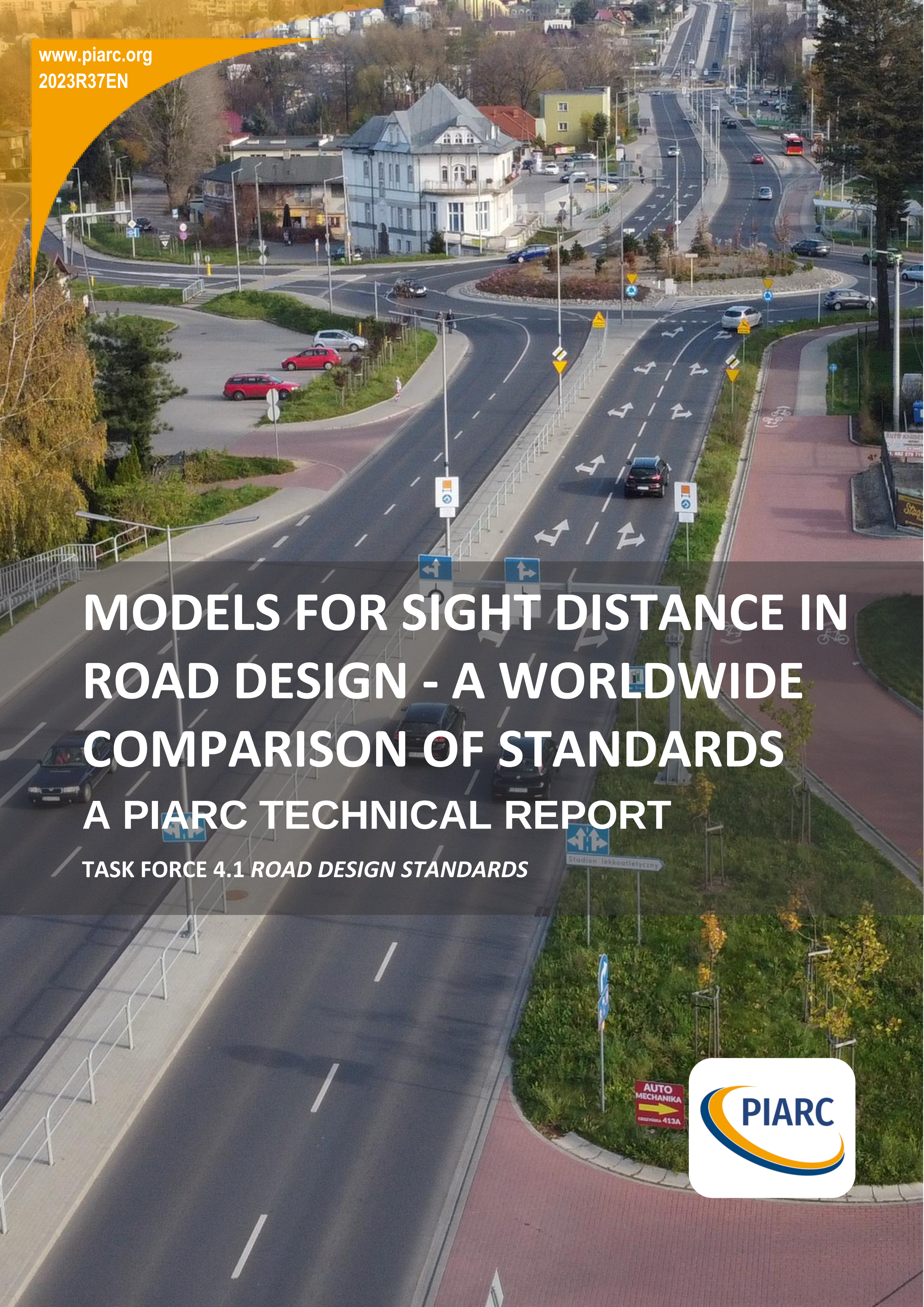
www.piarc.org
2023R37EN



MODELS FOR SIGHT DISTANCE IN ROAD DESIGN - A WORLDWIDE COMPARISON OF STANDARDS

A PIARC TECHNICAL REPORT

TASK FORCE 4.1 *ROAD DESIGN STANDARDS*

STATEMENTS

The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

The study that is the subject of this report was defined in the PIARC Strategic Plan 2020–2023 and approved by the Council of the World Road Association, whose members are representatives of the member national governments. The members of the Technical Committee responsible for this report were nominated by the member national governments for their special competences.

Any opinions, findings, conclusions, and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of their parent organisations or agencies.

This report is available from the internet site of the World Road Association (PIARC): http://www.piarc.org

World Road Association (PIARC)
Arche Sud 5° niveau
92055 La Défense cedex, France

International Standard Book Number: 978-2-84060-825-7

Front cover © Krystian WOŹNIAK (Poland)

MODELS FOR SIGHT DISTANCE IN ROAD DESIGN - A WORLDWIDE COMPARISON OF STANDARDS

A PIARC TECHNICAL REPORT

TASK FORCE 4.1 *ROAD DESIGN STANDARDS*

AUTHORS/ ACKNOWLEDGEMENTS

The document was prepared by Task Force 4.1 Road Design Standards of the World Road Association (PIARC) in 2023.

The Task Force members and contributors to the preparation of this report were:

- Janusz BOHATKIEWICZ (Poland)
- Hector Manuel BONILLA CUEVAS (Mexico)
- Ana Luísa CABRITA (Portugal)
- Zuzana CARSKÁ (Czech Republic)
- Lorenzo DOMENICHINI (Italy)
- Noel DWYER (Australia)
- Matthieu HOLLAND (France)
- Mariusz KIEC (Poland)
- Fernando LÓPEZ-MENCHERO DÍEZ (Spain)
- Régis LORANT (Belgium)
- Jason LOWE (South Africa)
- Bruno MARQUIS (Canada-Quebec)
- Masaru NOHIRA (Japan)
- Markus PIJAVEC (Austria)
- Víctor REYES GONZALEZ (Chile)
- Yoshihiro TANAKA (Japan)
- Jiandong ZHANG (China)

The editors of this report are Janusz BOHATKIEWICZ(Poland), Hector Manuel BONILLA CUEVAS (Mexico), Lorenzo DOMENICHINI (Italy), Alessandro GROSSI (Italy) Mariusz KIEC (Poland), Fernando LÓPEZ-MENCHERO DÍEZ (Spain), Bruno MARQUIS (Canada-Quebec), Masaru NOHIRA (Japan), Andrea PALIOTTO (Italy), Markus PIJAVEC (Austria) for the English version.

Mariusz KIEC (Poland), Fernando LÓPEZ-MENCHERO DÍEZ (Spain) were responsible within the Task Force for the final review and quality control for the production of this report.

The Task Force was chaired by Mariusz KIEC (Poland). Margaret NGOTHO OGAI (Kenya), Matthieu HOLLAND (France), Fernando LÓPEZ-MENCHERO DÍEZ (Spain) were English, French, and Spanish-speaking secretaries, respectively.

EXECUTIVE SUMMARY

2023R37EN

MODELS FOR SIGHT DISTANCE IN ROAD DESIGN
A WORLDWIDE COMPARISON OF STANDARDS

A PIARC TECHNICAL REPORT

This report is the second of two planned publications of PIARC Task Force 4.1 “Road Design Standards” in the period 2020 – 2023. PIARC considered the importance of comparing international road design standards to check their updated status and the degree of their readiness to face the forthcoming innovations in road mobility.

The full report presents a review of selected models in the field of road design standards based on a literature review, which was the first publication of PIARC TASK Force 4.1. It is the first document in many years comparing models applied in road design standards from several countries. The document aims to compare selected models adopted in different countries and evaluate the possible need for their adaptation to the requirements of a rapidly changing world in the field of road transport systems (new technologies, changes in mobility modes, and availability of multiple diffused data sources). This report also assesses possibilities of transferring models to other road design standards mainly in Low- or Middle-Income Countries.

The comparison and conclusions were drafted based on the review road design standards collected among the members of Task Force 4.1. Ultimately, the comparison covered 18 countries, depending on the models, around the world: Australia, Austria, Belgium-Flanders, Belgium-Wallonia, Canada, Czechia, France, Germany, Hungary, Italy, Japan, Mexico, Poland, Portugal, Romania, South Africa, Spain, Ukraine, United States of America.

The full report focuses on reviewing the following models related to sight distance: stopping sight distance, overtaking sight distance, decision-making sight distance, as well as maximum and minimum grades for road profiles. A review of models is supported by detailed information from road design standards which is reported in the Appendix.

More details about road design standards, which were used for the comparison of selected models for road design are included in the literature review report "State of the Art in Road Design Standards (2022R22EN)" published in 2022.

CONTENTS

1. INTRODUCTION 3

1.1. THE PURPOSE OF THE REPORT 4

1.2. THE STRUCTURE OF THE REPORT. 4

2. METHODOLOGY 5

3. ROAD DESIGN MODELS 6

3.1. STOPPING SIGHT DISTANCE (SSD) 6

3.2. OVERTAKING SIGHT DISTANCE (OSD) 24

3.3. DECISION-MAKING SIGHT DISTANCE (DSD) 29

3.4. MAXIMUM AND MINIMUM GRADES, CRITICAL LENGTHS OF GRADES 32

4. CONCLUSIONS 39

5. RECOMMENDATIONS 41

6. GLOSSARY 42

7. REFERENCES 43

APPENDIX: COMPARISON OF SELECTED MODELS FOR SIGHT DISTANCE IN ROAD DESIGN 44

ANNEX A – STOPPING SIGHT DISTANCE 45

ANNEX B – OVERTAKING SIGHT DISTANCE 103

ANNEX C – DECISION-MAKING SIGHT DISTANCE 121

ANNEX D – MAXIMUM AND MINIMUM GRADES, CRITICAL LENGTHS OF GRADES 142

1. INTRODUCTION

Many geometric design models are used in road design as the basis for planning, design, and operation of roads (sections, curves, intersections, interchanges). Geometric design models are important for the fulfillment of road safety standards and provide efficient traffic flow. As shown by the PIARC literature review ("State of the Art in Road Design Standards (2022R22EN)" published in 2022), design standards differ from country to country in their approach to design, including the models. These differences result from the use of various models, parameters, and variables that influence the geometric parameters of road design.

Work on updating road design standards is underway in some countries. However, the comparison of specific models has not been reviewed for many years and their current reliability needs to be checked. Therefore, it is necessary to collect knowledge from all over the world and conduct a review of selected basic models used in road design in order to assess their reliability and offer recommendations for their use. It is particularly important for countries that do not conduct their research in this area, and often they often use the experience and guidelines of other countries. Additionally, an aspect indicating the need to prepare a report is the need to review the models and adapt them to the requirements of the rapidly changing world in the field of road transport systems (new technologies, changes in means of transport, changes in traffic safety requirements), as well as to assess the possibility of transferring the models to other road design standards, mainly in low- and middle-income countries.

In recent years, there have been quite a few detailed comparisons of models and requirements in selected aspects of road design. One example of such a study is the CEDR Transnational Road Research Program report, “European Sight Distances in Perspective – EUSight”, issued in 2016 [2], regarding stopping sight distances.

This report presents an overview of road design standards models based on a literature review [1], which was the first publication of PIARC Task Force 4.1., and it is the second of two planned publications of the PIARC Task Force 4.1 "Road design standards" in 2020 – 2023.

In the report, sight distance models ensuring road safety requirements related to the sight distance on road sections and requirements for the use of minimum and maximum longitudinal slopes were selected for comparison. The review of models related to sight distance included: stopping sight distance, overtaking sight distance, and decision-making sight distance. Sight distance models in road design are essential for evaluating and optimizing visibility conditions along roadways. These models can enhance safety, reduce the risk of accidents, and give adequate sight distances to make informed and safe driving decisions for drivers. The assessment did not take into account sight distances at intersections due to the large scope of cases that could be analyzed and the limited range of the report.

The comparison and conclusions were based on a review of road design standards collected among members of Task Force 4.1. Ultimately, the comparison covered 18 countries (depending on the models), from around the world: Australia, Austria, Belgium-Flanders, Belgium-Wallonia, Canada, Czechia, France, Germany, Hungary, Italy, Japan, Mexico, Poland, Portugal, Romania, South Africa, Spain, Ukraine, United States of America.

The review of the models is supported by thorough information contained in the Appendix, which contains details of the analyzed road design standards.

More details on the road design standards used to compare selected road design models can be found in the PIARC literature review report "State of the Art in Road Design Standards (2022R22EN)".

1.1. THE PURPOSE OF THE REPORT

The aim of the full report is the comparison of selected models for sight distance in road design from several countries based on guidelines. The following models related to sight distances: stopping sight distance, overtaking sight distance, decision-making sight distance, as well as maximum and minimum grades for road profiles, were reviewed. Detailed analysis parameters adopted in models at the national regulations were conducted. Comparison of analogies and differences have been defined based on the reviewed models and applied to highlight recommendations, conclusions, and next steps related to selected models in geometric road design.

1.2. THE STRUCTURE OF THE REPORT.

The full report mainly consists of a review of road design models related to sight distances based on guidelines from several countries. A review of models is supported by detailed information from road design standards reported in the Appendix.

The report “Models for Sight Distance in Road Design. A Worldwide Comparison of Standards” has four main chapters and an appendix:

- Methodology – explaining in detail how the model comparison was carried out.
- Road Design Models – the main chapter of the report. This chapter presents a description and comparison of the basis of selected models of road design standards.
- Conclusions and Next Steps.
- Recommendations – including separately presented recommendations for PIARC, decisions makers, and LMICs
- Appendix – consisting of 4 annexes (Annexes A-D) containing detailed information on the compared models from the guidelines for road design standards.

2. METHODOLOGY

In the period 2020-2023 PIARC Task Force 4.1 – “Road Design Standards” has focused on the review of road design standards. Two deliverables were planned during the period, i.e. the literature review [1] and the full report. This full report has been performed based on a literature review [1], which was the first deliverable of the Task Force, as well as a detailed description of selected road design models. The main source of material is from TF 4.1 members from their respective countries and areas of interest. Material has been analyzed and developed for inclusion in the full report according to PIARC requirements.

Four models used in road design were selected for comparison and evaluation. Three of them are related to sight distance: Stopping Sight Distance, Overtaking Sight Distance, and Decision-Making Sight Distance, and one is related to road profile, which is Maximum and Minimum Grades and Critical Lengths of Grades.

In order to conduct this review, detailed data were obtained from Task Force members for each of the analyzed models. The main body of the report includes a description and comparison of models. A detailed sequence of the followed steps in the methodology applied in the report are presented below:

- Overview and general information about the analyzed model, including a definition and a short description of the model
- Selection of a list of relevant countries, based on the countries that were represented by the members of TF 4.1, as well as taking into account other countries whose road design standards are widely used and well known, e.g. Germany and the USA.,
- Selection of compared models with the description of the most important part of models from the relevant national Guideline(s),
- Identification of main parameters influencing the assessment of the value of the compared variable. This part defines the main parameters that may occur when selecting variables for the design.
- Comparison of models, which was carried out in the form of tables and figures. The comparison includes a description of calculation procedures, type of considered parameters as well as application scope and an assessment of the analyzed numerical values.
- Conclusions, which include a summary of the review for each model

A part of the model review is the appendix, which includes relevant information about the compared models selected directly from road design standards, therefore providing a valuable source of knowledge. The appendix contains tables including countries, reference documents (Road Design Standards), and a description of the approach to determining the model value. The appendix includes four annexes for each model.

For some documents in a language other than English, the relevant extracts in the original language were translated into English with the aid of automatic online resources and may contain errors.

Due to the structure of the report (combining the main text with an appendix), the references to the model data are included in the appendix.

3. ROAD DESIGN MODELS

This chapter presents in detail the analyzed models used in road design. The collected data from 18 countries allowed for the comparison of models related to sight distance: Stopping Sight Distance (18 - number of countries), Overtaking Sight Distance (14), and Decision-Making Sight Distance (14), and one is related to road profile, which is Maximum and Minimum Grades and critical lengths of grades (13).

Sight distance models are crucial tools for ensuring the safety of drivers by analyzing and optimizing the visibility along roadways in road design. Sight distance refers to the distance a driver can see ahead on the road in different situations (stopping, overtaking, decision-making), and it is a critical factor in preventing crashes.

The value of sight distance can be influenced by many factors, such as:

- speed (operating, design), which has to reflect the speed at which vehicles are expected to drive. Higher values of speed generally require longer sight distances.
- reaction time, which has an impact on distance driving during the time elapsed from the instant the driver recognizes an obstacle on the roadway ahead until it starts to brake.
- friction coefficient of road,
- admissible deceleration,
- disposition of the obstacle,
- horizontal and vertical alignment including curvatures, and longitudinal slope of the road.

Given that the longitudinal slope has a significant impact on the stopping sight distance, this aspect was included in this chapter.

The comparison of sight distance models does not consider the problem related to sight distance at intersections (crossing sight distance). This is due to the problem complexity mainly related to:

- a large range of cases that may occur when trajectories of various road users intersect or merge,
- presence of different road users, not only vehicles but also vulnerable road users.
- coexistence of different types of road infrastructure (intersections, roundabouts, pedestrian and bike crossings, driveways)
- heterogeneous location (urban, rural)

Therefore the problem of sight distance at intersections requires separate analysis, on account of the the limited volume of the full report.

3.1. STOPPING SIGHT DISTANCE (SSD)

3.1.1. Overview and general information

The Stopping Sight Distance (SSD) is by definition the length of the roadway ahead that is visible to the driver and which should be sufficiently long to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path. This is the definition we find in AASHTO Green Book, A Policy on Geometric Design of Highways and Streets (2018, 7th edition, § 3.2.2). This definition, however, is very similar in all studied countries.

The required stopping distance is usually calculated as the addition of two components:

- The first component is the distance covered by a vehicle during the time elapsed from the instant the driver recognizes the existence of an obstacle on the roadway ahead until the instant that the driver actually applies the brakes. This is called perception, reaction, or brake reaction time. This distance is a linear function of the speed and the duration of the considered interval until the reaction, ranging from 1.5 to 3 seconds depending on the country.
- A second component is the braking distance, which is the distance covered by a vehicle during the time the driver is using the brakes to stop the vehicle.

The most commonly used variables for determining the SSD are the design speed and the longitudinal slope. The reaction time is usually a fixed variable, although in Italy and Belgium-Flanders, it varies with the speed. In Italy, the reaction time decreases with the speed, whereas in Belgium-Flanders it is the other way round.

Other used variables are either the friction coefficient or the admissible deceleration, the radius of the curved alignment, and the road class. In Italy, additional variables like the aerodynamic coefficient, the resistant surface, the vehicle mass, and the air volumic mass are considered. In France, the quality of the infrastructure goes into the calculation of the SSD through a variable called level of performance.

The final result is the definition of the SSD in the form of grouped classes (A-E) represented by the following formulas:

Class A	$SSD = 88.4 + \frac{-126 + 1.81 \cdot v_{dp} - 105 \cdot i}{1 - 0.404 \ln\cdot \left(v_{dp}\right) + 1.51 \cdot e^{i}}$	Poland, as of April 2022
Class B	$D_A = D_1 + D_2 = \frac{V_0}{3.6} \cdot \tau - \frac{1}{3.6^2} \int_{V_0}^{V_1} \frac{V}{g \cdot \left[f_l(V) \pm \frac{i}{100}\right] + \frac{R_a(V)}{m} + r_0(V)} dV$	Italy
Class C	$SSD = \frac{R_t v}{3.6} + \frac{v^2}{254 \cdot (f_l + i)}$	Most countries: Australia, Chile, Mexico, Portugal, Spain
Class C’	$SSD = \frac{R_t v}{3.6} + \frac{v^2}{254 \cdot (\frac{a_c}{g} + i)}$	Canada, USA, South Africa
Class C’’	$SSD = \frac{R_t v}{3.6} + (1 + m_c(R)) \cdot \frac{v^2}{254 \cdot \left(\gamma_v + i\right)} \cdot K(N_{PV})$	France
Class D	Values depending on speed and longitudinal slope	Poland, until April 2022
Class E	Values depending on speed & sometimes also road type	Japan, Romania, Ukraine

The main difference between formulas C and C’ is the use of either a friction coefficient f_l, usually depending on the speed, or an admissible deceleration a_c. The friction coefficient is usually a frictional value that is not issued from a test, but rather a conventional parameter which results to be equivalent to $\frac{a_c}{g}$. In formula C’’, which is applied in France, $m_c(R)$ is a penalty coefficient depending on the radius of the curve and $K(N_{PV})$ is the level of performance.

The approaches described as D and E classes are in reality not directly expressed by means of formulas, but rather by means of tables, where the value of the stopping sight distance in meters is expressed in a cell which is inferred from the aforementioned variables.

In the following sections the analysis of these formulas is presented more in detail.

3.1.2. Use of SSD in different national design standards

A summary of the use of the analyzed national design standards from the following countries (19) is provided:

- Australia
- Austria
- Belgium-Flanders
- Belgium-Wallonia
- Canada
- Czechia
- France
- Germany
- Hungary
- Italy
- Japan
- Mexico
- Poland
- Portugal
- Romania
- South Africa
- Spain
- Ukraine
- United States of America

The summary contains extracts from each design standard relating to the topic with the reviewers' comments.

A detailed review of the models is included in the appendix (Annex A) of this report.

3.1.3. Summary of the main parameters used and calculation procedures

Table 1 illustrates a summary of the main parameters considered in the models, equations, tables, etc. for the definition of the SSD by country. Within the table, the following items have been considered.

Definition of SSD: all studied country standards deal with the subject and define a calculation method, although the sophistication and extent of this method may be either basic, intermediate, or elaborate depending on the country.

Type of standard: it is highlighted if the design standards provide an equation, a chart, or a table to define the SSD.

Considered parameters: Most countries consider the following parameters speed, longitudinal slope, and either friction coefficient or admissible deceleration. Perception and reaction time are also usually considered, either with a fixed or variable value. More simplistic guidelines just consider speed, whereas more sophisticated ones also include a radius of the curve or other dynamic parameters.

Other: Other parameters used for the definition of the SSD by country are presented in this category.

Country	**Type of standard**			**Type of considered parameters**							
	Equation	**Chart**	**Table**	**Speed**	**Longitudinal slope**	**Friction coefficient**	**Admissible deceleration**	**Radius**	**Time**	**Road class**	**Other**
Australia	X	X	X	X	X	X		X	X		
Austria	X		X	X	X		X		Fixed		
Belgium – Flanders	X		X	X	X	X			Increases with speed		
Belgium – Wallonia			X	X	X			X			
Canada	X		X	X	X		X		Fixed		
Chile	X	X	X	X	X	X			Fixed		
Czechia	X		X	X	X	X				X	
France	X			X	X		X	X	Fixed	X	Performance level
Germany		X			X					X	
Hungary		X	X	X	X						
Japan			X	X							
Italy	X	X	X	X	X	X	-	-	Diminishes with speed	-	Aerodynamic resistance =F(Aerodynamic coefficient, resistant surface, air volumic mass) Vehicle mass Unitary rolling resistance (neglected)
Mexico	X	-	X	X	X	X	-	-	A main value is given, with other alternatives for special situations.	-	Variations for trucks are mentioned, but not separately used.
Poland (before April 2022)	-	-	X	X	X	-	-	-	-	-	The calculation behind is not given. However, the height of the observation aim depending on speed is specified.
Poland (after April 2022)	X	-	X	X	X	-	-	-	-	-	-
Portugal	X	-	X	X	X	X	-	-	Fixed	-	-
Romania	-	-	X	X	-	-	-	-		X	For highways both minimum and recommended values are given.

Country	Type of standard			Type of considered parameters							
	Equation	Chart	Table	Speed	Longitudinal slope	Friction coefficient	Admissible deceleration	Radius	Time	Road class	Other
South Africa	X	X	X	X	X	-	X	-	Fixed	-	Special prescriptions are laid for rural roads, with similar sight distance values, but rounded to closest multiple of 5 m.
Spain	X	X	-	X	X	X		-	Fixed	-	-
Ukraine	-	-	X	X	-	-	-	-	-	-	-
USA	X	-	X	X	X		X	-	Fixed	-	-

Table 1: Summary of the main parameters considered in the SSD models.

Table 2 presents in detail for all previously presented national models (see Table 1) the formulas used, variable features in the calculation of SSD, rounding method, and formula class. For some models, comments have been added to facilitate the interpretation of the SSD model (observations).

Country	Model	Class	Variables	Rounding method	Observations
Australia	$SSD = \frac{R_t v}{3.6} + \frac{v^2}{254 \cdot (d \pm 0.01i)}$	C	Speed, longitudinal slope, coefficient of deceleration (friction factor – *d*), reaction time	No rounding	*d* depends on the type and condition of the road. Typically 0,36 is used, but 0,26 applies to very good condition highways.
Austria	$SSD = \frac{R_t v}{3.6} + \frac{v^2}{254 \cdot (\frac{5}{9.81} + i)}$	C'	Speed, longitudinal slope, admissible deceleration	No rounding	5 m/s² (acceleration rate) / 9.81 (*g*) replaces the friction coefficient.
Belgium - Flanders	$SSD = \frac{R_t v}{3.6} + \frac{v^2}{254 \cdot (f_l + p)}$	C	Speed, longitudinal slope, friction coefficient	In the full table no rounding, in the summary table rounding to the closest multiple of 5	In Italy we have the opposite, R_t decreases with speed.
Belgium - Wallonia	Different values are given in a table. These values depend on speed (120, 90, 50 km/h), longitudinal slope, and superelevation=f(radius). Values are given with two decimals: Formula is unknown.	D'	Speed, longitudinal slope, radius	-	-

Country	**Model**	**Class**	**Variables**	**Rounding method**	**Observations**
Canada	$SSD = 0.278 \cdot v + \frac{v^2}{254 \cdot (\frac{3.4}{9.81} + i)}$	C'	Speed, longitudinal slope, admissible deceleration	Following multiple of five	3.4 m/s² (acceleration rate) / 9.81 (g) replaces friction coefficient
Chile	$SSD = \frac{t_p v}{3.6} + \frac{v^2}{254 \cdot (r \pm i)}$	C	Speed, longitudinal slope, friction coefficient	For v≤50 km/h rounding up or down to the closest unit For v≥60 km/h Following multiple of five	Special cases are to be considered: a) horizontal curves b) sight distance in vertical alignments c) design of vertical curves d) structures.
Czechia	$SSD = \frac{R_t v}{3.6} + \frac{v^2}{254 \cdot (f_l + i)}$	C	Speed, longitudinal slope, friction coefficient, road class	For v < 80 km/h following multiple of five; For v≥80 km/h following multiple of 10	Final sight distance to be rounded up to the nearest higher 10 m multiple. Stopping sight distance in 1-lane 2-way roads is 2xD_z. Stopping sight distance in 1-lane 2-way roads when overtaking is enabled is 4x*Dz*.
France	$SSD = \frac{R_t v}{3.6} + (1 + m_c(R)) \cdot \frac{v^2}{254 \cdot (\gamma_v + i)} \cdot K(N_{PV})$	C''	Speed, longitudinal slope, admissible deceleration, radius, performance level	-	m_c =(0; 0.2) depending on the radius: $m_{c(R)}$=0.6-0.4R/Rdn; In straights m_c=0 γ_v= 0.41 to 0.46 average frictionally deceleration (x9.81) depending on speed. For speed >70 km/h, γ_v=0.41 K(N_{PV}) = (0.9;1.1) depending on performance level. Here the value 1 has been taken.
Germany	Different values are given in a chart. These values depend on the design class (EKL1, EKL2, EKL3, EKL4) and slope. The formula is unknown. Here we have	D	longitudinal slope, road class	-	Road class is linked to speed.

Country	Model	Class	Variables	Rounding method	Observations
	extracted values for EKL2 with a planning speed of 100 km/h. The auxiliary tables contain the following classes: EKL1 (110 km/h), EKL2 (100 km/h), EKL3 (90 km/h), EKL4 (70 km/h).				
Hungary	No formula available	C/C'	Speed, longitudinal slope	-	Formula not available. The applied formulation and coefficients must be very similar to the one we find in Chile, but with a different kind of rounding.
Italy	$D_A = D_1 + D_2 = \frac{V_0}{3.6} \cdot \tau - \frac{1}{3.6^2} \int_{V_0}^{V_1} \frac{V}{g \cdot \left[f_l(V) \pm \frac{i}{100} \right] + \frac{R_a(V)}{m} + r_0(V)} dV$	B	Speed, longitudinal slope, friction coefficient, aerodynamic resistance =F(Aerodynamic coefficient, resistant surface, air volumic mass) Vehicle mass Unitary rolling resistance (neglected)	Rounded up to the next unit	*D_1* = length stretched in time τ *D_2* = breaking length *V_0* = initial speed = design speed In Belgium-Flanders we have the opposite, R_t increases with speed
Japan	Values depend only on speed	E	Speed	-	-
Mexico	$SSD = \frac{R_t v}{3.6} + \frac{v^2}{254 \cdot (f_l \pm p)}$	C	Speed, longitudinal slope, friction coefficient, and variations for trucks are mentioned, but not separately used.	Rounded to 10 superior	Rounded to 10 superior m. A second approach whereby SSD= $v^2/(3.6^2*2*a)= v^2/88$ (where $a=3.4m/s^2$) is possible.
Poland (before	Values depend on speed and longitudinal slope	D	Speed, longitudinal	-	Values are repeated in some adjacent cells.

Country	Model	Class	Variables	Rounding method	Observations
April 2022)			slope; the calculation behind is not given. However, the height of the observation aim depending on speed is specified.		
Poland (after April 2022)	$SSD = 88.4 + \frac{-126 + 1.81 \cdot v_{dp} - 105 \cdot i}{1 - 0.404 \ln \cdot (v_{dp}) + 1.51 \cdot e^{i}}$	A	Speed, longitudinal slope	Rounded up to 1 m	Values are repeated in some adjacent cells
Portugal	$SSD = \frac{R_t v}{3.6} + \frac{v^2}{254 \cdot (f_l + i)}$	C	Speed, longitudinal slope, friction coefficient,	Rounded to multiple of 10	-
Romania	Values depend on speed and road class: 1) suburban roads 2) (express roads)	E	Speed, road class, For highways both minimum and recommended values are given.	-	-
South Africa	$SSD = 0.694 \cdot v + \frac{0.004 \cdot v^2}{0.3 + i}$	C'	Speed, longitudinal slope, admissible deceleration; special prescriptions are laid for rural roads, with similar sight distance values, but rounded to the closest multiple of 5 m.	Rounded to the closest multiple of 10, except for 30 km/h where it is rounded to the closest multiple of 5.	3 m/s² (acceleration rate) / 9.81 (g) replaces the friction coefficient.
Spain	$SSD = \frac{R_t v}{3.6} + \frac{v^2}{254 \cdot (f_l + i)}$	C	Speed, longitudinal slope, friction coefficient	No rounding	-
Ukraine	Values depend only on speed.	E	Speed	-	-

Country	**Model**	**Class**	**Variables**	**Rounding method**	**Observations**
USA	$SSD = 0.278 \cdot v + \frac{v^2}{254 \cdot (\frac{3.4}{9.81} + i)}$	C'	Speed, longitudinal slope, admissible deceleration	Rounding to the following multiple of 5	AASHTO [3] also provides indications for: Parameters considered in determining the length of a crest vertical curve to provide side distance: (3.4.6) Design controls for crest/sag vertical curves based on stopping sight distance (tables 3-35 and 3-37) Sight distance at under-crossings (3.4.6.4) 3.4 m/s^2 (acceleration rate) / 9.81 (g) replaces the friction coefficient.

Table 2: Summary of formulas and variables used in the SSD models

Several additional variables in SSD calculations significantly affect the sight distance calculation result. These include reaction time, friction coefficient, or deceleration to gravity ratio. Therefore, these values are summarized in the following tables (Tables 3-5).

R_t values	**Countries**
Variable	Australia: between 1.5 and 2.5 s, depending on vehicle type and road condition. Belgium-Flanders: $R_t \approx 0.785 + v/70$ Italy: $R_t \approx 2.8 - 0.01 \cdot V$
1.2 s	Austria
1.5 s	Czechia
1.8 s	France
2 s	Chile, Hungary, Portugal, Spain
2.5 s	Canada, Mexico, South Africa, USA

Table 3: Value of reaction time applied in C, C', C'' formulas

Countries using C formulation	**f_l for v=80 km/h**	**f_l for v=100 km/h**	**f_l for v=120 km/h**
Australia	0.36	0.36	0.36
Chile	0.36	0.33	0.31
Czechia	0.43	0.40	0.38
Mexico	0.285	0.269	-----
Portugal	0.32	0.32	0.31
Spain	0.348	0.32	0.291

Table 4: Value of friction coefficient applied in C formulas:

Countries using C’ and C’’ formulations	**a_c**	**Equivalent $f_l = \gamma_v = \frac{a_c}{9.81}$**
South Africa	3 m/s^2	0.306
Canada. USA	3.4 m/s^2	0.347
France	4 to 4.5 m/s^2	0.41 to 0.46 depending on speed. For speed >70 km/h. γ_v=0.41
Austria	5 m/s^2	0.510

Table 5: Value of ac and ac/g applied in C’, C’’ formulas:

Other very important factors in SSD evaluation are the driver's eye height (it can be a constant value or a value related to the type of vehicle – passenger car, heavy vehicle, bus), object height (mainly related to speed, but also to location and possible occurrence of other risks), and location of drivers and obstacle. Table 6 summarizes above mentioned variables.

Country	Driver's eye height	Object height	Horizontal disposition
Australia	• 1.1 m (cars); • 2.4 m (trucks)	0.2 m	-----
Austria	1.0 m	0 m	• Driver's eye: Center of the inner lane for the direction of travel. • Obstacle: Center of the lane on the inside of the curve for the direction of travel
Belgium - Flanders	-----	Observation point: • At a left-hand curve: 1.25 m from the edge marking on the left • At a right-hand curve: 2.25 m from the edge marking on the right	• Point of view: The entire outer rear light (0.2 m x 0.2 m) on the inner lane, underside at 0.50 m, • above the road surface and outside at 2.30 m from the inside edge marking (based on a lane width of 3.50 m)
Belgium - Wallonia	-----	-----	-----
Canada	• Cars: 1.08 m • Buses: 1.8 m • Large trucks: 2.3 m	• Rear lights: 0.60 m • Risk of fallen trees: 0.15 m	Driver's eye and obstacle: Center of the inner lane for the direction of travel
Czechia	-----	-----	-----
Chile	1.1 m	0.20 m	The driver's eye and obstacle are located on the lane axis.
France	1.1 m	• 0.70 m for a vehicle on isolated roads • 0.50 m for non-isolated roads • On major roads, this height can be 0.85 m • When considering the risk of fallen stones, then h=0.15 m	Driver's eye is placed 0.25 to the left from the central axis of their lane, for a 3.5 m lane --> 2.0 m from the right border. The object is placed 0.75 m to the left or right of the lane axis if it is a vehicle on isolated roads.
Germany	1 m	1 m	Driver's eye and obstacle will be located in the middle of the left lane
Italy	1.10 m	0.1 m	An obstacle is located along the axis of the driver's lane.
Japan/ Hungary	-----	-----	----
Mexico	1.08	0.6	A visual line is drawn as a tangent to the lateral road slope.
Poland (before April 2022)	• 1.0 m (cars); • 2.5 m (trucks)	• v > 100, 0.45 m • 81 < v ≤ 100, 0.30 m • 61 < v ≤ 80, 0.15m • v ≤ 60 km/h, 0 m	The observation point and observed aim are aligned.
Poland (after April 2022)	• 1.1 m (cars); • 2.5 m (trucks)	• v≥70 km/h, 0.50 m • v ≤70 km/h, 0.25 m	The observation point and observed aim are aligned.

Portugal	1.05 m	0.15 m	-----
Romania	-----	-----	-----
South Africa	• 1.05 m for cars • 1.8 m for buses and simple trucks • between 1.9 and 2.4 for semi-trailers	0 m Risk of road washouts, pavement markings in critical locations, 0.15 m Risk of fallen trees or rocks; risk of log or construction debris falling from a truck 0.60 m vehicle tail or brake light	-----
Spain	1.10 m	0.5 m; occasionally between 0.20 m and 0.50 m	Obstacles can remain partly hidden (in a portion ≤ 1 m) by intermediate obstacles, like bridge abutments, pillars, and barriers if the total section of the obstacles has been previously visualized.
Ukraine	-----	-----	-----
USA	• 1.08 m for cars • 1.8 m to 2.40 m for trucks, with a typical value of 2.33 m	0.6 m	The vertical component of sight distance is measured along the centerline of the roadway. The horizontal component is measured along the centerline of the inside lane on a horizontal curve.

Table 6: Driver's eye height, object height, and horizontal disposition in SSD calculation

3.1.4. Applications and comparison

This paragraph contains three tables (tables 7-9) and their graphic representation (figures 1-3) with the required stopping sight distance as a comparison of the different stopping sight distance lengths coming out from the national models and references. For the sake of clarity, reference slopes of –4%, 0%, and +4% have been taken as samples.

V (km/h) (*)	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**
Australia	-	42	58	78	99	123	150	179	210	244	280	-
Austria	-	27	38	50	64	80	98	117	138	161	185	-
Belgium - Flanders	-	30	45	60	85	110	145	185	230	285	350	-
Belgium -Wallonia	-	-	49	-	-	-	181	-	-	308	-	-
Canada	35	50	70	90	115	140	170	200	235	270	310	-
Chile	26	39	54	75	100	125	160	195	235	280	335	-
Czechia	20	30	40	60	80	100	130	160	190	220	260	-
France	25	37	52	68	87	108	131	156	184	213	245	-
Germany	-	-	-	-	97	-	144	172	203	-	-	-

V (km/h) (*)	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**
Hungary	25	35	50	70	95	120	155	190	240	295	350	-
Italy	29	41	56	74	95	119	148	181	219	263	263	263
Japan	30	40	55	75	-	110	-	160	-	210		-
Mexico (**)	40	50	70	100	130	160	200	250	300	350	420	490
Poland (before April 2022)	25	40	55	80	100	140	170	200	260	310	350	-
Poland (after April 2022)	26	37	53	72	96	123	154	189	229	274	323	379
Portugal	-	-	60	80	110	130	160	200	240	280	360	450
Romania (min.) (***)	-	-	-	70	-	100	-	150 (140)	-	200	-	325
Romania (opt.)	-	-	-	-	-	230	-	300	-	375	-	450
South Africa	30	50	70	100	120	150	180	220	260	300	350	-
Spain	-	38	54	74	98	126	158	196	240	293	362	445
Ukraine	35	50	70	90	115	145	175	210	250	290	335	-
USA	35	50	70	90	115	140	170	200	235	270	310	350

(*) design, operating or other type of speed.

(**) the values for 120 km/h and 130 km/h have been extrapolated, since these speeds are not allowed by legislation.

(***) the value in brackets is for express roads

Table 7: Required stopping sight distance, slope = -4%

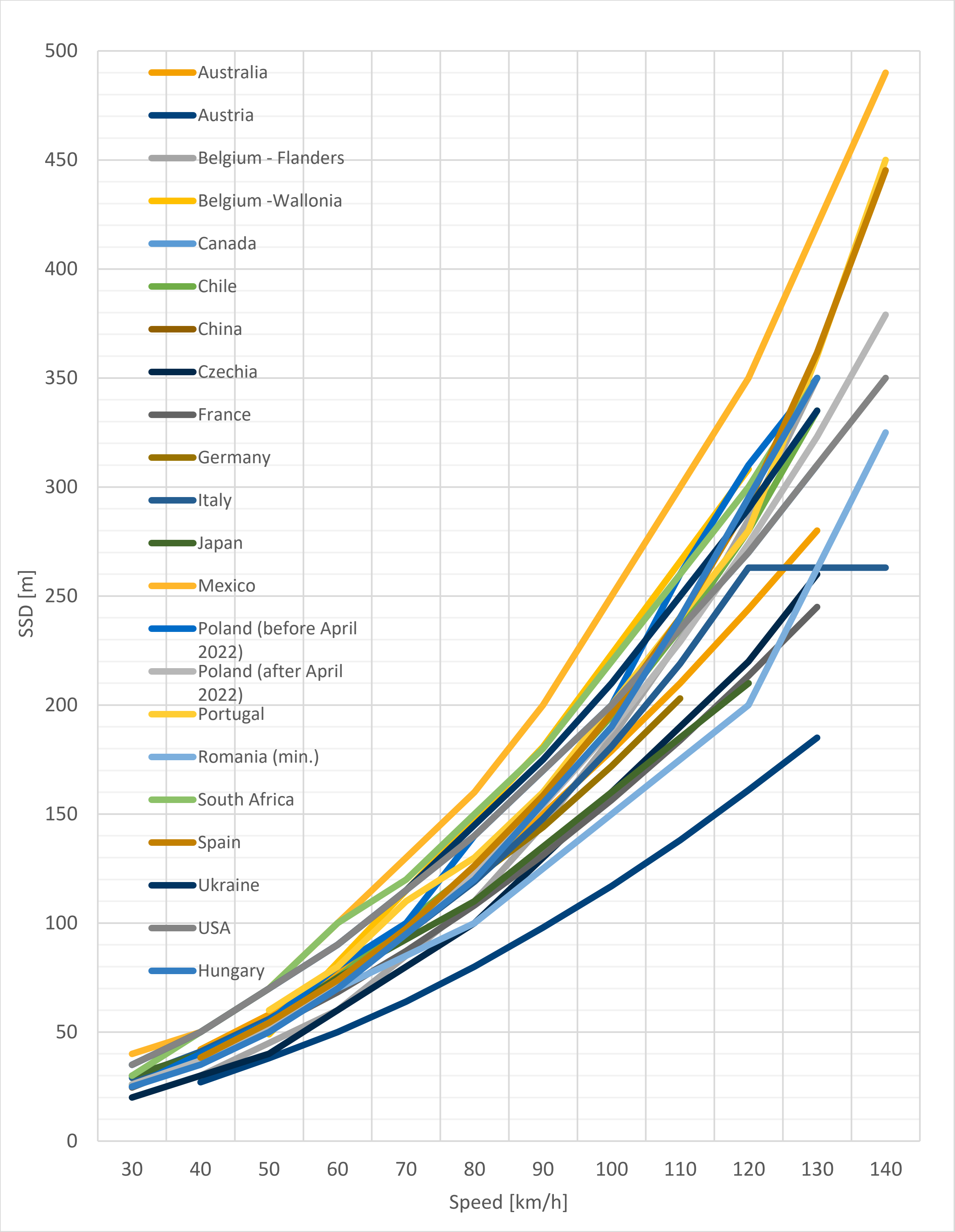


Figure 1: Required stopping sight distance, slope = -4%.

V (km/h) (*)	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**
Australia	-	40	55	73	92	114	139	165	193	224	257	-
Austria	-	26	36	48	61	76	93	110	130	151	174	-
Belgium - Flanders	-	30	40	60	80	105	135	170	210	260	315	-
Belgium -Wallonia	-	-	44,6	-	-	-	141	-	-	263	-	-
Canada	35	50	65	85	105	130	155	185	215	250	285	-
Chile	25	37	52	70	90	115	145	175	210	250	300	-
Czechia	20	30	40	55	75	100	120	140	170	200	240	-
France	24	35	49	65	82	102	123	146	171	198	-	-
Germany	-	-	-	-	90	-	134	160	186	-	-	-
Hungary	25	35	50	65	85	110	140	170	210	255	300	-
Italy	28	40	54	70	89	111	136	165	198	235	236	236
Japan	30	40	55	75	-	110	-	160	-	210	-	-
Mexico (**)	40	50	70	90	120	150	180	220	260	310	370	420
Poland (before April 2022)	20	35	50	70	90	120	150	180	230	270	310	-
Poland (after April 2022)	26	36	51	69	90	114	142	174	209	247	290	337
Portugal	-	-	60	80	100	120	150	180	220	250	320	390
Romania (min.) (***)	-	-	-	70	-	100	-	150 (140)	-	200	-	325
Romania (opt.)	-	-	-	-	-	230	-	300	-	375	-	450
South Africa	30	50	70	90	110	140	170	200	230	270	310	-
Spain	-	37	52	70	91	117	145	179	217	261	319	386
Ukraine	35	50	70	90	115	145	175	210	250	290	335	-
USA	50	65	85	105	130	155	185	215	250	285	320	35

(*) design, operating, or other type of speed.

