit 3-14 of the 2001 AASHTO policy]. If the road value for radius is less than the recommended minimum radius, then the process of checking superelevation for that curve is terminated and the appropriate output message is created. If the road value for radius is greater than or equal to the recommended minimum radius, then the PRM compares the road value for superelevation to the 1994 AASHTO policy values presented in Tables III-7 to III-11 [Exhibits 3-21 to 3-25 of the 2001 AASHTO policy]. The PRM performs straight-line interpolation between tabular values for radius and superelevation.

For conditions resulting in policy values of "NC" (normal crown) or "RC" (remove adverse crown), the PRM reports policy values as "NC" and "RC," respectively. If the policy value for a given design speed, radius, and maximum superelevation falls between "RC" and the first numeric value in Tables III-7 to III-11 of the 1994 AASHTO policy [Exhibits 3-21 to 3-25 of the 2001 AASHTO policy], then the PRM sets "RC" equal to the road normal cross slope and interpolates between the numeric value and the road normal cross slope. For example, for a maximum superelevation of 8 percent, design speed of 80 km/h and a curve radius of 1750 m, the superelevation in Table III-9 of the 1994 AASHTO policy [Exhibit 3-23 of the 2001 AASHTO policy] falls between "RC" (for R=2000 m) and 2.4 percent (for R=1500 m). If the road value for normal cross slope is 2 percent, then the PRM interpolates between 2 and 2.4 percent to arrive at a policy value of 2.2 percent.

Boundary conditions for superelevation designated as "NC" are handled in a more direct manner and interpolation between "NC" and "RC" is not required. The minimum radius for which "NC" design is appropriate is taken directly from the appropriate look-up table. For a given design speed, radii falling between "NC" and "RC" designations are assumed to be "RC." For example, in Table III-9 in the 1994 AASHTO policy [Exhibit 3-23 in the 2001 AASHTO policy], given a design speed of 80 km/h and a radius of 2400 m, the policy value would be "RC."

The PRM reports that the road value for superelevation is close to controlling criteria if it is within plus or minus 0.1 percent of the relevant policy value in Tables III-7 through III-11 of the 1994 AASHTO policy [Exhibits 3-21 to 3-25 in the 2001 AASHTO policy]. For example, if the relevant policy value is 3.4 percent and the road value is within the range of 3.3 to 3.5 percent, then the PRM will report that the road value is close to controlling criteria.

The PRM also compares the maximum superelevation rate specified for the analysis against the range of recommended values referenced in policy. The PRM reports whether the specified maximum superelevation falls within or outside the range of recommended values referenced in policy. For rural local roads, the PRM references page 421 of the 1994 AASHTO policy [page 387 of the 2001 AASHTO policy]; the range of recommended values for maximum superelevation is from 6 to 10 percent for paved surfaces, and from 6 to 12 percent for aggregate surface roads. For rural collectors, the PRM references page 464 of the 1994 AASHTO policy [page 428 of the 2001 AASHTO policy]. For rural arterials, the PRM references page 486 of the 1994 AASHTO policy [page 450 of the 2001 AASHTO policy]. For rural collectors and arterials, the range of recommended values referenced in policy is 6 to 12 percent.

5.2.3 Boundary Conditions and Rounding

Road and policy values for superelevation rates are rounded to the nearest 0.01 percent.

5.2.4 Special Conditions

Three conditions are addressed in this section: compound curves, back-to-back spiral curves, and horizontal points of intersection (PIs).

For compound curves, the PRM checks separately the superelevation of each simple circular curve in the compound curve set.

For back-to-back spiral curves, there is no section of alignment that is defined as a simple circular curve. The PRM should check the superelevation at the common point of the two spirals (SS). At this point, there is a local superelevation rate. This local superelevation rate is checked against the recommended design superelevation referenced in policy.

Horizontal points of intersection without a curve, i.e., horizontal deflections, are not evaluated by this check. The PRM output provides no notice or mention of this condition.

5.2.5 Output

Results of the check are summarized in two tables of the PRM Analysis Report: one for design superelevation of each curve, and one for maximum superelevation specified for the analysis.

In the table for design superelevation, each row represents a horizontal curve. The table includes the following columns:

- Stations-Start and End: the station limits of the horizontal curve.
- Superelevation-Road and Policy:
    - The road value is the full superelevation rate for the curve within the highway segment defined by the start and end stations.
    - The policy value is the recommended design superelevation rate referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 16., *Summary of Comment Statements for Superelevation Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 16. Summary of Comment Statements for Superelevation Check

Comment	Description of the Situation
Road value is within controlling criteria	The road value for superelevation is equal to the policy value for design superelevation rate referenced in policy.
Road value is close to controlling criteria	The road value for superelevation is within plus or minus 0.1 percent of the design superelevation rate referenced in policy.
Road value varies from controlling criteria	The road value for superelevation differs by more than plus or minus 0.1 percent from the policy value for design superelevation rate referenced in policy.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up tables.

The table for maximum superelevation includes a single row for the analysis limits. The table includes the following columns:

- Stations-Start and End: the analysis limits.
- e_{max} Bounds-Road and Policy:
  - The road value is the maximum superelevation specified for the analysis.
  - The policy values are the range of maximum superelevation referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 17., *Summary of Comment Statements for* e_{max} *Bounds Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 17. Summary of Comment Statements for e_{max} Bounds Check

Comment	Description of the Situation
Road value is within controlling criteria	The maximum superelevation rate specified for the analysis is within the range of recommended values referenced in policy.
Road value varies from controlling criteria.	The maximum superelevation rate specified for the analysis is outside the range of recommended values referenced in policy.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up table.

5.3 Superelevation Transition (not available in the current release of IHSDM)

The term superelevation transition design refers to the longitudinal and lateral design of the edges of pavement in advance of a horizontal curve that requires development of superelevation. The portion of the alignment over which the pavement slope is changed from a normal cross slope design to full superelevation is referred to as the transition. AASHTO describes two ways in which the transition can be designed: without spiral curves (i.e., from tangent to circular horizontal curve), and with a simple spiral curve between the tangent and circular curve.

Development of the superelevation is a final design detail. It is part of the process wherein elevations for both edges of pavement are designed or calculated. To test for transition design adherence to policy requires that the design be completed for the centerline as well as both edges of pavement.

Transitions effected on unspiraled alignments include two elements: tangent runout, and superelevation runoff. Tangent runout is that portion of the alignment over which the adverse cross slope is removed. Superelevation runoff represents the length of highway over which the development of full superelevation occurs, i.e., from the end of runout to the point at which full superelevation is achieved in the curve.

The AASHTO policy contains criteria on the lengths of runoff and on the relationship of pavement edge profiles to centerline profiles. In the case of two-lane rural highways, the axis of rotation typically used to attain superelevation is by way of revolving the traveled way with normal cross slopes about the centerline.

Another design control for the transition is the distribution of the superelevation runoff along the transition. For unspiraled designs, AASHTO references recommended values for the percentage of runoff located prior to the point of curvature (PC). For spiral transition designs, AASHTO notes that the development of full superelevation occurs on the spiral, with full superelevation at the point of spiral to curve (SC).

In most cases, superelevation transition design is a consideration in the design of tangent to curve alignment. In rare instances, transitions also are required for compound curvature. A review of the AASHTO Policy did not show any recommended values for lengths of superelevation transitions between compound curves; therefore, the PRM does not cover this instance.

When users request the superelevation transition check, the PRM checks all aspects of transition design, including runoff length, percentage of runoff on the tangent, whether or not the transition is within a spiral curve, the length of spiral, and the maximum relative profile gradient.

5.3.1 Input Data Requirements

To check the superelevation transition design, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Maximum superelevation for the analysis (4, 6, 8, 10, and 12 percent)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)
- Vertical alignment data (vertical curves and tangents, VPI stations and elevations)
- Design speed

- Through lane width
- Through lane cross slope
- Superelevation of each curve (derived from cross slope)

5.3.2 The PRM Process

AASHTO policy describes five methods to distribute superelevation and side friction on highway curves. Method 5 distributes superelevation and side friction in a curvilinear relation with the inverse of the radius of curve. This method is commonly used for all curves with radii greater than the minimum radius of curvature on rural highways. The PRM employs Method 5 to check superelevation transition design for horizontal curves.

The PRM identifies a transition as being either an unspiraled transition or a spiral curve transition. For unspiraled transitions (tangent to curve, or curve to tangent), the program determines the location where runoff begins and where the actual full superelevation on the given curve is achieved and calculates the length of runoff transition.

For unspiraled transitions, the computed superelevation runoff length is compared to the recommended lengths of runoff referenced in Tables III-7 through III-11 in the 1994 AASHTO policy and Exhibits 3-21 through 3-25 of the 2001 AASHTO policy. The runoff lengths included in the 1994 AASHTO policy tables are for two- or four-lane cross-sections. In the case of three- or six-lane cross-sections, the length for a two-lane transition is multiplied by 1.2 or 2.0, respectively. The 2001 AASHTO policy provides adjustment factors for number of lanes rotated in Exhibit 3-28.

For unspiraled transitions, the PRM also checks the percentage of superelevation runoff effected on the tangent. The 1994 AASHTO policy references a recommended range of between 60 percent and 80 percent of the superelevation occurring on the tangent of an unspiraled transition. The 2001 AASHTO policy references a recommended range of between 60 and 90 percent of the superelevation occurring on the tangent of an unspiraled transition.

For spiral curve transitions, the PRM determines the location where the runoff begins and ends and determines whether the superelevation runoff is "effected over the whole of the transition curve," as recommended in the 1994 and 2001 AASHTO policies, this point. If the TS is within plus or minus 2 m [10 ft] of the start of the superelevation runoff and the ST is within 2 m of the start of full superelevation, then the PRM reports that the superelevation runoff is within the spiral. Then, the PRM determines the length of spiral and compares this length to the recommended length of runoff referenced in Tables III-7 through III-11 of the 1994 AASHTO policy, or in Exhibits 3-21 through 3-25 of the 2001 AASHTO policy. The appropriate length of spiral is the same as the length of runoff. The program incorporates straight-line interpolation between tabular values for radius, superelevation, and minimum length of runoff. The AASHTO policy addresses these lengths as minimums; hence, spirals longer than those specified by AASHTO are reported by the PRM as within the recommended values referenced in policy.

The PRM also checks relative gradients for profiles between the edge of the traveled way and the centerline against the recommended maximum relative gradients referenced in Table III-13 in the 1994 AASHTO policy and Exhibit 3-27 in the 2001 AASHTO.

5.3.3 Boundary Conditions and Rounding

The road and policy values in the runoff length and length of spiral analysis tables are rounded to the nearest 0.01 m [0.01 feet]. The road and policy values in the output tables for percentage of runoff on tangent and relative profile gradient are rounded to the nearest 0.01 percent.

5.3.4 Special Conditions

The horizontal alignment may contain compound curvature. Such curvature may require different superelevation rates for the two radii. The AASHTO Policy does not provide explicit guidelines for design of superelevation transitions in such cases. Therefore, the PRM is not able to check superelevation transitions between compound curves.

Boundary conditions exist in the design procedures that are accommodated in the program. These boundary conditions are between the NC and RC sections, and between RC and superelevated sections.

When radii resulting in policy values between RC and the first numeric value in a column are used, the PRM interpolates between RC and the first numeric value in the table. For example, given a normal cross-slope of 2.0 percent, design speed = 60 km/h, radius = 1100 m, and E-max = 8 percent, the policy value (from Table III-9) would be determined by interpolating between RC and 2.2 percent. Since the normal cross-slope is 2.0 percent, RC = 2.0 percent for radius = 1000 m. The policy value for radius = 1100 m would then be (2.0 + 2.2)/2 = 2.1 percent.

Boundary conditions for superelevation designated as NC are handled in a more direct manner and interpolation between NC and RC is not required. The minimum radius for which NC design is appropriate is taken directly from the appropriate look-up table. For a given design speed, radii falling between "NC" and "RC" designations are assumed to be RC. For example, in Table III-9, given a design speed of 80 km/h and a radius of 2400 m, the policy value would be RC.

Horizontal points of intersection without a curve, i.e., horizontal deflections, are not evaluated by this check. The PRM output provides no notice or mention of this condition.

In certain instances the alignment in the vicinity of the transition may pass through an intersection. In doing so, profile values for one or both edges of pavement may not be available. This is not interpreted as a violation of policy, but it will preclude completion of the analysis as outlined above. These cases are noted in the PRM analysis report.

In checking the location of the superelevation transition relative to the spiral curve, a tolerance range of plus or minus 2 m [10 ft] on each end of the spiral curve is established.

5.3.5 Output

Results of the check are summarized in a series of tables in the PRM Analysis Report; one for each of the following dimensions: runoff length, percent runoff on tangent, Is (superelevation) transition within spiral-, length of spiral, maximum relative profile gradient. The tables have the same general format. Each row represents one of the transitions (i.e., into or out of horizontal curve). The tables include the following common columns:

- Stations-Start and End: the station limits of the horizontal curve.
- End of curve-Exit or Entry, in the direction of increasing stations.
- Dimension checked-Road and Policy: The road value for the highway segment and the relevant policy value against which it is checked.

- The road value is the dimension of the highway being evaluated within the segment defined by the start and end stations.
- The policy value is the limiting value within the recommended range of values referenced in the selected policy.

- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 18., *Summary of Comment Statements for Superelevation Transition Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 18. Summary of Comment Statements for Superelevation Transition Check

Comment	Description of the Situation
Road value is within recommended values	The road value of the dimension being reported (i.e., runoff length, percent runoff on tangent, transition within spiral, length of spiral, and relative profile) falls within the range of recommended values referenced in policy.
Road value varies from recommended values	The road value of the dimension being reported (i.e., runoff length, percent runoff on tangent, transition within spiral, length of spiral, and relative profile) falls outside the range of recommended values referenced in policy.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up tables

5.4 Length of Horizontal Curve

The length of curve is a design parameter that results from the selection of a design radius for a given deflection angle. AASHTO policy references recommended values for minimum length of curve in its discussion of general controls for horizontal alignment. The basis for the recommendation is primarily aesthetics, i.e., to avoid the appearance of a kink in the alignment at curves with small deflection angles.

5.4.1 Input Data Requirements

To check length of horizontal curve, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)
- Functional classification (local, collector, or arterial)
- Design speed

5.4.2 The PRM Process

The PRM determines the length of each horizontal curve from the IHSDM highway data file for the highway being evaluated. For simple circular curves, the length of the curve is the road value. For curves with spirals on either or both ends, the road value for length of curve is the sum of the lengths of circular and spiral curves. For compound curves, the road value is the sum of the lengths of the two simple curves comprising the compound curve. These road values are then compared to the relevant policy values, which are determined as outlined below.

AASHTO policy values for length of horizontal curve vary by functional classification are referenced on p. 224 of the 1994 AASHTO policy and pp. 233-234 of the 2001 AASHTO policy. They are a function of design speed. Table 19., *Recommended minimum length of curve referenced in policy for arterials* summarizes the formulas for recommended minimum lengths for main highways. Table 20., *Recommended minimum length of curve with small deflection angles* summarizes formulas for recommended minimum length of curves with small deflection angles, which apply to all functional classifications.