(**) the values for 120 km/h and 130 km/h have been extrapolated, since these speeds are not allowed by legislation.

(***) the value between brackets is for express roads

Table 8: Required stopping sight distance, slope = 0%

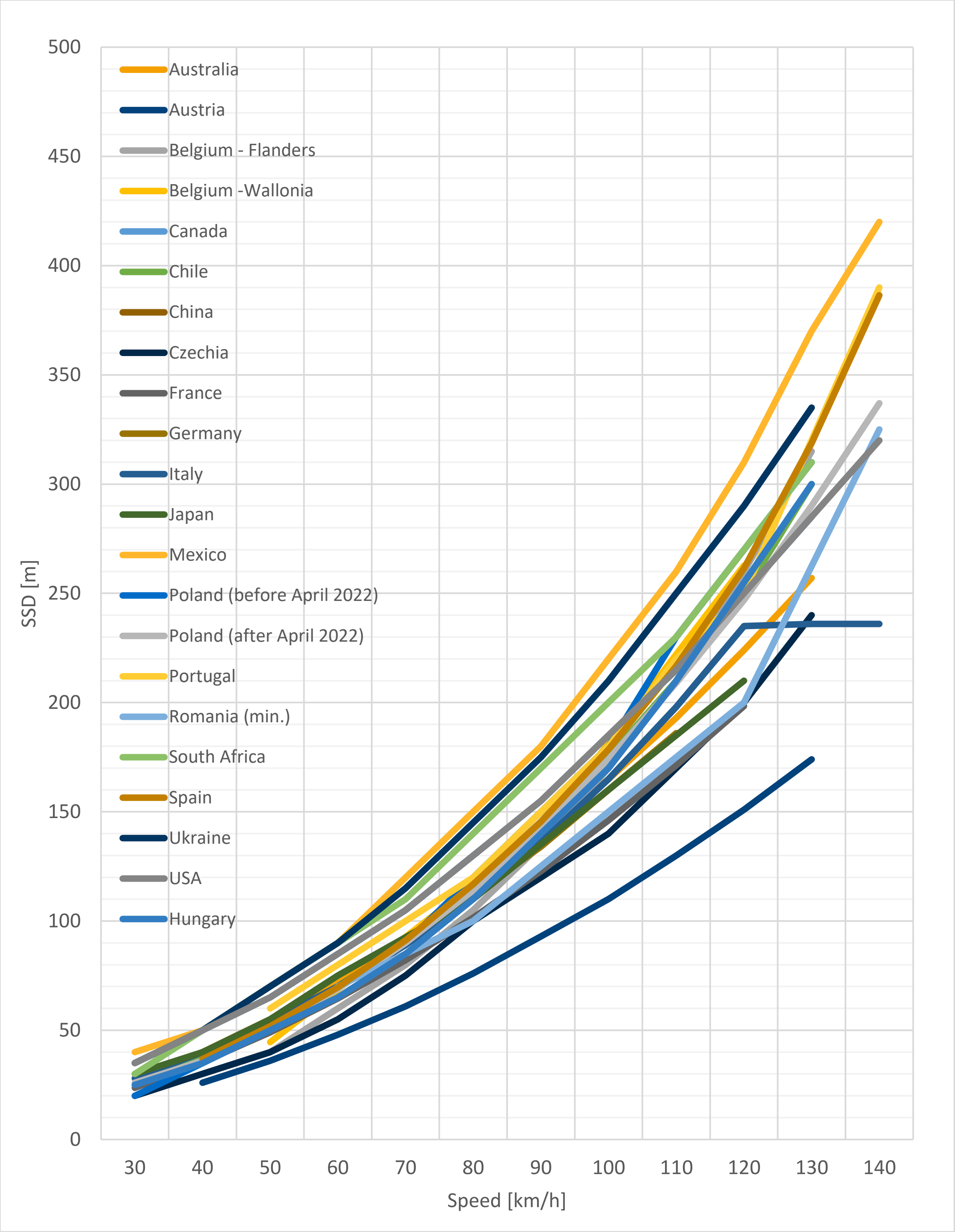


Figure 2: Required stopping sight distance, slope = 0%.

V (km/h) (*)	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**
Australia	-	38	52	69	87	107	130	154	180	208	239	-
Austria	-	25	35	46	58	72	88	105	123	143	164	-
Belgium - Flanders	-	25	40	55	75	100	130	160	195	240	290	-
Belgium -Wallonia	-	-	41	-	-	-	126	-	-	230	-	-
Canada	30	45	65	80	100	125	145	175	200	230	265	-
Chile	24	36	50	70	85	110	135	165	195	230	275	-
Czechia	20	30	40	55	70	90	110	140	160	190	230	-
France	23	34	47	62	78	96	116	138	161	186	213	-
Germany	-	-	-	-	85	-	127	150	175	-	-	-
Hungary	20	35	45	65	80	105	130	160	195	230	270	-
Italy	28	39	52	68	85	105	127	153	182	214	214	214
Japan	30	40	55	75	-	110	-	160	-	210	-	-
Mexico (**)	30	50	70	90	110	140	170	200	240	280	330	380
Poland (before April 2022)	20	35	45	60	85	110	130	170	200	250	290	-
Poland (after April 2022)	26	35	49	65	85	107	132	160	191	225	263	303
Portugal	-	-	60	70	90	110	140	160	200	230	290	340
Romania (min.) (***)	-	-	-	70	-	100	-	150 (140)	-	200	-	325
Romania (opt.)	-	-	-	-	-	230	-	300	-	375	-	450
South Africa	30	50	60	80	110	130	160	190	220	250	290	-
Spain	-	36	50	66	86	109	135	165	199	238	287	344
Ukraine	35	50	70	90	115	145	175	210	250	290	335	-
USA	30	45	65	80	100	125	145	175	200	230	265	300

(*) design, operating, or other type of speed.

(**) the values for 120 km/h and 130 km/h have been extrapolated, since these speeds are not allowed by legislation.

(***) the value between brackets is for express roads.

Table 9: Required stopping sight distance, slope = +4%

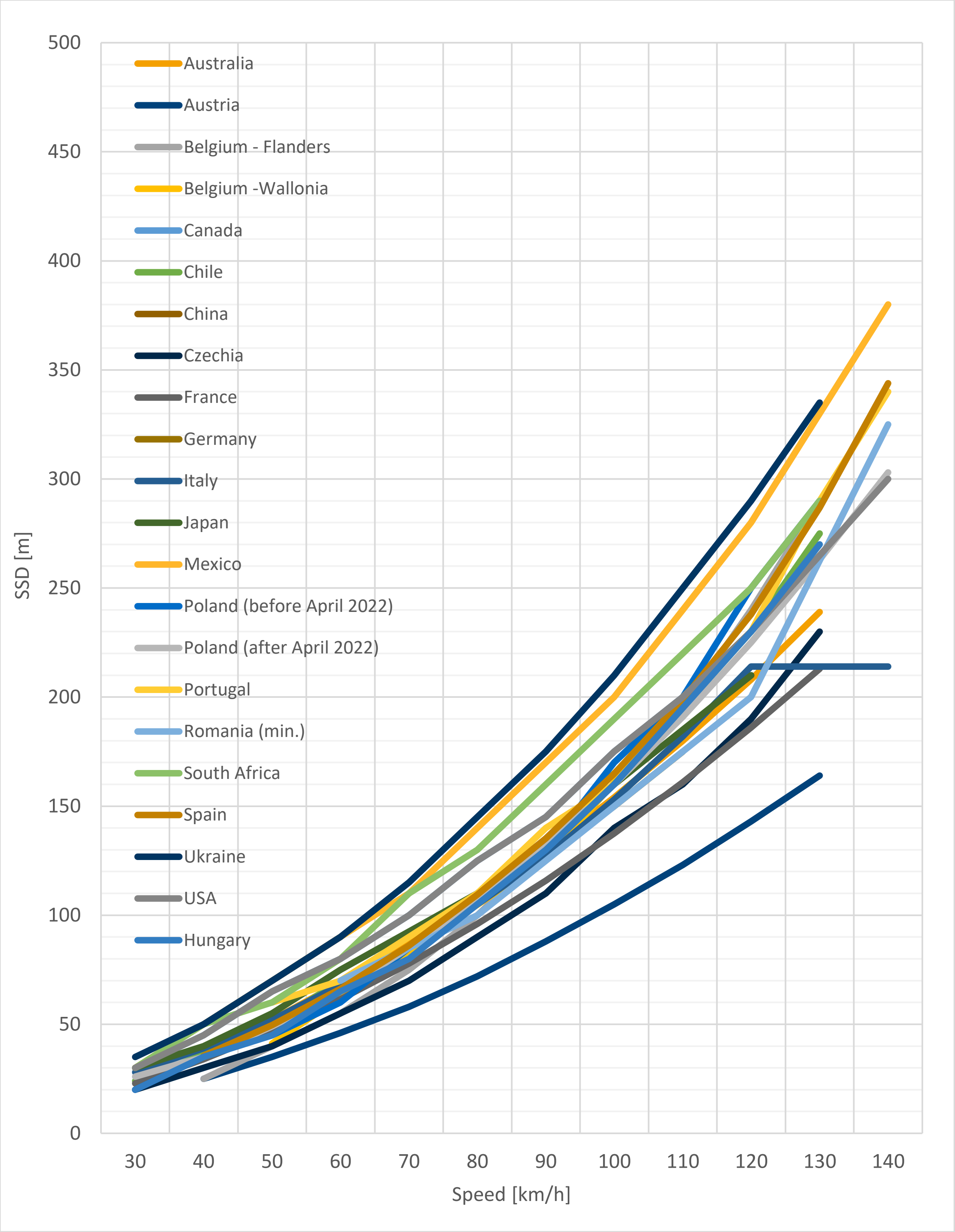


Figure 3: Required stopping sight distance, slope = +4%.

3.1.5. Reviewer comments

From the results of the model comparison made in chapter 3.1, the following observations can be inferred:

1. Required stopping sight distances are comprised within a range where Mexico and (for notable ascending slopes) Ukraine feature the highest values and Austria the lowest ones. The relation between the highest and the lowest values is approximately 2 to 1.

2. The values of the required stopping sight distances increase significantly with a descending slope and decrease with an ascending slope. For a slope of -4% this value is about 15% higher and for a slope of 4% this value is about 10% lower.
3. Most countries use a 2-member formula where the first member entails the distance during the perception and reaction time, and the second member entails the mechanical braking distance.
4. Disparities between countries reveal their preference either towards a conservative/safe or towards a functional and economical approach.
5. Friction coefficients are usually virtual values, not directly resulting from real scale tests, and are equivalent to a deceleration which is turned into an adimensional coefficient by means of its scaling to *g*.
6. Too precise formulae are in contradiction with a too rough final rounding: a balance between a sophisticated formula and a sensible rounding should be met.

Further challenges:

1. Comparison of SSD in special sections: structures, ancillary carriageways, etc.
2. Compatibility of the system of calculated values between human-driven and self-driven vehicles.
3. Comparison of country practices when compliance with SSD is not possible.
4. Follow-up of data when national guidelines are updated (e.g. Poland, Wallonie, etc.)

3.2. OVERTAKING SIGHT DISTANCE (OSD)

3.2.1. Overview and general information

The OSD is by definition the length of the stretch of road from which a driver must perceive free from other vehicles in the opposite direction of travel in order to be able to safely perform the overtaking manoeuvre.

The variables that influence user behaviour are theoretically different, such as the speed and dimensions of the overtaking vehicle, the speed and dimensions of the overtaken vehicle, the sensitivity with respect to the perception of the risk that one intends to run, the sensitivity concerning the perception of an oncoming vehicle, and so on.

The most commonly used parameter for determining the OSD is the design speed. This is associated, either explicitly or implicitly, with an overtaking scheme that serves to define the time intervals for moving to the opposite lane, overtaking the vehicle, and re-entering the lane.

The final result is the definition of the OSD in the form of an equation as a function of speed, a series of values in table form as the speed varies or, more rarely, constant values.

The speed for calculating the OSD for some countries takes into account the operating speed or limit speed. The type of speed considered in the model can also have different names but it is possible to establish a connection with one of the traditional ones (design, operating, or limit).

In general, the OSD is equal to double the manoeuvre that is actually used for overtaking since it considers that another vehicle arrives in the opposite direction at the same speed as the overtaking vehicle. Therefore, the overtaking scheme underlying the OSD calculation is valid for only one vehicle at a time.

3.2.2. Use of OSD in different national design standards

In the following a summary of the use of OSD is provided for all the national design standards analyzed (14), which are:

- Australia
- Belgium
- Canada
- China
- England
- France
- Germany
- Italy
- Japan
- Mexico
- Poland
- Portugal
- Spain
- United States of America

The summary contains extracts from each design standard relating to the topic with the reviewers' comments.

A detailed review of the models is included in the appendix (Annex B) of this report.

3.2.3. Summary of the main parameters used and calculation procedure

The following table illustrates a summary of the main parameters considered in the models, equations, tables, and so on for the definition of the OSD by country. Within the table, the following items have been considered.

Definition of OSD: it is specified if the country standard deals with the subject and defines a calculation method,

Type of standard: it is highlighted if the design standards provide an equation, a table, or a constant value to define the OSD.

Type of considered speed or other parameters: the name of the speed as it has been used in the standard reference to define the OSD value. Some type of speed looks like something else (design speed, speed limit). The type of speed clearly used in the reference is indicated with «X» and what is the implicit type of speed is indicated with «(X)».

Notes: include some useful indications about the definition of OSD by country.

Country	OSD defined	Type of standard			Type of considered Speed or other parameters						Notes
	Yes/No	Equation	Table	Constant	Design	Limit	Section	Operating	Base	Other: Stopping distance	
Australia	Yes	X	X					X			Operating speed refers to the 85th percentile speed.
Belgium	Yes	X	X			(X)			X		"Base speed" looks like "speed limit".
Canada	Yes	X	X		X						
Chile	Yes		X		X						Consider a slope effect when this is more than 6%.
China	No	-	-	-	-	-	-	-	-	-	-
Czechia	Yes	X			(X)		(X)			X	Stopping distance is a function of "section speed" that looks like "design speed".
France	Yes			X							
Germany	Yes			X							
Italy	Yes	X			X						
Japan	No	-	-	-	-	-	-	-	-	-	-
Mexico	Yes	X			X						The slope effect is left to the designer's sensitiveness.
Poland	Yes				X						
Portugal	Yes	X	X		(X)			X	X		"Base speed" corresponds to "design speed". Operating speed refers to the 85th percentile speed.
Spain	Yes		X		X						
USA	Yes		X		X						Consistent with field observation of passing manoeuvres.

X clearly referred in the equation/table

(X) implicitly linked to the equation/table

Table 10: Summary of the main parameters considered in the OSD models.

Table 11 presents all previously presented national models (see Table 10) in detail the formulas used and the description of variables applied to calculating OSD.

Country	Model	Variables
Australia	$OED = G_{T85}\frac{(V+u)}{3.6}$ Overtaking Establishment Sight Distance (OED) + Table with reference values for different design speeds (more useful because of the absence of G_{T85} definition)	G_{T85} = 85th percentile critical time gap secs u = V/1.17 (speed of slow vehicle) V = operating speed
Belgium	$D_d = 4\,V$ (it's «overtaking distance» and not a «sight distance»)	D_d = overtaking distance V = base speed (examples with 90 and 50 km/h, looks like speed limit)
Canada	$PSD = d_1 + d_2 + d_3 + d_4$ $d_1 = \frac{t_1}{3.6}\left(V - m\frac{at_1}{2}\right)\;;\, d_2 = \frac{Vt_2}{3.6}\;;$ $d_3 = 33{\sim}92\,m\;;\, d_4 = \frac{2d_2}{3}$ PSD = passing sight distance + Table with reference values for different design speeds	d_1 = distance traveled during the initial manoeuvre d_2 = distance traveled while passing the vehicle d_3 = clearance length (space between the vehicle at the end of passing and the vehicle in the opposite direction) d_4 = distance traversed by an opposing vehicle a = average acceleration (km/h / s) V = average speed of passing vehicle (km/h) t_1 = time of initial manoeuvre (s) t_2 = time the passing vehicle
Chile	Table with reference values for different design speeds	-
Czechia	$D_p = 4D_z$ D_p = overtaking sight distance (Expression not directly from standard text)	D_z = stopping distance at the same speed of passing at 0% grade (m)
France	500 m minimum	-
Germany	600 m minimum (general and heavy vehicles) 300 m minimum for overtaking slower vehicles	-

Country	**Model**	**Variables**
Italy	$D_S = 5.5\ V$	V = design speed (km/h)
Mexico	$D_R = 7.5V_P$ D_R = overtaking sight distance	V_P = design speed (km/h)
Poland	Table with reference values for different design speeds	-
Portugal	$D_U = 7\ VT$ + Table with reference values for different design speeds	VT = operating speed (85%)
Spain	Table with reference values for different design speeds	-
USA [3]	Table with reference values for different design speeds based on overtaking model with differential speed of 19 km/h	-

Table 11: Summary of formulas and variables used in the OSD models

3.2.4. Applications and comparison.

This paragraph contains a table (table 12) and a graphic comparison (figure 4) of the different overtaking sight distance lengths coming out from the national models and references.

Table 12: Comparison of different overtaking sight distance

V (km/h) (*)	**Australia**	**Belgium (^)**	**Canada**	**Chile**	**Czechia (#)**	**France (&)**	**Germany (&)**	**Italy (@)**	**Mexico (&)**	**Poland**	**Portugal (&)**	**Spain (*)**	**USA (!)**
30	-	-	-	180	-	-	-	-	225	-	210	-	120
40	-	320	275	240	-	-	-	220	300	-	280	300	140
50	-	400	345	300	240	-	-	275	375	-	350	360	160
60	-	480	420	370	400	500	-	330	450	400	420	440	180
70	570	560	485	440	-	500	600	385	525	450	490	520	210
80	710	640	560	500	600	500	600	440	600	500	560	600	245
90	850	720	620	550	800	500	600	495	675	550	630	680	280
100	1020	800	680	600	1000	500	600	550	750	600	700	800	320
110	1230	880	740	-	-	500	600	-	825	650	770	-	355
120	-	960	800	-	-	-	-	-	-	700	840	-	395
130	-	-	860	-	-	-	-	-	-	-	-	-	440

(*) design, operating, or other type of speed.

(&) It has been extended until the reasonable minimum value of the speed range that is not explicitly defined in the standard.

(^) multiplied by 2 the "overtaking distance" according to the criterion of symmetry concerning the arrival of a vehicle in the opposite direction.

(#) a minimum value of overtaking distance related to the minimum value of stopping distance Dz.

(@) the range of speed for rural secondary roads is 60-100 and for rural local roads is 40-100. Both with undivided carriageways.

(!) based on field measurements.

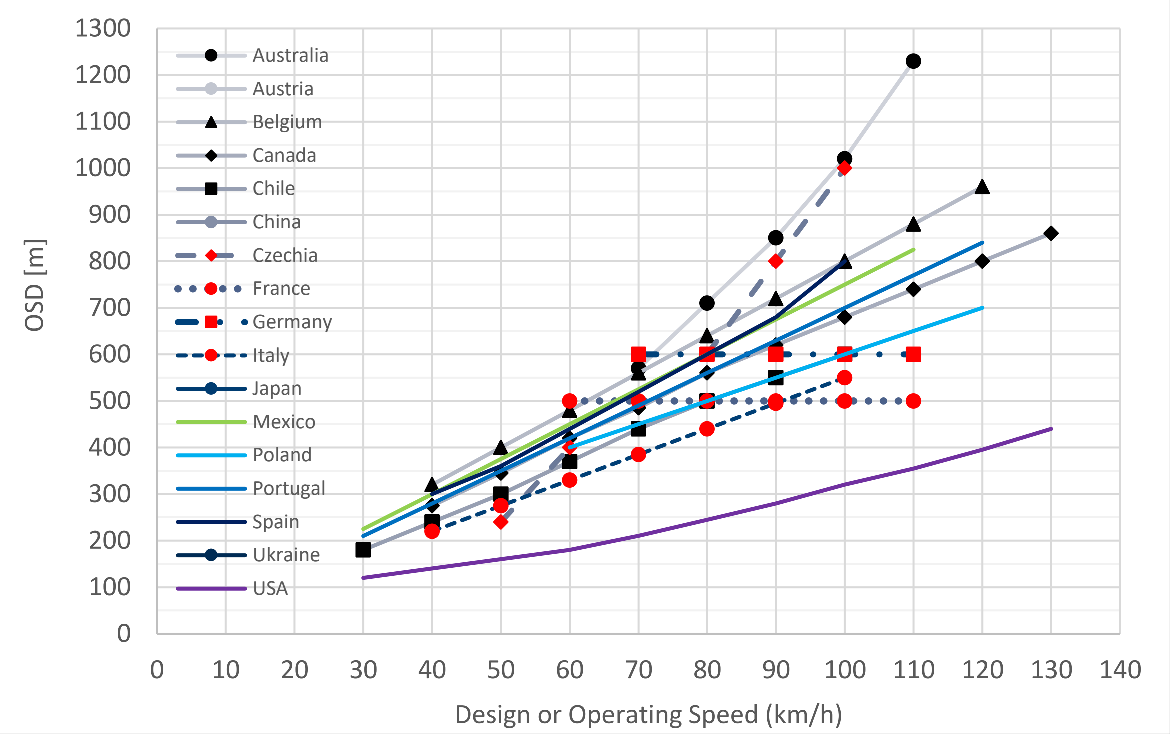


Figure 4: Comparison of different overtaking sight distance

3.2.5. Reviewer comments

From the results of the comparison OSD models made in chapter 3.2.4, the following observations can be deduced:

1. Most of the curves obtained from the various OSD calculation methodologies have a very similar slope. This group includes all the curves between the curve of Belgium and that of Italy.
2. The two constant-value models (France and Germany) tend to settle on the average values of the group highlighted in point 1. They prove to be more cautious than most models for low speeds (60-80 km/h), while for high speeds (90-110 km/h) they result in OSDs generally lower than those obtained from most models.
3. The curve of Australia appears to be the one that at the same speed determines higher OSD values.
4. The US curve shows significantly lower values than all the other curves. On the other hand, it is the only calculation model that uses field measurements on actual overtaking lengths.

3.3. DECISION-MAKING SIGHT DISTANCE (DSD)

3.3.1. Overview and general information

Decision-making Sight Distance (DSD), also called by many design standards as simply Decision Sight Distance (DSD), is a distance that must account for human processing capabilities. Consequently, the DSD must be defined based on Human Factors principles. The driver is continuously facing different road configurations, different locations, and different road surroundings while driving. The brain requires time to see, perceive, and decide how to deal with a specific situation and act. This time ranges from a few seconds to several seconds, depending on the specific situation and on the readiness of the driver for that situation. Different situations and different conditions require different times to be processed. Generally, actions that require more complex decisions require more time: changing lanes because to reach an exit ramp on a motorway requires more time than to decelerate while approaching a curve.

Even if this concept is used in almost all the analyzed design standards, its use varies from country to country and sometimes it refers to different situations and conditions. Despite these differences, the inclusion of DSD in road design seems to be crucial to improve road safety.

Finally, it must be underlined that DSD is different from SSD even though its formulation may be the same. Indeed, while DSD considers the time required to make conscious or semi-automatic decisions, the SSD refers to automatic actions, that is the abrupt braking in front of an obstacle.

3.3.2. Use of DSD in different national design standards

In the following countries, a summary of the use of DSD is provided for all the national design standards analyzed (14), which are:

- Australia
- Belgium
- Canada
- China
- England
- France
- Germany
- Italy
- Japan
- Mexico
- Poland
- Portugal
- Spain
- United States of America

The summary contains extracts from each design standard relating to the topic with the reviewers' comments.

A detailed review of the models is included in the appendix (Annex C) to this report.

3.3.3. Summary of the main parameters used and calculation procedure

The following table illustrates a summary of the main parameters considered for the calculation, choice, or definition of the DSD by each country. Within the table, the following items have been considered.

Use of DSD: it is specified whether the DSD is used or not and if yes, if its meaning is clearly stated.

Type of standard: it is highlighted whether the design standards provide an equation to calculate the DSD or if they provide tables.

Considered parameters: the parameters used to choose the DSD value or which shall be included in the equation to calculate the DSD.

Country	DSD used		Type of standard		Considered Parameters						
	Yes/No	Clearly Defined	Equation	Table	Speed*	Time**	Environment	Adjusted Deceleration	Curve Radius	Location type***	SSD
Australia	Yes	-	X	-	X	X	-	X	X	-	-
Belgium	Yes	X	-	X	X	X	-	-	-	X	-
Canada	Yes	X	-	X	X	X	X	-	-	X	-
Chile	No	-	-	-	-	-	-	-	-	-	-
China	Yes	X	X	X	X		X	-	-	X	X
England	No	-	-	-	-	-	-	-	-	-	-
France	Yes		X	-	X	X	-	-	-	-	-
Germany	Yes		X	X	-	-	-	-	-	-	X
Italy	Yes		X	-	X	X	-	-	-	X	
Japan	No	-	-	-	-	-	-	-	-	-	-
Mexico	Yes	X	-	X	X	X	X	-	-	X	--
Poland	Yes		X	-	-	-	-	-	-	-	X
Portugal	Yes	X	X	-	X	-	-	-	-	-	-
Spain	Yes	X	-	X	X	X	-	-	-	-	-
USA	Yes	X	X	X	X	X	X	-	-	X	-

* Design speed or operating speed
** Directly considered, even if fixed
*** if DSD changes from one location to another. IF DSD is present only for a specific location type, the cell will be kept empty.

Table 13: Summary of the main parameters considered in the DSD models.

The following table 14 illustrates a summary of the equations provided and the values required for the calculation. Countries having no equations to calculate the DSD have not been included.

Country	Equation	Variables
Australia	The length of the visible curve must be calculated	d = deceleration [m/s^2] R = curve radius
China	For difficult terrain and geological conditions:	V = design speed [km/h]

Country	Equation	Variables
	1.25*SSD	SSD = Stopping Sight Distance Environment = terrain
France	3*V	V = design speed [m/s]
Germany, Poland	1.3*SSD	SSD = Stopping Sight Distance
Italy	9.5*V	V = design speed [m/s]
Portugal	$3.3*V_T$	V_T = traffic speed [km/h]

Table 14: Summary of formulas and variables used in the DSD models.

3.3.4. Reviewer comments

It should be noted that the design standards of each country often consider DSD differently. In the most recent design standards this is a distance to be considered, in the older regulations it is generally not presented explicitly. Furthermore, DSD is not always required for every point of the road in all regulations. Most regulations promote its use only in particular conditions or only for certain elements of the road. Often the judgments of those specific conditions are left to the designer (for example the use of DSD is required “when information is difficult to perceive and process, or when the maneuver is unexpected or unusual”). This highlights the purpose of many design standards to be of reference for the design, but to not constrain the designer's choices under every circumstance, because all roads have some peculiarities that must be analyzed specifically with different design solutions.

Whatever the case, the adoption of DSD in all the new design standards demonstrates its importance as a parameter that influences the level of safety of a road, which is recommended in almost every location where a change in the driver behavior is required, and which is strictly mandatory under specific circumstance (particularly complex or unexpected location).

3.4. MAXIMUM AND MINIMUM GRADES, CRITICAL LENGTHS OF GRADES

3.4.1. Overview and general information

Longitudinal slope refers to the grade along the road. Slope values are crucial in road design and operation, influencing factors related to drainage, safety, and overall traffic performance. The selection of the value of the longitudinal slope of the road as well as its maximum length of grades depends strongly on many factors, including:

- road technical classes/category
- speed
- location (rural, urban)
- occurrence of intersections, interchanges
- road drainage conditions,

In addition to the above-mentioned factors, the longitudinal slope affects the length of the braking distance, which is directly related to the estimation of the stopping visibility distance. Therefore, the longitudinal slope is included in most formulas for calculating SSD.

3.4.2. Use of maximum and minimum grades in different national design standards

In the following countries (13), data/requirements for grades in road design standards are available and were analyzed:

- Austria
- Australia
- Belgium
- Canada
- Czechia
- France
- Italy
- Japan
- Mexico
- Poland
- Portugal
- Spain
- South Africa

The summary contains extracts from each design standard relating to the maximum and minimum slopes as well as critical lengths of slopes with the reviewers' comments. The content only represents a simplified summary. Exceptions or special cases are usually not shown. The respective road design standards must be consulted for details.

A detailed review of the models is included in the appendix (Annex D) of this report. The translation of design standards’ extracts is provided by automatic online translators thus the translation may contain minor errors.

3.4.3. Summary of the main parameters used and calculation procedure

The following tables (tables 15-17) illustrate if and which information is available in road design standards, respectively which criteria are defined. The tables also include limit values of design parameters related to maximum and minimum grades, as well as critical lengths of grades in different national design standards.

Data/requirements available in RDS: it shows if the different grades, considering the minimum, maximum, length of slopes, and locations of connection with other roads are defined or not. In table 15, “X” means that data is available in road design standards.

What the criteria depend on: it shows what the values/specifications specified in the design standards depend on the most (table 16).

Minimum and maximum values of the examined criteria: it shows the most important values (maximum/minimum)

Country	Maximum grades	Minimum grades	Critical lengths of grades	Grades in junctions	Grades in intersections/	Grades in roundabouts
Austria	X	X	-	X	-	X
Australia	X	X	X	-	X	X
Belgium	X	X	(X)	-	-	-
Canada	X	X	(X)	-	X	-
Chile	-	-	-	-	-	-
Czechia	X	X	X	X		X
France	X	X	X		X	X
Italy	X	-	-	X	X	-
Japan	X	-	-	-	-	-
Mexico	X	-	-	-	-	-
Poland	X	X	-	-	X	X
Portugal	-	-	-	X	X	X
Spain	-	-	-	-	X	X
South Africa	X	X	X	X	X	X

X explicit values for grades
(X) no explicit values in road design standards

Table 15: Requirements and data included in road design standards

Country	**Maximum grades**	**Minimum grades**	**Critical lengths of grades**	**Grades in junctions**	**Grades in intersections/ interchanges**	**Grades in roundabouts**
Austria	Road category & speed & curve radius	Crossfall min. 2,5%		Road type		If circular lane or legs
Australia	Operating speed & terrain type	Type of longitudinal drainage/type of pavement	longitudinal slope		Road type vehicle type ramp type	
Belgium	Speed	Crossfall min. 2,5%				
Canada	Road category	Road surface & location			Design speed road type	
Chile						
Czechia	Road category & terrain type	Min. longitudinal slope 0,5%	Longitudinal slope & road category		Intersection space or legs	If space, leg, or ring road
France	Road category & speed	Road category			Road type	Safety/stability of trucks
Italy	Road category			Road type	The slope of the incoming road	
Japan	Road category & design speed					
Mexico	Road category					
Poland	Road category & design speed	location			Road category & location	Road category & location
Portugal						
Spain						
South Africa	Terrain & design speed	Longitudinal slope min. 0,5%	Speed reduction & longitudinal slope		Road category	Road category

Table 16: Factors influencing longitudinal slopes in road design standards

Table 17: Minimum and maximum values of longitudinal slopes in road design standards

Criteria		Country													
		AUT	**AUS**	**BEL**	**CAN**	**CHL**	**CZE**	**FRA**	**ITA**	**JAP**	**MEX**	**POL**	**POR**	**SPA**	**S.AF**
Maximum grades (%)	**Motorways/ expressways**	4	3-6	4	5-7		3	5/6	6	2 (5)	6	4			3-5
	Major roads	6	3-8	6	7			6			7				4-7
	Minor roads	8-10	6-10	8	10						12				5-8
	Absolute maximum	12	10	8	13		12	7	10	12	12	12			8
Minimum grades (%)	**Minimum cross fall**	2,5	2-3	2,5	2-3										
	Absolute minimum	0,3 (0,5)	0,3 (0,5)		0,35 (0,5)		0,5	0,5 (1)				0 / 0,3			0,5
Critical lengths of grades (m)	**Maximum**		300-1800*					130**							100-550**
Grades in junctions (%)	**Maximum**	4-6	3 (4)				3/4		5-10				6		8
Grades in intersections/ interchanges (%)	**Maximum**				3-4			6				3-6 ***	6	6[#]	8/20[##]
Grades in roundabouts (%)	**cross fall**	1,5-4	2,5-3 (4)				3,5								
	Maximum longitudinal grade	4	2-4 (6)				4/6^	3-6				3-6 ***	6	2	8/20[##]

* depends on gradient

** a steep slope section > 130m should be avoided

*** depends on road category

[#] recommended slope for legs 3%

depends on road category
^ 4% for arms; 6% for roundabout space

3.4.4. Reviewer comments

It should be noted that design standards often define grades differently. Some standards differentiate between road categories, others between speeds or terrain types. It also shows that there are just a few countries that define critical lengths of grades – some do at least give recommendations for climbing lanes by steep slopes over a defined length. It can also be seen that in some countries there are no specifications for certain criteria.

When looking at the maximum grades, it is noticeable that maximum gradients of 2-7% are possible for motorways; most commonly, a maximum gradient of 3-5% is recommended. The absolute maximum of grades (for minor roads or roads with less traffic) is about 7-13; most commonly, a maximum gradient of 12% is defined. The specifications for the minimum cross slopes are defined in just a few countries and are about 2-3%, but probably for others, it is a typical value (not defined directly). The absolute minimum of grades is (to ensure adequate drainage) approx. 0,3 to 0,5%. This is roughly the same for all countries considered. By the criteria of grades in junctions, intersections/interchanges, and roundabouts it is difficult to get some data/requirements for grades. Sometimes it is not clear whether the road design standards mean the same for different terms or not. A mixture of the terms junction, intersection, and interchange can sometimes be observed.

In most road types, a maximum longitudinal grade of 6% is established. The most frequently mentioned value for the maximum longitudinal grade of roundabouts is between 3-6%.

4. CONCLUSIONS

In the full report detailed comparison of selected road design models was conducted. The full report has been limited to three models related to sight distance: Stopping Sight Distance, Overtaking Sight Distance, and Decision-Making Sight Distance, and one model related to road profile, which is Maximum and Minimum Grades and critical lengths of grades. For the above-mentioned models, a comparison of the approaches used in the models, the values obtained from the models, model parameters, and their variability was carried out. This document focuses mainly on road design standards based on member countries involved in the work of TF 4.1.

Due to the limited scope of the report, as well as the very large variability in the models used, affecting the scope of comparisons in individual guidelines, the models were limited concerning the planned ones [1]. However, similar work should be continued in the following years.

During the review of models, the following specific conclusions were identified that should be addressed in recommendations for PIARC, decision-makers, and LMICs:

The general conclusions are the following:

- The analyzed models use the human factor and stochastic adoption of model parameters only to a limited extent
- Models are not updated for many years, which is due to the lack of changes in standards even more than 30 years, which means that models are not updated to take into account new knowledge and changes in technology and mobility.
- Existing road design models do not consider the advantages that could be offered by the knowledge provided by big data analysis and new technology.
- Existing road design models do not consider the transition to automatic driving and its related modes of transport.

The specific conclusions are the following:

- Most countries use a formula where the SSD is calculated as the sum of distance driving during the perception and reaction time is considered, as well as the mechanical braking distance.
- Required stopping sight distances in countries differ in the range where the relation between the highest and the lowest values is approximately 2 to 1. Such large differences result from the estimation of SSD in different countries, which may be the result of preference either towards a conservative/safe or towards a functional and economical approach.
- In most cases, the variables used to calculate SSD values (friction coefficients, deceleration, reaction time, etc.) are deterministic in nature.
- Most of the curves obtained from the various OSD calculation methodologies have a very similar slope (increase of OSD with speed), and only two constant-value models in speed ranges were identified (France and Germany). Models with constant values tend to settle on the average values of the group with curves.
- Only a few models are determined based on a calculation model that uses field measurements on actual overtaking lengths (USA).
- Design standards of each country often consider DSD differently. In the most recent design standards, this is clearly defined as a distance to be considered, but DSD is not always

required for every point of the road in all regulations. Most regulations promote its use only in particular conditions or only for certain elements of the road.

- Not all road design standards define critical lengths of slopes – some do at least give recommendations for climbing lanes by steep slopes over a defined length.
- The maximum longitudinal slope is related to the road class and the lowest values are adopted in motorways and express roads, which is expected. The absolute maximum of slopes (for local roads or roads with less traffic) is about 7-13%; most commonly, a maximum gradient of 12% is defined.
- The absolute minimum of grades is (to ensure adequate drainage) approx. 0,3 to 0,5%.
- Most guidelines define recommended longitudinal slopes at intersections, roundabouts, and interchanges.

5. RECOMMENDATIONS

The following general recommendations for PIARC, decisions makers, and LMICs have been identified by TF 4.1 members:

- Analysis related to the comparison of analogies and differences in road design models and compilation of a list of standards for the geometric design should be continued because they are conducted to a limited extent in the world. In the comparison particular, attention should be paid to countries that have recently updated their regulations, in order to monitor the effects of these changes (Poland, Belgium).
- Highly advisable is considering technological improvements and new knowledge acquired through the most recent research findings in updating road design standards. Changes are continuously revised, updated, and adapted to state-of-the-art technologies only in a few countries. Therefore access to new standards, models, and experiences resulting from their updating should be provided.
- Improving the availability of model comparisons and list of road design standards will allow for their easy implementation in countries where no research is carried out on the implementation of road design standards, including LIMCs.
- Human Factor principles in the existing standards are only partially considered. Therefore, Human Factors should be taken into account to a greater extent in road design standards, which DSD can be an example. The adoption of DSD in all analyzed the new design standards demonstrates its importance as a parameter that influences the level of safety of a road. Therefore, the Human Factors should be taken into account to a greater extent in road design models.
- Despite technological development, a conservative approach to road design is still used based on well-known models. Implications of the new mobility and technology in the geometric design of road infrastructure have not fully taken place yet. Existing road design models do not consider the transition to automatic driving and its related modes of transport. Therefore, it is recommended to assess the compliance with the system of calculated values between human-driven and self-driven vehicles.
- When developing new models for road design, it is necessary to take advantage of the opportunities offered by new technologies (in the assessment of vehicle behavior) and big data analysis in terms of data collection.

.

6. GLOSSARY

Term	Definition
a_c	admissible deceleration
CEDR	Conference of European Directors of Roads
DMSD	decision-making sight distance
DSD	decision-making sight distance
f_l	friction coefficient
Green Book	A Policy on Geometric Design of Highways and Streets, 7th Edition, AASHTO, 2018, US
LMICs	Low- or Middle-Income Countries
OSD	overtaking sight distance
RDS	Road Design Standard
R_t	reaction time
SSD	stopping sight distance
TF	Task Force PIARC

7. REFERENCES

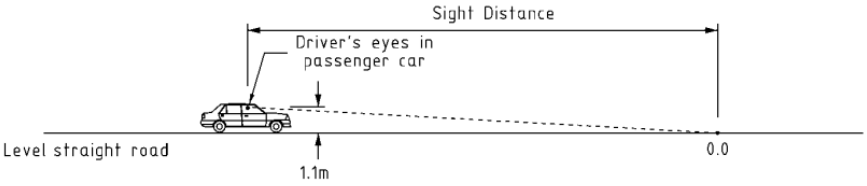
[1] PIARC report, 2022R22EN (2022) State of the Art in Road Design Standards.
[2] CEDR report (2016), European Sight Distances in Perspective – EUSight, CEDR Transnational Road Research Program.
[3] AASHTO Green Book (2018), A Policy on Geometric Design of Highways and Streets, 7th edition.

APPENDIX: COMPARISON OF SELECTED MODELS FOR SIGHT DISTANCE IN ROAD DESIGN

The appendix contains extracts from the reference standard for each country. The columns are divided by country, reference, and text of the extract. The following tables illustrate a description of the main parameters considered for the calculation, choice, or definition. The translation of extracts was provided by automatic online resources and may contain errors.

ANNEX A – STOPPING SIGHT DISTANCE

Australia

REF.	TEXT
Austroads Guide to Road Design Part 3: Geometric Design (2021) 5. Sight distance.	**5. Sight Distance** **5.1 General** Sight distance is defined as the distance, measured along the carriageway, over which visibility occurs between a driver and an object, single vehicle sight distance (refer to Figure 5.1) or between two drivers at specific heights above the carriageway in their lane of travel. For safe and efficient traffic operation on the road, sufficient sight distance must be provided to enable drivers to perceive and react to any hazardous situation. A driver's sight distance should be as long as practicable, but it is often restricted by crest vertical curves and obstructions on horizontal curves and the designer should consider all of these elements when developing the horizontal and vertical geometry of the road. The concept of sight distance provides a parameter that can be calculated and related to the geometry of the road. This concept is based on a number of somewhat stylised assumptions of particular hazards and corresponding driver behaviour. The hazard is assumed to be an object, of sufficient size to cause a driver to take evasive action, intruding into the driver's field of view. **Figure 5.1: Sight distance**  **5.2 Sight Distance Parameters** In order to use sight distance as a calculable parameter for the geometric design of roads, assumptions must be made about the following elements: • object height • driver eye height • driver perception – reaction time. The values chosen for different scenarios are outlined later in this section, but they have been developed using local and international research and engineering judgement. ***Object height*** The object height to be used in the calculation of sight distance is a compromise between the length of sight distance and the cost of construction. Stopping is generally in response to another vehicle or large hazard in the roadway. For example, to recognise a vehicle as a hazard at night, a line of sight to its headlights or taillights would be necessary. Larger objects would be visible sooner and provide longer stopping distances. To perceive a very small hazard, such as a surface defect, a zero object height would be necessary. However, at the required stopping sight distances for high speeds, small pavement variations and small objects (especially at night) may not be visible to most drivers. Thus, most drivers travelling at high speeds would have difficulty in stopping before reaching such a small obstruction. The length of crest vertical curves increases significantly as the object height approaches zero. For the geometric design of all roads, the object heights shown in Table 5.1 are to be used.

REF.	TEXT

5.2.1 Driver Eye Height

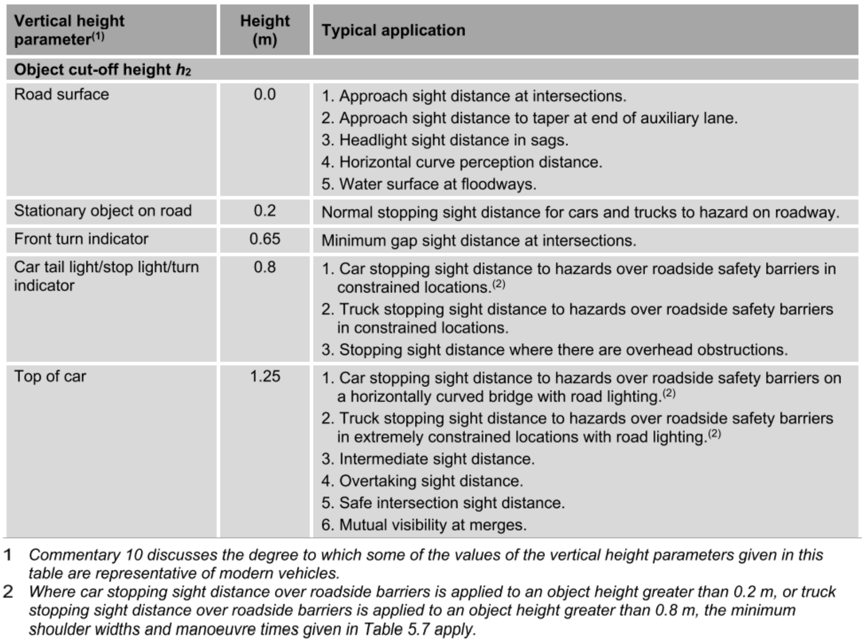
Driver eye height is a combination of the height of driver stature and driver seat height. Based upon recent research and consideration of the characteristics of the vehicle fleet, a car driver eye height of 1.10 m is to be used for the geometric design of all roads.