Table 19. Recommended minimum length of curve referenced in policy for arterials

	Formula	Units of Minimum Length (L)	Units of Design Speed (V)
Metric	L = 3V	meters	km/h
US Customary	L = 15V	feet	mi/h

Table 20. Recommended minimum length of curve with small deflection angles

	Formula	Units of Minimum Length (L)	Units of Design Speed (V)
Metric	L = [150+(5 - central angle) x 30]	meters	km/h
US Customary	L = [500+(5 - central angle) x 100]	feet	mi/h

Curve lengths on arterials are checked relative to the formula in both Table 19., *Recommended minimum length of curve referenced in policy for arterials* and Table 20., *Recommended minimum length of curve with small deflection angles* . Curve lengths on collector and local roads are checked relative to only Table 20., *Recommended minimum length of curve with small deflection angles* .

5.4.3 Boundary Conditions and Rounding

Road and policy values for length of horizontal curve are rounded to the nearest 0.01 m [0.01 ft].

5.4.4 Special Conditions

The AASHTO Policy reference to main highways has been interpreted as meaning roads functionally classified as arterial highways.

5.4.5 Output

Results of the check are summarized in one table of the PRM Analysis Report. In the table, each row represents a horizontal curve. The table includes the following columns:

- Stations-Start and End: the station limits of the horizontal curve.
- Computed Curve Length-Road and Policy:

- The road value is the length of the horizontal curve within the highway segment defined by the start and end stations.
- The policy value is the recommended minimum length of horizontal curve referenced in the selected policy for the specified design controls.

- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 21., *Summary of Comment Statements for Superelevation Transition Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 21. Summary of Comment Statements for Superelevation Transition Check

Comment	Description of the Situation
Road value is within recommended values	The computed length of horizontal curve is greater than or equal to the policy value for the length of horizontal curve.
Road value varies from recommended values	The computed length of horizontal curve is less than the policy value for the length of horizontal curve.
No data: (comment specific to missing data element)	Required data are missing.
Not applicable; design check not required	Horizontal curve with deflection angle greater than 5 degrees on local and collector roads.

5.5 Compound Curve Ratio

Compound curves are circular horizontal curves of different radii, with alignment in the same direction (i.e., not reverse curvature), with no tangent alignment between the curves. (Alignment comprised of consecutive curvature separated by a short tangent is referred to as broken-back alignment.) In its discussion of general controls for horizontal alignment, AASHTO policy references a recommended range of values for the ratio of the radii of the adjoining circular curves comprising the compound curve.

5.5.1 Input Data Requirements

To check compound curve ratio, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)

5.5.2 The PRM Process

The PRM determines the curve radii for two circular curves that share a common point (i.e., point of compound curvature) from the IHSDM highway data file for the highway being evaluated. The compound curve ratio is computed by dividing the larger radius by the smaller radius. These road values are then compared to the relevant policy values, which are determined as outlined below.

AASHTO (on p. 225 of the 1994 policy and p. 234 of the 2001 policy) recommends that the ratio of the larger radius to the smaller radius should be not exceed a maximum of 1.5.

5.5.3 Boundary Conditions and Rounding

Road and policy values for compound curve ratio are rounded to the nearest 0.01.

5.5.4 Special Conditions

No special conditions are identified for compound curve ratio. Where no compound curve exists, the PRM review for compound curve ratio does not apply.

5.5.5 Output

Results of the check are summarized in one table of the PRM Analysis Report. In the table, each row represents a compound curve. The table includes the following columns:

- Stations-Start and End: the station limits of the compound curve.
- Compound Curve Ratio-Road and Policy:
  - The road value is the ratio of the radii comprising the compound curve within the highway segment defined by the start and end stations.
  - The policy value is the maximum recommended ratio referenced in the selected policy.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 22., *Summary of Comment Statements for Compound Curve Ratio Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The station limits of each simple circular curve in the compound curve set.

Table 22. Summary of Comment Statements for Compound Curve Ratio Check

Comment	Description of the Situation
Road value is within recommended range of values	The compound curve ratio is less than or equal to or the policy value for compound curve ratio.
Road value varies from recommended range of values	The compound curve ratio is greater than the policy value for compound curve ratio.
No data: (comment specific to missing data element)	Required data are missing.

6. Vertical Alignment Checks

This section describes each individual PRM vertical alignment element check. Included in the discussion is a definition of the check, the input data requirements necessary to perform the check, PRM check process, boundary and rounding conditions, special conditions, and the output generated by the PRM for each check. Notes are made to illustrate the differences between the 1990/94 and 2001 editions of the AASHTO *A Policy on Geometric Design of Highways and Streets* (AASHTO policy). Discussions of the 1994 AASHTO policy (in metric units) also apply to the 1990 AASHTO policy (in English units). The following vertical alignment checks are included in this section (those denoted with * are controlling criteria):

- Vertical Tangent Grade*
- Vertical Curvature*

Table 23., *Summary of Input Data for Vertical Alignment Checks* is a summary of the input data required to perform each vertical alignment check.

Table 23. Summary of Input Data for Vertical Alignment Checks

Vertical Alignment Check/Input Data	Vertical Tangent Grade	Vertical Curvature
Project Type		*
Functional Classification	*	
Highway Terrain	*	
Design Speed	*	*
Vertical Alignment Data	*	*

6.1 Vertical Tangent Grade

Grade is defined as the rise or fall in elevation expressed as meters per 100 m [feet per 100 ft] horizontal and is expressed in percent. Grade is among the 13 controlling criteria.

Ascending grades are positive and descending grades are negative. A positive or negative gradient is determined with reference to stationing of a particular alignment. An alignment that increases in elevation in the direction of increasing stationing is said to have a positive grade.

6.1.1 Input Data Requirements

To check tangent grade, the PRM user must provide the following data

- Analysis limits (Start Station and End Station)
- Vertical alignment data (vertical curves and tangents, VPI stations and elevations)
- Functional classification (local, collector, or arterial)
- Highway terrain (level, rolling or mountainous)
- Design speed

6.1.2 The PRM Process

The PRM determines the tangent grade from the IHSDM highway data file for the highway being evaluated. These road values are then compared to the relevant policy values, which are determined as outlined below.

AASHTO policy recommends minimum and maximum grade values. A minimum grade of 0.30 percent is recommended with curbed highways and streets. Recommended maximum grades depend on functional classification and design speed and are provided in Tables V-4, VI-3, and VII-1 of the 1994 AASHTO policy and Exhibits 5-4, 6-4, and 7-2 of the 2001 AASHTO policy. Additionally, the maximum values referenced in the tables may be exceeded for short lengths of grade or on low-volume rural highways.

6.1.3 Boundary Conditions and Rounding

Road and policy values for tangent grade are rounded to the nearest 0.01 percent.

6.1.4 Special Conditions

Both the 1994 AASHTO policy (on pp. 233-234) and the 2001 AASHTO policy (on p. 242) include provisions that: for with short grades less than 150 m [500 ft] in length and for one-way downgrades, the maximum gradient may be 1 percent steeper than the values given in the tables; and for low-volume rural highways (which the PRM interprets as an ADT less than 400), the maximum gradient may be 2 percent steeper than the values given in the table.