For commercial vehicles, a driver eye height of 2.40 m is to be used. The 2.40 m truck driver eye height for sag curves is particularly important for checking the effect of overhead structures on sight distance.

When designing facilities for buses, the driver eye height is 1.80 m.

The driver eye heights and typical applications are listed in Table 5.1.

The change of car driver eye height will have implications for geometric design elements (such as length of vertical curves) used in other road design publications, which should be considered by the designer when this guide is used in conjunction with previously published guides.



Vertical height parameter(1)	Height (m)	Typical application
Object cut-off height h_2		
Road surface	0.0	1. Approach sight distance at intersections. 2. Approach sight distance to taper at end of auxiliary lane. 3. Headlight sight distance in sags. 4. Horizontal curve perception distance. 5. Water surface at floodways.
Stationary object on road	0.2	Normal stopping sight distance for cars and trucks to hazard on roadway.
Front turn indicator	0.65	Minimum gap sight distance at intersections.
Car tail light/stop light/turn indicator	0.8	1. Car stopping sight distance to hazards over roadside safety barriers in constrained locations.(2) 2. Truck stopping sight distance to hazards over roadside safety barriers in constrained locations. 3. Stopping sight distance where there are overhead obstructions.
Top of car	1.25	1. Car stopping sight distance to hazards over roadside safety barriers on a horizontally curved bridge with road lighting.(2) 2. Truck stopping sight distance to hazards over roadside safety barriers in extremely constrained locations with road lighting.(2) 3. Intermediate sight distance. 4. Overtaking sight distance. 5. Safe intersection sight distance. 6. Mutual visibility at merges.

1 *Commentary 10 discusses the degree to which some of the values of the vertical height parameters given in this table are representative of modern vehicles.*

2 *Where car stopping sight distance over roadside barriers is applied to an object height greater than 0.2 m, or truck stopping sight distance over roadside barriers is applied to an object height greater than 0.8 m, the minimum shoulder widths and manoeuvre times given in Table 5.7 apply.*

5.2.2 Driver Reaction Time

Reaction time is the time for a driver to perceive and react to a particular stimulus and take appropriate action. This time depends on:

- alertness of the driver
- recognition of the hazard
- the complexity of the decision or task involved.

Table 5.2 provides guidance for the use of three driver reaction times (1.5, 2.0 and 2.5 seconds) to be considered in the design process. It is desirable for designers to adopt a reaction time of 2.5 seconds for the geometric design of all roads. Where a lesser value is contemplated, designers need to consider the appropriateness of that value based on the expected road conditions and typical use listed below.

Designers shall also consult specific road agency guidance (where available) regarding use of 1.5 and 2.0 second reaction time, as approval from the responsible authority within that road agency may be required.

REF.	TEXT

Table 5.2: Driver reaction times

Reaction time R_T (s)	Typical road conditions	Typical use
2.5	• Unalerted driving conditions due to the road only having isolated geometric features to maintain driver interest • Areas with high driver workload/complex decisions • High speed roads with long distances between towns.	Absolute minimum value for high speed roads with unalerted driving conditions. General minimum value for: • high speed rural freeways • high speed rural intersections • isolated alignment features.
2.0	• Higher speed urban areas • Few intersections • Alerted driving situations in rural areas • High speed roads in urban areas comprising numerous intersections or interchanges where the majority of driver trips are of relatively short length.	Absolute minimum value for the road conditions listed in this row. General minimum value for most road types, including those with alert driving conditions.
1.5(1)	Alert driving conditions e.g.: • high expectancy of stopping due to traffic signals • consistently tight alignments for example, mountainous roads • restricted low speed urban areas • built-up areas – high traffic volumes • interchange ramps when sighting over or around barriers.	Absolute minimum value. Only used in very constrained situations where drivers will be alert. Can be considered only where the maximum operating speed is ≤ 90 km/h. Should not be used where other design minima have been used.

1 *A reaction time of 1.5 s cannot be used in Western Australia. Designers should refer to road agency supplements to confirm local practice.*

Notes:

The driver reaction times are representative for cars at the 85th percentile speed and for heavy vehicles. The deceleration rates for heavy vehicles cover the inherent delay times in the air braking systems for these vehicles.

The above times typically afford an extra 0.5 to 1.0 s reaction time to drivers who have to stop from the mean free speed. It is considered, for example, that the mean free speed is more representative of the speed travelled by older drivers.

Commentary 11 discusses the degree to which the reaction times given in this table are representative of driving conditions.

5.2.3 Longitudinal Deceleration

Longitudinal deceleration is the measure of the longitudinal friction between the vehicle tyres and the road surface. It depends on factors such as the speed of the vehicle, the tyre condition and pressure, the type of road surface and its condition, including whether it is wet or dry. Recommended values for the coefficient of deceleration for bituminous and concrete surfaces are shown in Table 5.3.

A range of longitudinal deceleration values is provided for use in the tables relating to Stopping Sight Distance for Cars (Table 5.5) and Minimum size crest vertical curves (Table 8.7). For most urban and rural road types, designers should adopt a longitudinal coefficient of deceleration, d = 0.36. Adoption of the design values using the longitudinal coefficient of deceleration, d = 0.46, should only be used in very constrained locations on low volume and less important roads, as noted in Table 5.3. Designers should refer also to Commentary 12 which discusses the degree to which the values of the coefficient of deceleration given in this table are representative of driving conditions.

REF.	TEXT

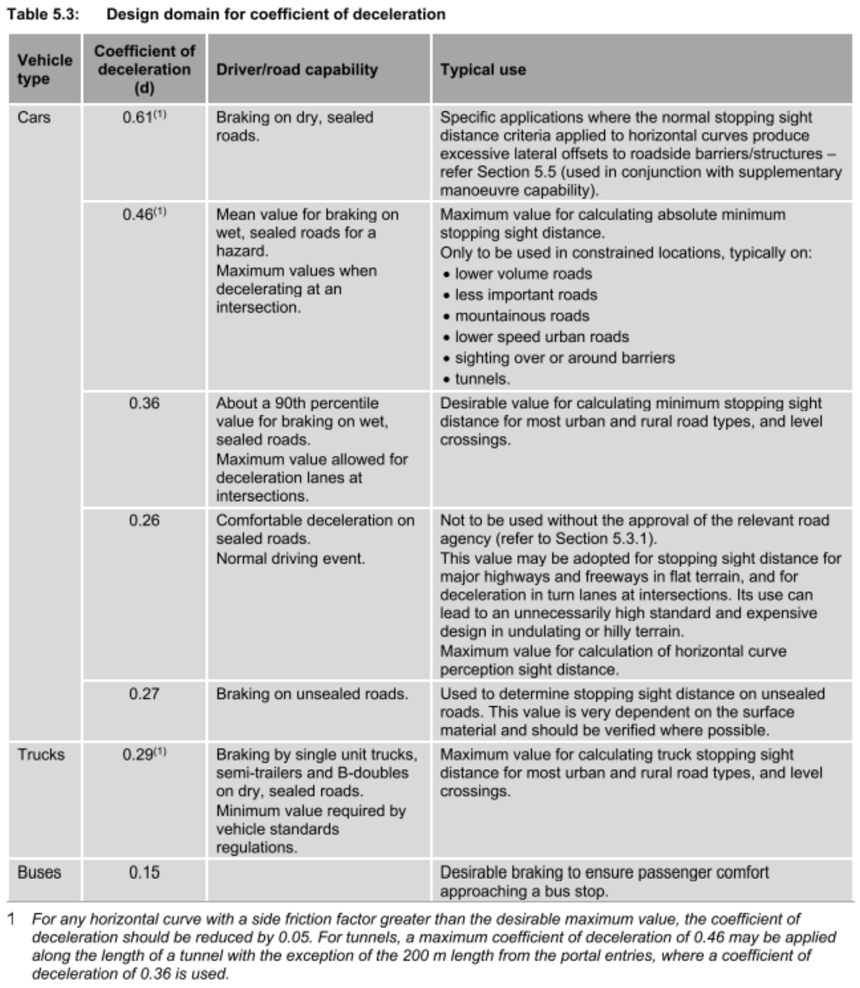


Table 5.3: Design domain for coefficient of deceleration

Vehicle type	Coefficient of deceleration (d)	Driver/road capability	Typical use
Cars	0.61[1]	Braking on dry, sealed roads.	Specific applications where the normal stopping sight distance criteria applied to horizontal curves produce excessive lateral offsets to roadside barriers/structures – refer Section 5.5 (used in conjunction with supplementary manoeuvre capability).
	0.46[1]	Mean value for braking on wet, sealed roads for a hazard. Maximum values when decelerating at an intersection.	Maximum value for calculating absolute minimum stopping sight distance. Only to be used in constrained locations, typically on: • lower volume roads • less important roads • mountainous roads • lower speed urban roads • sighting over or around barriers • tunnels.
	0.36	About a 90th percentile value for braking on wet, sealed roads. Maximum value allowed for deceleration lanes at intersections.	Desirable value for calculating minimum stopping sight distance for most urban and rural road types, and level crossings.
	0.26	Comfortable deceleration on sealed roads. Normal driving event.	Not to be used without the approval of the relevant road agency (refer to Section 5.3.1). This value may be adopted for stopping sight distance for major highways and freeways in flat terrain, and for deceleration in turn lanes at intersections. Its use can lead to an unnecessarily high standard and expensive design in undulating or hilly terrain. Maximum value for calculation of horizontal curve perception sight distance.
	0.27	Braking on unsealed roads.	Used to determine stopping sight distance on unsealed roads. This value is very dependent on the surface material and should be verified where possible.
Trucks	0.29[1]	Braking by single unit trucks, semi-trailers and B-doubles on dry, sealed roads. Minimum value required by vehicle standards regulations.	Maximum value for calculating truck stopping sight distance for most urban and rural road types, and level crossings.
Buses	0.15		Desirable braking to ensure passenger comfort approaching a bus stop.

1 *For any horizontal curve with a side friction factor greater than the desirable maximum value, the coefficient of deceleration should be reduced by 0.05. For tunnels, a maximum coefficient of deceleration of 0.46 may be applied along the length of a tunnel with the exception of the 200 m length from the portal entries, where a coefficient of deceleration of 0.36 is used.*

Notes:

Values of the coefficient of deceleration for check cases are given below. For any horizontal curve with a side friction factor greater than the desirable maximum value, the coefficient of deceleration should be reduced by 0.05.

Headlight sight distance in constrained cases on sealed roads – 0.61.

Stopping sight distance for a Type 1 road train on dry, sealed roads – 0.28.

Stopping sight distance for a Type 2 road train on dry, sealed roads – 0.26.

Coefficient of deceleration 0.26 for cars should only be used in flat terrain (easy country) and where a high standard facility is provided.

Unsealed road surfaces are highly variable and very little research has been undertaken to quantify friction coefficients under various climatic conditions. Designers should refer to the Unsealed Roads Manual, Guidelines to Good Practice 3rd Edition (Giummarra 2009) for detailed information regarding designing for unsealed roads. The values listed in Table 5.3 may be used for the design of unsealed roads but designers will need to make allowance for reductions in friction factor depending on the type of material on the surface, the moisture environment and vehicle types. These factors, in combination with the likely operating speeds for the conditions may have an impact on the sight distance required.

On poorly maintained roads with loose gravel on the surface, the friction which can be developed is reduced and stopping distances increase markedly. On unsealed roads, the friction factor may vary between 0.05 and 0.40, with the former applying on smooth wet surfaces and the latter on gravelly dry surfaces. As it is not practical to design for the lowest friction factors, designers may consider use of the longitudinal friction factor for unsealed roads, as shown in Table 5.4. In these circumstances, designers should take particular care with the location of intersections to ensure that adequate stopping sight distances are available on the approaches.

REF.	TEXT

Table 5.4: Coefficient of deceleration for unsealed roads

Speed (km/h)	Coefficient of longitudinal deceleration for cars (d)
30	0.27
40	0.27
50	0.27
60	0.27
70	0.26
80	0.25
90	0.24

5.3 Stopping Sight Distance (SSD)

Stopping Sight Distance (SSD) is the distance to enable a normally alert driver, travelling at the design speed on wet pavement, to perceive, react and brake to a stop before reaching a hazard on the road ahead.

SSD is derived from two components:

1. the distance travelled during the total reaction time
2. the distance travelled during the braking time from the design speed to a stop and their relationship is shown in Equation 1.

$$SSD = \frac{R_T V}{3.6} + \frac{V^2}{254(d + 0.01a)} \qquad 1$$

where

R_T = reaction time (sec)
V = operating speed (km/h)
d = coefficient of deceleration (longitudinal friction factor)
a = longitudinal grade (%, + for upgrades and – for downgrades)

Values of R_T and d must be assumed in order to compute the values of SSD appropriate to a specified initial speed; these can be obtained from Table 5.2 and Table 5.3 respectively.

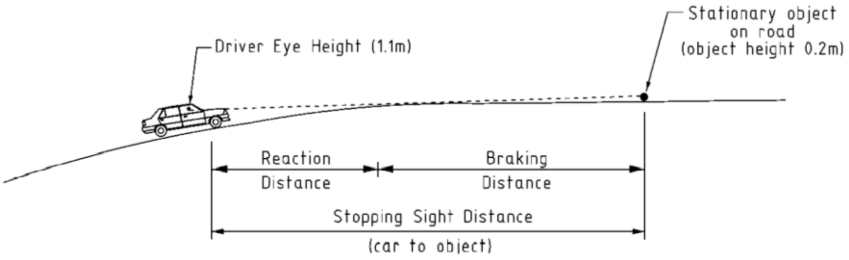
The provision of stopping sight distance is a mandatory design condition for all roads and intersections in the Normal Design Domain. Designers should provide stopping sight distance for both cars and trucks for all roads in daytime conditions.

5.3.1 Car Stopping Sight Distance

The concept of car stopping sight distance is illustrated in Figure 5.2. It is generally measured between the driver's eye (1.1 m) and a 0.2 m high, stationary object on the road. The object height of 0.2 m represents a hazard that cannot be driven over and hence requires the vehicle to stop to avoid a collision. However, there are special cases when a lower object height is used (e.g. to the pavement level at floodways).

In cases of sighting over roadside barriers in constrained cases, it may not always be practical to provide car stopping sight distance to a 0.2 m high object – refer Table 5.1 for heights in these instances. Note 1 of Table 5.7 indicates that minimum shoulder widths and minimum manoeuvre times apply where object heights of greater than 0.2 m are used for stopping sight distance over barriers. These minimum values are given in Table 5.7 and must be provided to enable drivers to avoid hazards that are lower than the chosen design object height.

Figure 5.2: Car stopping sight distance



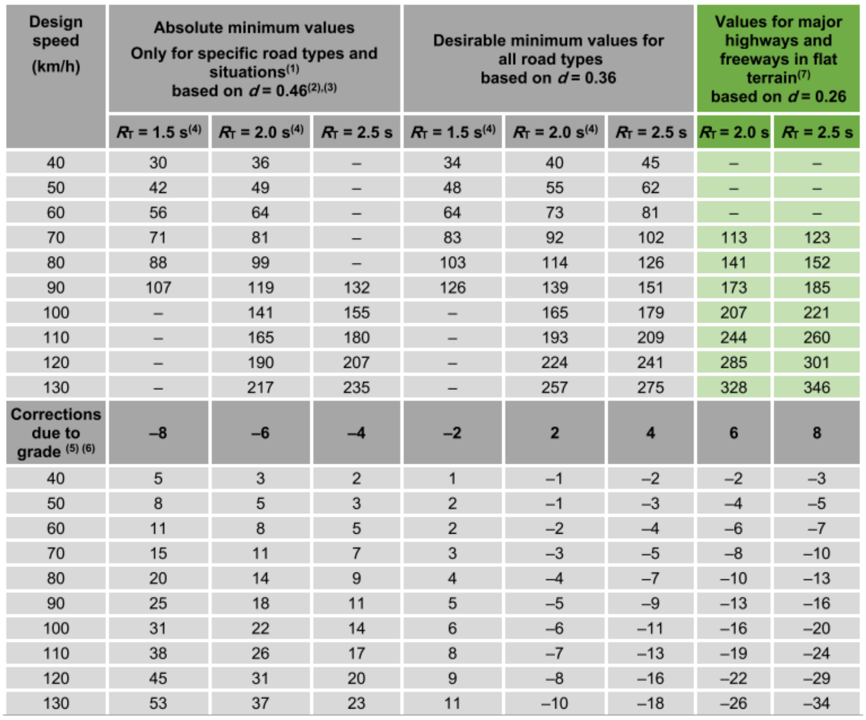
REF.	TEXT

Car stopping sight distance shall be available along all traffic lanes on all roads. This distance is considered to be the minimum sight distance that should be available to a driver at all times. Values for car stopping sight distances are listed in Table 5.5 using the coefficients of deceleration shown in Table 5.3. When using the car stopping sight distances listed in Table 5.5, designers shall include the grade correction factors where necessary to account for the additional distance that vehicles travel when braking on a downhill grade or reductions for an uphill grade.

With reference to Table 5.3:

- Generally it is only possible to use a value of d = 0.26 for 'major highways and freeways' at greenfield locations where topography permits an economic and environmentally sensitive design solution to be developed (i.e. flat terrain). This value should generally not be adopted for freeways or major highways in undulating or hilly terrain because of the relatively high cost involved and the greater visual and environmental impact. For these reasons, d = 0.26 (shaded area of Table 5.4) should only be used with written approval of the relevant road agency when project objectives are being established.
- Adoption of desirable minimum values for sight distance for 'most urban and rural road types' (d = 0.36) is considered appropriate for most existing highway and freeway upgrades (brownfields locations) and where topography dictates that a solution using 'desirable values for major highways and freeways' criteria would produce an unacceptable solution (either economically or environmentally).
- Appropriate design criteria for crest curves (sight distance) to be adopted in Table 5.5 for specific projects should be agreed to within a road agency when project objectives are being established.

Table 5.5: Stopping sight distances for cars on sealed roads



Design speed (km/h)	Absolute minimum values Only for specific road types and situations[1] based on $d = 0.46^{(2),(3)}$			Desirable minimum values for all road types based on $d = 0.36$			Values for major highways and freeways in flat terrain[7] based on $d = 0.26$	
	$R_T = 1.5$ s[4]	$R_T = 2.0$ s[4]	$R_T = 2.5$ s	$R_T = 1.5$ s[4]	$R_T = 2.0$ s[4]	$R_T = 2.5$ s	$R_T = 2.0$ s	$R_T = 2.5$ s
40	30	36	–	34	40	45	–	–
50	42	49	–	48	55	62	–	–
60	56	64	–	64	73	81	–	–
70	71	81	–	83	92	102	113	123
80	88	99	–	103	114	126	141	152
90	107	119	132	126	139	151	173	185
100	–	141	155	–	165	179	207	221
110	–	165	180	–	193	209	244	260
120	–	190	207	–	224	241	285	301
130	–	217	235	–	257	275	328	346
Corrections due to grade (5) (6)	**–8**	**–6**	**–4**	**–2**	**2**	**4**	**6**	**8**
40	5	3	2	1	–1	–2	–2	–3
50	8	5	3	2	–1	–3	–4	–5
60	11	8	5	2	–2	–4	–6	–7
70	15	11	7	3	–3	–5	–8	–10
80	20	14	9	4	–4	–7	–10	–13
90	25	18	11	5	–5	–9	–13	–16
100	31	22	14	6	–6	–11	–16	–20
110	38	26	17	8	–7	–13	–19	–24
120	45	31	20	9	–8	–16	–22	–29
130	53	37	23	11	–10	–18	–26	–34

1 *These values are only suitable for use in very constrained locations. Examples of this in Australia are:*
  - *lower volume roads*
  - *mountainous roads*
  - *lower speed urban roads*
  - *sighting over or around barriers.*

2 *On any horizontal curve with a side friction factor greater than the desirable maximum value, reduce the coefficient of deceleration by 0.05 and calculate the stopping distance according to Equation 1.*

3 *Where deceleration values greater than 0.36 are used, minimum seal widths for supplementary manoeuvre capability should be provided. For two-lane, two-way roads, a desirable minimum width of 12 m and a minimum of 9 m is applicable. This is especially important on horizontal curves with a side friction demand greater than the desirable maximum in Table 7.5.*

4 *Reaction times of 1.5 s cannot be used in Western Australia. A 1.5 s reaction time is only to be used in constrained situations where drivers will be alert. Typical situations are given in Table 5.2. The general minimum reaction time is 2.0 s.*

5 *If the roadway is on a grade, designers shall adjust stopping sight distance values by applying these grade corrections derived with d = 0.36. Downhill grades are shown as negative, with uphill listed as positive. The grade adopted is determined using the average grade over the braking length. Grade correction for d = 0.46 should be calculated separately using Equation 1. Generally, grade corrections are not necessary when using d = 0.26 because the deceleration value is conservative and because steep grades are not usually applied to roadways utilising d = 0.26.*

6 *Corrected stopping sight distances should be rounded conservatively to the nearest 5 m.*

7 *Green shaded area of Table 5.5 should only be used with the written approval of the relevant road agency when project objectives are being established.*

REF.	TEXT

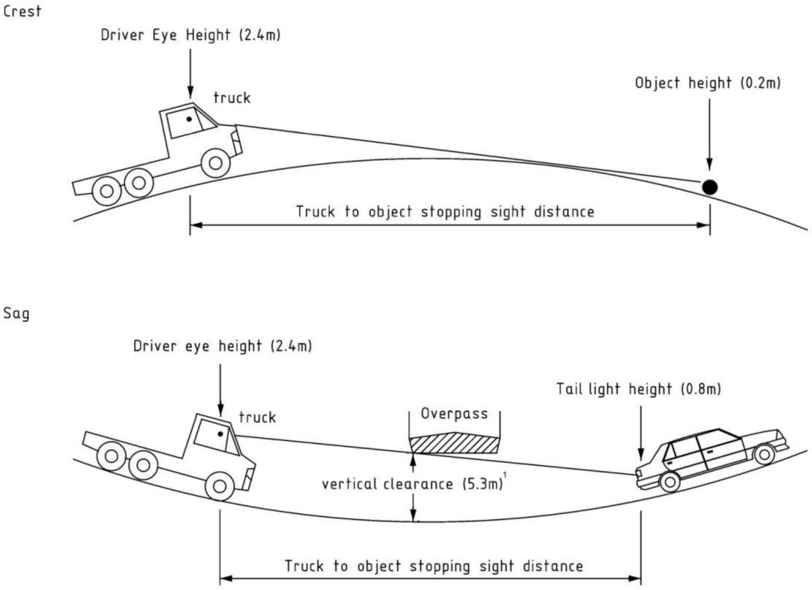
Note: Combinations of design speed and reaction times not shown in this table are generally not used. Either the resulting stopping distances are similar to other combinations of the parameters for the design speed, or they fall outside the realistic design speed for the road.

5.3.2 Truck Stopping Sight Distance

The design of all new roads should cater for the sight distance requirements of trucks. Research on truck braking performance characteristics (Donaldson 1986, Fancher 1986, PIARC 1995) suggest that the sight distance advantages provided by the higher driver eye level in trucks do not compensate for the inferior braking of trucks. The benefits of the higher eye level could also be lost at locations with lateral sight distance restrictions, e.g. cut batters or bridge piers.

Truck stopping sight distance is generally measured between the driver's eye (2.4 m) and a 0.2 m high, stationary object on the road. However, there are special cases when a lower object height is used (e.g. to the pavement level at floodways). In cases of sighting over roadside barriers in constrained cases, it may not always be practical to provide truck stopping sight distance to a 0.2 m high object – refer Table 5.1 for heights in these instances. Note 1 of Table 5.7 indicates that minimum shoulder widths and minimum manoeuvre times apply where object heights of greater than 0.8 m are used for stopping sight distance over barriers. These minimum values are given in Table 5.7 and must be provided to enable drivers to avoid hazards that are lower than the chosen design object height.

Figure 5.3: Truck stopping sight distance



Note: The vertical clearance of 5.3 m is a nominal figure only and should not be used as an acceptable vertical clearance for all structures. Refer to relevant road agency for vertical clearance requirements.

The stopping sight distance values for trucks are shown in Table 5.6. It should be noted that semi-trailers have a tendency to become unstable when braking on a curve and the effect becomes more pronounced as the radius reduces below 400 m. Where truck stopping distance is the critical design criterion, and the radius is less than 400 m, the distances from Table 5.5, after adjustment for gradient, should be increased by 10 per cent.

Whilst catering for the sight distance requirements for trucks on new roads, designers should especially consider the following locations, which could be hazardous to large vehicles:

- on approaches to speed change areas such as curve-tangent-curve points on compound curves, deceleration lanes and exit ramp noses
- on the approaches to areas where merging is required, such as lane drops
- on the approaches to construction zones, especially where the surface changes from sealed to unsealed
- sight distance through underpasses where the critical case is truck driver eye height (2.4 m) to car tail light (0.8 m)
- bus lanes on freeways adjacent to safety barriers
- areas where large vehicles are required to brake on low radius horizontal curves, e.g. at intersections, as large vehicles require additional distance for braking, especially when considering truck stability during turns within intersections – see below.

REF.	**TEXT**

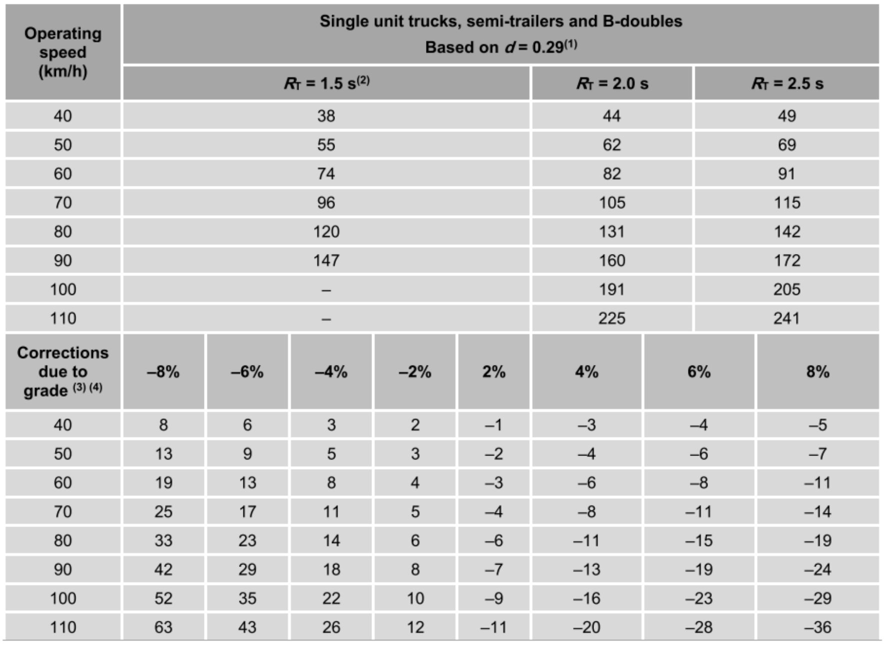
Designers are referred to the *Guide to Road Design Part 4A: Unsignalised and Signalised Intersections* (Austroads 2010a) for further information regarding Truck SSD at intersections. However, consideration should be given to providing Truck SSD at the following potentially hazardous locations:

- on the approaches to railway level crossings
- intersections with lateral sight distance restrictions. For example, intersections in hilly terrain or near bridge piers
- intersections on or near crest vertical curves
- on intersection approaches where truck speeds are close to or equal to car speeds
- at crest and sag points, truck stopping sight distance is measured as shown on Figure 5.3.

The designer should consider measures such as additional signs and line marking to improve safety if stopping sight distance is found to be inadequate for trucks and it is not possible to improve the geometric design. However, it is emphasised that signage and line marking are not substitutes for achieving standard design practices.

SSD values for trucks have been calculated using the coefficient of longitudinal deceleration shown in Table 5.3.

Table 5.6: Truck stopping sight distances



Operating speed (km/h)	**Single unit trucks, semi-trailers and B-doubles Based on d = 0.29(1)**		
	R_T = 1.5 s(2)	**R_T = 2.0 s**	**R_T = 2.5 s**
40	38	44	49
50	55	62	69
60	74	82	91
70	96	105	115
80	120	131	142
90	147	160	172
100	–	191	205
110	–	225	241

Corrections due to grade (3) (4)	**–8%**	**–6%**	**–4%**	**–2%**	**2%**	**4%**	**6%**	**8%**
40	8	6	3	2	–1	–3	–4	–5
50	13	9	5	3	–2	–4	–6	–7
60	19	13	8	4	–3	–6	–8	–11
70	25	17	11	5	–4	–8	–11	–14
80	33	23	14	6	–6	–11	–15	–19
90	42	29	18	8	–7	–13	–19	–24
100	52	35	22	10	–9	–16	–23	–29
110	63	43	26	12	–11	–20	–28	–36

1 *On any horizontal curve with a side friction factor greater than the desirable maximum value for trucks, the stopping sight distance values given should be based on a coefficient of deceleration that is reduced by 0.05.*

2 *Reaction times of 1.5 s cannot be used in Western Australia. A 1.5 s reaction time is only to be used in constrained situations where drivers will be alert. Typical situations are given in Table 5.2. The general minimum reaction time is 2.0 s.*

3 *If the roadway is on a grade, designers shall adjust stopping sight distance values by applying these grade corrections derived with d = 0.29. Downhill grades are shown as negative, with uphill listed as positive. The grade adopted is determined using the average grade over the braking length.*

4 *Corrected stopping sight distances should be rounded conservatively to the nearest 5 m.*

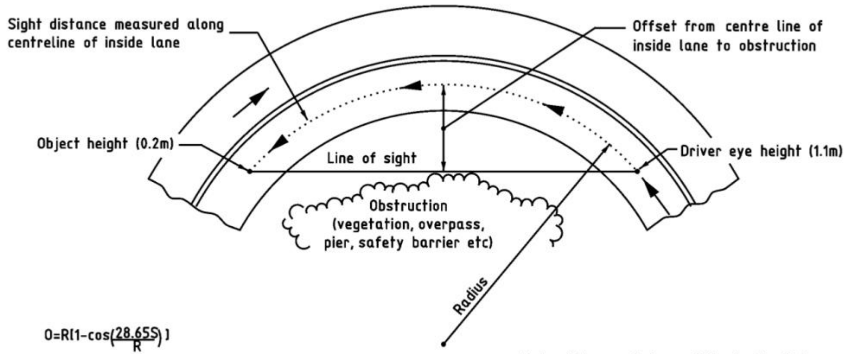
5.4 Sight Distance on Horizontal Curves

The minimum radii horizontal curves listed in Table 7.6 do not necessarily meet the sight distance requirements of drivers if there are obstructions on the inside of the curve. Where a lateral obstruction off the pavement such as a bridge pier, road safety barrier, cut slope or natural growth of vegetation restricts sight distance and cannot be removed, the radius of the curve should be selected to permit adequate sight distance for drivers of cars and trucks.

For the purposes of design, the construction of visually permeable road safety barriers, e.g. bridge parapet systems with steel railings or wire rope safety barriers, does not negate the need to provide appropriate horizontal geometry, in accordance with Figure 5.4.

REF.	TEXT

Figure 5.4: Line of sight on horizontal curves



$$O = R[1-\cos(\frac{28.65S}{R})]$$

$$S = \frac{R}{28.65}\ [\cos^{-1}(\frac{R-O}{R})]$$

Where:
R = radius in metres (at the centre of the inside lane)
S = sight distance in metres
O = offset in metres

Note:
Use this formula only when $S \leqslant$ the length of the circular curve. Angles in degrees

Notes: This graph is used for horizontal sight restrictions only.

Eye position is in the centre of the lane for cars;
1.15m from right-hand edge of lane for trucks turning left;
2.85m from left-hand edge of lane for trucks turning right.

To determine offset for truck:
1. Use stopping sight distance for truck and radius of centre of lane to calculate offset.
2. Subtract 0.30 from the value obtained in step 1 for truck turning left.
3. Add 0.55 to the value obtained in step 1 for a truck turning right.

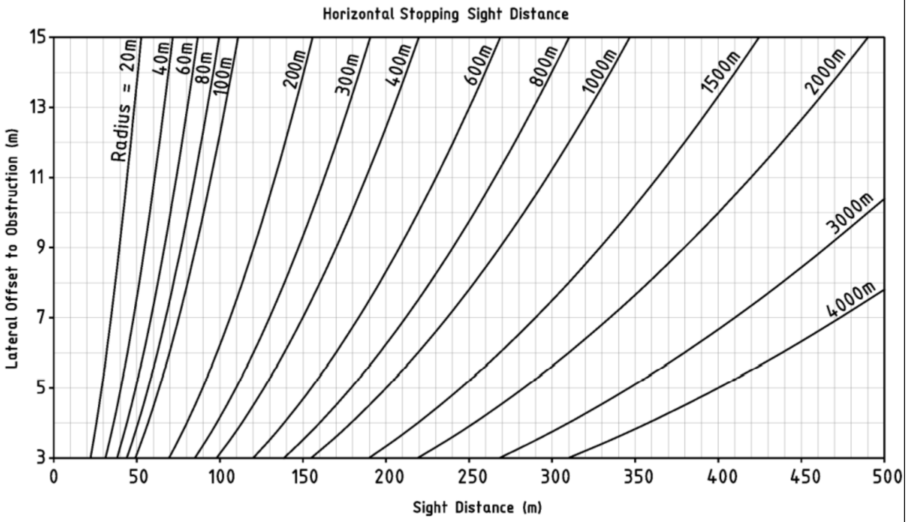
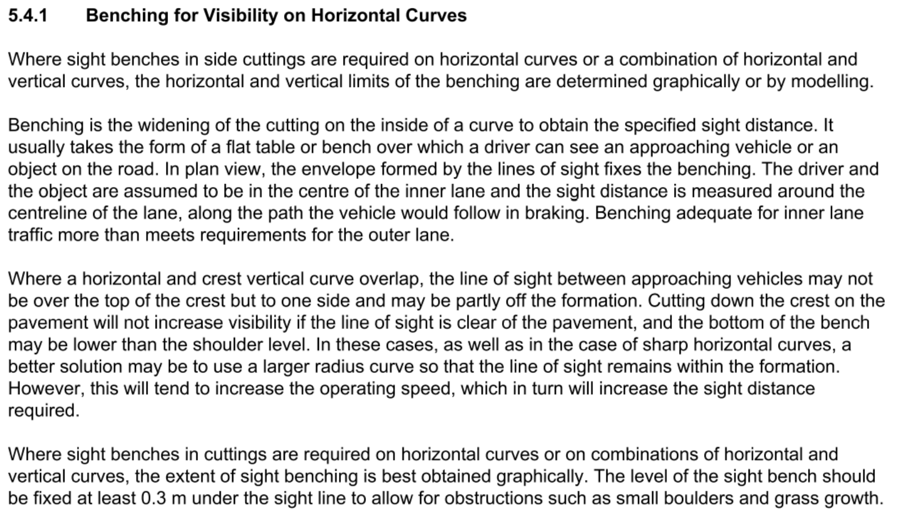


Figure 5.4 shows the relationship between horizontal sight distance, curve radius and lateral clearance to the obstruction and is valid when the sight distance at the appropriate design speed is not greater than the length of curve. This relationship assumes that the driver's eye and the sighted object are above the centre of the inside lane, 1.75 m in from the outer edge of lane based on a standard 3.5 m lane width. When the design sight distance is greater than the length of curve, a graphical solution is appropriate. Where possible, it is desirable to confirm the sight lines graphically.

REF.	TEXT



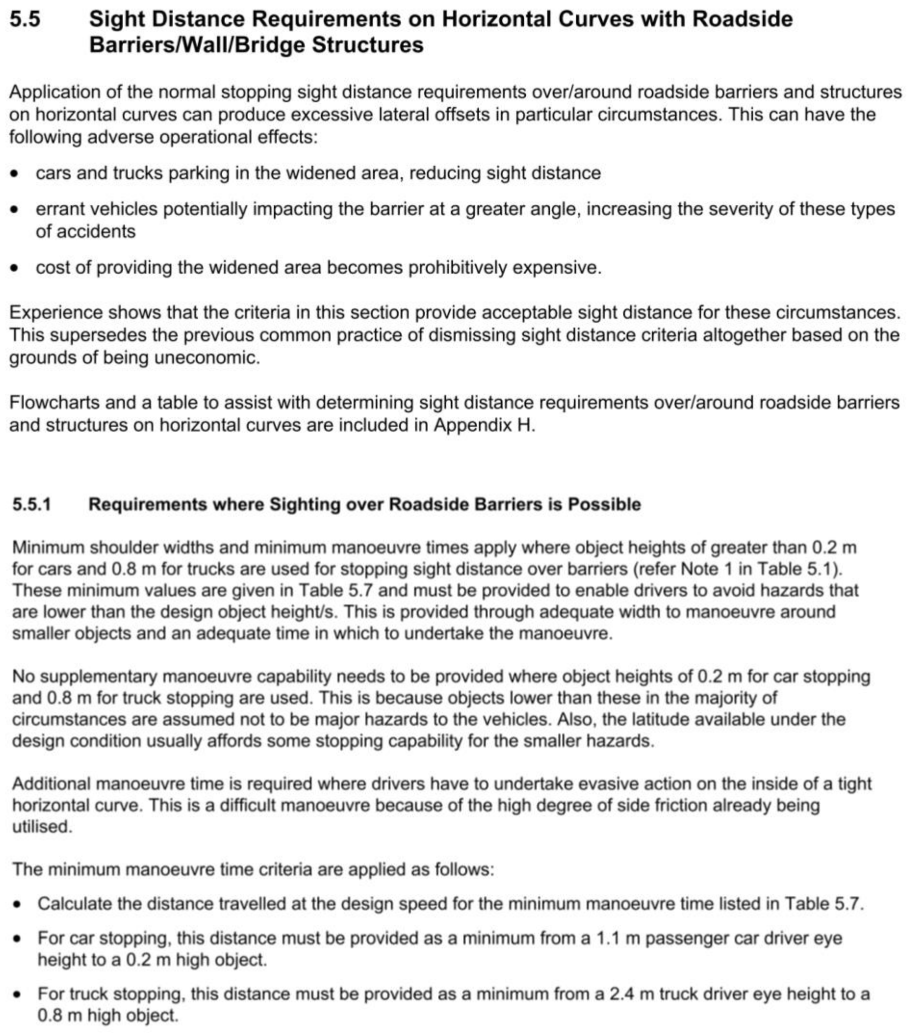
5.4.1 Benching for Visibility on Horizontal Curves

Where sight benches in side cuttings are required on horizontal curves or a combination of horizontal and vertical curves, the horizontal and vertical limits of the benching are determined graphically or by modelling.

Benching is the widening of the cutting on the inside of a curve to obtain the specified sight distance. It usually takes the form of a flat table or bench over which a driver can see an approaching vehicle or an object on the road. In plan view, the envelope formed by the lines of sight fixes the benching. The driver and the object are assumed to be in the centre of the inner lane and the sight distance is measured around the centreline of the lane, along the path the vehicle would follow in braking. Benching adequate for inner lane traffic more than meets requirements for the outer lane.

Where a horizontal and crest vertical curve overlap, the line of sight between approaching vehicles may not be over the top of the crest but to one side and may be partly off the formation. Cutting down the crest on the pavement will not increase visibility if the line of sight is clear of the pavement, and the bottom of the bench may be lower than the shoulder level. In these cases, as well as in the case of sharp horizontal curves, a better solution may be to use a larger radius curve so that the line of sight remains within the formation. However, this will tend to increase the operating speed, which in turn will increase the sight distance required.

Where sight benches in cuttings are required on horizontal curves or on combinations of horizontal and vertical curves, the extent of sight benching is best obtained graphically. The level of the sight bench should be fixed at least 0.3 m under the sight line to allow for obstructions such as small boulders and grass growth.



5.5 Sight Distance Requirements on Horizontal Curves with Roadside Barriers/Wall/Bridge Structures

Application of the normal stopping sight distance requirements over/around roadside barriers and structures on horizontal curves can produce excessive lateral offsets in particular circumstances. This can have the following adverse operational effects:

- cars and trucks parking in the widened area, reducing sight distance
- errant vehicles potentially impacting the barrier at a greater angle, increasing the severity of these types of accidents
- cost of providing the widened area becomes prohibitively expensive.

Experience shows that the criteria in this section provide acceptable sight distance for these circumstances. This supersedes the previous common practice of dismissing sight distance criteria altogether based on the grounds of being uneconomic.

Flowcharts and a table to assist with determining sight distance requirements over/around roadside barriers and structures on horizontal curves are included in Appendix H.

5.5.1 Requirements where Sighting over Roadside Barriers is Possible

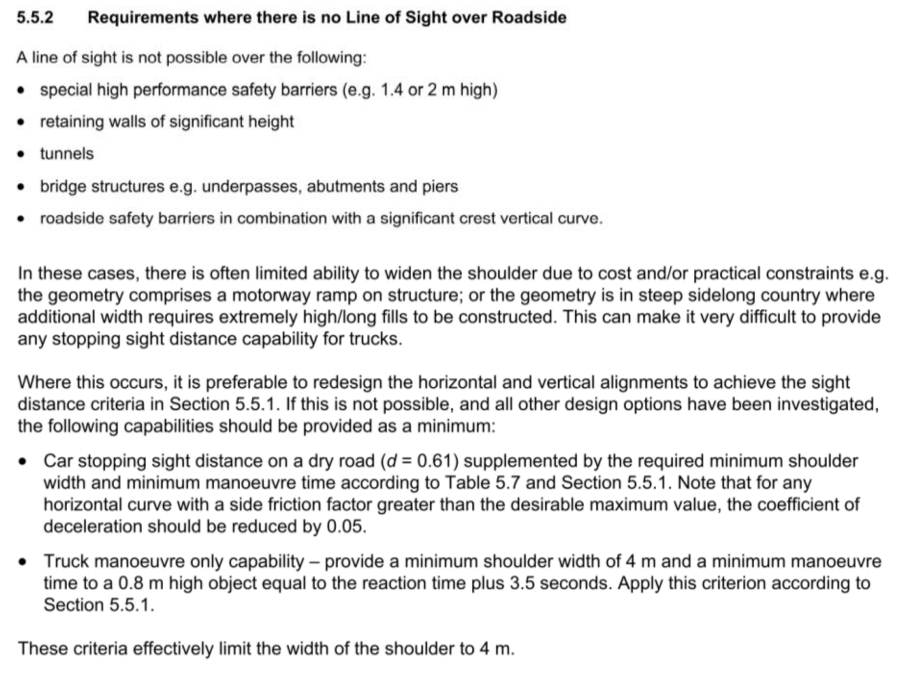
Minimum shoulder widths and minimum manoeuvre times apply where object heights of greater than 0.2 m for cars and 0.8 m for trucks are used for stopping sight distance over barriers (refer Note 1 in Table 5.1). These minimum values are given in Table 5.7 and must be provided to enable drivers to avoid hazards that are lower than the design object height/s. This is provided through adequate width to manoeuvre around smaller objects and an adequate time in which to undertake the manoeuvre.

No supplementary manoeuvre capability needs to be provided where object heights of 0.2 m for car stopping and 0.8 m for truck stopping are used. This is because objects lower than these in the majority of circumstances are assumed not to be major hazards to the vehicles. Also, the latitude available under the design condition usually affords some stopping capability for the smaller hazards.

Additional manoeuvre time is required where drivers have to undertake evasive action on the inside of a tight horizontal curve. This is a difficult manoeuvre because of the high degree of side friction already being utilised.

The minimum manoeuvre time criteria are applied as follows:

- Calculate the distance travelled at the design speed for the minimum manoeuvre time listed in Table 5.7.
- For car stopping, this distance must be provided as a minimum from a 1.1 m passenger car driver eye height to a 0.2 m high object.
- For truck stopping, this distance must be provided as a minimum from a 2.4 m truck driver eye height to a 0.8 m high object.

REF.	TEXT
	 **5.5.2 Requirements where there is no Line of Sight over Roadside** A line of sight is not possible over the following: - special high performance safety barriers (e.g. 1.4 or 2 m high) - retaining walls of significant height - tunnels - bridge structures e.g. underpasses, abutments and piers - roadside safety barriers in combination with a significant crest vertical curve. In these cases, there is often limited ability to widen the shoulder due to cost and/or practical constraints e.g. the geometry comprises a motorway ramp on structure; or the geometry is in steep sidelong country where additional width requires extremely high/long fills to be constructed. This can make it very difficult to provide any stopping sight distance capability for trucks. Where this occurs, it is preferable to redesign the horizontal and vertical alignments to achieve the sight distance criteria in Section 5.5.1. If this is not possible, and all other design options have been investigated, the following capabilities should be provided as a minimum: - Car stopping sight distance on a dry road (d = 0.61) supplemented by the required minimum shoulder width and minimum manoeuvre time according to Table 5.7 and Section 5.5.1. Note that for any horizontal curve with a side friction factor greater than the desirable maximum value, the coefficient of deceleration should be reduced by 0.05. - Truck manoeuvre only capability – provide a minimum shoulder width of 4 m and a minimum manoeuvre time to a 0.8 m high object equal to the reaction time plus 3.5 seconds. Apply this criterion according to Section 5.5.1. These criteria effectively limit the width of the shoulder to 4 m.

Austria

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr>
<td>RVS 03.03.23. FSV (Austrian Research Association for Road-Rail-Transport).
Transmission of the Guideline is not permitted.</td>
<td>
In Austria, the input values for the calculations of visibility are not completely included in the tables in the respective guidelines. In addition, the English term “stopping sight distance “ cannot be clearly translated into German, so there is a distinction between the following "stopping distances":

For the arithmetical dimensioning of the roads in Austria, the “required visibility” (=Erforderliche Sichtweite) specified in Table 10 (Chapter 7.4.1) of RVS 03.03.23 is used. In addition to the planning speed, the longitudinal slope of the road is also taken into account. The table is based on a pre-braking time of 1.2 seconds (for reaction time, response time of the brakes, etc.) and a braking deceleration of 5 m / s². The grip of the road (as well as whether is wet or dry) is taken into account in the braking deceleration, but not explicitly stated. -> This required visibility is used for dimensioning the roads. See the following figure from “RVS 03.03.23 Linienführung und Trassierung” of the “Österreichische Forschungsgesellschaft Straße-Schiene-Verkehr (FSV)“ (status: 01.08.2014)

7.4.1 Erforderliche Sichtweite

Generell sollen großzügige Sichtweiten sichergestellt werden. Zumindest aber hat für jede Fahrtrichtung die erforderliche Sichtweite S_{erf} (s. Tab. 10) immer vorhanden zu sein. Abweichungen von dieser Bestimmung sind nur für Fahrzeugrückhaltesysteme in begründeten Fällen zulässig.

Bei Änderung der Längsneigung (im Bereich von Kuppen und Wannen) ist die jeweils längere erforderliche Sichtweite zu verwenden.

Tabelle 10: Erforderliche Sichtweite S_{erf} [m]¹)

<table>
<tr><th colspan="2">V_P [km/h]</th><th>40</th><th>45</th><th>50</th><th>55</th><th>60</th><th>65</th><th>70</th><th>75</th><th>80</th><th>85</th><th>90</th><th>95</th><th>100</th><th>110</th><th>120</th><th>130</th></tr>
<tr><td rowspan="13">Längsneigung s [%]</td><td>–12</td><td>30</td><td>36</td><td>42</td><td>49</td><td>57</td><td>65</td><td>73</td><td>82</td><td>92</td><td>102</td><td>112</td><td>123</td><td>135</td><td></td><td></td><td></td></tr>
<tr><td>–10</td><td>29</td><td>35</td><td>41</td><td>48</td><td>55</td><td>62</td><td>71</td><td>79</td><td>88</td><td>98</td><td>108</td><td>119</td><td>130</td><td></td><td></td><td></td></tr>
<tr><td>–8</td><td>28</td><td>34</td><td>40</td><td>46</td><td>53</td><td>60</td><td>68</td><td>77</td><td>85</td><td>95</td><td>104</td><td>115</td><td>125</td><td></td><td></td><td></td></tr>
<tr><td>–6</td><td>27</td><td>33</td><td>39</td><td>45</td><td>52</td><td>59</td><td>66</td><td>74</td><td>83</td><td>92</td><td>101</td><td>111</td><td>121</td><td>143</td><td>166</td><td>192</td></tr>
<tr><td>–4</td><td>27</td><td>32</td><td>38</td><td>44</td><td>50</td><td>57</td><td>64</td><td>72</td><td>80</td><td>89</td><td>98</td><td>107</td><td>117</td><td>138</td><td>161</td><td>185</td></tr>
<tr><td>–2</td><td>26</td><td>31</td><td>37</td><td>43</td><td>49</td><td>56</td><td>63</td><td>70</td><td>78</td><td>86</td><td>95</td><td>104</td><td>114</td><td>134</td><td>156</td><td>179</td></tr>
<tr><td>0</td><td>26</td><td>31</td><td>36</td><td>42</td><td>48</td><td>54</td><td>61</td><td>68</td><td>76</td><td>84</td><td>93</td><td>101</td><td>110</td><td>130</td><td>151</td><td>174</td></tr>
<tr><td>+2</td><td>25</td><td>30</td><td>35</td><td>41</td><td>47</td><td>53</td><td>60</td><td>67</td><td>74</td><td>82</td><td>90</td><td>99</td><td>108</td><td>126</td><td>147</td><td>169</td></tr>
<tr><td>+4</td><td>25</td><td>29</td><td>35</td><td>40</td><td>46</td><td>52</td><td>58</td><td>65</td><td>72</td><td>80</td><td>88</td><td>96</td><td>105</td><td>123</td><td>143</td><td>164</td></tr>
<tr><td>+6</td><td>24</td><td>29</td><td>34</td><td>39</td><td>45</td><td>51</td><td>57</td><td>64</td><td>71</td><td>78</td><td>86</td><td>94</td><td>102</td><td>120</td><td>139</td><td>160</td></tr>
<tr><td>+8</td><td>24</td><td>28</td><td>33</td><td>38</td><td>44</td><td>50</td><td>56</td><td>62</td><td>69</td><td>76</td><td>84</td><td>92</td><td>100</td><td></td><td></td><td></td></tr>
<tr><td>+10</td><td>24</td><td>28</td><td>33</td><td>38</td><td>43</td><td>49</td><td>55</td><td>61</td><td>68</td><td>75</td><td>82</td><td>90</td><td>98</td><td></td><td></td><td></td></tr>
<tr><td>+12</td><td>23</td><td>28</td><td>32</td><td>37</td><td>42</td><td>48</td><td>54</td><td>60</td><td>66</td><td>73</td><td>80</td><td>88</td><td>96</td><td></td><td></td><td></td></tr>
</table>

¹) mit Vorbremszeit 1,2 s und Bremsverzögerung 5 m/s²

In contrast to this, there is the “real” stopping sight, which results from the specific calculation of the stopping distance. This results (according to the rule of thumb) from the reaction distance (= speed in km/h / 10 * 3) plus the braking distance (= speed in km/h / 10 * speed in km/h / 10). Depending on the desired accuracy, further influencing factors can be taken into account (emergency braking, service braking (=normal braking), grip, tires, braking force, weight, inclination, etc.).
In the case of nodes, crossings, etc., so-called viewing triangles must also be observed, where a corresponding viewing area must be kept free. A distinction is made between “approach view?” (Anfahrsicht) and “proximity view” (Annäherungssicht) Source: Markus Pijavec, January 2022.

</td>
</tr>
</table>

Belgium-Flanders

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr>
<td>VWI deel autosnelwegen - Chapter 5: Wegvak (2018)

5.1.1.1 Zichtlengte - 5.1.4.4 Minimale zichtlengte</td>
<td>

5.1.1.1 Sight length

The determining factor for sight is the sight length. Sight length is the distance over which the driver can oversee the part of the road directly in front of him. This is the distance between the observation point and the view point:

- An observation point is the point where the driver's eye is located.
- A view point is the point the driver is looking at.

The observation point in horizontal curves is in all cases on the inner lane of the bend. A truck is not determining because it features a lower (maximum) speed and a higher eye position (usually looking over an obstructing object). The height of a car driver’s eye is 1.20 m above the road and is determining. Based on passenger cars and a lane width of 3.50 m the observation point is located:

- At a left turn: 1.25 m from the left lateral mark
- At a right-hand bend: 2.25 m from right lateral mark

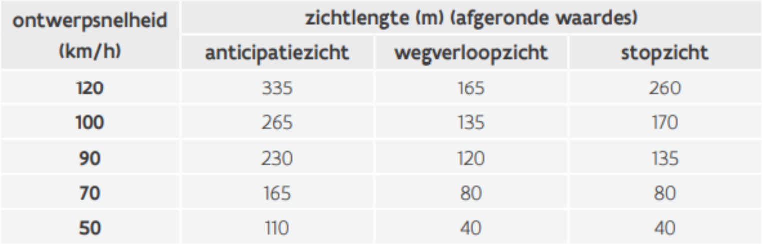
The view point differs per view criterion. This is discussed in the following chapters.

Sight length is strongly influenced by speed:

- The higher the speed, the further forward the driver looks (driving view)
- The higher the speed, the smaller the viewing angle (field of view)

An overview of the determining vision lengths per vision criterion is included in table 4. The requirements for road clearance and stop view must always be met. A good road design also meets the requirements for anticipation vision, but in exceptional cases a deviation may be justified. In chapters “5.1.2 Anticipation view” to “5.1.4 Stop view” these sight lengths are explained more in detail.

Table 4: Overview of normative vision length per vision criterion at a gradient of 0 %.



<table>
<tr><th rowspan="2">ontwerpsnelheid (km/h)</th><th colspan="3">zichtlengte (m) (afgeronde waardes)</th></tr>
<tr><th>anticipatiezicht</th><th>wegverloopzicht</th><th>stopzicht</th></tr>
<tr><td>120</td><td>335</td><td>165</td><td>260</td></tr>
<tr><td>100</td><td>265</td><td>135</td><td>170</td></tr>
<tr><td>90</td><td>230</td><td>120</td><td>135</td></tr>
<tr><td>70</td><td>165</td><td>80</td><td>80</td></tr>
<tr><td>50</td><td>110</td><td>40</td><td>40</td></tr>
</table>

Table 4: Overview of normative vision length per vision criterion at a gradient of 0 %

5.1.4 Stopping sight distance

5.1.4.1 Definition

The stopping sight distance or length of view on stationary traffic downstream is the distance over which a driver must be able to oversee the road in order to be able to

</td>
</tr>
</table>

REF.	TEXT

handle a possible traffic jam (over the entire roadway), so as to perceive, recognize and bring his vehicle to a stop in time.

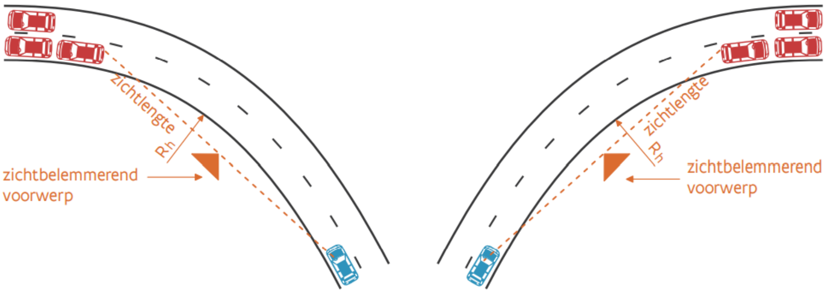


Figure 33: Stopping sight distance scheme

5.1.4.2 Structure of sight length

The view length for stop view is structured as follows:

- Recognition length: is negligible.
- Prt length: this length must be available as a visible length.
- Operational task: the length required for the comfortable braking action to a standstill must be as visible length.

The rear lamp of the preceding vehicle must be visible over the sum of these lengths.

5.1.4.3 Design situation

The starting points for determining the sight length for stop vision are: • Observation point:

- At a left bend: 1.25 m from the left lateral mark

- At a right-hand bend: 2.25 m from the right lateral mark

- Point of view: whole outer rear light (0.2 m x 0.2 m) on the inner lane, inferior at 0.50 m above the road surface and outside at 2.30 m from inside lateral mark (based on a lane width of 3.50 m)
- Daylight
- Comfortable delay
- Prt: based on unexpected event
- Negligible effect due to reduction in longitudinal friction in horizontal curves
- A longitudinal friction coefficient is used to calculate the required braking distance, which assumes that the wheels have just not locked (85% wheel slip) on a wet road surface, corrected with a safety factor. The values used for the longitudinal friction coefficient are given in Table 7.

5.1.4.4 Minimum sight length

Since the recognition length is negligible, the stop view length is equal to the sum of the prt length and the operational length. The minimum view length for stop view is calculated with the following formula.

REF.	TEXT

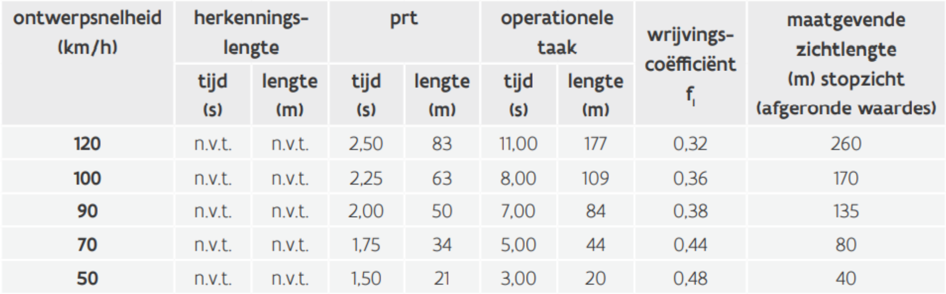
Stop view length = [prt * $\frac{V_0}{3,6}$] +[($\frac{V_0}{3,6}$)^2 *$\frac{1}{2g\ (f_l+\frac{p}{100})}$]

This is:

- prt: perception-reaction time (s)
- v_0: design speed (km/h)
- g: gravitational acceleration (9.8 m/s2)
- f_l: mean coefficient of friction in the longitudinal direction
- p : percentage of the long slope (negative on descent, positive on ascent)

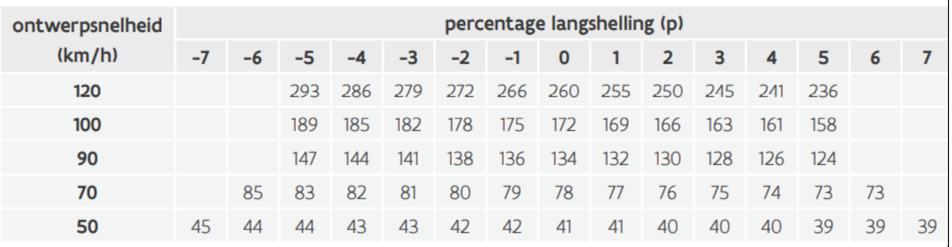
In table 7 the minimum stop sight lengths are given at a longitudinal gradient of 0%.

Table 8 lists the minimum stop sight lengths, calculated with the above formula, when the the carriageway has a long slope. The gradient to be maintained must be at least the average percentage of inclination between the point of view and the point of view. This average percentage should not be too deviate much from the maximum gradient at the view point or observation point since a vehicle must be able to come to a stop in time.



ontwerpsnelheid (km/h)	herkennings-lengte		prt		operationele taak		wrijvings-coëfficiënt f_l	maatgevende zichtlengte (m) stopzicht (afgeronde waardes)
	tijd (s)	lengte (m)	tijd (s)	lengte (m)	tijd (s)	lengte (m)		
120	n.v.t.	n.v.t.	2,50	83	11,00	177	0,32	260
100	n.v.t.	n.v.t.	2,25	63	8,00	109	0,36	170
90	n.v.t.	n.v.t.	2,00	50	7,00	84	0,38	135
70	n.v.t.	n.v.t.	1,75	34	5,00	44	0,44	80
50	n.v.t.	n.v.t.	1,50	21	3,00	20	0,48	40

Table 7: Minimum stopping sight distance (m) at a slope percentage of 0%.



ontwerpsnelheid (km/h)	percentage langshelling (p)														
	-7	**-6**	**-5**	**-4**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
120			293	286	279	272	266	260	255	250	245	241	236		
100			189	185	182	178	175	172	169	166	163	161	158		
90			147	144	141	138	136	134	132	130	128	126	124		
70		85	83	82	81	80	79	78	77	76	75	74	73	73	
50	45	44	44	43	43	42	42	41	41	40	40	40	39	39	39

Table 8: Minimum stopping sight distance (unrounded values in m) at different standard values of slope percentage.

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr><td></td><td>Figure 87: Stopping sight distance scheme

<table>
<tr><th rowspan="2">type zicht</th><th rowspan="2">d_z (m)</th><th rowspan="2">d_w (m)</th><th colspan="4">d_c (m)</th></tr>
<tr><th>1 rijstrook</th><th>2 rijstroken</th><th>3 rijstroken</th><th>4 rijstroken</th></tr>
<tr><td>anticipatiezicht</td><td rowspan="3">1,05</td><td rowspan="3">1,25</td><td>7,55</td><td>11,05</td><td>14,45</td><td>18,05</td></tr>
<tr><td>wegverloopzicht</td><td>3,80</td><td>7,30</td><td>7,10</td><td>7,10</td></tr>
<tr><td>stopzicht</td><td colspan="4">2,30</td></tr>
</table>
Table 62: Standard calculation parameters for the determination of horizontal bendings.</td></tr>
</table>

Belgium-Wallonie

REF.	TEXT
CT.98.12(01)-Caractéristiques routières et autoroutières (2003). 2.2.4.1. Distance d'arrêt	Stopping distance is the distance in which a vehicle can stop in front of an obstacle, including the distance of perception and reflex (DPR). The latter is included in the values indicated in table 5 which gives the stopping distances in straight alignment according to the speed and the slope, as well as the stopping distances in curves. These are expressed as a function of speed, slope and superelevation, for a radius of curvature equal to the minimum radius given in table 4. [Tables 4 and 5 contain too many data to be included here]

Canada

REF.	TEXT
Design Controls, Classification and Consistency. Geometric Design Guide for Canadian Roads. (2019/2020) 2.5 Sight distance	**2.5.1 INTRODUCTION** The ability to see ahead is of critical importance in the safe and efficient operation of a vehicle. Motor vehicles are operated by drivers who have significant differences in their level of experience, ability, and training. Sufficient sight distance must be provided to allow for drivers of all skill and training levels to stop or maneuver around obstacles on the roadway surface and make safe turns. Depending on the specific circumstances, the designer may use different measurements of sight distance, including: stopping sight distance, passing sight distance, and decision sight distance. Each of these is described in detail in subsequent sections of this chapter. Intersection sight distance is addressed in **Chapter 9 - Intersections**. In many applications, one of these types of sight distance will govern, and the designer need satisfy only one requirement. In other cases, such as vertical alignment design, a designer must optimise the design to achieve a satisfactory balance between provision of passing opportunities in some locations and adequate stopping sight distances in others. Where an intersection unavoidably falls on a crest curve, the designer sometimes needs to consider the interaction between stopping, decision, and intersection sight distances to achieve a suitable design. **2.5.2 CRITERIA USED IN CALCULATING SIGHT DISTANCE** Several variables are used by the designer when determining sight distance required for different applications. These are: • Perception-reaction time (see **Section 2.2.5.5**) • Driver eye height (see **Section 2.4.3.3**) • Vehicle op erating speed (see **Section 2.3.2**) • Object height • Deceleration rate The last two variables are discussed below. **2.5.2.1 Object Height** In calculating sight distance, the designer must consider the type of object that is likely to be encountered on the roadway, which a driver will have to avoid by stopping or maneuvring. Because of the potential variation in object type, selection of object height has significantly more impact on sight distance requirements than, for example, driver eye height. **Table 2.5.1** presents commonly used object heights for various design scenarios.

REF.	TEXT

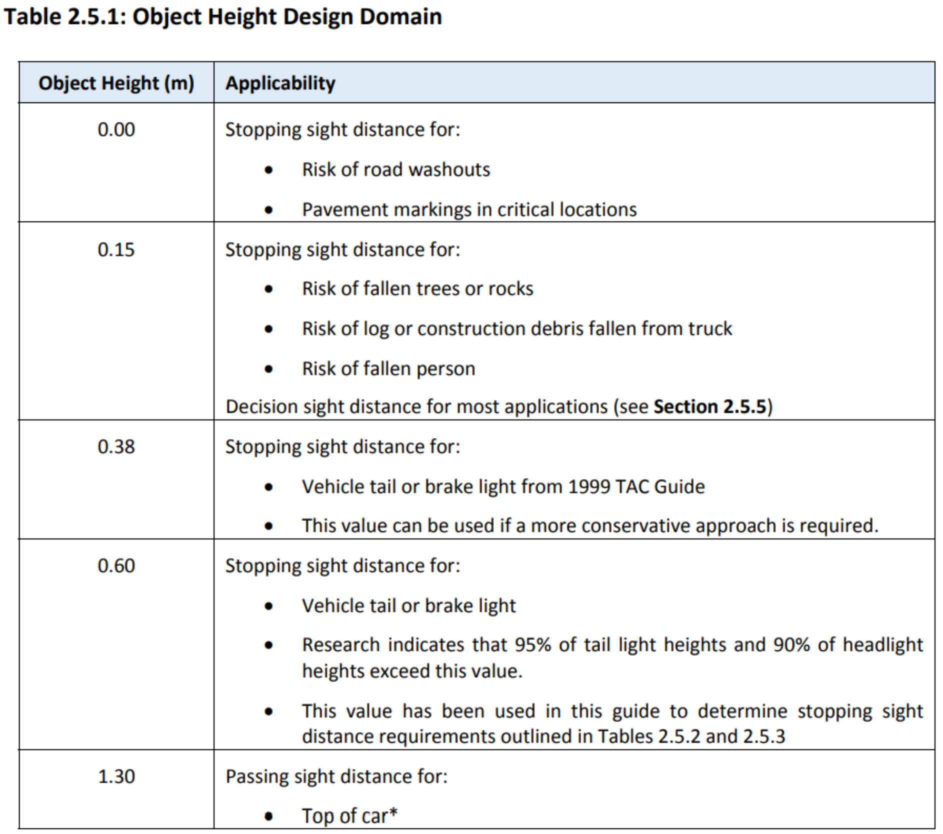


Table 2.5.1: Object Height Design Domain

Object Height (m)	Applicability
0.00	Stopping sight distance for: • Risk of road washouts • Pavement markings in critical locations
0.15	Stopping sight distance for: • Risk of fallen trees or rocks • Risk of log or construction debris fallen from truck • Risk of fallen person Decision sight distance for most applications (see **Section 2.5.5**)
0.38	Stopping sight distance for: • Vehicle tail or brake light from 1999 TAC Guide • This value can be used if a more conservative approach is required.
0.60	Stopping sight distance for: • Vehicle tail or brake light • Research indicates that 95% of tail light heights and 90% of headlight heights exceed this value. • This value has been used in this guide to determine stopping sight distance requirements outlined in Tables 2.5.2 and 2.5.3
1.30	Passing sight distance for: • Top of car*

* Note: Some jurisdictions use an object height of 1.15 m for the top of a car, based on the premisethat a driver needs to see at least 150 mm of the vehicle to discern its presence. This is supported by a study of driver visual capabilities which suggested that a high contrast object 150 mm high is the minimum height **detectable** at AASHTO stopping sight distances, and that drivers do not have the capability to **recognize** objects that are less than 300 mm in height, regardless of contrast, at or beyond minimum stopping sight distances.51 This practice is not widely used.

In applying object heights less than 0.15 m the following points should be considered.

- The frequency of collisions occurring as a result of vehicles striking objects less than 0.15 m in height has been shown to be very low.
- As discussed above, a driver’s ability to discern small objects at a distance is limited
- In general, a driver must see at least the top 0.15 m of an object in order to detect its presence.
- If such an object is of limited lateral size (e.g., a rock) a driver may well be able to take evasive action rather than stop, particularly on a roadway with low traffic volumes.
- Evasion might not be possible if the object were a fallen tree, but in many parts of the country this is an unlikely hazard since trees are not present or because local jurisdictions do not allow trees to remain close to the roadway. In areas where logging trucks are present, the designer should consider the possibility of a log falling onto the roadway from a truck.

The designer should adopt an object height based on the probability of a particular object occurring on the roadway, as shown on **Table 2.5.1**. If fallen trees or rocks are a real risk, an object height of 0.15 m is recommended. Otherwise, for stopping sight distance, a tail light height of 0.60 m is recommended. For passing sight distance, an object height of 1.30 m will allow the driver to discern the top of an oncoming typical car. A zero object

REF.	TEXT

height is recommended where road washouts are a serious risk, for example on approaches to bridges and culverts in mountainous areas. It is only recommended for pavement markings in critical situations such as at intersections or interchanges, as the driver's ability to discern the markings cannot be relied upon, and traffic signs should be used instead.

2.5.2.2 Deceleration Rate

Approximately 90 percent of all drivers decelerate at rates greater than 3.4 m/s^2. Such deceleration is within a driver's capability to stay within their lane and maintain steering control during the braking maneuver on wet surfaces. Therefore 3.4 m/s^2 is a comfortable deceleration for most drivers and is recommended as the deceleration threshold for determining stopping sight distance.

Most vehicle braking systems and the tire-pavement friction levels of most roadways are capable of providing a deceleration rate of at least 3.4 m/s2. Also, the friction available on most wet pavement surfaces and the capabilities of most vehicle braking systems can provide braking friction that excedes this deceleration rate.

2.5.3 STOPPING SIGHT DISTANCE

Braking distance is the distance that it takes to stop a vehicle once the brakes have been applied. On a level roadway this distance can be determined using the following formula:

$$d_b = 0.039\frac{V^2}{a}$$

Where:

d_b = Braking distance (m)

V = Design speed (km/h)

a = Deceleration rate (m/s2)

Stopping sight distance is the sum of the distance travelled during the perception and reaction time and the braking distance.

$$\mathrm{SSD} = 0.278\mathrm{Vt} + 0.039\frac{V^2}{a}$$

Where:

SSD = Stopping sight distance (m)

t = Brake reaction time, 2.5 s

V = Design speed (km/h)

a = Deceleration rate (m/s2)

Table 2.5.2 gives the minimum stopping sight distances on level grade, on wet pavement, for a range of Design Speeds. These values are used for vertical curve design, intersection geometry and the placement of traffic control devices. The stopping sight distances quoted in **Table 2.5.2** may need to be increased for a variety of reasons related to grade and vehicle type as noted below.

Table 2.5.2: Stopping Sight Distance on level roadways for Automobiles

REF.	**TEXT**

Design speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance	
			Calculated (m)	Design (m)
20	13.9	4.6	18.5	20
30	20.9	10.3	31.2	35
40	27.8	18.4	46.2	50
50	34.8	28.7	63.5	65
60	41.7	41.3	83.0	85
70	48.7	56.2	104.9	105
80	55.6	73.4	129.0	130
90	62.6	92.9	155.5	160
100	69.5	114.7	184.2	185
110	76.5	138.8	215.3	220
120	83.4	165.2	248.6	250
130	90.4	193.8	284.2	285

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 3.4 m/s2 used to determine calculated sight distance.

The Effect of Grade

Braking distances will increase on downgrades and decrease on upgrades. When the roadway is on a grade, formula 2.5.1 for braking distance is modified as follows:

$$d_b = \frac{V^2}{254[a/9.81+G]}$$

Where:

d_b = Braking distance (m)

V = Design speed (km/h)

a = Deceleration rate (m/s2)

G = Grade (m/m) (G is positive if vehicles uphill and negative if downhill)

It has been noted that many drivers, particularly those in automobiles, do not compensate completely (i.e., by acceleration or deceleration) for the changes in speed caused by grade. It should also be noted that in many cases the sight distance available on downgrades is greater than on upgrades, which can help to provide the necessary corrections for grade. The following **Table 2.5.3** summarizes the stopping sight distances on grades for a variety of Design Speeds.

Table 2.5.3: Stopping Sight Distance on Grades

REF.	TEXT

Design Speed (km/h)	Stopping Sight Distance (m)					
	Downgrades (%)			Upgrades (%)		
	3	6	9	3	6	9
20	20	20	20	19	18	18
30	32	35	35	31	30	29
40	50	50	53	45	44	43
50	66	70	74	61	59	58
60	87	92	97	80	77	75
70	110	116	124	100	97	93
80	136	144	154	123	118	114
90	164	174	187	148	141	136
100	194	207	223	174	167	160
110	227	243	262	203	194	186
120	263	281	304	234	223	214
130	302	323	350	267	254	243

2.5.3.1 Stopping Sight Distance: Variations for Trucks

The stopping sight distance outlined in **Tables 2.5.2** and **2.5.3** are based on passenger car operations and do not explicitly consider design for truck operations. In general trucks need longer stopping sight distances for a given speed than passenger vehicles. However, one balancing factor is that a truck driver can generally see further than a passenger car driver due to an eye height advantage. As a result, a separate stopping sight distances for trucks are not generally used in highway design.

In some instances the higher eye height is not an advantage or maybe a disadvantage — for example, trucks have no advantage when a sightline obstruction is located on inside of a horizontal curve. Also, trucks are at a disadvantage on sag vertical curves where visibility is “cut off” by an overpass and at the end of long downgrades. In these situations it is desirable to provide stopping sight distances that exceed the values in **Tables 2.5.2** and **2.5.3**.

Chile

REF.	TEXT
Manual de carreteras. Volumen N°3 Instrucciones y Criterios de Diseño - Edición 2021. 3.202.2 Distancia de parada	**30.202.2 STOPPING DISTANCE** On every point of the road or path, in accordance with the definition formulated in 3.201.302, a driver driving with a speed V, on the centre of their lane, must have at least the visibility equivalent to the required distance to stop before an immobile obstacle, situated on the centre of that lane. The obstacle is considered as having a height equal or bigger than 0,20 m, and the driver's eyes are situated 1,10 m over the surface of the axis of their circulation lane. The stopping distance on a straight alignment with a uniform slope is calculated with the expression: $SSD = \frac{t_p v}{3{,}6} + \frac{v^2}{254 \cdot (r \pm i)}$ D_p= Stopping distance (m) V= V_p or V* following definition in 3.201.302 T_p= perception + reaction time (s) R = friction coefficient, humid pavement. I= longitudinal slope (m/m) +i when driving upwards, -i when driving downwards. The first member of the expression represents the driven distance during the perception + reaction time (d_{tp}), and the second one the driven distance during the braking until the complete stop next to the obstacle (d_f) Table 3.202.2.A exhibits the partial values calculated by means of the aforementioned expression and the rounded value for D_p. In addition, it has to be considered that V* corresponds to the speed assigned to the stretch and the values of "t_p" and "r" have been updated according with nowadays tendencies. The values written for D_p are the minimum admissible in horizontal. Corrected values by effect of slope are presented in table 3.202.2.A. If on a road or path section reaching the minimum stopping sight distance for a given V* results unfeasible, the relevant sector should be signalized with the maximum permitted speed. This should be an ultimate resource to be used only in very qualified cases, which should be authorized by the Directorate of Viality.

REF.	TEXT
	See below

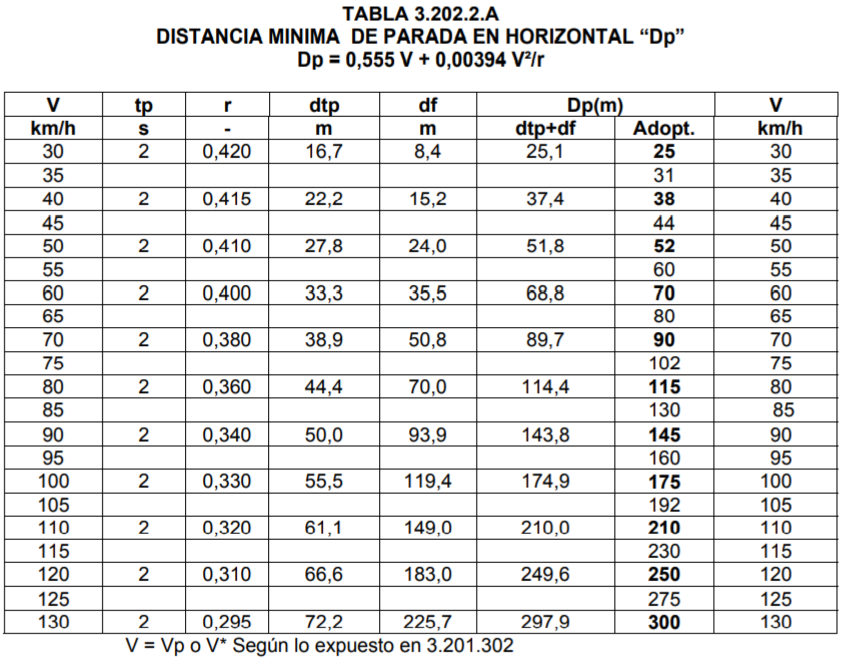


TABLA 3.202.2.A
DISTANCIA MINIMA DE PARADA EN HORIZONTAL "Dp"
Dp = 0,555 V + 0,00394 V²/r

V	tp	r	dtp	df	Dp(m)		V
km/h	s	-	m	m	dtp+df	Adopt.	km/h
30	2	0,420	16,7	8,4	25,1	**25**	30
35						31	35
40	2	0,415	22,2	15,2	37,4	**38**	40
45						44	45
50	2	0,410	27,8	24,0	51,8	**52**	50
55						60	55
60	2	0,400	33,3	35,5	68,8	**70**	60
65						80	65
70	2	0,380	38,9	50,8	89,7	**90**	70
75						102	75
80	2	0,360	44,4	70,0	114,4	**115**	80
85						130	85
90	2	0,340	50,0	93,9	143,8	**145**	90
95						160	95
100	2	0,330	55,5	119,4	174,9	**175**	100
105						192	105
110	2	0,320	61,1	149,0	210,0	**210**	110
115						230	115
120	2	0,310	66,6	183,0	249,6	**250**	120
125						275	125
130	2	0,295	72,2	225,7	297,9	**300**	130

V = Vp o V* Según lo expuesto en 3.201.302

3.202.201 Stopping distance in singular points. In sections diverging from the basic case, i.e. straight layout with uniform longitudinal profile, the calculation of the elements shall be verified or carried out with a view to ensuring a minimum sight equivalent to the required stopping distance in every point. These cases are treated in:

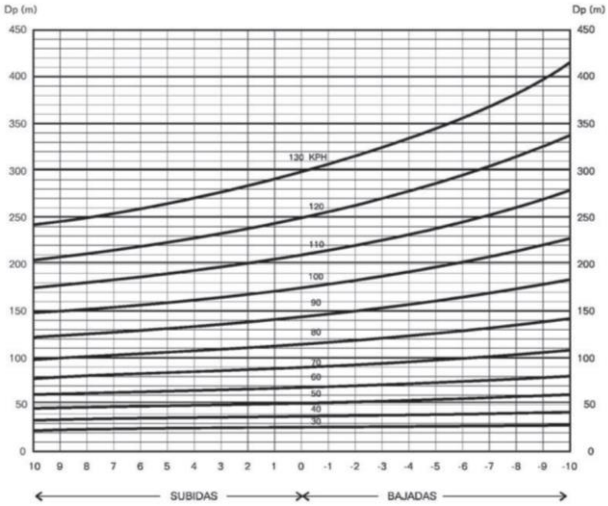
A) Verification of "D_p" in horizontal curves (3.202.402)

b) Graphic verification of the stopping distance on elevation (3.202.403)

c) Design of vertical curves by means of "D_p" criterion (3.204.403)

d) Verification of "D_p" under structures (3.203.403(3)b)

ILUSTRACION GRAFICA



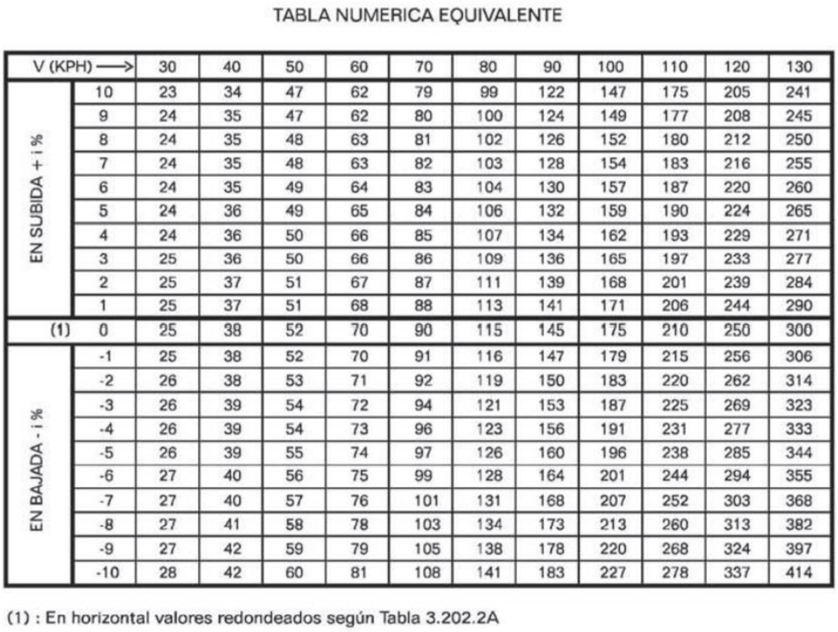
REF.	TEXT
	

TABLA NUMERICA EQUIVALENTE

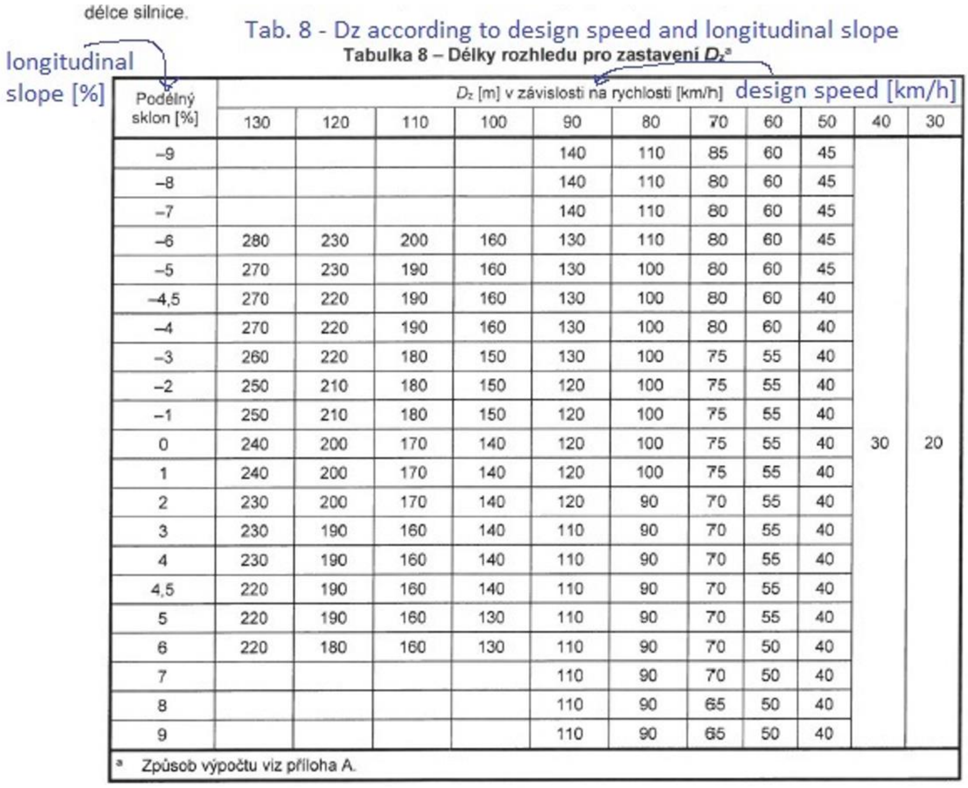
	V (KPH) ⟶	30	40	50	60	70	80	90	100	110	120	130
EN SUBIDA + i %	10	23	34	47	62	79	99	122	147	175	205	241
	9	24	35	47	62	80	100	124	149	177	208	245
	8	24	35	48	63	81	102	126	152	180	212	250
	7	24	35	48	63	82	103	128	154	183	216	255
	6	24	35	49	64	83	104	130	157	187	220	260
	5	24	36	49	65	84	106	132	159	190	224	265
	4	24	36	50	66	85	107	134	162	193	229	271
	3	25	36	50	66	86	109	136	165	197	233	277
	2	25	37	51	67	87	111	139	168	201	239	284
	1	25	37	51	68	88	113	141	171	206	244	290
(1)	0	25	38	52	70	90	115	145	175	210	250	300
EN BAJADA - i %	-1	25	38	52	70	91	116	147	179	215	256	306
	-2	26	38	53	71	92	119	150	183	220	262	314
	-3	26	39	54	72	94	121	153	187	225	269	323
	-4	26	39	54	73	96	123	156	191	231	277	333
	-5	26	39	55	74	97	126	160	196	238	285	344
	-6	27	40	56	75	99	128	164	201	244	294	355
	-7	27	40	57	76	101	131	168	207	252	303	368
	-8	27	41	58	78	103	134	173	213	260	313	382
	-9	27	42	59	79	105	138	178	220	268	324	397
	-10	28	42	60	81	108	141	183	227	278	337	414

(1) : En horizontal valores redondeados según Tabla 3.202.2A

Czechia

REF.	TEXT
ČSN 736101 (736101) Design of highways and motorways (2018) 8.5 Délka rozhled/Sight length Příloha A (normativní) / Annex A Výpočet délky rozhledu/ Calculation	**8.5 Sight distance** 8.5.1 On all roads and highways, the necessary sight distance must be ensured in their entire length to stop the vehicle in front of an obstacle on the roadway. The sight distances (D_z) are listed in Table 8. On one-lane roads with two-way traffic, the length of the stop distance is equal to 2xD_z. A sight obstacle is any obstacle (slope of an earthwork, guardrail, greenery, drainage work, wall, etc.) obstructing the driver's view of a considered obstacle on the lane of circulation. When assessing the length of the stopping distance, it is also necessary to take into account the longitudinal profile of the road. 8.5.2 Stopping sight distance before a railway crossing is determined by ČSN 73 6380.

REF.	TEXT
of sight length	8.5.3 In directionally undivided two-lane roads, sight distances of at least 4xDz with respect to table 8 are considered for enabling overtaking. The length of the overtaking sight should be ensured on the longest possible road length.



délce silnice.

longitudinal slope [%]

Tab. 8 - Dz according to design speed and longitudinal slope

Tabulka 8 – Délky rozhledu pro zastavení D_z[a]

Podélný sklon [%]	D_z [m] v závislosti na rychlosti [km/h] design speed [km/h]										
	130	120	110	100	90	80	70	60	50	40	30
–9					140	110	85	60	45	30	20
–8					140	110	80	60	45		
–7					140	110	80	60	45		
–6	280	230	200	160	130	110	80	60	45		
–5	270	230	190	160	130	100	80	60	45		
–4,5	270	220	190	160	130	100	80	60	40		
–4	270	220	190	160	130	100	80	60	40		
–3	260	220	180	150	130	100	75	55	40		
–2	250	210	180	150	120	100	75	55	40		
–1	250	210	180	150	120	100	75	55	40		
0	240	200	170	140	120	100	75	55	40		
1	240	200	170	140	120	100	75	55	40		
2	230	200	170	140	120	90	70	55	40		
3	230	190	160	140	110	90	70	55	40		
4	230	190	160	140	110	90	70	55	40		
4,5	220	190	160	140	110	90	70	55	40		
5	220	190	160	130	110	90	70	55	40		
6	220	180	160	130	110	90	70	50	40		
7					110	90	70	50	40		
8					110	90	65	50	40		
9					110	90	65	50	40		

[a] Způsob výpočtu viz příloha A.