6.1.5 Output

Results of the check are summarized in a single table of the PRM Analysis Report. In the table, each row represents a segment of uniform grade. The table includes the following columns:

- Stations-Start and End: the station limits of the tangent grade.
- Tangent Grade-Road and Policy:
  - The road value is the grade for the vertical tangent being evaluated within the highway segment defined by the start and end stations.
  - The policy value is the recommended range of values referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 24., *Summary of Comment Statements for Tangent Grade Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 24. Summary of Comment Statements for Tangent Grade Check

Comment	Description of the Situation
Road value is within controlling criteria	The tangent grade is less than or equal to the recommended maximum grade referenced in policy and greater than 0.3 percent.
Road value varies from controlling criteria	The tangent grade is greater than the policy value for tangent grade.
Road value may vary from recommended values, check drainage	The tangent grade is less than 0.3 percent.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up tables

6.2 Vertical Curvature

Vertical curves are used to transition from one tangent grade to another. Equal-tangent (i.e., symmetrical) parabolic curves are typically used in highway design. The curve is defined by the first grade, length of curve, and the second grade. Vertical curves are referred to as crest vertical curves or sag vertical curves. Design policy on vertical curves is based upon stopping-sight distance requirements. Vertical alignment is among the 13 controlling criteria.

6.2.1 Input Data Requirements

To check a vertical curve, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Type of project/study (new construction or reconstruction) [Applicable to 1994 AASHTO policy]
- Vertical alignment data (vertical curves and tangents, VPI stations and elevations)
- Design speed

6.2.2 The PRM Process

The PRM determines the length and algebraic difference in grades for each vertical curve from the IHSDM highway data file for the highway being evaluated. The PRM then computes the rate of vertical curvature, K, i.e., the length of curve divided by the algebraic difference in grades or the horizontal distance to effect a 1 percent change in gradient along the vertical curve. These computed K values are then compared to the relevant policy values, which are determined as outlined below.

AASHTO policy values for vertical curve length depend on the design speed, type of vertical curve (sag or crest) and the algebraic difference in grades between the first and second grade. Recommended minimum K values are provided in Tables III-35 and III-37 in the 1994 AASHTO policy [Exhibits 3-76 and 3-79 in the 2001 AASHTO policy] for crest and sag vertical curves, respectively. The 1994 AASHTO policy provides a range of K values for each design speed. The PRM uses the upper value as the policy value for new construction and the lower value as the policy criterion for reconstruction. The 2001 policy references a single K value for each design speed. This value is used as the policy value in PRM for new construction and reconstruction.

The PRM also reports an effective design speed for each curve. The effective design speed is the speed for which the K value for the curve would be equal to the recommended minimum K value for that speed. The PRM computes effective design speed by interpolation of values in the AASHTO policy tables for recommended minimum K values.

6.2.3 Boundary Conditions and Rounding

The road and policy values for K in the vertical curve output tables are rounded to the nearest 0.01 m [0.1 ft].

6.2.4 Special Conditions

No special conditions are identified for vertical curve. Where no vertical curve exists, the PRM review for vertical curve does not apply.

6.2.5 Output

Results of the check are summarized in one table of the PRM Analysis Report. Each row in the table represents a vertical curve. The table includes the following columns:

- Stations-Start and End: the station limits of the vertical curve.
- K value-Road and Policy:
  - The road value is the computed K value for the vertical curve within the highway segment defined by the start and end stations.
  - The policy value is the recommended minimum K value referenced in the selected policy for the specified design controls.
- Effective Design Speed
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 25., *Summary of Comment Statements for Vertical Curve K Value Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 25. Summary of Comment Statements for Vertical Curve K Value Check

Comment	Description of the Situation
Road value is within controlling criteria	The K value for the vertical curve is greater than or equal to the recommended minimum K value referenced in policy.
Road value varies from controlling criteria	The K value for the vertical curve is less than the recommended minimum K value referenced in policy.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up tables.

7. Sight Distance Checks

This section describes each individual PRM sight distance check. Included in the discussion is a definition of the check, the input data requirements to perform the check, the PRM check process, boundary and rounding conditions, special conditions, and the output generated by the PRM for each check. Notes are made to illustrate the differences between the 1990/94 and 2001 editions of the AASHTO Policy on Geometric Design of Highways and Streets (AASHTO policy). Discussions of the 1994 AASHTO policy (in metric units) also apply to the 1990 AASHTO policy (in English units).

The following sight distance checks are included in this section (those denoted with * are controlling criteria):

- Stopping Sight Distance*
- Passing Sight Distance
- Decision Sight Distance

Table 26., *Summary of Input Data for Sight Distance Checks* is a summary of the input data required to perform each sight distance check.

Table 26. Summary of Input Data for Sight Distance Checks

Sight Distance Check/Input Data	Stopping Sight Distance	Passing Sight Distance	Decision Sight Distance
Design Speed	*	*	*
Horizontal Alignment Data	*	*	*
Vertical Alignment Data	*	*	*
Through Lane Data	*	*	*
Auxiliary Lane Data	*	*	*
Obstruction Offset	*	*	*
DSD Stations			*
Type of Avoidance Maneuver			*

7.1 Stopping Sight Distance

AASHTO defines sight distance as the length of highway ahead visible to the driver. Stopping sight distance (SSD) is the distance required by a driver to stop a vehicle traveling at or near the design speed of a highway before reaching a stationary object in its path. SSD is among the 13 controlling criteria.

Stopping sight distance is made up of two components and is defined as follows in the 2001 AASHTO Policy on Geometric Design of Highways and Streets:

> Stopping-sight distance is the sum of two distances: (1) the distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied, and (2) the distance needed to stop the vehicle from the instant brake application begins. These are referred to as brake reaction distance and braking distance, respectively.

AASHTO provides equations to calculate recommended minimum SSD for each design speed. These equations are based on a number of assumptions regarding the vehicle operating speed and driver behavior in situations that require braking. AASHTO recommends values for each variable and provides a summary table of recommended minimum SSD for each design speed.

7.1.1 Input Data Requirements

To check SSD, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Type of project/study (new construction or reconstruction)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)
- Vertical alignment data (vertical curves and tangents, VPI stations and elevations)
- Design speed
- Through lane width
- Auxiliary lane width
- Obstruction offset: this input variable is the distance from the centerline of the highway to sight obstructions. If the user does not specify a value, the PRM uses a default value, which is the distance from the centerline to the edge of shoulder.

7.1.2 The PRM Process

The PRM computes the SSD from the horizontal and vertical alignment and cross section data in the IHSDM highway data file for the highway being evaluated. The available SSD is a function of the highway geometry and roadside features and, therefore, is not constant along an alignment or analysis section. Available SSD may be restricted by either the horizontal or vertical alignment, and it will vary as the vehicle-driver approaches and passes along horizontal and vertical curves. The PRM determines the available SSD by analyzing both vertical and the horizontal geometry at critical sections of the highway alignment. At short increments through these critical sections, the PRM records the lesser of the two values (i.e., limited by vertical or horizontal geometry) as the available SSD for each location. The PRM compares available SSD to the relevant policy values for SSD, which are determined as outlined below. Whenever either the available vertical or horizontal stopping sight distance is less than the policy values, the PRM reports the station limits over which this occurs.

The 1994 AASHTO policy values for SSD are based on a driver eye height of 1070 mm [3.5 ft] and an object height of 150 mm [0.5 ft]. The two components that make up SSD are based on 2.5 seconds of brake-reaction time and a tire-road friction coefficient that varies with speed. In the 1994 Policy, a range of assumed vehicle speeds are associated with each design speed. This range of assumed speeds results in a range of recommended minimum SSD values associated with each design speed. These values are summarized in Table III-1. For a given design speed, the PRM uses the upper values of SSD as the policy values for new construction and the lower values for reconstruction.

The 2001 AASHTO policy values for SSD are based on a driver eye height of 1080 mm [3.5 ft] and an object height of 600 mm [2.0 ft]. The two components that make up SSD are based on 2.5 seconds of brake-reaction time and a vehicle deceleration rate of 3.4 m/s2 [11.2 ft/s2]. Recommended minimum SSD values vary with design speed; a single policy value is associated with each design speed, and the PRM uses this value for new construction and reconstruction. The values are summarized in Exhibit 3-1.