Appendix A (normative)

Calculation of the sight distance D_z

A.1 Stopping distance

The stopping sight distance is consists of:

a) the path travelled by the vehicle for the driver's observation and reaction time (1.5 s is assumed);

b) the distance required to completely stop a braked vehicle on wet roads, assuming driving at a given speed with the smallest permitted tire tread depth of 1.6 mm;

c) the safety distance of the vehicle from the obstacle.

The basic stopping sight distance D'z in m can be calculated from the formula:

$$SSD = \frac{1{,}5 \cdot v}{3{,}6} + \frac{v^2}{2 \cdot g_n \cdot 3{,}6^2 \cdot (f_v + 0{,}01 \cdot s)}$$

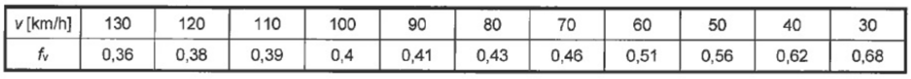
Where we have:

- v vehicle speed in km/h
- g_n normal gravity acceleraton (g_n =9,81 m/s^2);
- f_v calculation friction coefficient for braking on wet surface with depth of the pneumatic pattern of value 1,6 mm according to table A.1;
- s longitudinal slope gradient v% (including the sign).

REF.	TEXT

Final sight distance Dz is rounded up from calculated basic sight distance D’z to the nearest higher 10 m (in case that speed v ≥ 80 km/h) or to the nearest higher 5 meters (in case that speed v <80 km/h);

Tab. A.1-Coefficient of brake friction f_v



v [km/h]	130	120	110	100	90	80	70	60	50	40	30
f_v	0,36	0,38	0,39	0,4	0,41	0,43	0,46	0,51	0,56	0,62	0,68

Additional note: Ssight distance Dz= basic sight distance D’z + “safety distance in front of the obstacle”.

France

REF.	TEXT

Cerema

Conception des routes et autoroutes.

Révision des règles sur la visibilité et sur les rayons en angle saillant du profil en long (2018).

3.2 - Définition de la distance d'arrêt et de ses niveaux de performance

3.2 - Definition of stopping distance and its performance levels

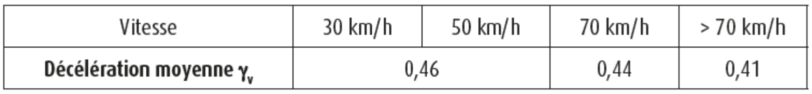
The stopping distance d_a is composed of the distance travelled during the perception-reaction time, increased of that travelled during the braking action (the one making possible to pass from the initial speed to a zero speed).

Braking distance increases in curves for dynamic reasons related to the difficulty of the driving task. This increase, called “malus in curve” and noted as m_c depends on the radius of the bend. The stopping distance is thus given by the following formula:

$$SSD = \frac{R_t v}{3.6} + (1+m_c(R)) \cdot \frac{v^2}{254 \cdot (\gamma_v + i)} \cdot K(N_{PV})$$

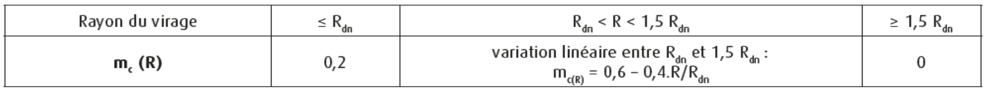
With:

- d_a: the stopping distance, in m;
- T_{PR}: perception-reaction time, equal to 1.8 seconds;
- v: initial speed, in m/s;
- p: gradient, in algebraic value (m/m);
- γ_v: average deceleration in a stopping manoeuvre, expressed as a fraction of g = 9,81 m/s².



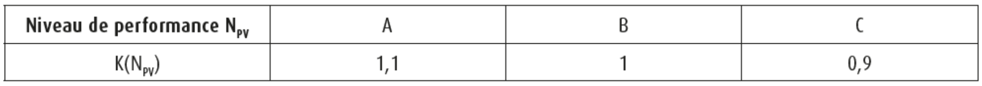
Vitesse	30 km/h	50 km/h	70 km/h	> 70 km/h
Décélération moyenne γ_v	0,46		0,44	0,41

- m_c(R): curve penalty. It is taken into account as follows$^{(1)}$:



Rayon du virage	≤ R_{dn}	$R_{dn} < R < 1,5\ R_{dn}$	≥ 1,5 R_{dn}
m_c (R)	0,2	variation linéaire entre R_{dn} et 1,5 R_{dn} : $m_{c(R)} = 0,6 - 0,4.R/R_{dn}$	0

- K(N_{PV}) : a coefficient reflecting the performance level.

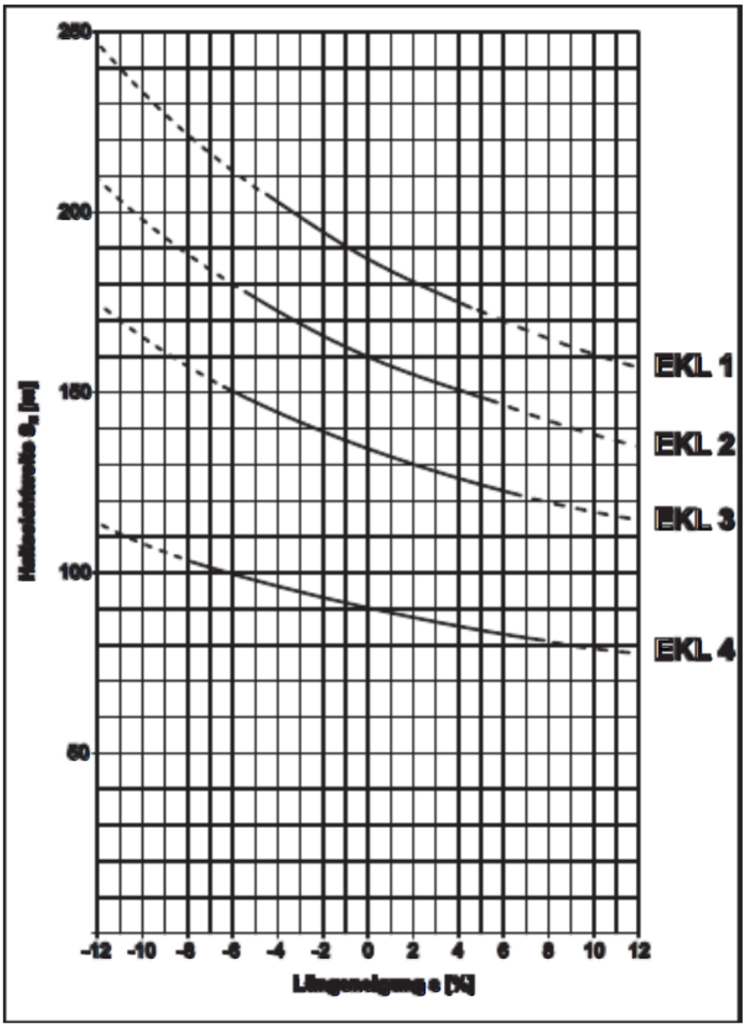


Niveau de performance N_{PV}	A	B	C
K(N_{PV})	1,1	1	0,9

REF.	TEXT
	Numerical application: $d_a=(V/2+(1+m_c)\frac{0{,}394\,V^2}{41+P})K$, with V expressed in km/h and P expressed in % **Conditions of verification** **Observation point:** This is the eye of a light vehicle driver, positioned at a height of 1.10 m from the ground, and 0.25 m to the left of the central axis of its lane (in the common case of a lane 3.50 m wide, this amounts to considering that the observation point is 2.00 m from the right border of the lane). ∞ **Observed point:** For roads isolated from their environment, in the case of a vehicle, the observed point is the least restrictive of the two rear lights, positioned at a height of 0,70 m from the ground, and 0.75 m apart from left or to the right of the axis of the road in question. For roads not isolated from their environment (two-way roads, interurban arteries, urban AU70 thoroughfares, etc.), a height of 0.10 m is more appropriate in view of the possible presence of other categories of users (with a lateral positioning identical to the previous case). In addition, on roads with separate carriageways, isolated or not from their environment (passageways, freeway features, interurban arteries, urban dual carriageways, overtaking lanes on 2x1 lane roads), the height of the point observed on the left lane can be raised to 0.85 m(2). In all cases, the particular conditions of use or operation of the lane, or of the situations identified (during diagnostics) must be taken into account, and may lead to retain, locally or globally, a different height for the obstacle. In particular, for roads exposed to frequent rockfalls, this height should be reduced to 0.15 m. (1)For two-way roads and interurban arteries, the conditions taken into account in the 1994 ARP guide to define the non superelevated radius, which are very significantly different from those adopted in the other guides, lead to adjusting the previous rule as follows: calculate m_c with the R_{dn} values given in the “2x1 lane roads” guide (i.e. 400 m). For example, for a radius of 500 m, m_c = 0.1. (2)This position corresponds to the minimum height of the third brake light (feu stop) fitted to the vast majority of private vehicles. It also ensures visibility on a significant part of the bodywork of vehicles in daytime conditions, and that of the optical main rear optical devices (red lights, distress signals, etc.) for the majority of light vehicles.

Germany

REF.	TEXT
Richtlinienfür die Anlage von Landstraßenfür die Anlage von Landstraßen Ausgabe 2012 RAL §5.5	**5.5 Sight distance** **5.5.1 Required stopping sight distance** At every point of the road and even with wet pavement, obstacles must be recognizable from a distance allowing a timely stop to the truck driver driving

REF.	TEXT
5.5 Sichtweiten 5.5.1 Erforderliche Haltesichtweite	with a speed which is the one applicable to the relevant EKL class (required stopping sight). Figure 23 shows the required stop sight distance as a function from the design class and the longitudinal slope. To give the driver a timely orientation about the the course of the road in front of him and thereby driving without allowing increased attention requirements, longer sight distances than the required stopping sight distances are usually necessary. That's why the available visibility on the largest part of the route should be at least 30% over the required stopping sight distances.  Picture 23: Required stopping sight distance S_H depending on the EKL (road class) and the longitudinal slope. **5.5.2 Available sight distance** The available visibility results from the alignment in plan and elevation, as well as the cross section and the design of the environment. It is described by means of a line of sight between an eye point and a target point. Eye point and target point are located 1.00 m above the middle of the right lane or, in the case of EKL 4 roads, over the middle of the lane (see Appendix 5). For

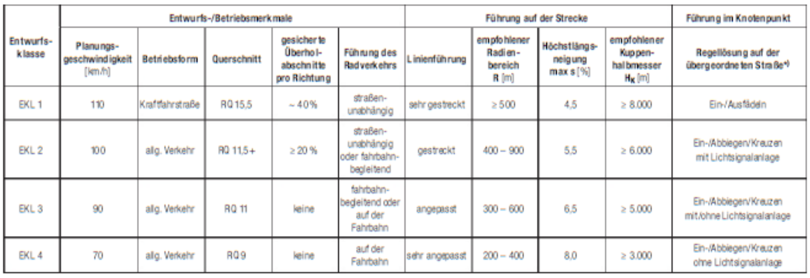
<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr><td></td><td>

directional lanes, the available visibility has to be verified in left turns, taking into account that eye point and target point are satiated 1.00 m above the centre of the left lane.

The available visibility is - for each direction of travel separately - to be determined spatially and represented in visibility bands, also taking into account the layout of the road and the disposition of the adjacent terrain, flyovers, and road equipment (e.g. vehicle restraint systems, noise barriers, ancillary screens).

5.5.3 Verification of the stopping sight distance

For safety reasons, it must be verified whether at each point the available visibility is greater than that required stopping sight distance. This is done in sections. When comparing the existing visibility with the required stopping sight distances the average longitudinal inclination will be considered for each section. In case the available sight distance falls below the required stopping sight distance and this deficit may be due to unsurmountable environmental conditions, it is necessary to verify whether a limitation of the maximum permissible speed is required.



<table>
<tr><th rowspan="2">Entwurfs-klasse</th><th colspan="5">Entwurfs-/Betriebsmerkmale</th><th colspan="4">Führung auf der Strecke</th><th>Führung im Knotenpunkt</th></tr>
<tr><th>Planungs-geschwindigkeit [km/h]</th><th>Betriebsform</th><th>Querschnitt</th><th>gesicherte Überhol-abschnitte pro Richtung</th><th>Führung des Radverkehrs</th><th>Linienführung</th><th>empfohlener Radien-bereich R [m]</th><th>Höchstlängs-neigung max s [%]</th><th>empfohlener Kuppen-halbmesser H_K [m]</th><th>Regellösung auf der übergeordneten Straße*)</th></tr>
<tr><td>EKL 1</td><td>110</td><td>Kraftfahrstraße</td><td>RQ 15,5</td><td>~ 40 %</td><td>straßen-unabhängig</td><td>sehr gestreckt</td><td>≥ 500</td><td>4,5</td><td>≥ 8.000</td><td>Ein-/Ausfädeln</td></tr>
<tr><td>EKL 2</td><td>100</td><td>allg. Verkehr</td><td>RQ 11,5+</td><td>≥ 20 %</td><td>straßen-unabhängig oder fahrbahn-begleitend</td><td>gestreckt</td><td>400 – 900</td><td>5,5</td><td>≥ 6.000</td><td>Ein-/Abbiegen/Kreuzen mit Lichtsignalanlage</td></tr>
<tr><td>EKL 3</td><td>90</td><td>allg. Verkehr</td><td>RQ 11</td><td>keine</td><td>fahrbahn-begleitend oder auf der Fahrbahn</td><td>angepasst</td><td>300 – 600</td><td>6,5</td><td>≥ 5.000</td><td>Ein-/Abbiegen/Kreuzen mit/ohne Lichtsignalanlage</td></tr>
<tr><td>EKL 4</td><td>70</td><td>allg. Verkehr</td><td>RQ 9</td><td>keine</td><td>auf der Fahrbahn</td><td>sehr angepasst</td><td>200 – 400</td><td>8,0</td><td>≥ 3.000</td><td>Ein-/Abbiegen/Kreuzen ohne Lichtsignalanlage</td></tr>
</table>

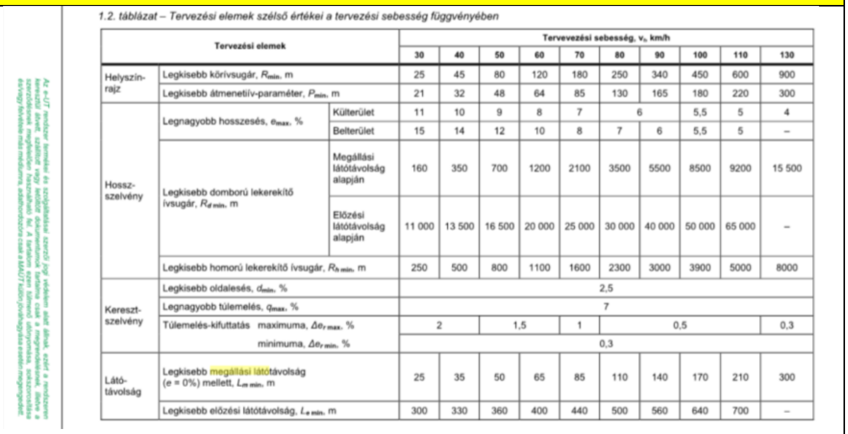
Table 9: Design classes and basic formal features

</td></tr>
</table>

Hungary

REF.	TEXT
Hungarian Road and Rail Society. Road Design Guidelines (in Hungarian) e-UT 03.01.11, Hungarian Road and Rail Society: Budapest, Hungary, 2008	Hungarian Road and Rail Society. Road Design Guidelines (in Hungarian) e-UT 03.01.11, Hungarian Road and Rail Society: Budapest, Hungary, 2008. The guideline also regulates some further subtle details such as where the measurements should be taken, how it should be done in horizontal curves etc. This table shows the design parameters depending on design speed. The yellow shaded text says: minimum stopping sight distance. Design speeds are the columns ranging from 30 to 130 km/h.

REF.	TEXT

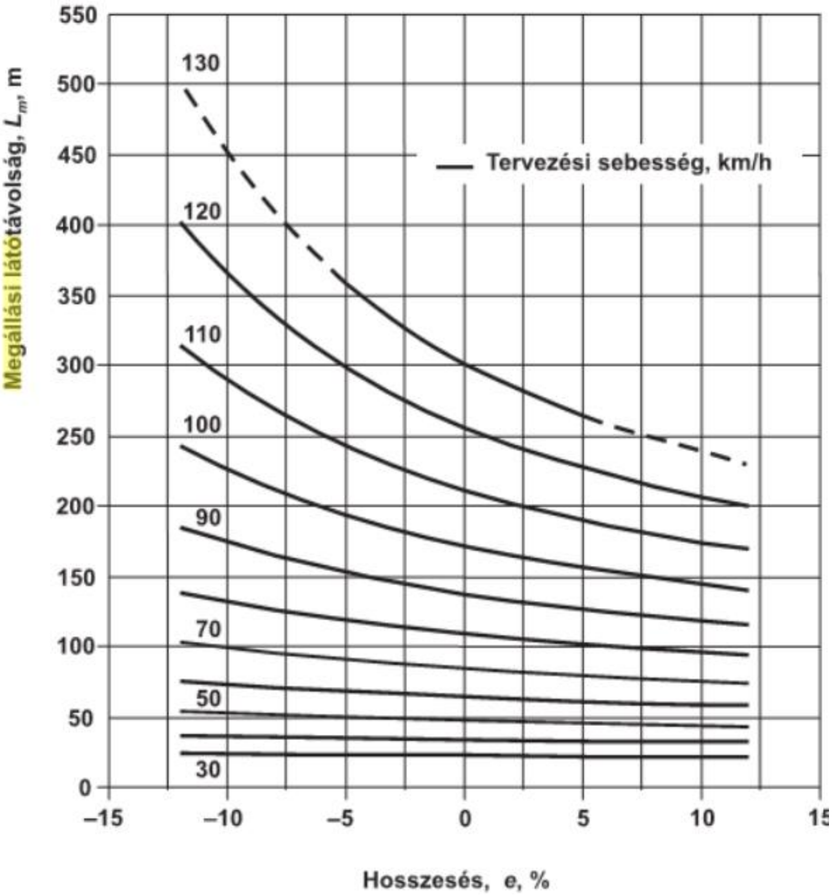


1.2. táblázat – Tervezési elemek szélső értékei a tervezési sebesség függvényében

Tervezési elemek			Tervevezési sebesség, v_t, km/h									
			30	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**130**
Helyszín-rajz	Legkisebb körívsugár, $R_{min.}$ m		25	45	80	120	180	250	340	450	600	900
	Legkisebb átmenetiív-paraméter, $P_{min.}$ m		21	32	48	64	85	130	165	180	220	300
Hossz-szelvény	Legnagyobb hosszesés, $e_{max.}$ %	Külterület	11	10	9	8	7	6		5,5	5	4
		Belterület	15	14	12	10	8	7	6	5,5	5	–
	Legkisebb domború lekerekítő ívsugár, $R_{d\,min.}$ m	Megállási látótávolság alapján	160	350	700	1200	2100	3500	5500	8500	9200	15 500
		Előzési látótávolság alapján	11 000	13 500	16 500	20 000	25 000	30 000	40 000	50 000	65 000	–
	Legkisebb homorú lekerekítő ívsugár, $R_{h\,min.}$ m		250	500	800	1100	1600	2300	3000	3900	5000	8000
Kereszt-szelvény	Legkisebb oldalesés, $d_{min.}$ %		2,5									
	Legnagyobb túlemelés, $q_{max.}$ %		7									
	Túlemelés-kifuttatás maximuma, $\Delta e_{r\,max.}$ %		2		1,5		1	0,5				0,3
	minimuma, $\Delta e_{r\,min.}$ %		0,3									
Látó-távolság	Legkisebb megállási látótávolság (e = 0%) mellett, $L_{m\,min.}$ m		25	35	50	65	85	110	140	170	210	300
	Legkisebb előzési látótávolság, $L_{e\,min.}$ m		300	330	360	400	440	500	560	640	700	–

Legkisebb megállási látótávolság = minimum stopping distance; mellet = next to

It has to be ensured that at an eye-height of 1.00 m the road user is able to spot (in his/her traffic lane) any object with a height of 0.1 m (in case of design speed of 110 km/h an object with a height of 0.30 m, and in case of 130 km/h 0.50 m) in order to stop the vehicle. Stopping sight distance depends on design speed (see table above) as well as slope (see graph below – vertical axis stopping sight distance, horizontal axis slope).



"e" means the longitudinal grade.

Italy

REF.

D.M. 5/11/2001 N°6792

Norme funzionali e geometriche per la costruzione delle strade (2001)

5.1.2. Distanza di visibilita’ per l’arresto

TEXT

5.1.2. Stopping sight distance

It is evaluated with the following expression:

$$D_A = D_1 + D_2 = \frac{V_0}{3.6} \cdot \tau - \frac{1}{3.6^2} \int_{V_0}^{V_1} \frac{V}{g \cdot \left[f_1(V) \pm \frac{i}{100}\right] + \frac{Ra(V)}{m} + r_0(V)} \mathrm{dV}$$

Where:

D_1 = space travelled in time τ

D_2 = braking distance

V_0 = vehicle speed at the start of braking, equal to the design speed accurately deduced from the speed diagram (see par. 5.4) [km /h]

V_1 = final vehicle speed, where $V_1 = 0$ in case of stopping [km /h]

i = longitudinal slope of the route [%]

τ = total reaction time (perception, reflection, reaction and action) [s]

g = acceleration due to gravity [m /s^2]

R_a = aerodynamic resistance [N]

m = vehicle mass [kg]

f_l = limit value of the coefficient of adhesion that can be longitudinally engaged for braking

r_0 = unitary rolling resistance, negligible [N /kg]

The aerodynamic resistance Ra is calculated with the following expression:

$$R_a = \frac{1}{2x3.6^2} \rho C_x S V^2$$

Where:

C_x = aerodynamic coefficient

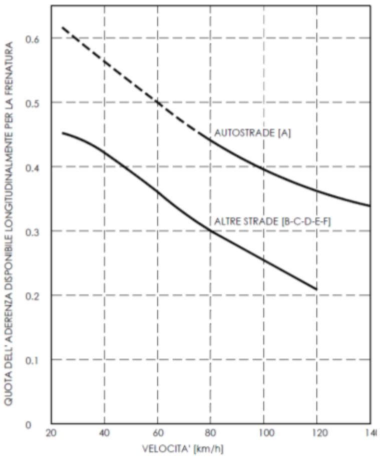
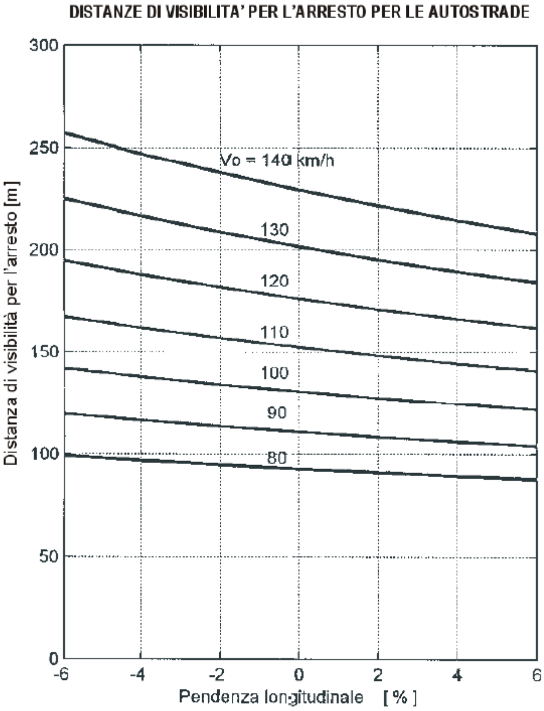
S = resistant surface [m^2]

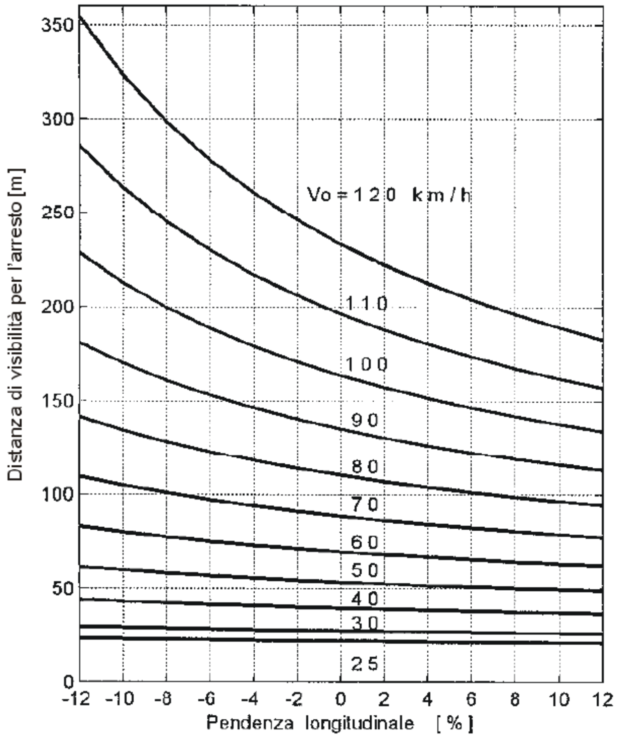
ρ = density of air in standard conditions [kg /m^3]

For f_l, the following two series of values can be adopted, one relating to motorways and the other valid for all other types of roads (see Fig. 5.1.2.a). Those values are also compatible with slightly wet road surface (thickness of the water film of 0.5 mm).

VELOCITA’ km/h	25	40	60	80	100	120	140
f_l Autostrade	-	-	-	0.44	0.40	0.36	0.34
f_l Altre strade	0,45	0.43	0.35	0.30	0.25	0.21	-

Higher f_l values have been adopted for motorways in consideration of the fact that on this type of roads, characterized by high geometric standards as well as quality road surfaces, the user tends to use the available adherence to a greater extent. The f_l values referring to motorways can be adopted for main extra-urban roads (type B) if the qualities of the road surface are comparable to those of type A roads and are maintained over time.

REF.	TEXT
	 Fig. 5.1.2.a The distances calculated in this way are valid both in straight and in curves. For the overall reaction time, linearly decreasing values are assumed with speeds ranging from 2.6 s for 20 km /h, to 1.4 s for 140 km / h, in consideration of the more concentrated attention with high speeds. $\tau = (2.8 - 0.01\ V)$ [s] with V in km / h. In particular situations such as crossings or sections that are difficult to make out and interpret (complex intersections, subsequent confluences or deviations, etc.) the above time must be increased by 1 second in the case of an extra-urban road and up to 3 seconds in an urban setting. Figures 5.1.2.b and 5.1.2.c report the visibility distances for stopping calculated as shown above, as a function of a constant longitudinal slope. In case a variable slope (vertical agreements), the average value can be assumed for it.  FOR THE OTHER ROADS

REF.	TEXT
	 Fig. 5.1.2.c The diagrammes of figures 5.1.2.b and 5.1.2.c are calculated for the case of a stopping car with the following aerodynamic resistance features (with reference to an average car): C_x = aerodynamic coefficient = 0.35 S = resistant surface = 2.1 [m^2] m = vehicle mass = 1250 [kg] ρ = density of air in standard conditions = 1.15 [kg /m^3] With these conditions and V expressed in km/ h $\frac{R_a}{m} = 2.61\ x\ 10^{-5}\ x\ V^2$ [N/kg]

Japan

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr><td>Road Structure Ordinance (1970)
Article 19</td><td>Article 19
1. Sight distance shall not be less than the values below, as listed in the following table according to design speed.
2. For roads with two lanes (except for one-way roads), sufficient sections of oncoming highway visible to the driver shall be provided for overtaking.
<table>
<tr><th>Design Speed (km/h)</th><th>Transition Section Length (m)</th></tr>
<tr><td>120</td><td>210</td></tr>
<tr><td>100</td><td>160</td></tr>
<tr><td>80</td><td>110</td></tr>
<tr><td>60</td><td>75</td></tr>
<tr><td>50</td><td>55</td></tr>
<tr><td>40</td><td>40</td></tr>
<tr><td>30</td><td>30</td></tr>
<tr><td>20</td><td>20</td></tr>
</table>
</td></tr>
</table>

Mexico

REF.	TEXT
Manual de Proyecto Geométrico (Manual for Road Geometric Design, 2018) F.3.1. Distancia de visibilidad de parada	**F.3.1. Stopping sight distance** It is the distance with visibility necessary for a driver, travelling at design speed, to be able to stop his vehicle before reaching a fixed object located in their path. It is provided at any point on all roads. The stopping sight distance consists of two segments: the reaction distance, which is the distance travelled from the moment the driver perceives an object on the road and decides to stop, until the moment the vehicle brakes are applied; and the braking distance, which is the distance required for the vehicle to stop, from the moment the driver applies the brakes. **F.3.1.1. Reaction distance** It is the distance travelled by the vehicle from the moment the driver recognizes the presence of a dangerous object or situation on the road to the moment the brakes are applied. This distance can be easily determined if the vehicle is assumed to be travelling at a uniform speed and the driver's reaction time is known. As established in section C.1.3 of this chapter, the reaction time, sometimes called the perception-reaction time, of 2.5

REF. **TEXT**

seconds, is adequate for 90% of the situations that may arise. However, in complex situations, such as those occurring at intersections, longer times may be required. The reaction distance (d_R), in meters, is determined assuming that the vehicle travels at the design speed (V), in km/h, during the reaction time (t), in s. So:

$$d_R = \frac{V}{3.6} t$$

F.3.1.2. Braking distance

The braking distance (d_F), in meters, of a vehicle on a flat road, travelling at design speed (V), in km/h, is determined by equating the work done by the braking force to the kinetic energy of the vehicle:

$$F\, d_F = \frac{1}{2} m V^2 \quad ; \quad (W f_l)\, d_F = \frac{1}{2} \frac{W}{g} V^2 \quad ; \quad d_F = \frac{V^2}{254 f_l}$$

A more recent approach in the determination of the stopping distance, more in line with current automotive technology, is to consider a rate of deceleration (a) that is comfortable for most drivers. Such rate has been considered to be 3.4 m/s^2, so:

$$d_F = \frac{\left(\frac{V}{3.6}\right)^2}{2a} = \frac{V^2}{(25.92)\,(3.4)} = \frac{V^2}{88}$$

It is observed that this comfort criterion is equivalent to considering a coefficient of longitudinal friction of 0.346, which is only exceeded by the coefficients at design speeds of 30 and 40 km/h, for which it is applicable only for those speeds.

F.3.1.3. Stopping sight distance for the design

Stopping sight distance is the sum of the reaction distance plus the braking distance. If rounded to the next ten meters, these distances result (see Table I.4):

Table I.4 Stopping sight distances

Velocidad de proyecto, en km/h	30	40	50	60	70	80	90	100	110
Coeficiente de fricción longitudinal	0.346	0.346	0.324	0.308	0.295	0.285	0.276	0.269	0.261
Distancia de reacción, en m	20.83	27.78	34.72	41.67	48.61	55.56	62.5	69.44	76.39
Distancia de frenado, en m	10.24	18.21	30.36	46.05	65.39	88.48	115.39	146.16	182.85
Distancia de visibilidad de parada (DVP), en m	35	50	65	85	105	130	160	185	220

3.1.4. Effect of the slope

On vertical tangents, with a longitudinal slope of p in m/m, if the same criterion is used, the braking distance will be given by:

$$dF = \frac{V^2}{254\,(f \pm p)} t$$

In this way, braking distances on uphill slopes are shorter and on downhills longer.

F.3.1.5. Variation for trucks

REF.	TEXT
	The above stopping sight distances reflect light vehicle operation and may be questionable for trucks for which longitudinal friction is less efficient and therefore require longer stopping distances. However, there are factors tending to compensate for the additional length required by trucks; On the one hand, a truck operator can perceive road obstructions in advance due to the higher position of his eyes with respect to the road surface, and on the other hand, the reaction time is usually shorter. For this reason, sight distances for trucks and light vehicles are not used separately in the project. **F.3.2. Decision sight distance** Stopping sight distances are often poor when drivers must make complex decisions, when information is difficult to perceive and process, or when the maneuvre is unexpected or unusual. In such cases, decision sight distance should be used instead of stopping sight distance. The decision sight distance is the minimum distance necessary for a driver, circulating at design speed, to be able to maneuvre his vehicle in advance in the presence of a situation whose complexity demands greater perception-reaction times than those usually required in road. This distance is determined with the same expressions, but considering the following reaction time (t), in seconds, for the maneuvres of stopping and changing speed or trajectory (see Table I.5): Table I.5

Stopping, rural area	3s
Stopping, urban area	9s
Changes, rural area	10s-11s
Changes, suburban area	12s-13s
Changes, urban area	13s-14s

The resulting decision sight distances are appropriate for varying degrees of maneuvre complexity. Due to the added safety and maneuverability afforded by these lengths, it is recommended that they be used only in truly troublesome locations. In the event that it is not feasible to provide these distances due to special circumstances of horizontal and vertical alignment, the possibility of using preventive signage allowing drivers to be alerted about the conditions that they will find ahead on their way will be studied.

Poland (until September 2022)

REF.	TEXT
Regulation of the Minister of Transport and Maritime Economy on technical conditions for public roads and	1. On each lane of G and higher class roads (A-motorway, S-express road, GP – main road with fast traffic, G – main road), at least the SSD should be provided to allow the driver of the vehicle travelling with operating speed, and in the case of other road classes (Z-collector roads, L- local roads, D-

<table>
<tr>
<td>their location.
Regulation, No 43, pos. 430.1999

Part 2, Cap. 2, Page 2417</td>
<td>

residential roads) with a speed of 10 km / h greater than the design speed, to stop the vehicle in front of an obstacle.

The requirement is fulfilled if:

a) the observation aim over the centre of the lane is visible from the observation point 1.0 m above the centre of the same lane at a distance not less than that specified in the table:

<table>
<tr><th rowspan="2">Speed (km/h)</th><th colspan="11">Min SSD [m]</th></tr>
<tr><th>≤−10%</th><th>−8%</th><th>−6%</th><th>−4%</th><th>−2%</th><th>0%</th><th>2%</th><th>4%</th><th>6%</th><th>8%</th><th>≥10%</th></tr>
<tr><td>130</td><td>-</td><td>-</td><td>390</td><td>350</td><td>330</td><td>310</td><td>300</td><td>290</td><td>280</td><td>-</td><td>-</td></tr>
<tr><td>120</td><td>-</td><td>-</td><td>340</td><td>310</td><td>290</td><td>270</td><td>260</td><td>250</td><td>240</td><td>-</td><td>-</td></tr>
<tr><td>110</td><td>-</td><td>-</td><td>280</td><td>260</td><td>240</td><td>230</td><td>220</td><td colspan="2">200</td><td colspan="2">-</td></tr>
<tr><td>100</td><td colspan="2"></td><td>220</td><td>200</td><td colspan="3">180</td><td colspan="2">170</td><td colspan="2">-</td></tr>
<tr><td>90</td><td colspan="2">190</td><td colspan="2">170</td><td colspan="3">150</td><td colspan="2">130</td><td colspan="2">120</td></tr>
<tr><td>80</td><td colspan="2">160</td><td colspan="2">140</td><td colspan="3">120</td><td colspan="2">110</td><td colspan="2">100</td></tr>
<tr><td>70</td><td colspan="2">110</td><td colspan="2">100</td><td colspan="3">90</td><td colspan="2">85</td><td colspan="2">80</td></tr>
<tr><td>60</td><td colspan="4">80</td><td colspan="3">70</td><td colspan="4">60</td></tr>
<tr><td>50</td><td colspan="4">55</td><td colspan="3">50</td><td colspan="4">45</td></tr>
<tr><td>40</td><td colspan="4">40</td><td colspan="7">35</td></tr>
<tr><td>30</td><td colspan="4">25</td><td colspan="7">20</td></tr>
</table>

b) the height of the observation aim is specified in the table:

<table>
<tr><th>Speed (km/h)</th><td>>100</td><td>100–81</td><td>80–61</td><td>≤60</td></tr>
<tr><th>Height of the observation aim (m)</th><td>0,45</td><td>0,30</td><td>0,15</td><td>0,00</td></tr>
</table>

</td>
</tr>
</table>

Poland (from September 2022)

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr>
<td>Dz.U. 2022 poz. 1518

Rozporządzenie Ministra Infrastruktury z dnia 24 czerwca 2022 r. w sprawie przepisów techniczno-budowlanych dotyczących dróg publicznych</td>
<td>

(1) The assessment of the visibility conditions for stopping the vehicle in front of an obstacle should be carried out because the road structure, objects or devices in the road lane and the road environment may limit the vehicle driver's observation space to an extent unacceptable in technical and construction regulations. The visibility conditions in each lane are assessed by comparing the actual and required SSD. It is recommended to shape the planned road and its surroundings in such a way that the actual SSD along the road change smoothly, without suddenly reducing the sight distance, especially in places where high vehicle speeds are expected.

(2) The required SSD should be calculated from the formula:

$$SSD = 88{,}4 + \frac{-126+1{,}81\,V_{dp}-105\,i}{1-0{,}404\ln(V_{dp})+1{,}51\,e^{i}} \qquad (1)$$

where:

SSD – min SSD [m],
V_{dp} – design speed [km/h],
i – average longitudinal slope of the lane along the length of SSD L_z [-].
Range for formula: V_{dp} = {30, 140} and i = {-0,1, +0,1}.

(3) The design speed is constant along the road section, while the longitudinal slope of the lane in which the vehicle is stopped may vary. Then, when determining the value of the required stopping distance, the average

</td>
</tr>
</table>

REF.	TEXT
	longitudinal slope of the lane along the length SSD should be taken at each observation point. The calculated values of the required SSD according to formula (1) should be rounded up to one meter.

Tab. 1 Min SSD (m)

Longitudinal slope [%]	Design speed [km/h]											
	140	130	120	110	100	90	80	70	60	50	40	30
-12	-	-	-	-	-	-	-	110	82	59	41	28
-11,5	-	-	-	-	-	-	-	109	81	58	40	28
-11	-	-	-	-	-	-	-	108	81	58	40	27
-10,5	-	-	-	-	-	-	-	107	80	57	40	27
-10	-	-	-	-	-	-	-	106	79	57	40	27
-9,5	-	-	-	-	-	-	-	105	79	57	39	27
-9	-	-	-	-	-	-	-	104	78	56	39	27
-8,5	-	-	-	-	-	-	-	103	77	56	39	27
-8	-	-	-	-	208	168	133	102	77	56	39	27
-7,5	-	-	-	-	205	166	131	101	76	55	39	27
-7	-	-	-	-	203	164	130	101	76	55	38	27
-6,5	-	-	-	-	200	162	129	100	75	55	38	27
-6	403	343	289	241	198	160	127	99	74	54	38	26
-5,5	397	338	285	238	196	159	126	98	74	54	38	26
-5	390	333	281	235	194	157	125	97	73	54	38	26
-4,5	384	328	277	232	191	155	124	96	73	53	38	26
-4	379	323	274	229	189	154	123	96	72	53	37	26
-3,5	373	319	270	226	187	152	122	95	72	53	37	26
-3	367	314	267	224	185	151	120	94	71	52	37	26
-2,5	362	310	263	221	183	149	119	93	71	52	37	26
-2	357	306	260	218	181	148	118	93	70	52	37	26
-1,5	352	302	257	216	179	146	117	92	70	51	37	26
-1	347	298	253	213	177	145	116	91	69	51	37	26
-0,5	342	294	250	211	175	144	115	90	69	51	36	26
0	337	290	247	209	174	142	114	90	69	51	36	26
0,5	332	286	244	206	172	141	113	89	68	50	36	26
1	328	283	241	204	170	140	112	88	68	50	36	26
1,5	323	279	239	202	168	138	111	88	67	50	36	26
2	319	276	236	200	167	137	111	87	67	50	36	26
2,5	315	272	233	197	165	136	110	87	67	50	36	26
3	311	269	230	195	163	135	109	86	66	49	36	26
3,5	307	266	228	193	162	133	108	85	66	49	36	26
4	303	263	225	191	160	132	107	85	65	49	35	26
4,5	299	259	223	189	159	131	106	84	65	49	35	25
5	296	256	220	187	157	130	105	84	65	48	35	25
5,5	292	254	218	186	156	129	105	83	64	48	35	25
6	288	251	216	184	154	128	104	83	64	48	35	25
6,5	-	-	-	-	153	127	103	82	64	48	35	25
7	-	-	-	-	152	126	102	82	63	48	35	25
7,5	-	-	-	-	150	125	102	81	63	47	35	25
8	-	-	-	-	149	124	101	81	63	47	35	25
8,5	-	-	-	-	-	-	-	80	62	47	35	25
9	-	-	-	-	-	-	-	80	62	47	35	25
9,5	-	-	-	-	-	-	-	79	62	47	35	25
10	-	-	-	-	-	-	-	79	61	47	35	25
10,5	-	-	-	-	-	-	-	78	61	46	34	25
11	-	-	-	-	-	-	-	78	61	46	34	25
11,5	-	-	-	-	-	-	-	77	61	46	34	25
12	-	-	-	-	-	-	-	77	60	46	34	25

Portugal

REF.

NORMA DE TRAÇADO

REVIS ÃO

II.6.2

(November 2010)

II.6.2. Distância de visibilidade de paragem.

TEXT

II.6.2. Stopping Sight Distance

The stopping sight distance is the minimum distance necessary for a driver, travelling at a certain speed, to be able to safely stop the vehicle, if necessary, after seeing an obstacle on the pavement.

The stopping sight distance is the minimum sight distance that must be ensured when it is not economically feasible to ensure a longer sight distance.

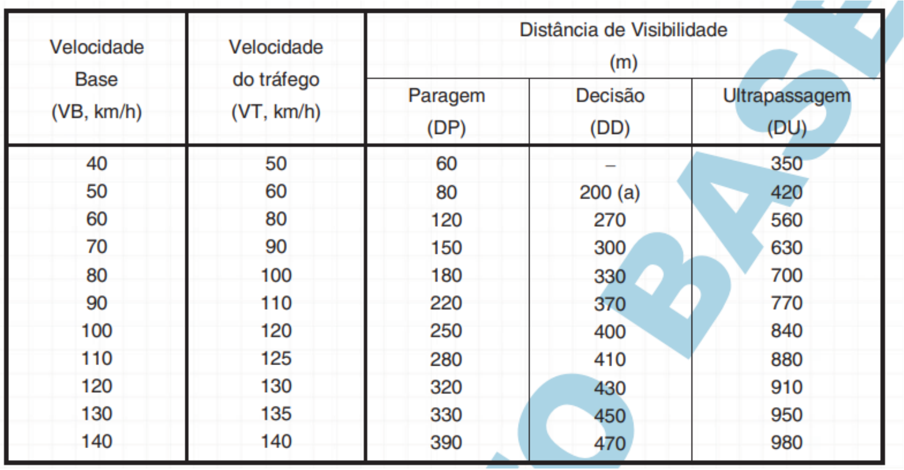
The stopping sight distance is measured between the driver's eyes (1.05 m above the pavement) and an obstacle on the pavement 0.15 m high.