7.1.3 Boundary Conditions and Rounding

The road values in the SSD output tables are rounded to the nearest meter [foot].

7.1.4 Special Conditions

The SSD check evaluates the three-dimensional characteristics of an existing or proposed highway alignment. The PRM is not able to determine if vertical obstructions over the highway will restrict the available SSD. An example would be a structure located over a sag vertical curve. Such a structure could block a driver’s sight lines and restrict the available SSD.

7.1.5 Output

Results of the check are summarized in both a tabular and a graphical form in the PRM Analysis Report.

In the table for the SSD check, each row represents a highway segment through which available SSD remains either greater than or less than the recommended minimum value referenced in policy. The table includes the following columns:

- Stations-Start and End: the station limits of the highway segment.
- Direction of Travel-Increasing or decreasing stations.

- Stopping Sight Distance-Road and Policy:
  - The road value is the minimum available SSD within the highway segment defined by the start and end stations. A road value is reported only for segments for which the available SSD is less than the recommended minimum SSD values referenced in policy.
  - The policy value is the recommended minimum SSD referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 27., *Summary of Comment Statements for Stopping Sight Distance Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 27. Summary of Comment Statements for Stopping Sight Distance Check

Comment	Description of the Situation
Road value is within controlling criteria	The available stopping sight distance is greater than or equal to the policy value for stopping sight distance.
Road value varies from controlling criteria; source of SD limitation is vertical alignment	The available stopping sight distance is less than the policy value for stopping sight distance. The vertical alignment limits the available stopping sight distance.
Road value may vary from controlling criteria; check obstructions beyond shoulder; source of SD limitation is horizontal alignment	The horizontal alignment limits the available stopping sight distance. The user did not specify an obstruction offset for the station in which the sight line is obstructed; therefore, the PRM computed available stopping sight distance using the default, i.e., a sight obstruction at the edge of shoulder.
Road value may vary from controlling criteria; check obstructions beyond Obstruction Offset; source of SD limitation is horizontal alignment	The horizontal alignment limits the available stopping sight distance. The user-specified obstruction offset is beyond the edge of pavement for the station at which the sight line is obstructed and is used to compute the available stopping sight distance.
Road value may vary from controlling criteria; check obstructions beyond pavement; source of SD limitation is horizontal alignment	The horizontal alignment limits the available stopping sight distance. The user-defined obstruction offset is closer than the edge of pavement for the station at which the sight line is obstructed and, therefore, the available stopping sight distance is based on the edge of pavement.
No data: (comment specific to missing data element)	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up tables

Comment	Description of the Situation
Can't calculate available vertical (or horizontal) SD	The available stopping sight distance extends beyond the end of the highway and cannot be calculated because data are not available beyond the analysis limits.

Figure 1, *Example of Graphical Output of Stopping Sight Distance Check* is an example of the graphical output generated by the PRM. The value of the available SSD on this graph is limited to an SSD threshold of two times the recommended minimum SSD.

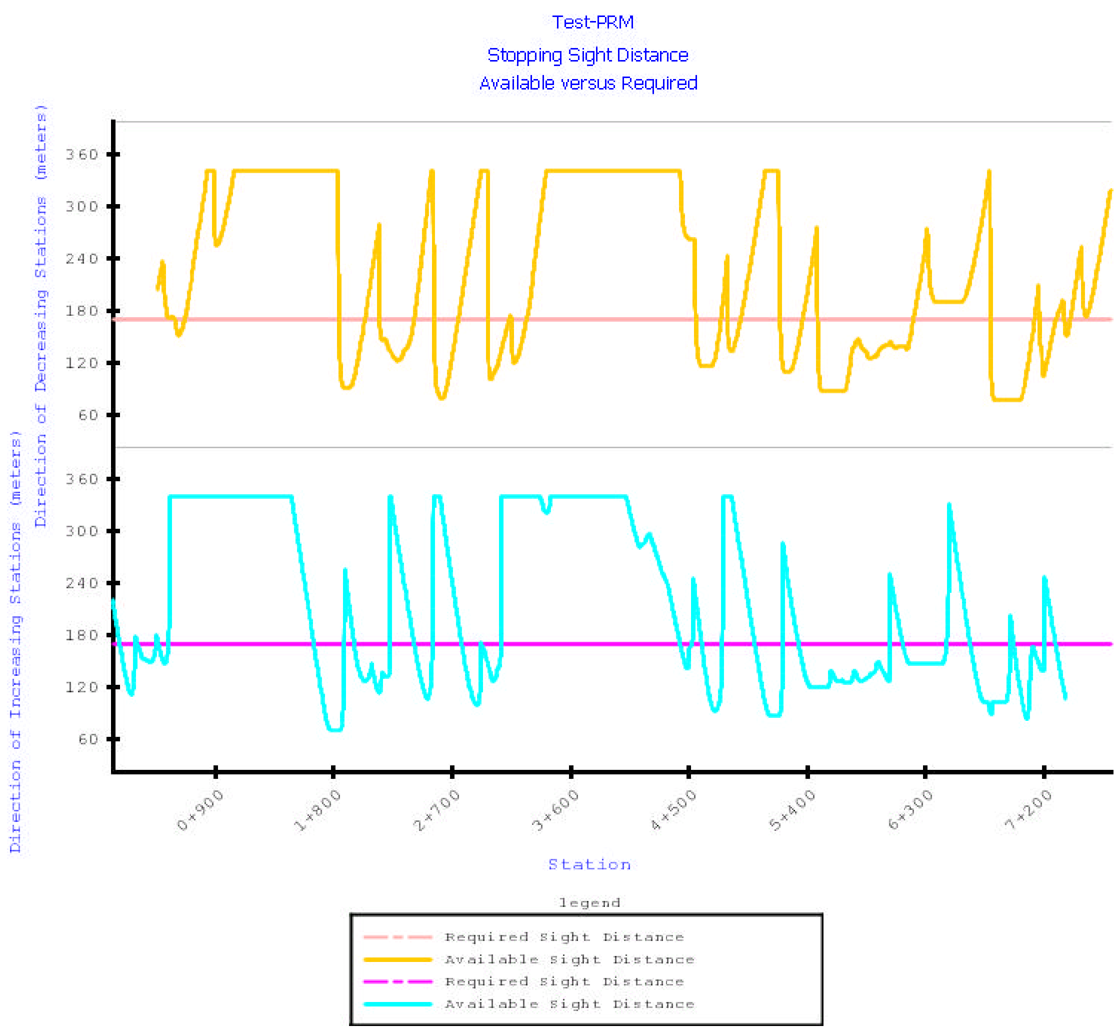


Figure 1 Example of Graphical Output of Stopping Sight Distance Check

7.2 Passing Sight Distance

The AASHTO Policy defines passing sight distance (PSD) as the length of visible highway needed to safely complete normal passing maneuvers when a passing vehicle overtakes a slow-moving vehicle by moving into a lane that is normally used by opposing traffic. PSD is not required along an entire highway. Also, PSD need not be considered when two or more traffic lanes are provided in the same direction of travel. Thus, the decision on where to provide PSD is based on the particular design conditions. In those circumstances where PSD is to be provided, the Policy provides a single value for the highway design speed. Underlying assumptions and derivation of PSD values are included in the AASHTO Policy.

7.2.1 Input Data Requirements

To check PSD, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)
- Vertical alignment data (vertical curves and tangents, VPI stations and elevations)
- Design speed
- Through lane width
- Auxiliary lane data (number, type, width)
- Obstruction offset: this input variable is the distance from the centerline of the highway to sight obstructions. If the user does not specify a value, the PRM uses a default value, which is the distance from the centerline to the edge of shoulder.

7.2.2 The PRM Process

The PRM determines the available PSD from the horizontal and vertical alignment and cross section data in the IHSDM highway data file for the highway being evaluated. The available PSD is a function of the highway geometry and roadside features and, therefore, is not constant along an alignment or analysis section. Available PSD may be restricted by either the horizontal alignment or crest vertical curves. Within tangents and sag vertical curves, PSD is not limited by highway geometry. The PRM determines the available PSD by analyzing both vertical and horizontal geometry at critical sections of the proposed or existing highway alignment. At short increments through these critical sections, the PRM records the lesser of the two values (i.e., limited by vertical or horizontal geometry) as the available PSD for each location. These road values (available PSD) are then compared to the recommended minimum PSD values, which are determined as outlined below.

The 1994 AASHTO policy values for PSD are based on a driver eye height of 1070 mm [3.5 ft] and an object height of 1300 mm [4.25 ft]. The policy values are based on assumed speed relationships between the passed, passing and opposing vehicles. The policy is also based on the contingency that an overtaking driver may abort the pass after entering the opposing travel lane. Additionally, it provides for clearances between the passing and passed vehicles and the passing and opposing vehicles. The policy value is determined as the sum of four distances: perception/reaction distance, overtaking distance, passing distance, and opposing vehicle distance. The four elements of the PSD are estimated and then rounded into a single policy value for each design speed, and these recommended minimum PSD values are summarized in Table III-5. Although higher PSD values are recommended on upgrades, specific guidance is not provided.

The 2001 AASHTO policy values for PSD are based on a driver eye height of 1080 mm [3.5 ft] and an object height of 1080 mm [3.5 ft]. The Policy values are based on assumed speed relationships between the passed, passing and opposing vehicles. The Policy is also based on the contingency that an overtaking driver may abort the pass after entering the opposing travel lane. Additionally, it provides for clearances between the passing and passed vehicles and the passing and opposing vehicles. The policy value is determined as the sum of four distances: perception/reaction distance, overtaking distance, passing distance, and opposing vehicle distance. The four elements of the PSD are estimated and then rounded into a single policy value for each design speed, and these recommended minimum PSD values are summarized in Exhibit 3-7. Although higher PSD values are recommended on upgrades, specific guidance is not provided.

7.2.3 Boundary Conditions and Rounding

The road and policy values in the PSD output tables are rounded to the nearest 0.01m [0.01 ft].

7.2.4 Special Conditions

This check evaluates the three-dimensional characteristics of an existing or a proposed highway alignment. The PRM is not able to determine if vertical obstructions over the highway will restrict the available PSD. An example would be a structure located over a sag vertical curve. Such a structure could block a driver's sight lines and restrict the available PSD.

7.2.5 Output

Results of the check are summarized in both a tabular and a graphical form in the PRM Analysis Report. In the table for the PSD check, each row represents a highway segment through which available PSD remains either greater than or less than the recommended minimum value referenced in policy. The table includes the following columns:

- Stations-Start and End: the station limits of the highway segment.
- Direction of Travel-Increasing or decreasing stations.
- Passing Sight Distance-Road and Policy:
    - The road value is the minimum available PSD within the highway segment defined by the start and end stations. A road value is reported only for segments for which the available PSD is below the recommended minimum passing sight distance values referenced in policy.
    - The policy value is the recommended minimum PSD referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 28., *Summary of Comment Statements for Passing Sight Distance Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 28. Summary of Comment Statements for Passing Sight Distance Check

Comment	Description of the Situation
Road value is within recommended values	The available passing sight distance is greater than or equal to the policy value for passing sight distance.
Road value varies from recommended values; source of SD limitation is vertical alignment	The available passing sight distance is limited by the vertical alignment and is less than the policy value for passing sight distance.
Road value may vary from recommended values; check obstructions beyond shoulder; source of SD limitation is horizontal alignment	The horizontal alignment limits the available passing sight distance. The user did not specify an obstruction offset for the station in which the sight line is obstructed; therefore, the PRM computed available passing sight distance using the default, i.e., a sight obstruction at the edge of shoulder.
Road value may vary from recommended values; check obstructions beyond Obstruction Offset; source of SD limitation is horizontal alignment	The horizontal alignment limits the available passing sight distance. The user-specified obstruction offset is beyond the edge of pavement for the station at which the sight line is obstructed and is used to compute the available passing sight distance.
Road value may vary from recommended values; check obstructions beyond pavement; source of SD limitation is horizontal alignment	The horizontal alignment limits the available passing sight distance. The user-defined obstruction offset is closer than the edge of pavement for the station at which the sight line is obstructed and, therefore, the available passing sight distance is based on the edge of pavement.
No data: comment specific to missing data element	Required data are missing.
No policy: comment specific to the variable	Controlling variables are out of the range of the policy look up tables
Can’t calculate available vertical (or horizontal) SD	The available stopping sight distance extends beyond the end of the highway and cannot be calculated because data are not available beyond the analysis limits.

A note at the bottom of the table reports the percentage of the alignment for which available PSD is greater than or equal to the recommended minimum PSD referenced in policy. This measure is used in highway capacity calculations.

The PRM also generates a graph showing the PSD along the highway. The value of the available PSD on this graph is limited to a PSD threshold equal to two times the recommended minimum PSD. Figure 2, *Example of Graphical Output for Passing Sight Distance Check* provides an example of the graph.