The stopping sight distance (DP) is determined by adding two parts, the first one representing the distance travelled during the driver's perception-reaction time (taken as 2 s), and the second the braking distance which is a function of the traffic speed (VT, in km/h), the longitudinal friction coefficient (f_l) and the inclination of the slope (+i or -i, ascending and descending, respectively, expressed in %/100). The following expression is adopted for the calculation of the SSD:

$$SSD = \frac{VT}{1{,}8} + \frac{VT^2}{254 \cdot (f_l \pm i)}$$

The values of the stopping sight distances shown in Table IV were calculated for the case of a flat slope. On slopes with a higher inclination, the effective stopping sight distance must be determined using the expression indicated for calculating the SSD.

The minimum values of the stopping sight distance that must be considered in the projects are those indicated in Table IV.

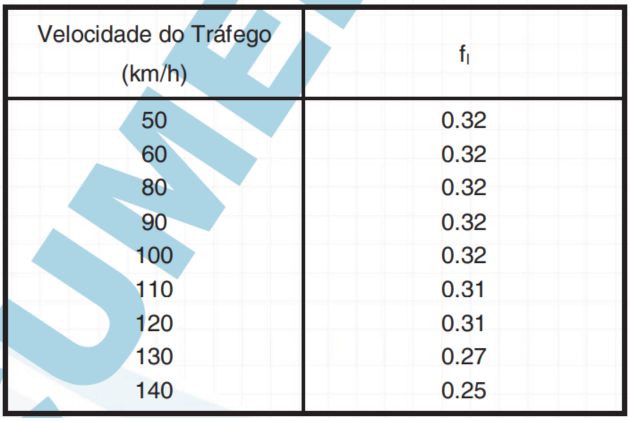


Velocidade Base (VB, km/h)	Velocidade do tráfego (VT, km/h)	Distância de Visibilidade (m)		
		Paragem (DP)	Decisão (DD)	Ultrapassagem (DU)
40	50	60	–	350
50	60	80	200 (a)	420
60	80	120	270	560
70	90	150	300	630
80	100	180	330	700
90	110	220	370	770
100	120	250	400	840
110	125	280	410	880
120	130	320	430	910
130	135	330	450	950
140	140	390	470	980

(a) Value to consider when the value of VT <60km/h

Table V shows the values of the adopted longitudinal friction coefficients (f_l), as a function of speed.

Table V – Longitudinal friction coefficients

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr><td></td><td>

<table>
<tr><th>Velocidade do Tráfego (km/h)</th><th>f_l</th></tr>
<tr><td>50</td><td>0.32</td></tr>
<tr><td>60</td><td>0.32</td></tr>
<tr><td>80</td><td>0.32</td></tr>
<tr><td>90</td><td>0.32</td></tr>
<tr><td>100</td><td>0.32</td></tr>
<tr><td>110</td><td>0.31</td></tr>
<tr><td>120</td><td>0.31</td></tr>
<tr><td>130</td><td>0.27</td></tr>
<tr><td>140</td><td>0.25</td></tr>
</table>
</td></tr>
</table>

Romania

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr><td>Ordinul nr. 622 din 23/10/2003
Normativ privind proiectarea autostrăzilor extraurbane
Secțiunea a 2-a Vizibilitatea. Art. 63.
Anexa 2</td><td>

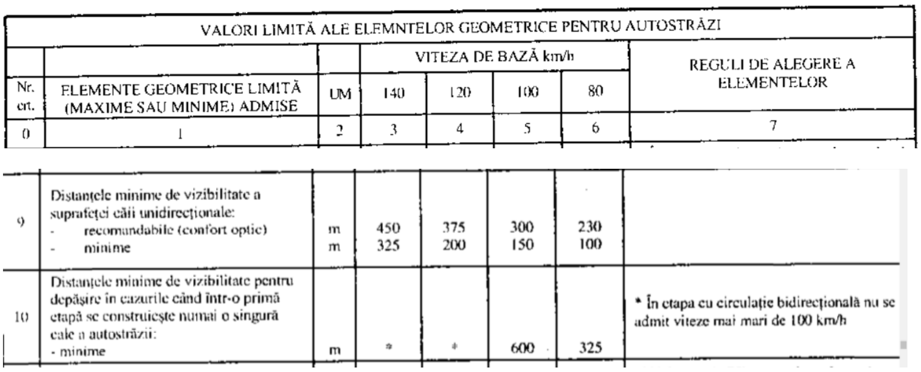
Section a 2-a Visibility

Art. 63.- (1) Visibility is ensured in the ground plan depending on the design speed, by clearing the space inside the curves of any obstacles such as: earth or rock logs, buildings, fences, trees, plantations, pillars, etc. and in longitudinal profile through vertical connections with appropriate radii. Visibility must also be ensured for accessing junction areas of roads and service spaces.

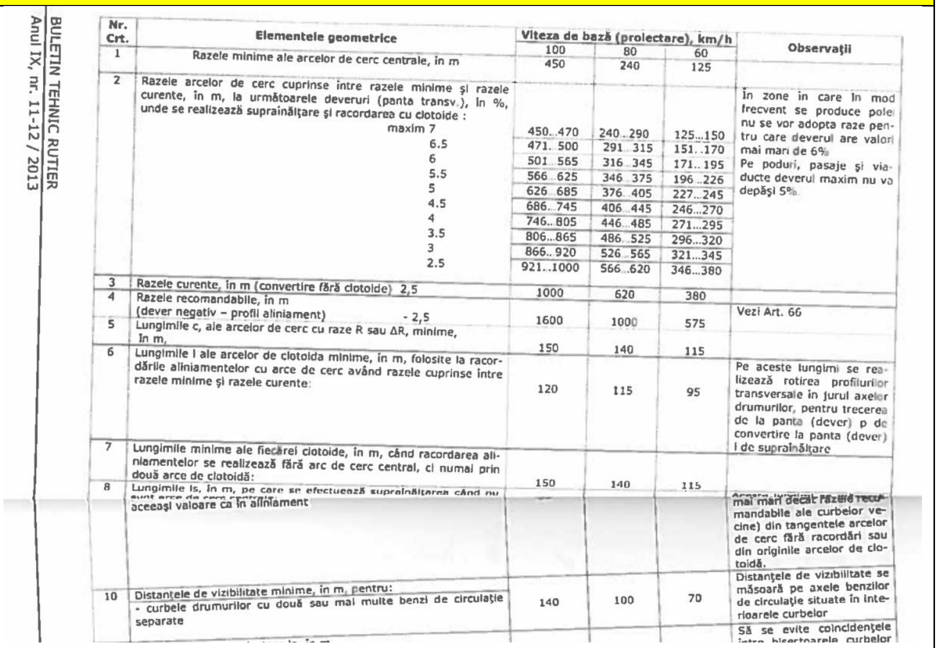
(2) The visibility of the road surface given in point 9 of Annex 2 is ensured at distances greater than the braking distances for the respective operation speeds.

(3) Should a road infrastructure begin with the construction of a first carriageway of a highway, in order to create overtaking possibilities, visibility must be ensured for distances indicated in point 10 of annex 2.

Annex 2 (see 9: Stopping sight distance; 10: overtaking sight distance):


<table>
<tr><th colspan="8">VALORI LIMITĂ ALE ELEMNTELOR GEOMETRICE PENTRU AUTOSTRĂZI</th></tr>
<tr><th rowspan="2">Nr. crt.</th><th rowspan="2">ELEMENTE GEOMETRICE LIMITĂ (MAXIME SAU MINIME) ADMISE</th><th rowspan="2">UM</th><th colspan="4">VITEZA DE BAZĂ km/h</th><th rowspan="2">REGULI DE ALEGERE A ELEMENTELOR</th></tr>
<tr><th>140</th><th>120</th><th>100</th><th>80</th></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>9</td><td>Distanțele minime de vizibilitate a suprafeței căii unidirecționale:
- recomandabile (confort optic)
- minime</td><td>m
m</td><td>450
325</td><td>375
200</td><td>300
150</td><td>230
100</td><td></td></tr>
<tr><td>10</td><td>Distanțele minime de vizibilitate pentru depășire în cazurile când într-o primă etapă se construiește numai o singură cale a autostrăzii:
- minime</td><td>m</td><td>*</td><td>*</td><td>600</td><td>325</td><td>* În etapa cu circulație bidirecțională nu se admit viteze mai mari de 100 km/h</td></tr>
</table>

Express roads:
</td></tr>
</table>

REF.	TEXT
Decizia Directorului General al Comaniei Naționale de Administrare a Infrastructuri Rutiere 1669 16/11/2017 Normativ privind proiectarea drumurilor expres pe reteaua rapida de comunicații (2013). Anexa 1	

BULETIN TEHNIC RUTIER
Anul IX, nr. 11-12 / 2013

Nr. Crt.	Elementele geometrice	Viteza de bază (proiectare), km/h 100	80	60	Observaţii
1	Razele minime ale arcelor de cerc centrale, în m	450	240	125	
2	Razele arcelor de cerc cuprinse între razele minime şi razele curente, în m, la următoarele deveruri (panta transv.), în %, unde se realizează supraînălţare şi racordarea cu clotoide : maxim 7	450..470	240..290	125...150	În zone în care în mod frecvent se produce polei nu se vor adopta raze pentru care deverul are valori mai mari de 6%. Pe poduri, pasaje şi viaducte deverul maxim nu va depăşi 5%.
	6.5	471..500	291..315	151..170	
	6	501..565	316..345	171..195	
	5.5	566..625	346..375	196..226	
	5	626..685	376..405	227...245	
	4.5	686..745	406..445	246...270	
	4	746..805	446..485	271...295	
	3.5	806...865	486..525	296...320	
	3	866..920	526..565	321...345	
	2.5	921..1000	566..620	346...380	
3	Razele curente, în m (convertire fără clotoide) 2,5	1000	620	380	
4	Razele recomandabile, în m (dever negativ – profil aliniament) - 2,5	1600	1000	575	Vezi Art. 66
5	Lungimile c, ale arcelor de cerc cu raze R sau ΔR, minime, în m,	150	140	115	
6	Lungimile l ale arcelor de clotoida minime, în m, folosite la racordările aliniamentelor cu arce de cerc având razele cuprinse între razele minime şi razele curente:	120	115	95	Pe aceste lungimi se realizează rotirea profilurilor transversale în jurul axelor drumurilor, pentru trecerea de la panta (dever) p de convertire la panta (dever) i de supraînălţare
7	Lungimile minime ale fiecărei clotoide, în m, când racordarea aliniamentelor se realizează fără arc de cerc central, ci numai prin două arce de clotoidă:	150	140	115	
8	Lungimile ls, în m, pe care se efectuează supraînălţarea când nu [illegible] aceeaşi valoare ca în aliniament				[illegible] mai mari decât razele recomandabile ale curbelor vecine) din tangentele arcelor de cerc fără racordări sau din originile arcelor de clotoidă.
10	Distanţele de vizibilitate minime, în m, pentru: - curbele drumurilor cu două sau mai multe benzi de circulaţie separate	140	100	70	Distanţele de vizibilitate se măsoară pe axele benzilor de circulaţie situate în interioarele curbelor
					Să se evite coincidenţele

South Africa

REF.	TEXT
Sanral Geometric Design Guidelines (2015). 3.5. Sight distance.	**3.5 SIGHT DISTANCE** **3.5.1 General** A critical feature of safe road geometry is adequate sight distance. As an irreducible minimum, drivers must be able to see objects in the road with sufficient time to allow them to manoeuvre around them or to stop. Other forms of sight distance are pertinent. They are: • Passing sight distance, which is required for substantial portions of the length of two-lane roads; • Intersection sight distance, to allow a driver on the minor road to evaluate whether it is safe to cross or enter the opposing stream of traffic;

REF.	TEXT
	• Decision sight distance where, for example, a driver must be able to see and respond to road markings;
	• Headlight sight distance, typically applied to sag vertical curves, and
	• Centre line barrier sight distance.
	It is also necessary to consider the terrain or obstructions on the inside of horizontal curves when evaluating adequate sight distance.
	3.5.2 Deceleration rates
	Although research in North America has shown that drivers can choose (or apply) a deceleration of greater than 5 m/sec2, there is a large degree of variability in driver and vehicle capabilities and the 90th percentile deceleration is of the order of 3.4 m/sec^2.
	The Institute of Transportation Engineers' Traffic EngineeringHandbook states that decelerations of up to 3.0 m/sec^2 are reasonably comfortable for passenger car occupants. This deceleration rate has been adopted for these guidelines.
	3.5.3 Object height
	The object height to be used in calculation of stopping sight distance is often a compromise between the length of the resultant sight distance and the cost of construction.
	Stopping is generally in response to another vehicle or large hazard in the roadway. To recognize a vehicle as a hazard at night, a line of sight to its headlights or taillights would be necessary. Larger objects would be visible sooner and provide longer stopping distances. To perceive a very small hazard, for example, a surface obstruction, a zero object height may be necessary.
	However, at the required stopping sight distances for high speeds, small pavement variations and small objects (especially at night) would not be easily visible. Thus, most drivers travelling at high speeds would have difficulty in stopping before reaching a small obstruction.
	A driver will usually attempt to take evasive action rather than to stop for small objects on the roadway. Although not recommended as a design parameter, the time available to manoeuvre is a useful measure when examining variations of geometry in restricted situations or reconstruction projects. In this case, the appropriate object is the pavement surface.
	The designer should adopt an object height based on the probability of a particular object occurring on the roadway, as shown in Table 3.4 below. For stopping sight distance, a conservative tail light height of 0,60 m is recommended.
	If fallen trees or rocks are a real risk, an object height of 0.15 m is recommended. In this context, research has established that the probability of a collision involving an object of a height of 0.15 m or less is infinitesimally small. For passing sight distance, an object height of 1.30 m will allow the driver to discern the top of an oncoming car. A zero object height is recommended where road washouts are a serious risk. It is also recommended for pavement markings in situations such as at intersections or interchanges, where these provide essential guidance.

REF.	TEXT

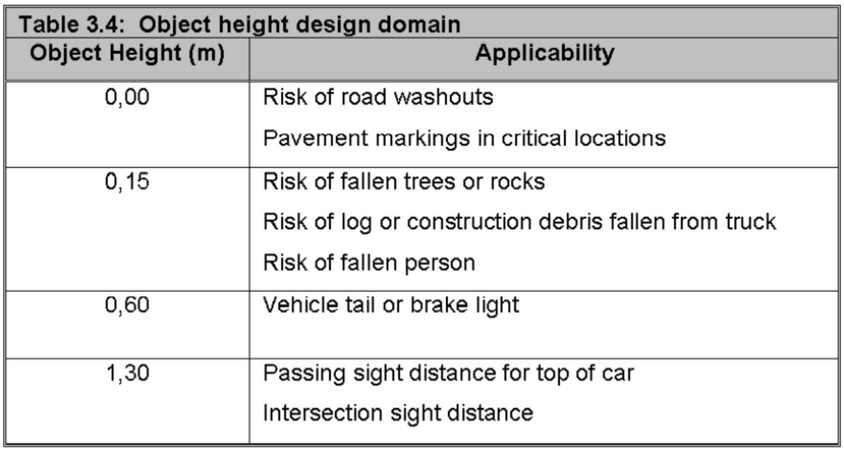


Table 3.4: Object height design domain

Object Height (m)	Applicability
0,00	Risk of road washouts Pavement markings in critical locations
0,15	Risk of fallen trees or rocks Risk of log or construction debris fallen from truck Risk of fallen person
0,60	Vehicle tail or brake light
1,30	Passing sight distance for top of car Intersection sight distance

3.5.4 Stopping sight distance

The minimum sight distance on a roadway should be sufficient to enable a vehicle travelling

at the design speed on a wet pavement to stop before reaching a stationary object in its path.

Stopping sight distance is the sum of two distances:

- the distance traversed by the vehicle from the instant the driver sights an obstruction to the instant the brakes are applied, and
- the distance required to stop the vehicle from the instant the brakes are applied

These are referred to as brake reaction distance and stopping distance, respectively.

These two components, using a reaction time of 2,5 seconds and a deceleration rate of 3.0 m/s^2, result in the relationship

$$s = v\,(0.694 + 0.013v)$$

where: s = stopping sight distance, m

v = initial speed, km/h

Stopping sight distances calculated using this equation are given in Table 3.5, rounded up for design purposes. Also shown in the table for general interest are the values of stopping sight distance adopted in the 2000 AASHTO Policy on the Geometric Design of Highways and Streets, the "Green Book 2000".

In the measurement of stopping sight distance, the driver's eye height is taken as being at 1,05 m and the object height is as defined in Table 3.4.

REF.	TEXT

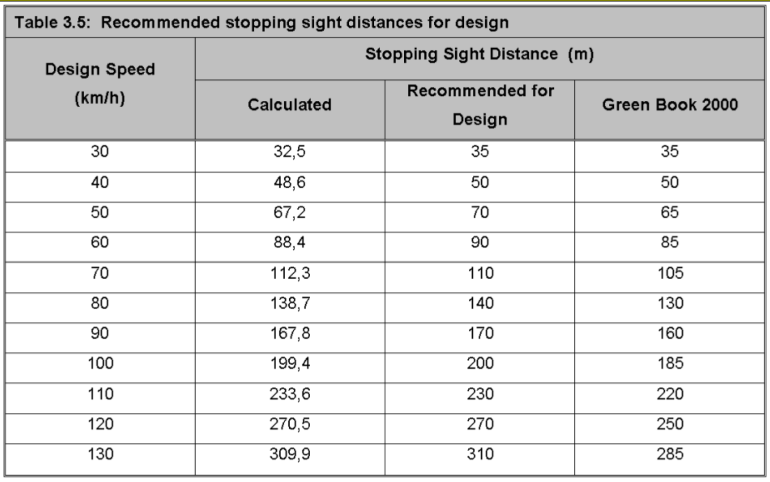


Table 3.5: Recommended stopping sight distances for design

Design Speed (km/h)	Stopping Sight Distance (m)		
	Calculated	Recommended for Design	Green Book 2000
30	32,5	35	35
40	48,6	50	50
50	67,2	70	65
60	88,4	90	85
70	112,3	110	105
80	138,7	140	130
90	167,8	170	160
100	199,4	200	185
110	233,6	230	220
120	270,5	270	250
130	309,9	310	285

3.5.5 Effect of gradient on stopping sight distance

When a highway is on a gradient, the equation for stopping sight distance becomes

$$s = v\,(0{,}694 \pm \frac{0{,}004v}{0{,}3+G})$$

in which G is the percentage gradient divided by 100, with upgrades being positive and downgrades negative and the other terms as previously stated. The brake reaction time is assumed to be the same as for level conditions. The stopping sight distance for design speeds from 30 to 130 km/h as corrected for gradient is illustrated in Figure 3.2.

The sight distance at any point on the highway is generally different in each direction, particularly on straight roads in rolling terrain. As a general rule, the sight distance available on

downgrades is longer than on upgrades, more or less automatically providing the necessary corrections for grade. This is because down grades are normally followed by sag vertical curves, with the following grade also being visible to the driver.

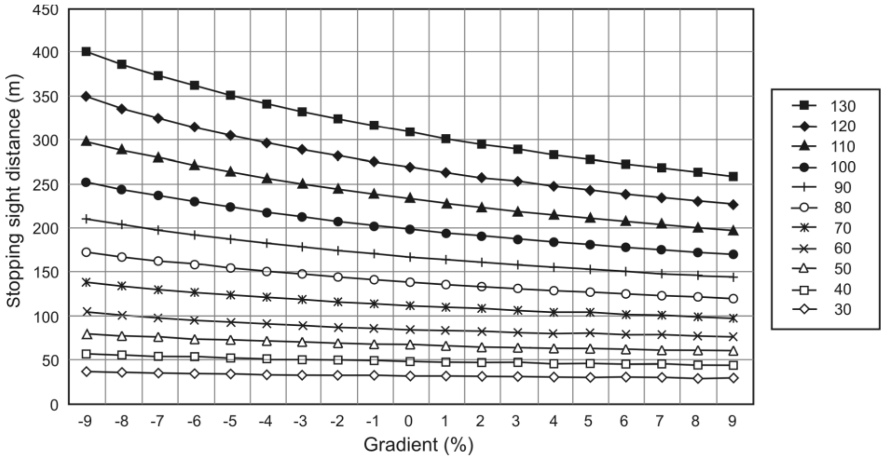
3.5.6 Variation of stopping sight distance for trucks

The recommended minimum stopping sight distance model directly reflects the operation of passenger cars and trucks with antilock braking systems. Trucks with conventional braking systems require longer stopping distances from a given speed than do passenger cars.

However, AASHTO suggests that the truck driver is able to see the vertical features of the obstruction from substantially further because of the higher driver eye height. In addition, posted speed limits for trucks in South Africa are considerably lower than for passenger vehicles. Separate stopping sight distances for trucks and passenger cars are, therefore, not generally used in highway design.

There is, however, evidence to suggest that the sight distance advantages provided by the higher driver eye level in trucks do not always compensate for their inferior braking. Some reasons for the longer truck braking distances include:

- Poor braking characteristics of empty trucks. The problem relates to the suspension and tyres that are designed for maximum efficiency under load;
- Uneven load between axles;
- Propensity of truck drivers not to obey posted speed limits;

REF.	TEXT
TRH 17, YEAR 1988 (Rural roads) **2.5.1. Stopping sight distance (SSD)**	• Inefficient brakes of articulated trucks, and • Effect of curvature. where some of the friction available at the road/tyre interface is used to hold the vehicle in a circular path. To balance between the costs and benefits in designing for trucks, truck stopping sight distances should be checked at potentially hazardous locations. In general, the deceleration rate for trucks is 1.5 m/s^2. The driver's eye height is taken as being at 1.8 m and the object height is as defined in Table 3.4. The designer should also consider measures such as additional signs to improve road safety if stopping sight distance is found to be inadequate for trucks and it is not possible to improve the geometric design. However, it is emphasized that provision of signage is not a substitute for appropriate design practices.  **Figure 3.2: Stopping distance corrected for gradient** **2.5.1. Stopping sight distance (SSD)** Stopping distance involves the capabiilty of the driver to bring his vehicle safely to a standstill, and is thus based on speed, driver reaction time and skid resistance. The total distance travelled in bringing the vehicle to a stop comprises two components: - the distance covered during the driver's reaction period. - the distance required to decelerate to 0 km/h. The stopping distance is expressed as S=0,694v+ v2/254f Where: s = total distance travelled (m) v = speed (km/h) f = brake force coefficient

REF.	TEXT

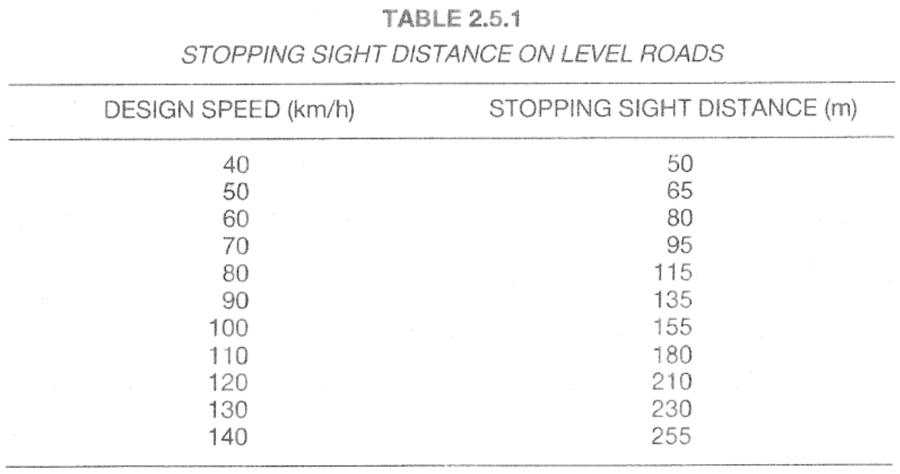


TABLE 2.5.1

STOPPING SIGHT DISTANCE ON LEVEL ROADS

DESIGN SPEED (km/h)	STOPPING SIGHT DISTANCE (m)
40	50
50	65
60	80
70	95
80	115
90	135
100	155
110	180
120	210
130	230
140	255

Sopping sight distances based on operating speeds and the appropriate brake force coefficients have been adopted for design, and are given in Table 2.5.1.

Stopping sight distance is measured from an eye height of 1.05 m to an object height of 0.15m. This object height is used because an obstacle of a lower height would not normally represent a significant hazard. Object height is take into account because measuring the sight distance to the road surface would substantially increase the length of the vertical curve and hence the earthworks required.

The gradient has a marked effect on the stopping distance requirements, and Figure 2.4.1 (a) is an expansion of Table 2.5.1 demonstrating this effect.

Stopping sight distance can also be affected by a visual obstruction (such as a cut slope) next to the carriageway on the inside of a horizontal curve, as shown in Figure 2.5.1 (b).

Spain

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr>
<td>Norma 3.1-IC Trazado, de la Instrucción de Carreteras

Orden FOM/273/2016, 16/02/2016

3.2.1 Distancia de parada.</td>
<td>

3.2.1 STOPPING DISTANCE.

The stopping distance (D_p) is defined as the total distance travelled by a vehicle required to stop before an unexpected obstacle in its path, as measured from its position on the moment of the appearance of the object motivating the stop. Includes distance travelled during the perception, reaction, and braking times. It will be estimated with the expression:

$$SSD = \frac{V \cdot t_P}{3,6} + \frac{V^2}{254 \cdot (f_l + i)}$$

Being:

- D_p = Stopping distance (m).
- V = Speed at the beginning of the braking maneuvre (km/h).
- f_l = Coefficient of longitudinal wheel-pavement friction mobilized.
- i = Inclination of the slope (in parts per unit).
- t_p = Perception and reaction time (s).

For design purposes, the stopping distance will be considered as the distance obtained from the value of the design speed (Vp) of the section considered. The coefficient of mobilized longitudinal friction (f_l) in a braking maneuvre for different values of speed will be obtained from Table 3.1. For intermediate values of the speed, it can be linearly interpolated in the table. The value of the perception and reaction time will be two seconds (2 s).

TABLA 3.1.

COEFICIENTE DE ROZAMIENTO LONGITUDINAL MOVILIZADO (f_l) EN UNA MANIOBRA DE FRENADO.

<table>
<tr><td>V (km/h)</td><td>40</td><td>50</td><td>60</td><td>70</td><td>80</td><td>90</td><td>100</td><td>110</td><td>120</td><td>130</td><td>140</td></tr>
<tr><td>f_l</td><td>0,432</td><td>0,411</td><td>0,390</td><td>0,369</td><td>0,348</td><td>0,334</td><td>0,320</td><td>0,306</td><td>0,291</td><td>0,277</td><td>0,263</td></tr>
</table>

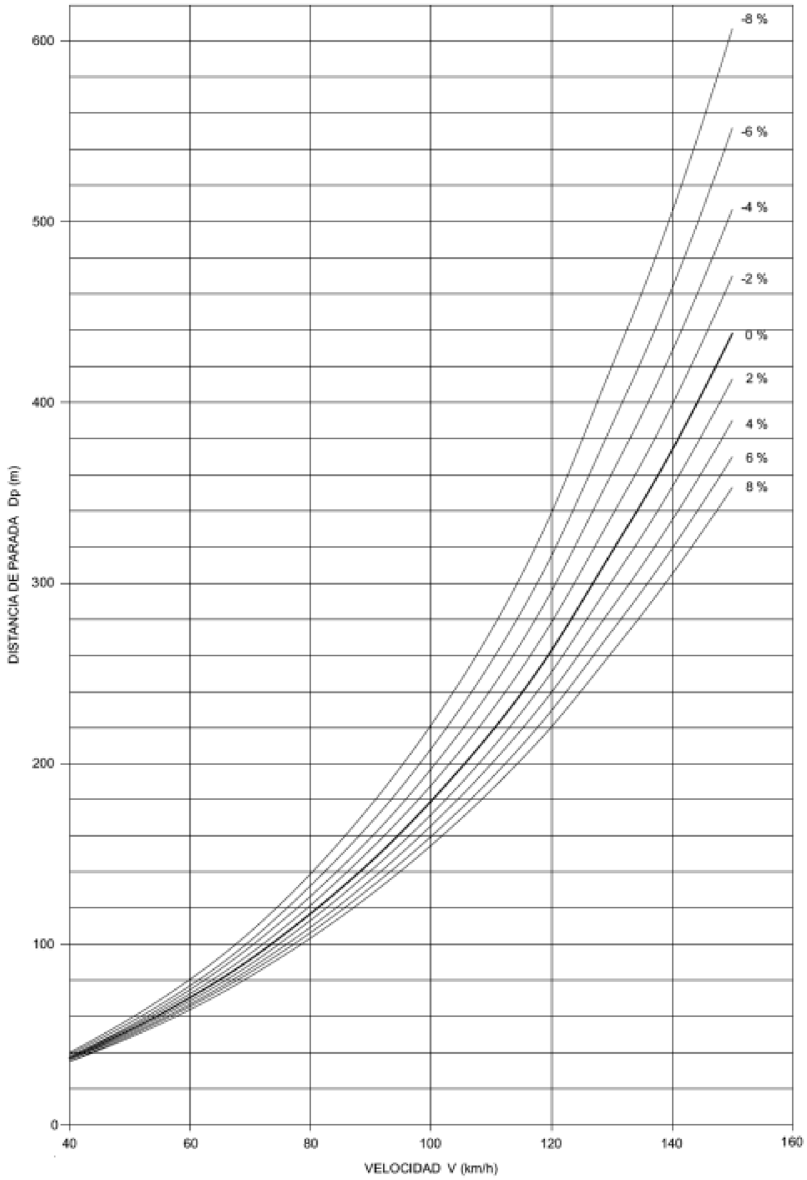
These values of the coefficients (f_l) of longitudinal friction provide some decelerations of the vehicle which are comfortable to the user who must stop, in a controlled manner, the vehicle before an obstacle in its trajectory. Figure 3.1 shows the values of the stopping distance as a function of the speed, for different inclinations of the slope.

</td>
</tr>
</table>

REF.	TEXT

FIGURA 3.1.

DISTANCIA DE PARADA.



3.2.2 STOPPING SIGHT DISTANCE

Stopping sight distance within a lane is defined as the distance between a vehicle and an obstacle located in its trajectory, at the moment in which the driver can spot it without the obstacle disappearing from his field of vision. The distance will be measured along the lane.

For the calculation of the stopping sight distance, the height of the will be set fifty centimeters (50 cm)[7] above the road surface, and can be located at any point in the cross section of the lane (obstacle section). In road sections where it is considered that there may be obstacles with a height of less than fifty centimeters (< 50 cm), the

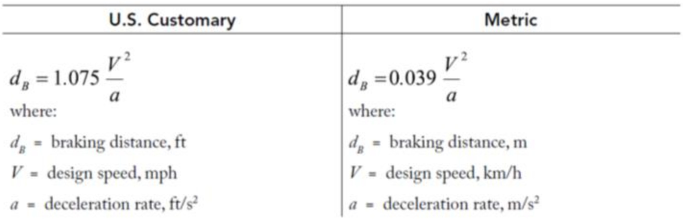
REF.	TEXT
	advisability of setting another obstacle height with a value of not less than twenty centimeters (≮ 20 cm) will be analysed. An obstacle is considered to be visible whenever a line of sight can be drawn between the driver's point of view and all upper points of the obstacle. It may be considered that the piers and abutments of structures, the containment systems of vehicles and the signaling and lighting elements of the road do not represent an intermediate obstacle to the line of sight provided that, once the section containing the obstacle has been completely seen, this section has resulted partially hidden by the intermediate obstacle in no more than one meter (≯ 1.00 m). The stopping sight distance must be greater than the stopping distance calculated with the design speed (V_p) of the corresponding section, in which case it is said that there is stopping sight distance. If on a motorway or dual carriageway there is a widening of lanes along the median and as a consequence, the stopping sight distance in the widened lane also decreases With respect to the existing one in the rest of the lanes, the speed limit may be maintained prior to the widening of the entire carriageway when the following conditions are simultaneously met:[8] • Stopping sight distance in the new lane will not be less than the stopping distance corresponding to a speed twenty kilometers per hour (≮ 20 km/h) lower than the existing before enlargement. • The surface layer of the lane must have friction features between tire and paving higher than those required by current regulations.[9] To guarantee the existence of stopping sight distance when enlargements are made by the median, in the initial design of a highway with separate carriageways, the consequences of future enlargements will be analysed in order to consider the possibility of projecting a median with a width greater than the minimum established in section 7.3.2. [7] Value considered representative of foreseeable obstacles. [8] Current traffic regulations prohibit heavy vehicles from driving on the third or fourth lane of the carriageway of a motorway or dual carriageway. [9] Requiring a surface macrotexture greater than 1.2 mm calculated in accordance with the Standard UNE-EN 13036-1: 2010. This standard may be replaced by others used in any of the other Member States of the European Union, or adhering to the Agreement on the European Economic Area, and in those States that have an agreement of customs association with the European Union, provided that it is shown that they have identical Technical specifications.

Ukraine

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr><td>ДБН В.2.3-4:2015, Автомобільні дороги. Частина І. Проектування
Table 5.5.</td><td>End of table 5.5.:
<table>
<tr><th>Designation of the elements.</th><th colspan="11">Parametres depending of the calculation speed, in km/h</th></tr>
<tr><td>Minimum sight distance:</td><td>30</td><td>40</td><td>50</td><td>60</td><td>70</td><td>80</td><td>90</td><td>100</td><td>110</td><td>120</td><td>130</td></tr>
<tr><td>-For vehicle stopping</td><td>35</td><td>50</td><td>70</td><td>90</td><td>115</td><td>145</td><td>175</td><td>210</td><td>250</td><td>290</td><td>335</td></tr>
<tr><td>-For vehicle attainment</td><td>-</td><td>120</td><td>150</td><td>180</td><td>220</td><td>270</td><td>320</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>
</td></tr>
</table>

USA

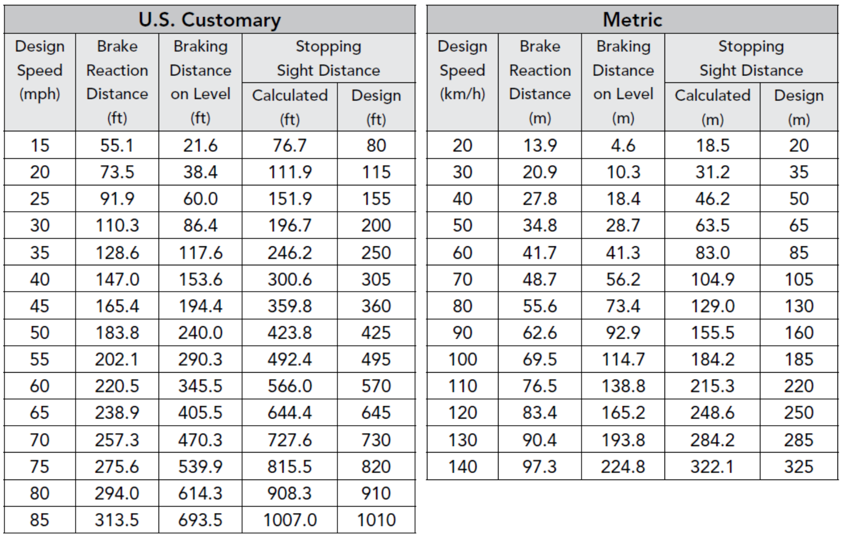
REF.	TEXT
AASHTO GREEN BOOK 2018 § 3.2.4 Stopping Sight Distance	**3.2.2 Stopping Sight Distance** Sight distance is the length of the roadway ahead that is visible to the driver. The available sight distance on a roadway should be sufficiently long to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path. 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. **3.2.2.1 Brake Reaction Time** Brake reaction time is the interval from the instant that the driver recognizes the existence of an obstacle on the roadway ahead that necessitates braking until the instant that the driver actually applies the brakes. Under certain conditions, such as emergency situations denoted by flares or flashing lights, drivers accomplish these tasks almost instantly. Under most other conditions, the driver needs not only to see the object but also to recognize it as a stationary or slowly moving object against the background of the roadway and other objects, such as walls, fences, trees, poles, or bridges. Such determinations take time, and the amount of time needed varies considerably with the distance to the object, the visual acuity of the driver, the driver’s reaction time, the atmospheric visibility, the type and the condition of the roadway, and the nature of the obstacle.

REF.	TEXT
	Vehicle speed and roadway environment probably also influence reaction time. Normally, a driver traveling at or near the design speed is more alert than one traveling at a lesser speed. A driver on a street in an urban area confronted by innumerable potential conflicts with parked vehicles, driveways, and cross streets is also likely to be more alert than the same driver on a limited-access facility where such conditions should be almost nonexistent. However, a driver on an urban street faces a high mental workload in trying to monitor additional conflicts, so there is no assurance that the driver will be able to quickly detect a need for immediate action from among the many potential sources of conflict. The study of reaction times by Johansson and Rumar (*41*) referred to in Section 2.2.6 was based on data from 321 drivers who expected to apply their brakes. The median reaction-time value for these drivers was 0.66 s, with 10 percent using 1.5 s or longer. These findings correlate with those of earlier studies in which alerted drivers were also evaluated. Another study (*46*) found 0.64 s as the average reaction time, while 5 percent of the drivers needed over 1 s. In a third study (*50*), the values of brake reaction time ranged from 0.4 to 1.7 s. In the Johansson and Rumar study (*41*), when the event that prompted application of the brakes was unexpected, drivers' response times were found to increase by approximately 1 s or more; some reaction times were greater than 1.5 s. This increase in reaction time substantiated earlier laboratory and road tests in which the conclusion was drawn that a driver who needed 0.2 to 0.3 s of reaction time under alerted conditions would need 1.5 s of reaction time under normal conditions. Minimum brake reaction times for drivers could thus be at least 1.64 s, 0.64 s for alerted drivers plus 1 s for the unexpected event. Because the studies discussed above used simple prearranged signals, they represent the least complex of roadway conditions. Even under these simple conditions, it was found that some drivers took over 3.5 s to respond. Because actual conditions on the highway are generally more complex than those of the studies, and because there is wide variation in driver reaction times, it is evident that the criterion adopted for use should be greater than 1.64 s. The brake reaction time used in design should be long enough to include the reaction times needed by nearly all drivers under most highway conditions. Studies documented in the literature (*19, 41, 46, 50*) show that a 2.5-s brake reaction time for stopping sight situations encompasses the capabilities of most drivers, including those of older drivers. The recommended design criterion of 2.5 s for brake reaction time exceeds the 90th percentile of reaction time for all drivers and was used in the development of Table 3-1. A brake reaction time of 2.5 s is considered adequate for conditions that are more complex than the simple conditions used in laboratory and road tests, but it is not adequate for the most complex conditions encountered in actual driving. The need for greater reaction time in the most complex conditions encountered on the roadway, such as those found at multiphase at-grade intersections and at ramp terminals on through roadways, can be found in Section 3.2.3, "Decision Sight Distance." **3.2.2.2 Braking Distance** The approximate braking distance of a vehicle on a level roadway traveling at the design speed of the roadway may be determined from the following:  **U.S. Customary** $d_B = 1.075 \frac{V^2}{a}$ where: d_B = braking distance, ft V = design speed, mph a = deceleration rate, ft/s^2 **Metric** $d_B = 0.039 \frac{V^2}{a}$ where: d_B = braking distance, m V = design speed, km/h a = deceleration rate, m/s^2

REF.	TEXT

Studies documented in the literature (*19*) show that most drivers decelerate at a rate greater than 14.8 ft/s^2 [4.5 m/s^2] when confronted with the need to stop for an unexpected object in the roadway. Approximately 90 percent of all drivers decelerate at rates greater than 11.2 ft/s^2 [3.4 m/s^2]. Such decelerations are within the driver's capability to stay within his or her lane and maintain steering control during the braking maneuver on wet surfaces. Therefore, 11.2 ft/s^2 [3.4m/s^2] (a comfortable deceleration for most drivers) is recommended as the deceleration threshold for determining stopping sight distance. Implicit in the choice of this deceleration threshold is the assessment that most vehicle braking systems and the tire-pavement friction levels of most roadways are capable of providing a deceleration rate of at least 11.2 ft/s^2 [3.4 m/s^2]. The friction available on most wet pavement surfaces and the capabilities of most vehicle braking systems can provide braking friction that exceeds this deceleration rate.

Table 3-1. Stopping Sight Distance on Level Roadways



U.S. Customary

Design Speed (mph)	Brake Reaction Distance (ft)	Braking Distance on Level (ft)	Stopping Sight Distance	
			Calculated (ft)	Design (ft)
15	55.1	21.6	76.7	80
20	73.5	38.4	111.9	115
25	91.9	60.0	151.9	155
30	110.3	86.4	196.7	200
35	128.6	117.6	246.2	250
40	147.0	153.6	300.6	305
45	165.4	194.4	359.8	360
50	183.8	240.0	423.8	425
55	202.1	290.3	492.4	495
60	220.5	345.5	566.0	570
65	238.9	405.5	644.4	645
70	257.3	470.3	727.6	730
75	275.6	539.9	815.5	820
80	294.0	614.3	908.3	910
85	313.5	693.5	1007.0	1010

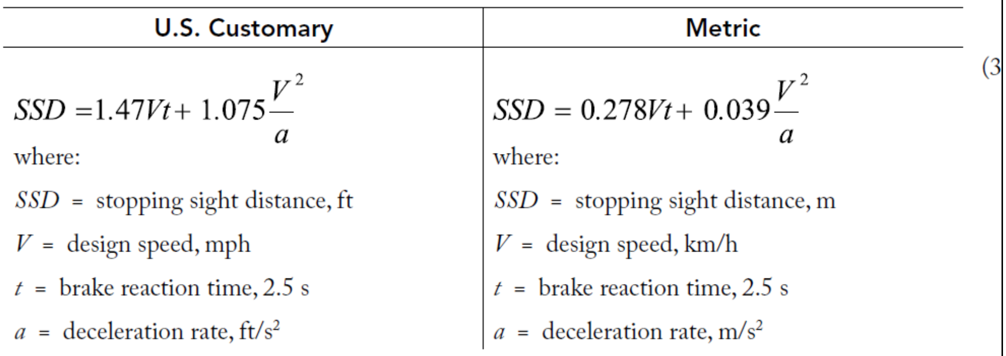
Metric

Design Speed (km/h)	Brake Reaction Distance (m)	Braking Distance on Level (m)	Stopping Sight Distance	
			Calculated (m)	Design (m)
20	13.9	4.6	18.5	20
30	20.9	10.3	31.2	35
40	27.8	18.4	46.2	50
50	34.8	28.7	63.5	65
60	41.7	41.3	83.0	85
70	48.7	56.2	104.9	105
80	55.6	73.4	129.0	130
90	62.6	92.9	155.5	160
100	69.5	114.7	184.2	185
110	76.5	138.8	215.3	220
120	83.4	165.2	248.6	250
130	90.4	193.8	284.2	285
140	97.3	224.8	322.1	325

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 11.2 ft/s^2 [3.4 m/s^2] used to determine calculated sight distance.

3.2.2.3 Design Values

The stopping sight distance is the sum of the distance traversed during the brake reaction time and the distance to brake the vehicle to a stop. The computed distances for various speeds at the assumed conditions on level roadways are shown in Table 3-1 and were developed from the following equation:



U.S. Customary

$$SSD = 1.47Vt + 1.075\frac{V^2}{a}$$

where:

SSD = stopping sight distance, ft

V = design speed, mph

t = brake reaction time, 2.5 s

a = deceleration rate, ft/s^2

Metric

$$SSD = 0.278Vt + 0.039\frac{V^2}{a}$$

where:

SSD = stopping sight distance, m

V = design speed, km/h

t = brake reaction time, 2.5 s

a = deceleration rate, m/s^2

(3

3.2.2.4 Effect of Grade on Stopping

When a highway is on a grade, Equation 3-1 for braking distance is modified as follows:

REF.	TEXT

U.S. Customary

$$d_B = \frac{V^2}{30\left[\left(\frac{a}{32.2}\right) \pm G\right]}$$

where:

d_B = braking distance on grade, ft

V = design speed, mph

a = deceleration, ft/s²

G = grade, rise/run, ft/ft

Metric

$$d_B = \frac{V^2}{254\left[\left(\frac{a}{9.81}\right) \pm G\right]} \qquad (3\text{-}3)$$

where:

d_B = braking distance on grade, m

V = design speed, km/h

a = deceleration, m/s²

G = grade, rise/run, m/m

In this equation, *G* is the rise in elevation divided by the distance of the run and the percent of grade divided by 100, and the other terms are as previously stated. The stopping distances needed on upgrades are shorter than on level roadways; those on downgrades are longer. The stopping sight distances for various grades shown in Table 3-2 are the values determined by using Equation 3-3 in place of the second term in Equation 3-2. These adjusted sight distance values are computed for wet-pavement conditions using the same design speeds and brake reaction times used for level roadways in Table 3-1.