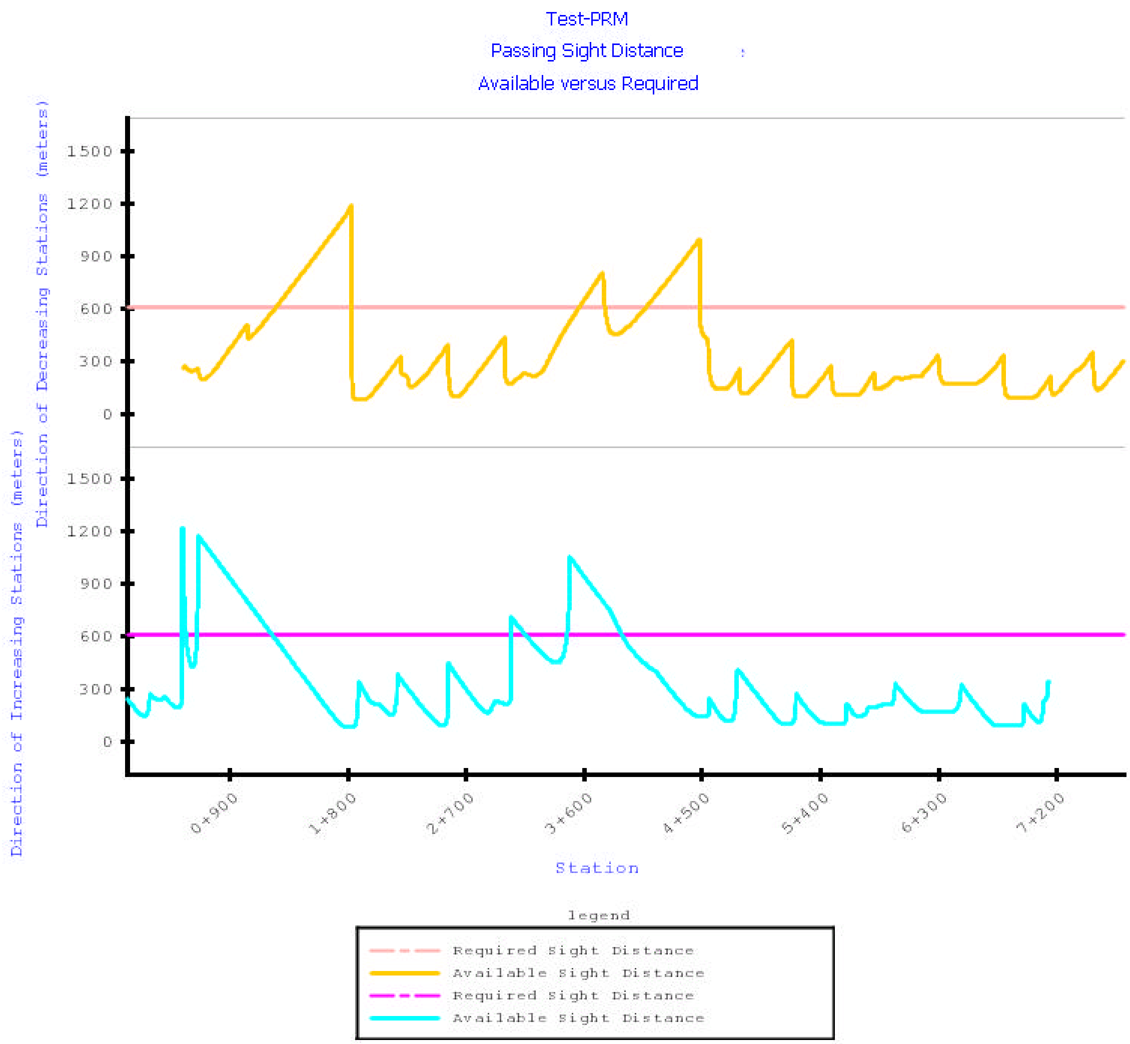


Figure 2 Example of Graphical Output for Passing Sight Distance Check

7.3 Decision Sight Distance

Decision sight distance (DSD) is defined in the 2001 AASHTO policy as follows:

> Decision sight distance is the distance required for a driver to detect an unexpected or otherwise difficult-to-perceive information source or condition in a highway environment that may be visually cluttered, recognize the condition or its potential threat, select an appropriate speed and path, and initiate and complete the maneuver safely and efficiently.

DSD is determined using the same parameters as stopping sight distance for object and eye height. The longer distances associated with DSD are based on greater times assumed to be required for drivers. The minimum DSD is determined for a vehicle traveling at the design speed. DSD is provided to drivers to ensure their ability to perform the appropriate avoidance maneuver.

Whereas stopping sight distance represents a continuous requirement, DSD is considered necessary only at selected locations.

7.3.1 Input Data Requirements

7.3.1 Input Data Requirements To check DSD, the PRM user must provide the following data:

- Analysis limits (Start Station and End Station)
- Horizontal alignment data (horizontal curves and tangents, curves directions and radii, deflection angles, headings, coordinates, and station equations)
- Vertical alignment data (vertical curves and tangents, VPI stations and elevations)
- Design speed
- Through lane width
- Auxiliary lane data
- Obstruction offset: this input variable is the distance from the centerline of the highway to sight obstructions. If the user does not specify a value, the PRM uses a default value, which is the distance from the centerline to the edge of shoulder.
- DSD stations (locations where drivers will have to either stop or make a maneuver involving a speed, path, or direction change)
- Type of avoidance maneuver (Avoidance Maneuver A, stop on rural road, or Avoidance Maneuver C, speed/path/direction change on rural road)

7.3.2 The PRM Process

The user must specify the locations (defined by stations) where the PRM should check DSD. The available DSD is a function of the highway geometry and roadside features and, therefore, is not constant along an alignment or analysis section. Available DSD may be restricted by either the horizontal or vertical alignment, and it will vary as the vehicle-driver approaches and passes along horizontal and vertical curves. The PRM determines the available DSD by analyzing both vertical and horizontal geometry of the highway alignment. At user-specified stations, the PRM records the lesser of the two values (i.e., limited by vertical or horizontal geometry) as the available DSD to each location.

AASHTO policy identifies five avoidance maneuvers that require varying DSD:

- Avoidance Maneuver A: Stop on rural road.
- Avoidance Maneuver B: Stop on urban road.
- Avoidance Maneuver C: Speed/path/direction change on rural road.
- Avoidance Maneuver D: Speed/path/direction change on suburban road.
- Avoidance Maneuver E: Speed/path/direction change on urban road.

Since the scope of IHSDM is limited to rural roads, the PRM checks only Avoidance Maneuvers A and C.

The 1994 AASHTO policy values for DSD are based on a driver eye height of 1070 mm [3.5 ft] and an object height of 150 mm [0.5 ft]. The 1994 policy provides a single policy value for each design speed and associated avoidance maneuver. These recommended minimum DSD values are summarized in Table III-3.

The 2001 AASHTO policy values for DSD are based on a driver eye height of 1080 mm [3.5 ft] and an object height of 600 mm [2.0 ft]. The 2001 Policy provides a single policy value for each design speed and associated avoidance maneuver. These recommended minimum DSD values are summarized in Exhibit 3-3.

7.3.3 Boundary Conditions and Rounding

The road and policy values in the Decision Sight Distance output tables are rounded to the nearest meter [ft].

7.3.4 Special Conditions

This check evaluates the three-dimensional characteristics of an existing or proposed highway alignment. The PRM is not able to check to determine if vertical obstructions over the highway will restrict the available decision sight distance. An example would be a structure located over a sag vertical curve. The structure could block the driver's sight lines and restrict the available DSD.

7.3.5 Output

Results of the check are summarized in a single table in the PRM Analysis Report. Each row represents a location to which the user has requested a check of DSD. The table includes the following columns:

- Stations-Object and Eye:
  - Object station is the station at which the avoidance maneuver should be completed.
  - Eye station is the station furthest upstream of the object station where decision sight distance is available.
- Direction of Travel-Increasing or decreasing stations.
- Decision Sight Distance-Road and Policy:
  - The road value is the available DSD to the object station. It is the distance between the eye and object stations.
  - The policy value is the recommended minimum DSD referenced in the selected policy for the specified design controls.
- Comment: A statement summarizing the comparison of the road value and policy value for the highway segment. Table 29., *Summary of Comment Statements for Decision Sight Distance Check* lists the possible comments for this check and provides a more detailed description of the situation they represent.
- Attributes: The design controls for the highway being evaluated that are used to determine the relevant policy value.

Table 29. Summary of Comment Statements for Decision Sight Distance Check

Comment	Description of the Situation
Road value is within recommended values	The available decision sight distance is greater than or equal to the recommended minimum decision sight distance referenced in policy.
Road value varies from recommended values; source of SD limitation is vertical alignment	The available decision sight distance is limited by the vertical alignment and is less than the policy value for decision sight distance.
Road value may vary from recommended values; check obstructions beyond shoulder; source of SD limitation is horizontal alignment	The horizontal alignment limits the available decision sight distance. The user did not specify an obstruction offset for the station in which the sight line is obstructed; therefore, the PRM computed available decision sight distance using the default, i.e., a sight obstruction at the edge of shoulder.
Road value may vary from recommended values; check obstructions beyond Obstruction Offset; source of SD limitation is horizontal alignment	The horizontal alignment limits the available decision sight distance. The user-specified obstruction offset is beyond the edge of pavement for the station at which the sight line is obstructed and is used to compute the available decision sight distance.
Road value may vary from recommended values; check obstructions beyond pavement; source of SD limitation is horizontal alignment.	The horizontal alignment limits the available decision sight distance. The user-defined obstruction offset is closer than the edge of pavement for the station at which the sight line is obstructed and, therefore, the available decision sight distance is based on the edge of pavement.
No data: comment specific to missing data element	Required data are missing.
No policy: (comment specific to the variable)	Controlling variables are out of the range of the policy look up tables
Can’t calculate available vertical (or horizontal) SD	The available stopping sight distance extends beyond the end of the highway and cannot be calculated because data are not available beyond the analysis limits.