Table 3-2. Stopping Sight Distance on Grades

U.S. Customary						
Design Speed (mph)	Stopping Sight Distance (ft)					
	Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%
15	80	82	85	75	74	73
20	116	120	126	109	107	104
25	158	165	173	147	143	140
30	205	215	227	200	184	179
35	257	271	287	237	229	222
40	315	333	354	289	278	269
45	378	400	427	344	331	320
50	446	474	507	405	388	375
55	520	553	593	469	450	433
60	598	638	686	538	515	495
65	682	728	785	612	584	561
70	771	825	891	690	658	631
75	866	927	1003	772	736	704
80	965	1035	1121	859	817	782
85	1070	1149	1246	949	902	862

Metric						
Design Speed (km/h)	Stopping Sight Distance (m)					
	Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%
20	20	20	20	19	18	18
30	32	35	35	31	30	29
40	50	50	53	45	44	43
50	66	70	74	61	59	58
60	87	92	97	80	77	75
70	110	116	124	100	97	93
80	136	144	154	123	118	114
90	164	174	187	148	141	136
100	194	207	223	174	167	160
110	227	243	262	203	194	186
120	263	281	304	234	223	214
130	302	323	350	267	254	243
140	341	367	398	302	287	274

On nearly all roads and streets, the grade is traversed by traffic in both directions of travel, but the sight distance at any point on the highway generally is different in each direction, particularly on straight roads in rolling terrain. As a general rule, the sight distance available on downgrades is larger than on upgrades, more or less automatically providing the appropriate corrections for grade. This may explain why some designers do not adjust stopping sight distance because of grade. Exceptions are one-way roadways or streets, as on divided highways with independent profiles. For these separate roadways, adjustments for grade may be needed.

3.2.2.5 Variation for Trucks

The recommended stopping sight distances are based on passenger car operation and do not explicitly consider design for truck operation. Trucks as a whole, especially the larger and heavier units, need longer stopping distances for a given speed than passenger vehicles. However, there is one factor that tends to balance the additional braking lengths for trucks with

REF.	TEXT
	those for passenger cars. The truck driver is able to see substantially farther beyond vertical sight obstructions because of the higher position of the seat in the vehicle. Separate stopping sight distances for trucks and passenger cars, therefore, are not generally used in highway design. There is one situation in which the goal should be to provide stopping sight distances greater than the design values in Table 3-1. Where horizontal sight restrictions occur on downgrades, particularly at the ends of long downgrades where truck speeds closely approach or exceed those of passenger cars, the greater height of eye of the truck driver is of little value. Although the average truck driver tends to be more experienced than the average passenger car driver and quicker to recognize potential risks, it is desirable under such conditions to provide stopping sight distance that exceeds the values in Tables 3-1 or 3-2. **3.2.2.5.1 New Construction vs. Projects on Existing Roads** The stopping sight distance criteria in Tables 3-1 and 3-2 are appropriate for use in new construction projects where no constraints are present, since stopping sight distances that meet these criteria can typically be readily implemented. Sight distance improvements for projects on existing roads are often very costly. Recent research (*35*) has found little or no difference in crash experience between crest vertical curves that meet the stopping sight distance criteria in Tables 3-1 and 3-2 and those that do not, except where a design feature where drivers may need to change direction or speed is hidden from the driver’s view. Therefore, in most cases, design elements at which the stopping sight distance is less than shown in Tables 3-1 and 3-2 may be left in place. However, where a roadway feature such as a horizontal curve, an intersection, a driveway, or a ramp terminal is hidden from the driver’s view by the sight distance limitation or where a crash history review as part of the project development process finds a documented crash pattern that may be correctable by a sight distance improvement, improvement of stopping sight distance to the criteria presented in Tables 3-1 and 3-2 should be considered. **3.2.5 Sight Distance for Multilane Highways** There is no need to consider passing sight distance on highways or streets that have two or more traffic lanes in each direction of travel. Passing maneuvers on multilane roadways are expected to occur within the limits of the traveled way for each direction of travel. Thus, passing maneuvers that involve crossing the centerline of four-lane undivided roadways or crossing the median of four-lane roadways should be prohibited. Multilane roadways should have continuously adequate stopping sight distance, with greater-than-design sight distances preferred. Design criteria for stopping sight distance vary with vehicle speed and are discussed in detail in Section 3.2.2, “Stopping Sight Distance.” **3.2.6 Criteria for Measuring Sight Distance** Sight distance is the distance along a roadway throughout which an object of specified height is continuously visible to the driver. This distance is dependent on the height of the driver’s eye above the road surface, the specified object height above the road surface, and the height and lateral position of sight obstructions within the driver’s line of sight. **3.2.6.1 Height of Driver’s Eye** For all sight distance calculations for passenger vehicles, the height of the driver’s eye is considered to be 3.50 ft [1.08 m] above the road surface. This value is based on a study (*19*) that found average vehicle heights have decreased to 4.25 ft [1.30 m] with a comparable decrease in average eye heights to 3.50 ft [1.08 m]. Because of various factors that appear to place practical limits on further decreases in passenger car heights and the relatively small increases in the lengths of vertical curves that would result from further changes that do occur, 3.50 ft [1.08 m] is considered to be the appropriate height of driver’s eye for measuring both stopping and passing sight distances.

REF.	TEXT
	For large trucks, the driver eye height ranges from 3.50 to 7.90 ft [1.80 to 2.40 m]. The recommended value of truck driver eye height for design is 7.60 ft [2.33 m] above the road surface. **3.2.6.2 Height of Object** For stopping sight distance and decision sight distance calculations, the height of object is considered to be 2.00 ft [0.60 m] above the road surface. For passing sight distance calculations, the height of object is considered to be 3.50 ft [1.08 m] above the road surface. **Stopping sight distance object**—The selection of a 2.00-ft [0.60-m] object height was based on research indicating that objects with heights less than 2.00 ft [0.60 m] are seldom involved in crashes (*19*). Therefore, it is considered that an object 2.00 ft [0.60 m] in height is representative of the smallest object that involves risk to drivers. An object height of 2.00 ft [0.60 m] is representative of the height of automobile headlights and taillights. Using object heights of less than 2.00 ft [0.60 m] for stopping sight distance calculations would result in longer crest vertical curves without a documented decrease in the frequency or severity of crashes (*19*). Object height of less than 2.00 ft [0.60 m] could substantially increase construction costs because additional excavation would be needed to provide the longer crest vertical curves. It is also doubtful that the driver's ability to perceive situations involving risk of collisions would be increased because recommended stopping sight distances for high-speed design are beyond most drivers' capabilities to detect objects less than 2.00 ft [0.60 m] in height (*19*). **3.2.6.4 Measuring Sight Distance** The design of horizontal alignment and vertical profile using sight distance and other criteria is addressed in Sections 3.3 through 3.5, including the detailed design of horizontal and vertical curves. Sight distance should be considered in the preliminary stages of design when both the horizontal and vertical alignment are still subject to adjustment. Stopping sight distance can easily be determined where plans and profiles are drawn using computer-aided design and drafting (CADD) systems. The line-of-sight that must be clear of obstructions is a straight line for the driver's eye position to an object on the road ahead, with the height of the driver's eye and the object as given above. The vertical component of sight distance is generally measured along the centerline of the roadway. The horizontal component of sight distance is normally measured along the centerline of the inside lane on a horizontal curve. By determining the available sight distances graphically on the plans and recording them at frequent intervals, the designer can review the overall layout and produce a more balanced design by minor adjustments in the plan or profile. Because the view of the highway ahead may change rapidly in a short travel distance, it is desirable to measure and record sight distance for both directions of travel at each station. Both horizontal and vertical sight distances should be measured and the shorter lengths recorded. In the case of a two-lane highway, passing sight distance should be measured and recorded in addition to stopping sight distance. Sight distance information, such as that presented in Figures 3-34 and 3-36 in Section 3.4.6, may be used to establish minimum lengths of vertical curves. Equation 3-37 can be used for determining the radius of horizontal curve or the lateral offset from the traveled way needed to provide the design sight distance. Examining sight distances along the proposed highway may be accomplished by measuring directly from the horizontal alignment and vertical profile in CADD systems. The following discussion presents a method for computing sight distances. Horizontal sight distance on the inside of a curve is limited by obstructions such as buildings, hedges, wooded areas, high ground, or other topographic features. These are generally plotted on the plans. Horizontal sight distance is measured in CADD along a horizontal roadway alignment. Figure 3-1 illustrates the manual method for measuring sight distance, which is now automated in CADD systems. Preferably, the stopping sight distance should be measured between points on one traffic lane and passing sight distance from the middle of the other lane.

REF.	TEXT

Such refinement on two-lane highways generally is not needed and measurement of sight distance along the centerline or traveled-way edge is suitable. Where there are changes of grade coincident with horizontal curves that have sight-limiting cut slopes on the inside, the line-ofsight intercepts the slope at a level either lower or higher than the assumed average height. In measuring sight distance, the error in use of the assumed 2.75- or 3.50-ft [0.84- or 1.08-m] height usually can be ignored.

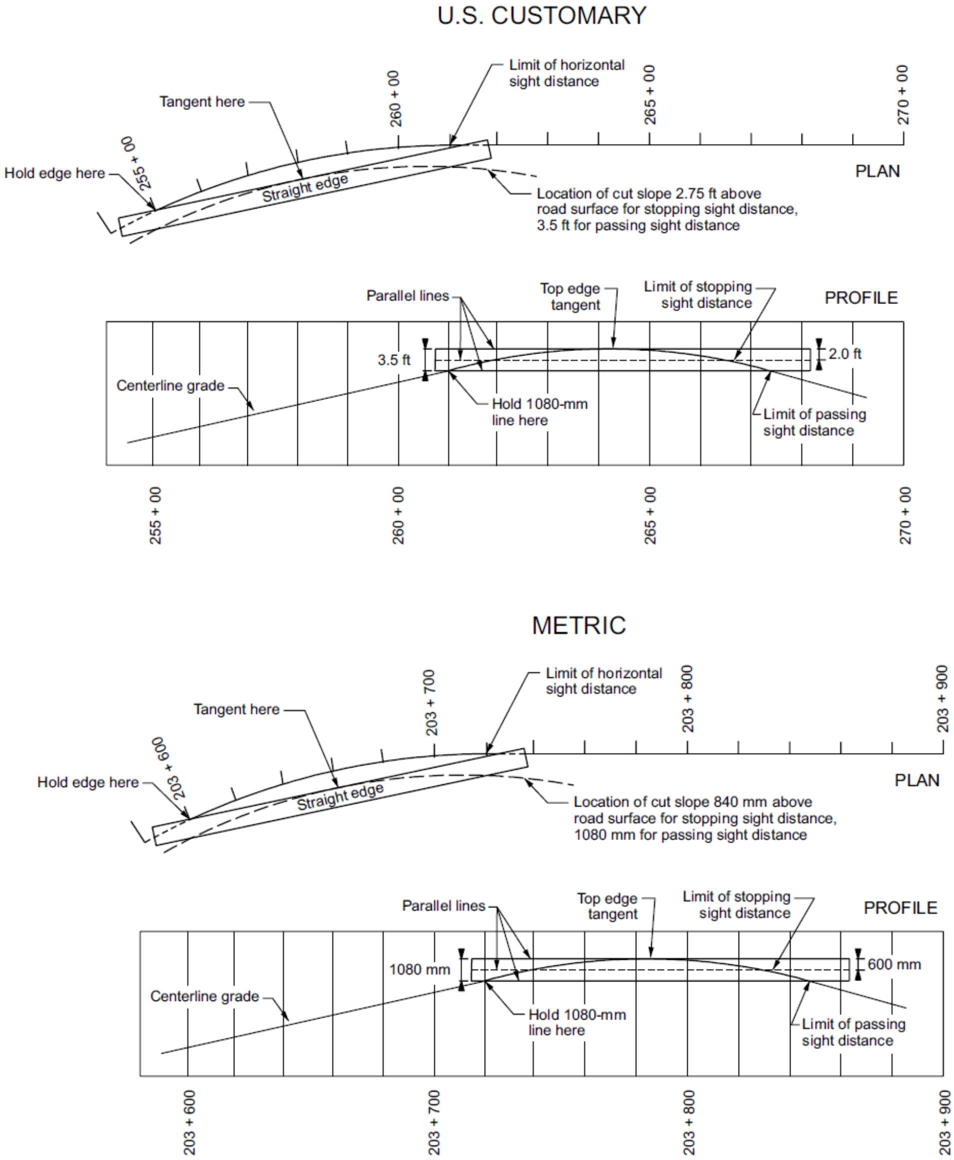


Figure 3-1. Illustration of the Method for Measuring Sight Distance

Sight distance calculations for two-lane highways may be used effectively to tentatively determine the marking of no-passing zones in accordance with criteria given in the MUTCD (*24*).

Sight distance calculations also are useful on two-lane highways for determining the percentage of length of highway on which sight distance is restricted to less than the passing minimum, which is important in evaluating capacity.

3.3.3.4 Effects of grades

On upgrades of 4 percent or more, the maximum superelevation rate should be limited to 9 percent for minimum-radius curves with design speeds of 55 mph [90 km/h] and higher, to minimize the potential for wheel-lift events on tractor semi-trailer trucks. Alternatively, if it can

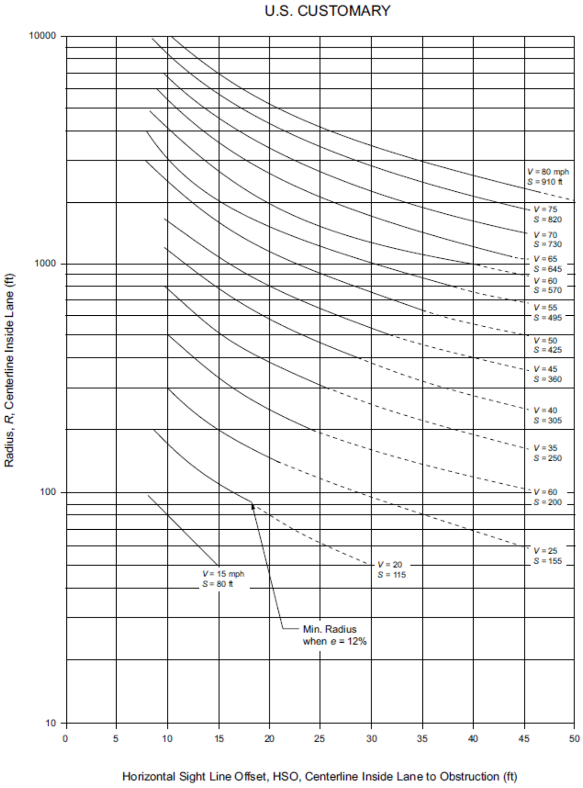
REF.	TEXT

be verified that the available sight distance is such that deceleration at the rate assumed in stopping sight distance design criteria, 11.2 ft/s2 [3.4 m/s2], is unlikely to be needed on upgrades of 4 percent or more, *e*max values up to 12 percent may be used for minimum-radius curves.

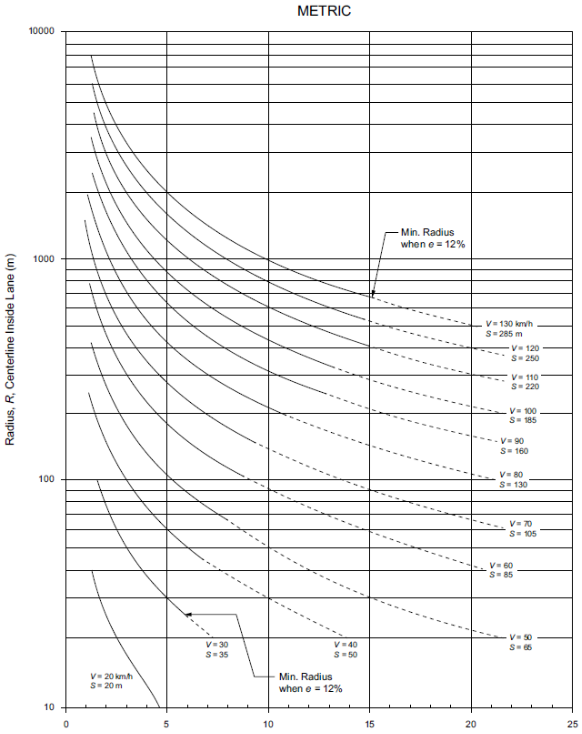
3.3.12.1 Stopping Sight Distance

For general use in design of a horizontal curve, the sight line is a chord of the curve, and the stopping sight distance is measured along the centerline of the inside lane around the curve.

The values of horizontal sight line offset (*HSO*) are determined by setting *S*, as shown in the diagrammatic sketch in Figure 3-13 and in Equation 3-37, equal to the stopping sight distance (*SSD*). Figure 3-14 shows the derived values of *HSO*. Equation 3-37 applies only to circular curves longer than the sight distance for the pertinent design speed. The relationships between *R*, *HSO*, and *V* in this chart can be quickly checked. For example, with a 50-mph [80-km/h] design speed and a curve with a 1,150-ft [350-m] radius, a clear sight area with a horizontal sight line offset of approximately 20 ft [6.0 m] is needed for stopping sight distance. As another example, for a sight obstruction at a distance *HSO* equal to 20 ft [6.0 m] from the centerline of the inside lane on a curve with a 575-ft [175-m] radius, the sight distance needed is approximately at the upper end of the range for a speed of approximately 40 mph [60 km/h].



REF.	TEXT



Horizontal Sight Line Offset, HSO, Centerline Inside Lane to Obstruction (m)

Figure 3-14. Horizontal Sightline Offset (HSO) to Provide Stopping Sight Distance on Horizontal Curves (Continued)

Horizontal sight restrictions may occur where there is a cut slope on the inside of the curve. For the 3.50 ft [1.08 m] eye height and the 2.00-ft [0.60-m] object height used for stopping sight distance, a height of 2.75 ft [0.84 m] may be used as the midpoint of the sight line where the cut slope usually obstructs sight. This assumes that there is little or no vertical curvature. For a highway with a 22 ft [6.6-m] traveled way, 4-ft [1.2-m] shoulders, an allowance of 4 ft [1.2 m] for a ditch section, and 1V:2H cut slopes (1 ft or 1 m vertically for each, 2 ft or 2 m horizontally), the sight obstruction is approximately 19 ft [5.75 m] outside the centerline of the inside lane.

This is sufficient for adequate sight distance at 30 mph [50 km/h] when curves have a radius of about 275 ft [90 m] or more and at 50 mph [80 km/h] when curves have a radius of about 1,230 ft [375 m] or more. Curves sharper than these would need flatter slopes, benching, or other adjustments. At the other extreme, highways with normal lateral dimensions of more than 52 ft [16 m] provide adequate stopping sight distances for horizontal curves over the entire range of design speeds and curves.

In some instances, retaining walls, bridge rails, concrete median barriers, and other similar features constructed on the inside of curves may be sight obstructions and should be checked for stopping sight distance. As an example, an obstruction of this type, located 4 ft [1.2 m] from the inside edge of a 24-ft [7.2-m] traveled way, has a horizontal sight line offset of approximately 10 ft [3.0 m]. At 50 mph [80 km/h], this provides sufficient sight distance when a curve has a radius of about 2,300 ft [700 m] or more. If the obstruction is moved an additional 1 ft [0.3 m] away from the roadway, creating a horizontal sight line offset of 11 ft [3.3 m], a curve with a radius of 2,000 ft [625 m] or more provides sufficient sight distance at the same 50 mph [80 km/h] speed.

The same finding would be applicable to existing buildings or similar sight obstructions on the inside of curves.

REF.	TEXT
	Where sufficient stopping sight distance is not available because a railing or a longitudinal barrier constitutes a sight obstruction, alternative designs should be considered. The alternatives are: (1) increase the offset to the obstruction, (2) increase the radius, or (3) reduce the design speed. However, the alternative selected should not incorporate shoulder widths on the inside of the curve in excess of 12 ft [3.6 m] because of the concern that drivers will use wider shoulders as a passing or travel lane. As can be seen from Figure 3-14, the method presented is only exact when both the vehicle and the sight obstruction are located within the limits of the simple horizontal curve. When either the vehicle or the sight obstruction is situated beyond the limits of the simple curve, the values obtained are only approximate. The same is true if either the vehicle, the sight obstruction, or both are situated within the limits of a spiral or a compound curve. In these instances, the value obtained would result in horizontal sight line offset values slightly larger than those needed to satisfy the desired stopping sight distance. In many instances, the resulting additional clearance will not be significant. Whenever Figure 3-14 is not applicable, the design should be checked either by utilizing graphical procedures or by utilizing a computational method. Raymond (*52*) provides a computational method for making such checks. Figure 3-14 is a design chart showing the horizontal sight line offsets needed for clear sight areas to provide the stopping sight distances presented in Table 3-1 for horizontal curves of various radii on flat grades. Figure 3-14 includes radii for all superelevation rates to a maximum of 12 percent. For the curves shown in Figure 3-14, the end of the solid line on the curve is the minimum radius where the superelevation is equal to 12 percent. The dashed portion of the curve is equal to values less than the standard minimum radius for a maximum superelevation rate of 12 percent.

ANNEX B – OVERTAKING SIGHT DISTANCE

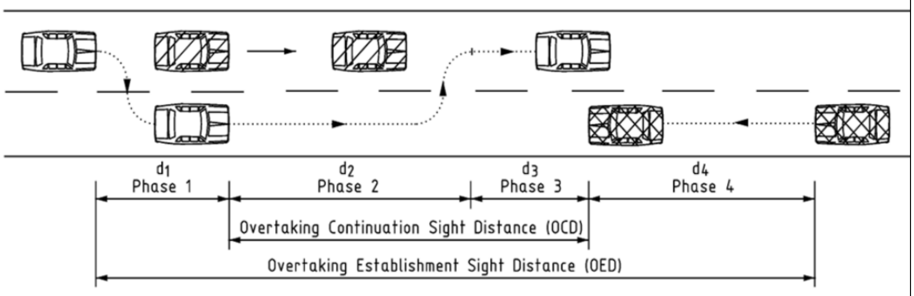
Australia

REF.	TEXT
Austroads Guide to Road Design (AGRD) Part 3 Cap. 5.6	5.6 Overtaking Sight Distance 5.6.1 General Overtaking sight distance is the distance required for the driver of a vehicle to safely overtake a slower moving vehicle without interfering with the speed of an oncoming vehicle. It is measured between the driver’s eye height (1.1 m) of the overtaking vehicle and the object height of an oncoming vehicle (1.25 m). Small dips may create uncertainty for drivers if sight distance to the pavement surface is not available, as the dip could conceal an oncoming vehicle. For this reason, designers should ensure that the road pavement is continuously visible for at least the minimum overtaking sight distance prescribed in Table 5.8 and Table 5.9. Overtaking sight distance is considered only on high speed, two-lane two-way roads. On these roads, the overtaking of slower moving vehicles is only possible when there is a suitable gap in the oncoming traffic accompanied by sufficient sight distance and appropriate line marking. Sections with adequate overtaking sight distance should be provided as frequently as possible, as they are an essential safety measure by reducing driver

REF.	TEXT
	frustration and risk taking. The desirable frequency is related to the operating speed, traffic volume and composition, terrain and construction cost. Overtaking demand increases rapidly as traffic volume increases, while overtaking capacity in the opposing lane decreases as volume increases. As a general rule, if overtaking sight distance cannot be economically provided at least once in each 5 km of road or the operating speed divided by 20 (km) which is three to five minutes of driving time apart, (Troutbeck 1981), consideration should be given to the construction of overtaking lanes (Section 9.4). In practice, overtaking zones will usually be the fortuitous result of road alignment and cross-section. Because of the large sight distances involved, it is often not practical to achieve overtaking zones through design alone (costly to provide). However, good design practice will include a check on the overtaking zones that are provided and may result in cases where an overtaking zone can be achieved through a practical refinement of the design. More commonly though, the proportion of road that provides overtaking is used in conjunction with traffic volumes to assess the level of service provided by a section of road and hence determine whether overtaking lanes are warranted. The Austroads parameters for determining the start and finish of overtaking zones dictate that there are few passing opportunities on New Zealand roads. The New Zealand practice to provide a desirable minimum overtaking sight distance for vertical curve design is to double safe stopping sight distance. (5.6.2) Overtaking Model The overtaking manoeuvre has a large number of variables, such as the: • judgement of the overtaking driver and the risks the driver is prepared to take • speed and size of vehicles to be overtaken • speed of the overtaking vehicle • speed of a potential oncoming vehicle • evasive action or braking undertaken by the vehicle or the overtaken vehicle. Overtaking is assessed by means of a model that was derived from research into overtaking on Australian rural roads (Troutbeck 1981). There are two main considerations with the overtaking model (Figure 5.5): • Establishment: A minimum sight distance that is adequate to encourage a given proportion of drivers to commence an overtaking manoeuvre. This is called the Overtaking Establishment Sight Distance (OED) as it establishes a length of road as a potential overtaking zone. OED is the sight distance required for most drivers of passenger cars to overtake other vehicles. • Continuation: A critical sight distance, which if maintained for some length of road after the OED has become available, will enable an overtaking driver to either complete or abandon a manoeuvre already commenced with safety. This is called the Overtaking Continuation Sight Distance (OCD). After the establishment sight distance first becomes available, an overtaking zone is assumed to extend as long as this shorter distance remains available, subject to the constraint in the next paragraph.

REF.	TEXT

Figure 5.5: **Overtaking manoeuvre**



(5.6.3) Determination of Overtaking Provision The values in this Guide (refer Table 5.8 and Table 5.9) are the distances for the 85th percentile overtaking manoeuvres, adopted from the research ARRB undertook during a major research project on overtaking on Australian rural roads (Troutbeck 1981). These distances indicate the overtaking sight distances to be used in determining the overtaking zones on MCV (multiple combination vehicle) routes. Briefly, Overtaking Establishment Sight Distance (OED, that corresponds to OSD) is derived from the size of the time gap accepted by a potential overtaking driver and is derived by the time taken to complete phases 1, 2, 3 and 4 of the total manoeuvre (Figure 5.5) and calculated using Equation 2.

$$\mathrm{OED} = G_{\mathrm{T85}} \frac{(V+u)}{3.6}$$

Where

GT85 = 85th percentile critical time gap secs

u = V/1.17 (speed of slow vehicle)

V = operating speed

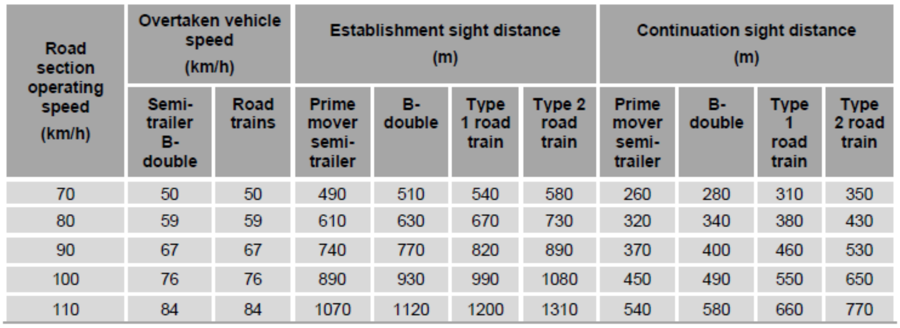
Overtaking Continuation Sight Distance (OCD) is derived from the time taken to complete phases 2 and 3 of the manoeuvre (Figure 5.5) on the following basis:

- The oncoming vehicle is assumed to travel at the operating speed.
- The overtaken vehicle is assumed to travel at a lesser speed, taken as the mean speed for its direction of travel.
- The sight distances with the 1.1 m driver eye height to 1.25 m object height are used in this guide.
- The distance travelled by oncoming traffic is represented in Figure 5.5 by phase 4.

In checking a length of road, the OCD will be found to be the critical parameter in allocating a ‘per cent allowing overtaking’ to the road section. The OCD ensures that the road distance used by the overtaking vehicle would be visible at the ‘point of no return’, and an approaching vehicle would be visible if it is within the zone where it could affect the manoeuvre.

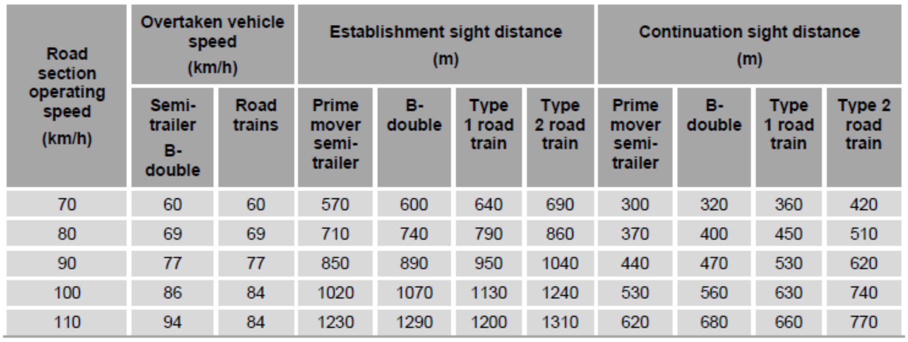
REF.	TEXT

Table 5.8: Overtaking sight distances for determining overtaking zones on MCV routes when MCV speeds are 10 km/h less than the operating speed



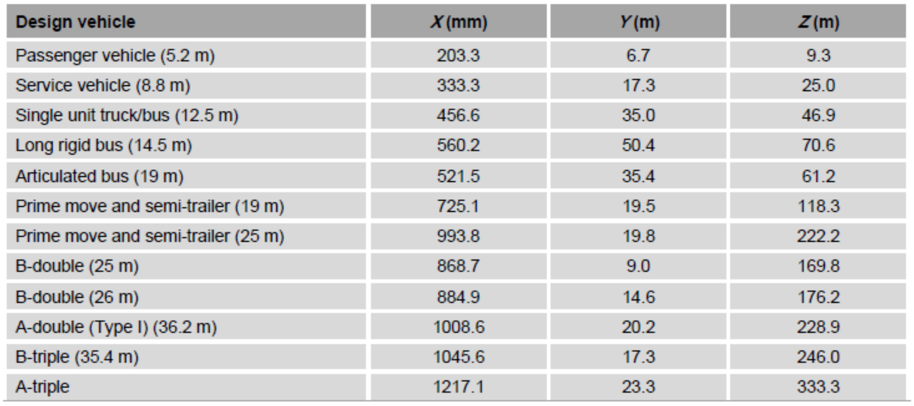
Road section operating speed (km/h)	Overtaken vehicle speed (km/h)		Establishment sight distance (m)				Continuation sight distance (m)			
	Semi-trailer B-double	Road trains	Prime mover semi-trailer	B-double	Type 1 road train	Type 2 road train	Prime mover semi-trailer	B-double	Type 1 road train	Type 2 road train
70	50	50	490	510	540	580	260	280	310	350
80	59	59	610	630	670	730	320	340	380	430
90	67	67	740	770	820	890	370	400	460	530
100	76	76	890	930	990	1080	450	490	550	650
110	84	84	1070	1120	1200	1310	540	580	660	770

Table 5.9: Overtaking sight distances for determining overtaking zones on MCV routes when MCV speeds are equal to the operating speed



Road section operating speed (km/h)	Overtaken vehicle speed (km/h)		Establishment sight distance (m)				Continuation sight distance (m)			
	Semi-trailer B-double	Road trains	Prime mover semi-trailer	B-double	Type 1 road train	Type 2 road train	Prime mover semi-trailer	B-double	Type 1 road train	Type 2 road train
70	60	60	570	600	640	690	300	320	360	420
80	69	69	710	740	790	860	370	400	450	510
90	77	77	850	890	950	1040	440	470	530	620
100	86	84	1020	1070	1130	1240	530	560	630	740
110	94	84	1230	1290	1200	1310	620	680	660	770

Table C19 2: Vehicle specific dimensions



Design vehicle	*X* (mm)	*Y* (m)	*Z* (m)
Passenger vehicle (5.2 m)	203.3	6.7	9.3
Service vehicle (8.8 m)	333.3	17.3	25.0
Single unit truck/bus (12.5 m)	456.6	35.0	46.9
Long rigid bus (14.5 m)	560.2	50.4	70.6
Articulated bus (19 m)	521.5	35.4	61.2
Prime move and semi-trailer (19 m)	725.1	19.5	118.3
Prime move and semi-trailer (25 m)	993.8	19.8	222.2
B-double (25 m)	868.7	9.0	169.8
B-double (26 m)	884.9	14.6	176.2
A-double (Type I) (36.2 m)	1008.6	20.2	228.9
B-triple (35.4 m)	1045.6	17.3	246.0
A-triple	1217.1	23.3	333.3

Note: Values calculated for 25 m semi-trailer will be slightly larger than required, due to the cab of the truck being narrower than the trailer.

Belgium

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr><td>CT.98.12(01), Caractéristiques routières et autoroutières
2.2.4.2</td><td>

Overtaking Distance (OD)

The OD is obtained by the following simplified expression:

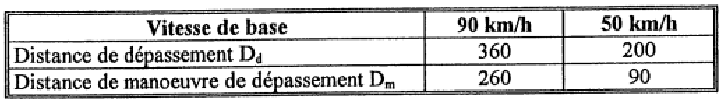
OD = 4 x V

Where V is the base speed. This OD is double the distance strictly necessary for overtaking in order to take into account the appearance of a vehicle arriving in the opposite direction at the same speed.

Overtaking manoeuvre distance (OMD)

The OMD is the distance allowing a vehicle, which has started an overtaking manoeuvre to renounce it by braking in the event of the appearance of a vehicle arriving in the opposite direction.

The OD (D_d) and OMD (d_m) are given according to the base speed* in table 2 below.

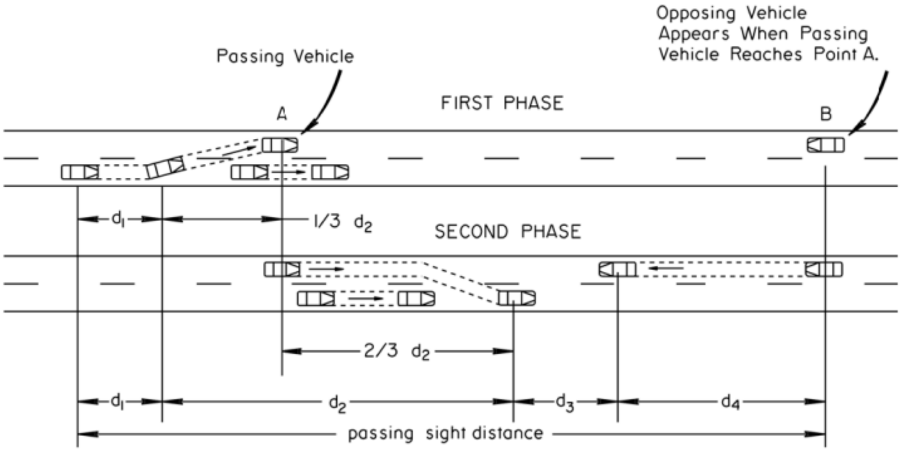


<table>
<tr><th>Vitesse de base</th><th>90 km/h</th><th>50 km/h</th></tr>
<tr><td>Distance de dépassement D_d</td><td>360</td><td>200</td></tr>
<tr><td>Distance de manoeuvre de dépassement D_m</td><td>260</td><td>90</td></tr>
</table>

* the base speed looks like “speed limit”.

</td></tr>
</table>

Canada

REF.	TEXT
Standards for geometric design of roads § B.2.4 Passing Sight Distance (linked to AASHTO 2004 models)	**Figure B-2-4a Elements of Passing Sight Distance for Two-Lane Undivided Highways** **(source: Exibit 3-4, AASHTO 2004)**  $d_1 = \frac{t_1}{3.6}(V - m + \frac{a\, t_1}{2})$ Where: - d_1 = the distance travelled during the initial manoeuvre - t_1 = time of the initial manoeuvre (s) - V = average speed of the passing vehicle (km/h) - m = difference in speed between passing and passed vehicle (km/h) - a = average acceleration (km/h/s) The time, average speed and average acceleration varies depending on the design speed **Distance while passing occupies left lane (d_2)** In studies, passing vehicles have been found to occupy the left lane from 9.3 to 10.4 seconds, depending on the design speed. These studies involved extensive field observations of driver behavior during passing manoeuvres. The distance travelled in the left lane by passing vehicle is: $d_2 = \frac{V\, t_2}{3.6}$ Where: - d_2 = the distance travelled while the passing vehicle occupies the left lane - V = average speed of the passing vehicle (km/h) - t_2 = time the passing vehicle occupies the left lane (s) **Clearance Length (d_3)**

REF.	TEXT

The clearance length between the opposing and passing vehicles at the end of the manoeuvre found in the passing study varied from 33 to 92 m. This length increases with increased design speed.

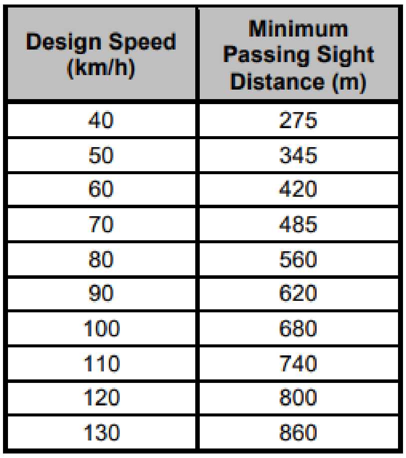
Distance traversed by an opposing vehicle (D_4)

Passing sight distance includes the distance traversed by an opposing vehicle during the passing manoeuvre to minimize the chance of a passing vehicle meeting an opposing vehicle while in the left lane. Conservatively, this should be the distance traversed by an opposing vehicle during the time it takes to complete a pass, or the time that the passing vehicle occupies the left lane. Such a distance is questionably long. During the first phase of the passing manoeuvre, the passing vehicle has not yet pulled alongside the vehicle being passed. Even though the passing vehicle occupies the left lane, its driver can return to the right lane if an opposing vehicle is seen. It is unnecessary to include this trailing time interval in computing the distance traversed by an opposing vehicle. This time interval, which can be computed from the relative positions of passing and passed vehicle, is about one-third the time the passing vehicle occupies the left lane. Therefore, the passing sight distance element for the opposing vehicle is the distance it traverses during two-thirds of the time the passenger vehicle occupies the left lane. The opposing vehicle is assumed to be travelling at the same speed as the passing vehicle, so:

$$d_4 = \frac{2\, d_2}{3}$$

The minimum passing sight distances for two-lane undivided highways are indicated in Table B-2-4a.

Table B-2-4a Minimum Passing Sight Distance on Two-Lane Undivided Highways



Design Speed (km/h)	Minimum Passing Sight Distance (m)
40	275
50	345
60	420
70	485
80	560
90	620
100	680
110	740
120	800
130	860

Chile

REF.	TEXT

<table>
<tr>
<td>30.06.2020, Highways Manual - Volume N ° 3 Instructions and

3.202.3</td>
<td>

3.202.3 Overtaking Sight Distance

The classic approach developed by AASHTO to calculate Da (OSD) implies defining a series of variables and situations that make up a model, generally conservative, of the different realities that arise in practice. Contrasting the values recommended by AASHTO with those used in Germany, Spain and Great Britain, mean values corresponding to the European trend were adopted, which are around 5% to 10% lower than those of AASHTO.

TABLE 3.202.3.A

MINIMUM OVERTAKING DISTANCE

<table>
<tr><th>Design Speed (km/h)</th><th>Minimum OSD (m)</th></tr>
<tr><td>30</td><td>180</td></tr>
<tr><td>40</td><td>240</td></tr>
<tr><td>50</td><td>300</td></tr>
<tr><td>60</td><td>370</td></tr>
<tr><td>70</td><td>440</td></tr>
<tr><td>80</td><td>500</td></tr>
<tr><td>90</td><td>550</td></tr>
<tr><td>100</td><td>600</td></tr>
</table>

3.202.301 Effect of slopes on the Passing Distance

The analysis of the speed distribution presented in sheets 3.102.404.A and B indicates that light vehicles only see their speed affected on very steep climbs. The different standards analyzed do not introduce corrections to the overtaking distance due to the effect of the slope, however, the acceleration capacity is less than on flat terrain and therefore it is convenient to consider a safety margin for slopes greater than +6.0%, according to is noted below:

- on slopes > 6.0%, use Da corresponding to Vp+10 km/h;
- If Vp = 100 km/h consider in these cases Da ≥ 650 m:

</td>
</tr>
</table>

Czechia

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr>
<td>ČSN 73 6101 Projektování silnic a dálnic (Design of Highways and Motorways)</td>
<td>

Overtaking and length of view

The overtaking sight distance OSD is four times view lengths for stopping at zero longitudinal inclination D_z (i = 0%): OSD = 4 D_z

Overtaking must be ensured when designing directionally undivided I and II roads classes by designing overtaking sections, namely:

- a) for roads with a viewing intensity ≤ 10,000 cars / day by inserting a section with a viewing length of at least 4 x Dz.0 every 8 km;

</td>
</tr>
</table>

REF.	TEXT
"Příloha B (normativní) Výpočet délky rozhledu pro zastavení nebo předjíždění" (Calculating sight distance for stopping or overtaking)	• b) for roads with a prospective intensity > 10 000 vehicles / day by increasing the number of lanes according to 9.5 every 12 km. When designing a road section shorter than 8 km, resp. 12 km, the following sections will be assessed for the possibility of overtaking. In the event that overtaking is not ensured in the following sections, measures must be proposed for overtaking on the solved section of the road. **For the estimation of Dz (i=0%)** The length of the view on a given section of road is decisive for the choice of the type of dividing line separating the opposite lanes. If in a specific case the values of the view length for stopping and the view length for overtaking are available according to ČSN 73 6101 (roads in open countryside) or ČSN 73 6110 (transit sections of municipal roads and local roads), these design lines are used to select the type of dividing line elements. If the above-mentioned design elements are not available for a specific case, it is based on the determination of the minimum view length (D_{min}), below the value of which it is desirable to use a longitudinal line continuous to prevent penetration into the part of the road intended for traffic in the opposite direction. The minimum viewing length means the distance at which the observer can see from a position 1 m above the ground level an object located 1 m above the ground level. This distance is affected by a number of factors, especially the speed of travel on the road section. The default is considered to be a speed not exceeding 85% of the vehicles or the maximum permitted speed in the section, if higher. Recommended D_{min} values derived from "section speed"**: • 100 km / h from 250 m to 320 m; • 90 km / h from 200 m to 250 m; • 80 km / h from 150 m to 200 m; • 60 km / h from 100 m to 150 m; • 50 km / h from 60 m to 100 m. ** It seems to be equal to design speed

France

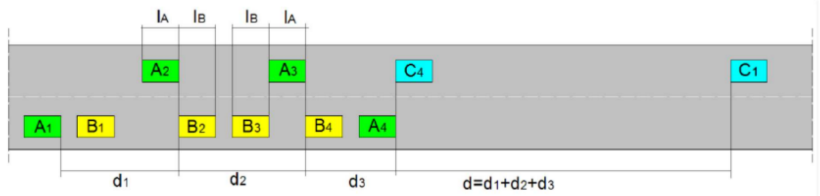
REF.	TEXT
ARP – Aménagement des routes principals (Handbook on design of major roads) 4.2. Exigences de visibilité Point d)	**Visibility for overtaking (OSD)***** This point concerns 2-lane roads, or 3-lane roads whose central lane is not assigned to a traffic direction.