8. IHSDM Documentation

IHSDM documentation is organized in a series of manuals oriented to specific user types and information needs. User types include first-time users, regular users, and system administrators. Information needs include: installing and configuring IHSDM, the mechanics of using the various features of the software, engineering insights to ensure appropriate use of the software and interpretation of outputs, and administering and maintaining the software installation.

The structure of the series of manuals is illustrated in the User Documentation Map. The manuals are listed and described below by the users and information needs they support:

- Manuals for First-Time Users: These manuals are oriented to assist new users in installing and configuring IHSDM and running it for the first time. Manuals include:
  - Getting Started Guide - An overview of the installation and use of IHSDM. This Guide should be sufficient for stand-alone installations. For client-server installations,

the more detailed IHSDM Installation Manual will be needed.

  - Installation Manual - A detailed reference to the installation and configuration of IHSDM.
  - Running IHSDM Software Manual - An overview of the basic operations in running the IHSDM software. The intent is to provide new users the information they need to run IHSDM for the first time.

- User’s Manuals: These Manuals are intended as references that regular users can consult when issues arise about the mechanics of using the IHSDM graphical user interface. Manuals include:
  - IHSDM User’s Manual - A reference for using the primary IHSDM graphical user interface. Other User’s Manuals provide additional details on specific components of the IHSDM graphical user interface:
    - Policy Review Module (PRM) User’s Manual - A reference for using the (stand-alone) Policy Review Module software graphical user interface.
    - Crash Prediction Module (CPM) User’s Manual - A reference for using the (stand-alone) Crash Prediction Module software graphical user interface.
    - Design Consistency Module (DCM) User’s Manual - A reference for using the (stand-alone) Design Consistency Module software graphical user interface.
    - Intersection Review Module (IRM) User’s Manual - A reference for using the (stand-alone) Intersection Review Module software graphical user interface.
    - Traffic Analysis Module (TAM) User’s Manual - A reference for using the (stand-alone) Traffic Analysis Module software graphical user interface.
    - Using the IHSDM Graphical User Interface - A reference for the operation of the individual components of the graphical user interface.
    - User Properties and Defaults Manual - A reference for editing IHSDM system properties, user properties, and user default values.
  - Frequently Asked Questions - A list of frequently asked questions related to the IHSDM software.
  - IHSDM Troubleshooting Guide - A reference for troubleshooting IHSDM software problems.
- Documentation of IHSDM Data: These documents provide detailed descriptions of all IHSDM data elements and references for importing and editing data.
  - IHSDM Highway Model - A reference for the IHSDM highway model, including descriptions of the data elements comprising the model.
  - LandXML Support - A reference for IHSDM support for the LandXML data standard.
  - Editing Highway Elements - A reference for using the Edit/View Highway Elements graphical user interface.
  - GEOPAK-TO-IHSDM Application Programmer’s Interface (API) User’s Manual - A reference for using the Application Program Interface (API) to export data from GEOPAK into a format that IHSDM can import.

- Engineer's Manual: The intent of these Manuals is to provide the engineering information necessary to make appropriate use of IHSDM evaluation capabilities and interpretation of results. Manuals include:
  - Policy Review Module (PRM) Engineer's Manual - A reference for the engineering issues of using the Policy Review Module.
  - Crash Prediction Module (CPM) Engineer's Manual - A reference for the engineering issues of using the Crash Prediction Module.
  - Design Consistency Module (DCM) Engineer's Manual - A reference for the engineering issues of using the Design Consistency Module.
  - Intersection Review Module (IRM) Engineer's Manual - A reference for the engineering issues of using the Intersection Review Module.
    - **Intersection Policy Review Sub-Manual** - Describes the procedures for checking an intersection design element against relevant policy, including references to the section of the AASHTO policy that contains the information used to develop the module and check the design. **(The Intersection Policy Review Sub-Manual is not available in the current release of IHSDM.)**
    - Intersection Diagnostic Review Engineer's Sub-manual - Describes in detail the concerns that the diagnostic review component considers and the models used to evaluate those concerns.
  - Traffic Analysis Module (TAM) Engineer's Manual - A reference for the engineering issues of using the Traffic Analysis Module.
- Manuals for System Administrators: These Manuals provide system administrators the information they need to maintain IHSDM installations.
  - System Administrator's Manual - A reference for using the IHSDM Administration Tool software graphical user interface. This manual also discusses customizing variable components of IHSDM, including analysis report templates, data dictionaries, and policy files.
  - PRM/IRM Policy Table Maintenance - A reference for editing design policy tables used in the Policy Review Module and Intersection Review Module.

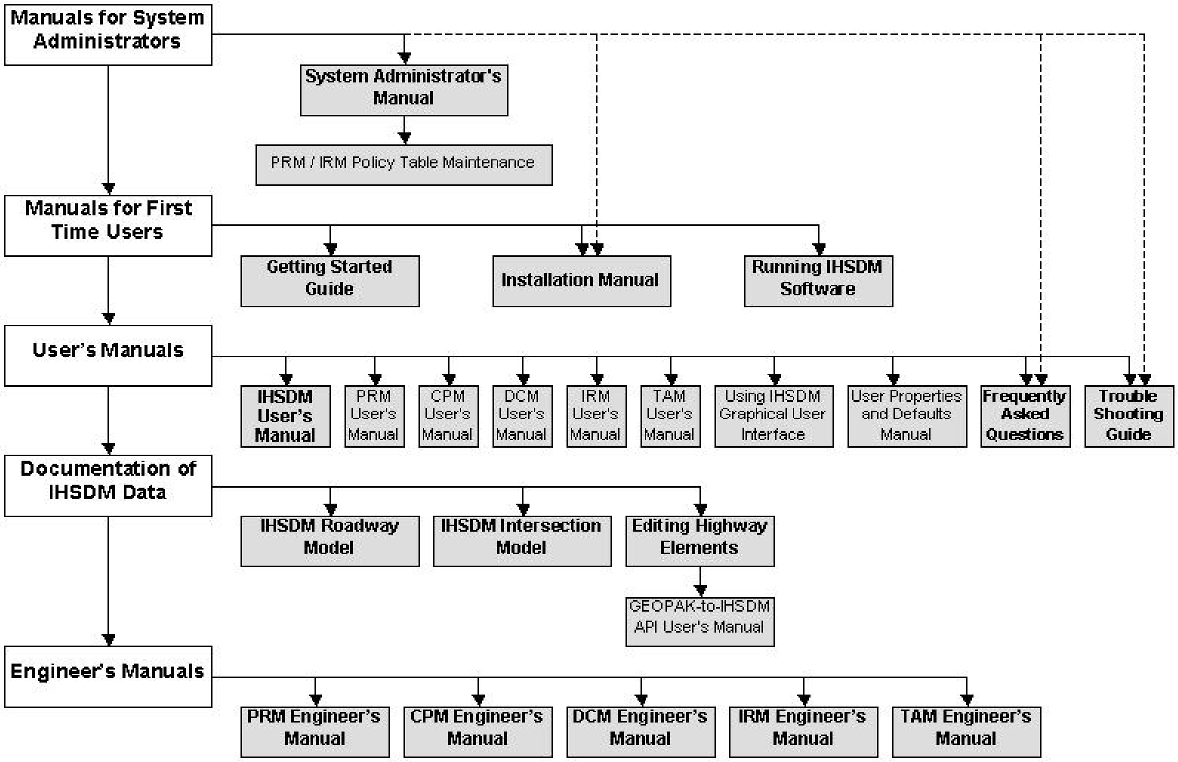


Figure 3 User Documentation Map