REF.	TEXT
	In practice, only visibility distances of the order of 500 m and more make it possible to ensure, for a significant percentage (30 to 50%) of situations (relative speeds of vehicles present, etc.), possibilities of overtaking sure. It is reasonable to seek to ensure such visibility distances (> 500 m) over a proportion of at least 25% of the length of the project (avoiding, if possible, concentrating this 25% on a single section of the route). Outside these zones, no constraint relating to the visibility of overtaking is to be taken into account. It should be noted that this objective (visibility greater than 500 m over 25% of the route) generally requires a much higher percentage of straight alignments, as straight alignments may suffer from visibility limitations due to the longitudinal profile (or contain intersections with central layout where overtaking is not possible). When the proportion of 25% is not reached, overtaking slots can make it possible to offer additional possibilities for overtaking. On very short projects, we can examine the overtaking visibility requirements on a portion of the route integrating symmetrically the track located on either side of the project (portion whose total length can go up to 5 km). Observation point: height 1 m, located on the axis of the roadway. Observed point: height 1 m, located on the axis of the roadway (3-lane road) or on the axis of the lane in the opposite direction (2-lane road; to simplify manual calculations, a point can be taken on the axis of the roadway). *** the French standards, from which the distance is taken, also contemplate for the creation of a central overtaking lane with two-way traffic.

Germany

REF.	TEXT
Richtlinienfür die Anlage von Landstraßenfür die Anlage von Landstraßen Ausgabe 2012 RAL §5.5.4	**Visibility and overtaking** To be able to overtake a lorry and complete it safely, visibility of at least 600 m is required. If the existing visibility is between 300 m and 600 m in dual carriageways it is not always clearly recognizable for the driver if he can use the visible part of a road for overtaking purposes, taking into account any oncoming traffic that may appear. If this critical area cannot be avoided through planning measures, it should be checked whether overtaking should be prohibited for safety reasons or whether overtaking slow-moving vehicles can remain permitted using additional 1049-11 VzKat signage. To safely overtake slow-moving vehicles, a visual range of at least 300 m is required.

Italy

REF.	TEXT
D.M. 5/11/2001 N°6792 5.1.3 Distanza di visibilità per il sorpasso (Overtaking sight distance)	**Overtaking sight distance (OSD)** The visibility distance for overtaking is a function of the design speed (V, km/h): OSD = 5.5 x V. The background model of the function is shown in the following image****. Overtaking takes place at constant speed in three phases: t1 = 4 s, t2 = 2 s and t3 = 4 s.  **** The phases are not described in the italian standard but are extracted from other literature references.

Mexico

REF.	TEXT
Manual de Proyecto Geométrico (Manual for Road Geometric Design, 2018) F.3.3. Distancia de visibilidad de rebase	**Passing sight distance** A section of road is said to have passing sight distance when the sight distance in that section is sufficient for the driver of a vehicle to overtake another vehicle traveling in the same lane, in the presence of a third vehicle traveling in the opposite direction. To define the minimum visibility distance for passing, the manoeuvre has been simulated, considering operating hypotheses that are not always fulfilled in reality. For example, in the United States of America (USA), this manoeuvre was characterized and the results indicated that the variation of the passing sight distance is almost linear with speed. According to the above, it is reasonable to establish passing sight distances equivalent to the distance travelled in 18 seconds at design speed, which would be above those currently recommended in the USA (bibliography 4.). Then, the minimum passing sight distance, DR in m, can be determined from the design speed, Vp in km/h, with the expression: $D_R = 7.5\ V_p$ **Grade Effect**

REF.	TEXT
	On vertical tangents with steep grades, the sight distance required to pass safely increases. The passing manoeuvre is easier for the vehicle traveling downhill because the driver can accelerate more quickly than on level ground and therefore can reduce the time needed to pass; however, because the passed vehicle can easily accelerate as well, undesirable competitive situations are created. The distances required for vehicles to pass safely uphill are greater than those required on level roads because the passing vehicle's ability to accelerate is reduced. This is somewhat offset by the fact that the vehicles passed are often trucks that slow down substantially on the climb. For passing manoeuvres to be carried out safely on ascending slopes, the passing sight distance will be greater than the calculated minimum. Although adjustments during the project are unavoidable, the designer must recognize the convenience of increasing the calculated values as much as possible. **Frequency and length of passing sections** The frequency and length of sections with sufficient visibility to pass depends mainly on the topography of the terrain, the design speed of the road and the cost involved. High-ranking two-lane highways must have enough stretches to carry out passing manoeuvres safely. If, in addition, high volumes of traffic are expected with significant percentages of trucks, it is virtually mandatory to provide enough stretches with adequate visibility to maintain the expected service levels and, particularly, to reduce transport operating cost overruns and accident rates. The capacity analyses (reference 4.) provide the elements to determine, in each case, the frequency and length of the stretches to be passed. F.3.3.3. Passing on multi-lane highways On highways with two or more lanes in each direction, it is not necessary to consider passing sight distances, since it is assumed that the manoeuvres are carried out in adjacent lanes with the same direction of traffic. Manoeuvres in which vehicles from one direction have to cross or encroach on the other's lanes, for example, passing or left or U-turns, are dangerous and should be avoided; That is why physical dividers between directions must be designed, such as separating strips or safety barriers.

Poland

REF.	TEXT
Regulation of the Minister of Transport and Maritime Economy on technical conditions for public roads and their location.	The Overtaking Visibility Distance is related to the “Road speed decisive”, that is comparable with a road design speed. The following table shows on the first row the values of speed (V) and in the second the value of overtaking visibility distance (OSD):

Regulation, No 43, pos. 430.1999 Part 2, Cap. 2, Page 2417	V (km/h)	120	110	100	90	80	70	60
	OSD (m)	700	650	600	550	500	450	400

Portugal

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr>
<td>NORMA DE TRAÇADO
REVIS ÃO
II.6 VISIBILITADE</td>
<td>
The overtaking manoeuvre varies greatly from driver to driver, from vehicle to vehicle, and also depends on the speed of the vehicle being overtaken.

Overtaking must be carried out without a vehicle traveling in the opposite direction and seen at the beginning of the overtaking manoeuvre having to reduce speed.

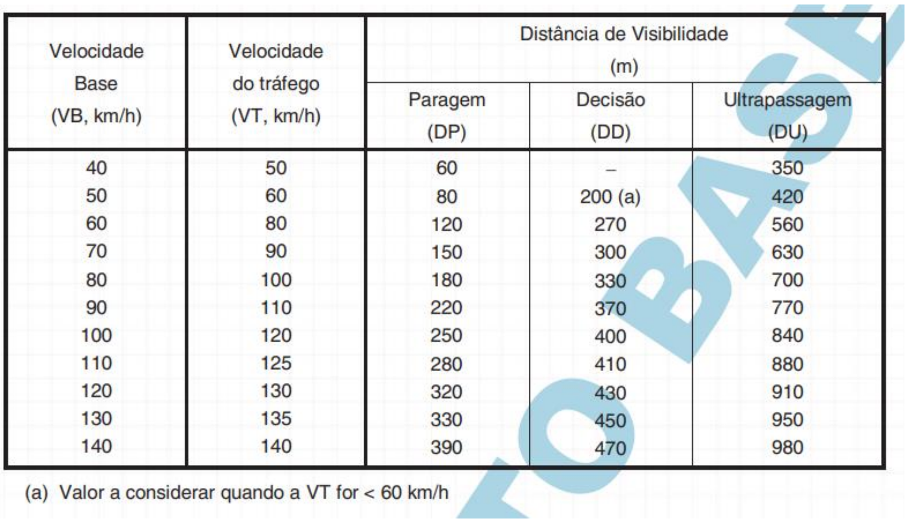
The overtaking sight distance is the minimum sight distance necessary for the driver of a vehicle to pass another vehicle safely and comfortably.

The overtaking visibility distance is only to be considered on two-lane roads. In certain cases it is more economical to build passing zones with three or four lanes, rather than ensuring the passing sight distance.

It is evident that the greater the visibility distance, the greater the number of drivers capable of carrying out the overtaking manoeuvre, therefore, as large a visible distance as possible is desirable.

Table IV shows the values of the overtaking sight distance corresponding to the different speeds. For the purposes of this Standard, the passing sight distance (DU, in m) can be determined by the following empirical expression, as a function of the “traffic speed” (VT, in km/h):

$$DU = 7\,VT$$
Where VT = “traffic speed” corresponding to operating speed (85% percentile)


<table>
<tr><th rowspan="2">Velocidade Base (VB, km/h)</th><th rowspan="2">Velocidade do tráfego (VT, km/h)</th><th colspan="3">Distância de Visibilidade (m)</th></tr>
<tr><th>Paragem (DP)</th><th>Decisão (DD)</th><th>Ultrapassagem (DU)</th></tr>
<tr><td>40</td><td>50</td><td>60</td><td>–</td><td>350</td></tr>
<tr><td>50</td><td>60</td><td>80</td><td>200 (a)</td><td>420</td></tr>
<tr><td>60</td><td>80</td><td>120</td><td>270</td><td>560</td></tr>
<tr><td>70</td><td>90</td><td>150</td><td>300</td><td>630</td></tr>
<tr><td>80</td><td>100</td><td>180</td><td>330</td><td>700</td></tr>
<tr><td>90</td><td>110</td><td>220</td><td>370</td><td>770</td></tr>
<tr><td>100</td><td>120</td><td>250</td><td>400</td><td>840</td></tr>
<tr><td>110</td><td>125</td><td>280</td><td>410</td><td>880</td></tr>
<tr><td>120</td><td>130</td><td>320</td><td>430</td><td>910</td></tr>
<tr><td>130</td><td>135</td><td>330</td><td>450</td><td>950</td></tr>
<tr><td>140</td><td>140</td><td>390</td><td>470</td><td>980</td></tr>
</table>
(a) Valor a considerar quando a VT for < 60 km/h

As explained in §II.5 of the standard, the “base speed” and “traffic speed” are defined as it follows:

• The “base speed” is “an arbitrary speed in the elaboration of a road project, which conditions some of the geometric characteristics of the road”, so it is comparable with the “design speed”.
• The “traffic speed” corresponding to the 85th percentile, which is taken as the “traffic speed”, is normally considered a critical speed, because small increases in the percentile from the 85th
</td>
</tr>
</table>

REF.	**TEXT**
	correspond to large increases in speed and speeds above this are normally dangerous for the most difficult conditions. considered unfavourable, so it is comparable with the operating speed at 85th percentile.

Spain

<table>
<tr><th>REF.</th><th>TEXT</th></tr>
<tr>
<td>Norma 3.1-IC Trazado, de la Instrucción de Carreteras

3.2.3 DISTANCIA DE ADELANTAMIENTO

3.2.4 VISIBILIDAD DE ADELANTAMIENTO
.</td>
<td>**3.2.3 PASSING DISTANCE**

For the purposes of applying this Standard and calculating the sections with overtaking distance on conventional roads, overtaking distance D_a is defined as the distance necessary for a vehicle to overtake another that is traveling at a slower speed, in the presence of a third that circulates in the opposite direction. It will be measured along the axis that separates the two directions of circulation and will be obtained taking into account the following conditions:

To start the overtaking ban (end of the discontinuous road marking), values less than those of the D_{a1} distance indicated in Table 3.2.

TABLA 3.2.
<table>
<tr><td>V_p (km/h)</td><td>40</td><td>50</td><td>60</td><td>70</td><td>80</td><td>90</td><td>100</td></tr>
<tr><td>D_{a1} (m)</td><td>50</td><td>75</td><td>100</td><td>130</td><td>165</td><td>205</td><td>250</td></tr>
</table>
To end the overtaking ban (beginning of the discontinuous road marking), the D_{a2} distance values indicated in Table 3.3.

TABLA 3.3.
<table>
<tr><td>V_p (km/h)</td><td>40</td><td>50</td><td>60</td><td>70</td><td>80</td><td>90</td><td>100</td></tr>
<tr><td>D_{a2} (m)</td><td>150</td><td>180</td><td>220</td><td>260</td><td>300</td><td>340</td><td>400</td></tr>
</table>
When between two overtaking prohibitions there is a section of discontinuous road marking shorter than that indicated in Table 3.3, both prohibitions will be combined, so that overtaking will not be allowed in sections shorter than the distance D_{a2}. The use of Tables 3.2 and 3.3 assumes that the maximum speed signalled in the section coincides with the design speed (V_P).

Note: there are no expression for the evaluation for the “overtaking distance” (not sight distance) but only table values. Overtaking sight distance is reported in the §3.2.4 below.

3.2.4 OVERTAKING SIGHT DISTANCE

On conventional roads, overtaking visibility will be considered as the available distance, measured along the axis that separates both directions of traffic, between the position of the vehicle that makes the overtaking manoeuvre and the position of the vehicle that circulates in the opposite direction, in the moment in which you can see it and without it disappearing from your sight until the end of said manoeuvre.

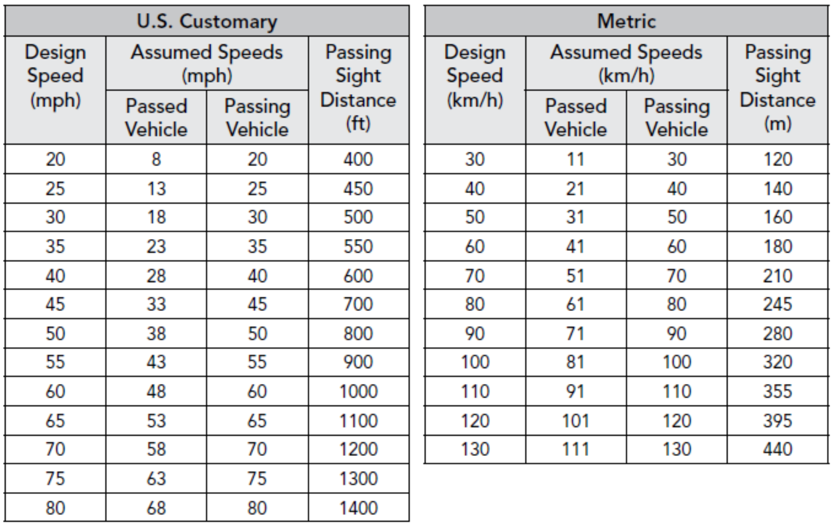
To determine the position of the vehicle traveling in the opposite direction, it will be admitted, in a simplified way, that it is visible when an unobstructed line of sight can be traced from the point of view of the vehicle carrying out the overtaking manoeuvre to a point on the vehicle traveling in the opposite direction. located at a height of one meter and ten centimeters (1.10 m) and at a distance of one meter</td>
</tr>
</table>

REF.	TEXT
	and fifty centimeters (1.50 m) from the axis that separates the two directions of traffic. Efforts will be made to obtain sections of the maximum possible length in which the overtaking visibility is greater than the overtaking distance D_{a2}. In order to guarantee a certain level of service on a conventional road, it will be necessary to know, at the project time, the traffic intensity in each direction with the percentage of heavy vehicles and study the possibilities of overtaking. If sufficient overtaking opportunities are not obtained to guarantee the aforementioned level of service, it will be necessary to consider the option of having overtaking lanes (section 8.7). Overtaking prohibition signage will be made in accordance with Standard 8.2-IC “Road Markings”.

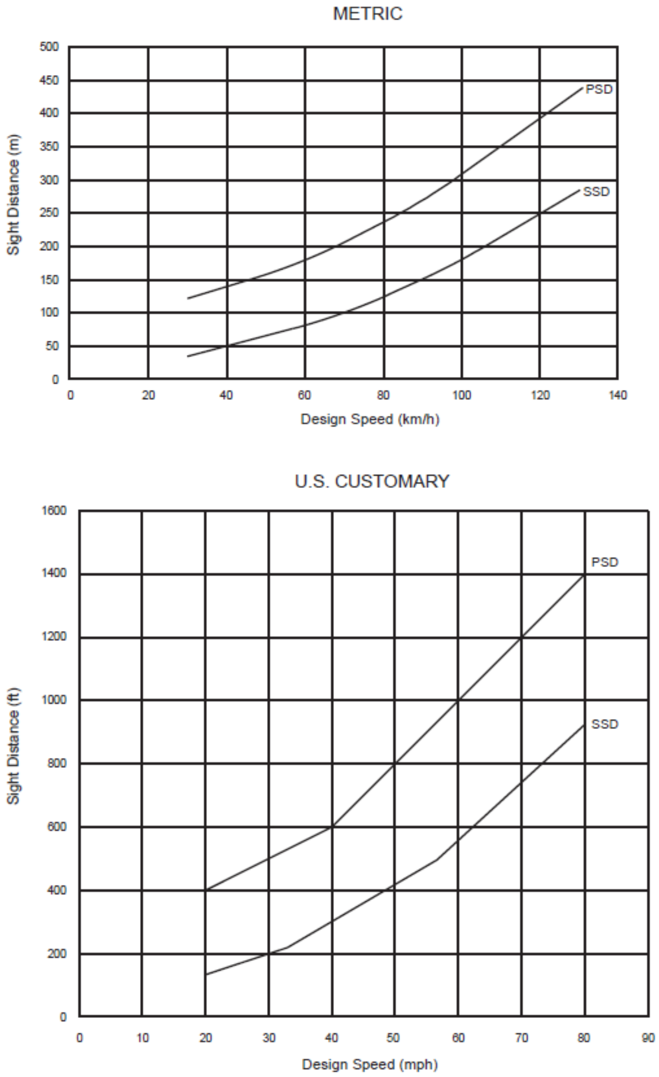
USA

REF.	TEXT
AASHTO GREEN BOOK 2018 § 3.2.4 Passing Sight Distance for Two-Lane Highways NCHRP REPORT 605 “Passing Sight Distance Criteria”	The design values for passing sight distance are presented in Table 3-4 and are shown in comparison to stopping sight distance criteria in Figure 3-1. It is apparent from the comparison in Figure 3-1 that more sight distance is needed to accommodate passing manoeuvres on a two-lane highway than for stopping sight distance that is provided continuously along the highway. Research has verified that the passing sight distance values in Table 3-4 are consistent with field observation of passing manoeuvres.

Table 3-4. Passing Sight Distance for Design of Two-Lane Highways



U.S. Customary				Metric			
Design Speed (mph)	Assumed Speeds (mph)		Passing Sight Distance (ft)	Design Speed (km/h)	Assumed Speeds (km/h)		Passing Sight Distance (m)
	Passed Vehicle	Passing Vehicle			Passed Vehicle	Passing Vehicle	
20	8	20	400	30	11	30	120
25	13	25	450	40	21	40	140
30	18	30	500	50	31	50	160
35	23	35	550	60	41	60	180
40	28	40	600	70	51	70	210
45	33	45	700	80	61	80	245
50	38	50	800	90	71	90	280
55	43	55	900	100	81	100	320
60	48	60	1000	110	91	110	355
65	53	65	1100	120	101	120	395
70	58	70	1200	130	111	130	440
75	63	75	1300				
80	68	80	1400				

	 **Figure 3-1. Comparison of Design Values for Passing Sight Distance and Stopping Sight Distance**

Other countries

The issue of the need to identify suitable points of the road layout in which to guarantee the possibility of overtaking is a common thread of the rules of all the countries analyzed for functionality requirements (service level). However, the issue of determining the OSD is not always argued to the point of proposing an equation or a reference table. The design rules of China and Japan, for example, make a brief mention of the need to ensure visibility for overtaking:

- China: "*Capacity and design volume of two way , two lane highways are subject to multiple factors including directional splits, overtaking sight distance, management level, and roadside interference*";
- Japan: "*For roads with two lanes (except for one-way roads), sufficient sections of oncoming highway visible to the driver shall be provided for overtaking*".

ANNEX C – DECISION-MAKING SIGHT DISTANCE

Australia

REF.	Text	Comments
Austroads Guide to Road Design (AGRD) Part 3 Cap. 5	**5.2.2 Driver reaction Time** Reaction time is the time for a driver to perceive and react to a particular stimulus and take appropriate action. This time depends on: • alertness of the driver • recognition of the hazard • the complexity of the decision or task involved. Table 5.2 provides guidance for the use of three driver reaction times (**1.5, 2.0 and 2.5 seconds**) to be considered in the design process. It is desirable for designers to adopt a reaction time of **2.5 seconds** for the geometric design of all roads. Where a lesser value is contemplated, designers need to consider the appropriateness of that value based on the expected road conditions and typical use listed below. **5.8 Intermediate Sight Distance** An intermediate sight distance equal to twice the stopping distance and measured from 1.1 to 1.25 m may be appropriate in some circumstances where two-way travel may occur in the same path, e.g. narrow, low volume rural roads with no line marking. Where it is difficult to achieve this sight distance, it is usually more practical to provide stopping sight distance only, with the pavement widened and marked with two lanes. **5.10 Horizontal Curve Perception Sight Distance** A major characteristic of low speed roads and intermediate speed roads is the way drivers will speed up on longer straights and through larger radius horizontal curves then slow down where necessary for smaller radius curves. These roads have been designed so that the geometric elements matched the operating speeds along the road. This means that when vehicles have to slow down for a horizontal curve, drivers must see a sufficient amount of the curve in order to perceive its curvature, react and slow down appropriately for the curve.	It considers a longer sight distance under specific conditions, and a specific sight distance approaching the curve.

REF.	Text	Comments
	If drivers are unable to perceive the curvature of the road, they may not slow down to an appropriate speed, which increases the risk of a single vehicle crash. Therefore, curves on these types of alignments should be designed for an operating speed that is no more than 5 km/h less than the operating speed on the approach to the curve. Normally, sufficient sight distance for a horizontal curve is provided through the practice of not having a horizontal curve start over a crest. Designers should also consider the locations of cut batters or other visual obstruction on the inside of a left turning horizontal curve, which can hide the degree of curvature of the road ahead, especially if the horizontal curve is used in conjunction with a spiral. However, there are times where this cannot be avoided and the following criteria should be applied in order to check that sufficient visibility is provided for the curve: • a driver eye height of 1.1 m • a zero object height because the driver needs to see the road surface in order to perceive the curvature. Road edge guide posts and cut batters can only be considered as supplementary aids • a driver needs to see sufficient length of the curve in order to judge its curvature. The driver must be able to see the minimum of: – 5 degrees of arc – about 80 m of arc – the whole curve • if the curve is transitioned however, at least 80% of the transition length and desirably all of the transition needs to be seen by the driver. The length of arc that needs to be perceived must be seen from a point that allows the driver to react then decelerate – refer Section 5.2.2 for guidance on the choice of reaction time. The deceleration should only require comfortable braking by drivers, therefore, a maximum deceleration rate of 2.5 m/s/s should be used. Typically, this means that a distance of 25 m will accommodate a 10 km/h speed reduction from 90 km/h and 40 m will accommodate a 15 km/h speed reduction. Deceleration distances should be adjusted for the effect of grade. The sight distance is the sum of the reaction distance, arc length for perception and deceleration distance. If the curve is transitioned, it	

REF.	Text	Comments
	is possible for the deceleration distance to coincide with up to the first half of the transition. If the curve is untransitioned, deceleration up to the curve tangent point can be assumed. Provision of horizontal curve perception distance may require a larger crest or lower benching than is required for stopping sight distance.	

Belgium

REF.		Comments
Vlaanderen – Vademecum Weginfra-stuctuur 5.1 Zicht	**Anticipatiezicht → approximable to DSD** **5.1.1.2 Structure of sight length** For all vision criteria, the normative vision lengths are made up of the following three components: • Recognition Length: The length over which the driver must be able to look ahead to detect an event or object unambiguously to recognize in unfavourable conditions such as rain, darkness or fog. • Perception reaction time length (prt length): the length travelled during the perception reaction time (prt). • Operational task: the length resulting from the time required for an operational task. The recognition length is that part of the road section that the driver must be able to perceive in order to to recognize and assess the situation. The perception-reaction time (prt) is the time it takes to successively make an observation, the to process the observation and to determine any necessary action. The PR is highly dependent of the way in which the driver performs his driving task at a given moment. As the vehicle speed goes higher, the prt gets longer because the driver then focuses more on the horizon. because of this his field of vision narrows and he is less sensitive to stimuli around him. The operational task is the time it takes to perform the required action. This time varies for any type of action. As a result, the options for corrective actions are also different for each action. Point of attention	DSD is implicitly considered, as it is expected to consider a time of "recognition" in addition to the time of perception and reaction. It also highlights how the position, size and shape of objects on the roadside can influence perception, as can speed. Moreover, it provides the “anticipation sight distance”

REF.		Comments
	Dimensioning horizontal and vertical arcs with table 4 does not necessarily lead to the smallest applicable radius of curvature. Here, visually-obstructing objects play in the inner arch, such as the shielding structures also play a role. An estimate of this size is shown in figure 31. For the calculation of this measure, reference is made to chapter “5.1.5 Observing, estimating and recognizing horizontal (tight) arcs”. **5.1.2 Anticipation view** **5.1.2.1 Definition** Anticipation view is the view of the interplay of elements that determine the recognition of the course of the road. Sight length is the length over which a driver must be able to perceive these elements in order to be able to comfortably process this information and react to it if necessary. If there is insufficient anticipation visibility, the driver will not have sufficient time to perceive and recognize a potential hazard. The driver then becomes uncertain about the road course and will exhibit unexpected and unsafe driving behaviour. **5.1.2.2 Structure of sight length** The view length for anticipation view is structured as follows: • Recognition length: this length must be available as a visible length. • Prt Length: Not applicable. • Operational task: Not applicable, the lateral control task and responding to longitudinal events occur within the recognition length. The view point must be visible over the sum of these lengths. **5.1.2.3 Critical situation** The starting points for determining the sight length for anticipation vision are: • Observation point: -- At a left turn: 1.25 m from the edge marking on the left -- At a right-hand bend: 2.25 m from the edge marking to the right	required to understand the situation of the road in front of the driver, and the “Road progression view” require to understand the road and react to road stimuli (contain a part of anticipation and a part of prt). It considers ad hoc distances for curve, for approaching the curve (considering anticipation, prt and maneuver) within the curve, and approaching the end of the curve, and ad hoc distances for merging or weaving traffic and a lane termination.

REF.		Comments

- Point of view: road marking or any continuously repeating element with a height greater than 0.5 m relative to the nearest pavement side of the relevant carriageway:

-- At one or two lanes: edge marking outside bend

-- For more than two lanes: the second lane marking (seen from own lane)

-- Shielding constructions

-- Public lighting

-- Signaling

-- Signage

-- Vegetation higher than 1.0 m

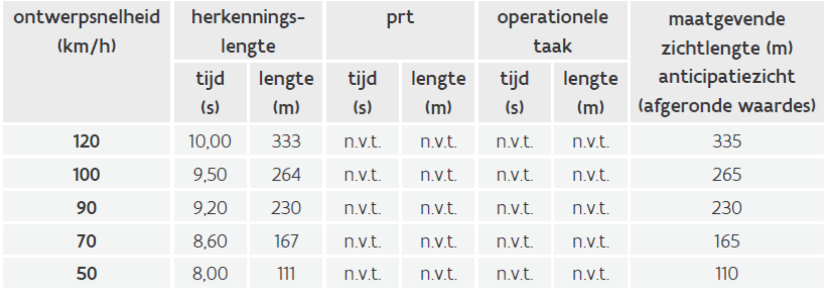
-- Soundproofing facilities

-- Tunnel wall

If a driver can recognize at least one of the above elements within his line of sight, he can use this to recognize the course of the road and, if necessary, anticipate this.

5.1.2.4 Minimum sight length

The minimum sight lengths for anticipation sight per design speed are shown in Table 5.



ontwerpsnelheid (km/h)	herkennings-lengte		prt		operationele taak		maatgevende zichtlengte (m) anticipatiezicht (afgeronde waardes)
	tijd (s)	lengte (m)	tijd (s)	lengte (m)	tijd (s)	lengte (m)	
120	10,00	333	n.v.t.	n.v.t.	n.v.t.	n.v.t.	335
100	9,50	264	n.v.t.	n.v.t.	n.v.t.	n.v.t.	265
90	9,20	230	n.v.t.	n.v.t.	n.v.t.	n.v.t.	230
70	8,60	167	n.v.t.	n.v.t.	n.v.t.	n.v.t.	165
50	8,00	111	n.v.t.	n.v.t.	n.v.t.	n.v.t.	110

5.1.3 Road progression view

5.1.3.1 Definition

The view length of the course of the road in continuous situations (road course view) is the length required by which a driver must be able to see the road in order to perform his driving task safely and comfortably.

Roadway view is necessary to:

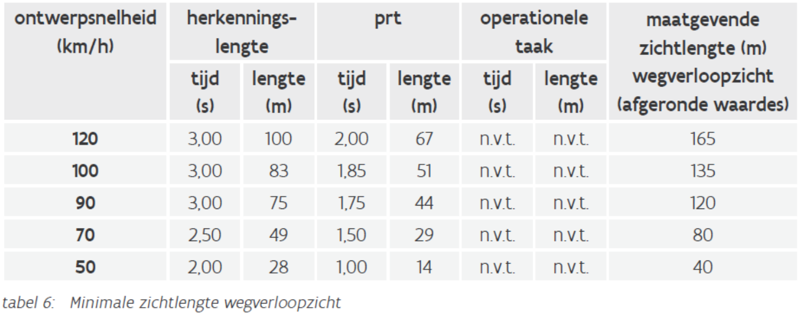
- To be able to control the transverse position of the vehicle

REF.		Comments
	• React safely and comfortably to events along the length of the road **5.1.3.2 Structure of sight length** The view length for road progression view is structured as follows: • Recognition length: this length must be available as a visible length. • Prt length: this length must be available as a visible length. • Operational task: Not applicable, the lateral control task and responding to longitudinal events occur within the recognition length. The view point must be visible over the sum of these lengths. **5.1.3.3 Critical situation** The starting points for determining the visibility length for the road profile are: • The normative situation is a view of a combined horizontal arc in a vertical arc. • Observation point: -- At a left turn: 1.25 m from the edge marking on the left -- At a right-hand bend: 2.25 m from the edge marking to the right • Viewpoint: -- With one or two lanes: edge marking outside bend must be completely and continuously visible over the entire visible length. -- With more than two lanes: the second longitudinal marking on the outer curve side (seen from its own lane) must be fully and continuously visible over the entire visible length. • Interruption: exceptionally incidentally for 2 driving seconds, for example as a result of a signal bridge. A vehicle in the left lane in an arc to the left is decisive because the driver sits on the left side of the car and is therefore closest to the edge marking. This situation has the greatest chance of obstruction of vision by objects that obstruct visibility next to the roadway. Seeing one's own lane and any adjacent lane then provides sufficient visibility of the road progress to be able to perform the driving task safely and comfortably.	

REF.		Comments

5.1.3.4 Minimum sight length

The minimum visibility lengths for walk-away visibility per design speed are shown in Table 6. These values apply to situations with a constant design speed.



ontwerpsnelheid (km/h)	herkennings-lengte		prt		operationele taak		maatgevende zichtlengte (m) wegverloopzicht (afgeronde waardes)
	tijd (s)	lengte (m)	tijd (s)	lengte (m)	tijd (s)	lengte (m)	
120	3,00	100	2,00	67	n.v.t.	n.v.t.	165
100	3,00	83	1,85	51	n.v.t.	n.v.t.	135
90	3,00	75	1,75	44	n.v.t.	n.v.t.	120
70	2,50	49	1,50	29	n.v.t.	n.v.t.	80
50	2,00	28	1,00	14	n.v.t.	n.v.t.	40

tabel 6: Minimale zichtlengte wegverloopzicht

5.1.5 Observing, estimating and recognizing horizontal (tight) arcs

To properly embed a horizontal (tight) arc into the composite design, visibility must be checked in three places:

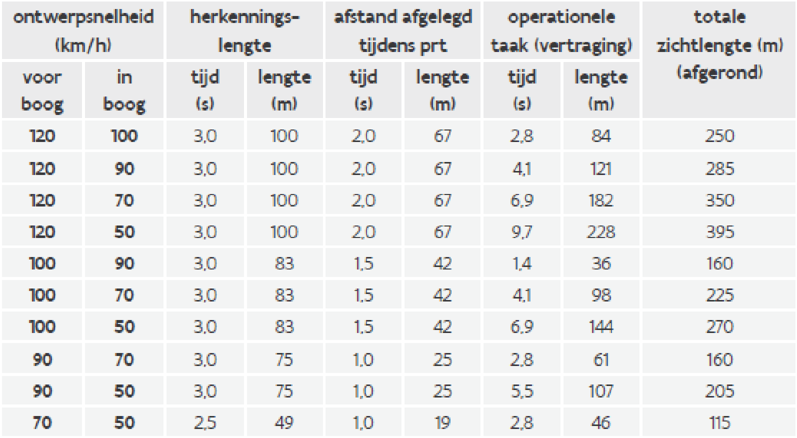
- Before the arc
- In the arc
- At the end of the arc

The preceding road section must provide sufficient visibility to be able to observe and recognize the horizontal arc. Correct estimation of the arc can be hindered by insufficient visibility of the arc due to an incorrect combination with the vertical alignment or because the arc does not match the operator’s expectations. In a horizontal arc, a driver must have sufficient visibility to react to situations occurring downstream. Timely observation of the end of the horizontal arc and the subsequent spatial element is necessary.

View of the arc before the arc

[…]

REF.		Comments

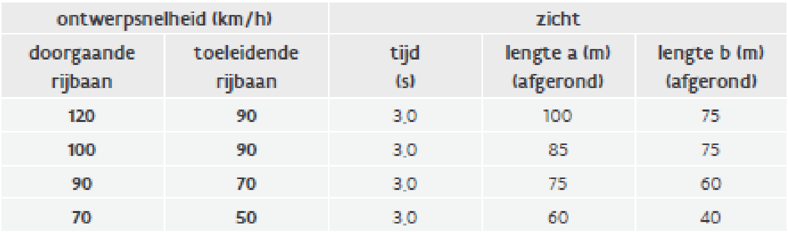


ontwerpsnelheid (km/h)		herkennings-lengte		afstand afgelegd tijdens prt		operationele taak (vertraging)		totale zichtlengte (m) (afgerond)
voor boog	in boog	tijd (s)	lengte (m)	tijd (s)	lengte (m)	tijd (s)	lengte (m)	
120	**100**	3,0	100	2,0	67	2,8	84	250
120	**90**	3,0	100	2,0	67	4,1	121	285
120	**70**	3,0	100	2,0	67	6,9	182	350
120	**50**	3,0	100	2,0	67	9,7	228	395
100	**90**	3,0	83	1,5	42	1,4	36	160
100	**70**	3,0	83	1,5	42	4,1	98	225
100	**50**	3,0	83	1,5	42	6,9	144	270
90	**70**	3,0	75	1,0	25	2,8	61	160
90	**50**	3,0	75	1,0	25	5,5	107	205
70	**50**	2,5	49	1,0	19	2,8	46	115

tabel 9: Standaardwaardes voor zicht op een krappe horizontale boog

5.1.5.1 View of merging or weaving traffic

[…]

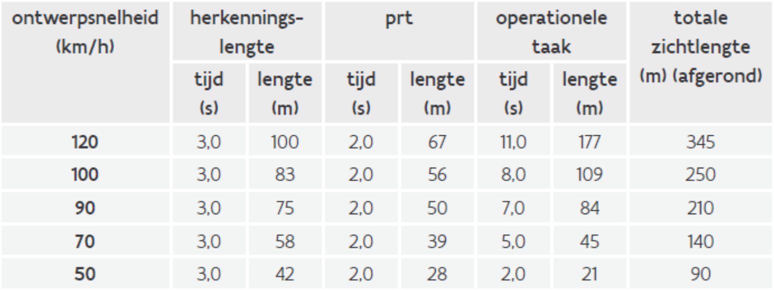


ontwerpsnelheid (km/h)		zicht		
doorgaande rijbaan	toeleidende rijbaan	tijd (s)	lengte a (m) (afgerond)	lengte b (m) (afgerond)
120	**90**	3,0	100	75
100	**90**	3,0	85	75
90	**70**	3,0	75	60
70	**50**	3,0	60	40

tabel 11: Standaardwaarden zichtlengte ten behoeve van zicht op invoegend of wevend verkeer

5.1.5.2 View of a lane termination

[…]



ontwerpsnelheid (km/h)	herkennings-lengte		prt		operationele taak		totale zichtlengte (m) (afgerond)
	tijd (s)	lengte (m)	tijd (s)	lengte (m)	tijd (s)	lengte (m)	
120	3,0	100	2,0	67	11,0	177	345
100	3,0	83	2,0	56	8,0	109	250
90	3,0	75	2,0	50	7,0	84	210
70	3,0	58	2,0	39	5,0	45	140
50	3,0	42	2,0	28	2,0	21	90

tabel 12: Standaardwaarden voor zicht op een rijstrookbeëindiging

Canada

REF.	**Text**	**Comments**
TAC 2017, **Geometric Design Guide for Canadian Roads** Chapter 2 - Design Controls, Classification and Consistency 2.5 Sight distance	**2.5.5 DECISION SIGHT DISTANCE** Stopping sight distance allows alert, competent drivers to come to a quick stop under ordinary circumstances. This distance is usually inadequate when drivers must make complex decisions, when information is difficult to find, when information is unusual, or when unusual maneuvers are required. Limiting the sight distance to the stopping sight distance may preclude drivers from performing unusual, evasive maneuvers. Similarly, stopping sight distance may not provide drivers with enough visibility to allow them to piece together warning signals and decide on a course of action. Because decision sight distance allows drivers to maneuver their vehicles or vary their operating speed rather than stop, decision sight distance is much greater than stopping sight distance for a given Design Speed. Designers should use decision sight distance wherever information may be perceived incorrectly, decisions are required, or control actions are required. Examples of situations where it could be desirable to provide decision sight distance include: • Complex interchanges and intersections • Locations where unusual or unexpected maneuvers occur • Locations where significant changes to the roadway cross section are made • Areas where there are multiple demands on the driver's decision-making capabilities from road elements, traffic control devices, advertising, traffic, etc. • Construction zones Table 2.5.6 shows the range of values for decision sight distance. The decision sight distance increases with the complexity of the evasive action that is taken by the driver and with the complexity of the	It considers the DSD for specific critical location.

<table>
<tr><th>REF.</th><th>Text</th><th>Comments</th></tr>
<tr><td></td><td>
surroundings. The values for decision sight distance given in the table were developed from empirical

data. When using these sight distances, the designer should consider eye and object heights appropriate

for specific applications. Refer to Section 2.4.3.3 Driver Eye Height and Section 2.5.2.1 Object Height for

additional information.

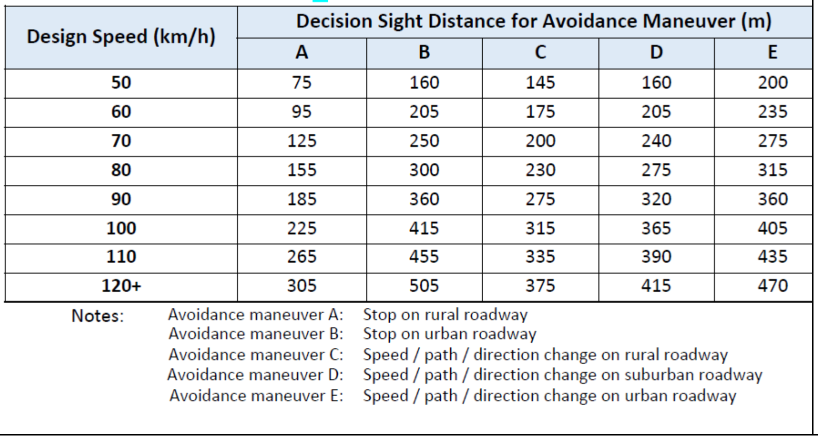
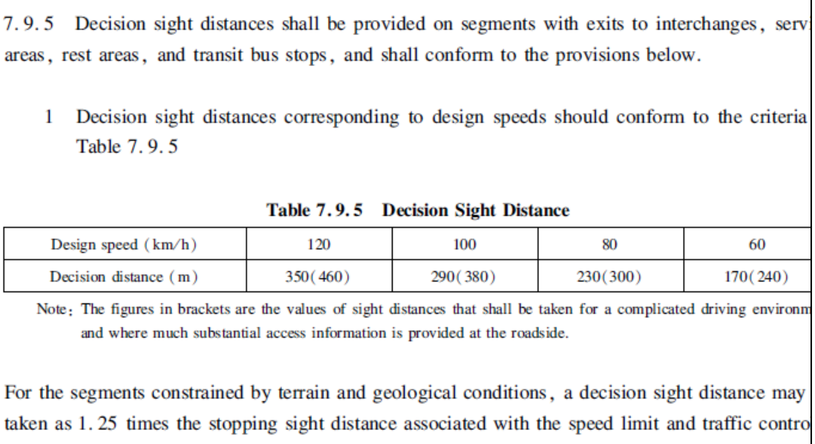


Table 2.5.6: Decision Sight Distance[68]
<table>
<tr><th rowspan="2">Design Speed (km/h)</th><th colspan="5">Decision Sight Distance for Avoidance Maneuver (m)</th></tr>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th></tr>
<tr><td>50</td><td>75</td><td>160</td><td>145</td><td>160</td><td>200</td></tr>
<tr><td>60</td><td>95</td><td>205</td><td>175</td><td>205</td><td>235</td></tr>
<tr><td>70</td><td>125</td><td>250</td><td>200</td><td>240</td><td>275</td></tr>
<tr><td>80</td><td>155</td><td>300</td><td>230</td><td>275</td><td>315</td></tr>
<tr><td>90</td><td>185</td><td>360</td><td>275</td><td>320</td><td>360</td></tr>
<tr><td>100</td><td>225</td><td>415</td><td>315</td><td>365</td><td>405</td></tr>
<tr><td>110</td><td>265</td><td>455</td><td>335</td><td>390</td><td>435</td></tr>
<tr><td>120+</td><td>305</td><td>505</td><td>375</td><td>415</td><td>470</td></tr>
</table>
Notes:
Avoidance maneuver A: Stop on rural roadway
Avoidance maneuver B: Stop on urban roadway
Avoidance maneuver C: Speed / path / direction change on rural roadway
Avoidance maneuver D: Speed / path / direction change on suburban roadway
Avoidance maneuver E: Speed / path / direction change on urban roadway
</td><td></td></tr>
</table>

Chile

REF.	Text	Comments
Manual de Carreteras Volumen 3		Nothing about DSD

China

<table>
<tr><th>REF.</th><th>Text</th><th>Comments</th></tr>
<tr><td>Specifications for Geometric
Design of Highways,
September 28,2017,
Issued by Ministry of Transport of the People’s Republic of China</td><td>

7.9.5 Decision sight distances shall be provided on segments with exits to interchanges, serv areas, rest areas, and transit bus stops, and shall conform to the provisions below.

1 Decision sight distances corresponding to design speeds should conform to the criteria Table 7.9.5

Table 7.9.5 Decision Sight Distance

<table>
<tr><td>Design speed (km/h)</td><td>120</td><td>100</td><td>80</td><td>60</td></tr>
<tr><td>Decision distance (m)</td><td>350(460)</td><td>290(380)</td><td>230(300)</td><td>170(240)</td></tr>
</table>

Note: The figures in brackets are the values of sight distances that shall be taken for a complicated driving environm and where much substantial access information is provided at the roadside.

For the segments constrained by terrain and geological conditions, a decision sight distance may taken as 1.25 times the stopping sight distance associated with the speed limit and traffic contro</td><td>Specific locations need a DSD equal to that in the table. If needed for specific terrain or geological conditions, the length is 1.25 time the SSD.</td></tr>
</table>

England

REF.	Text	Comments
Road Layout Design CD 109 Highway link design (formerly TD 9/93, TD 70/08) Revision 1 - March 2020		Nothing about DSD

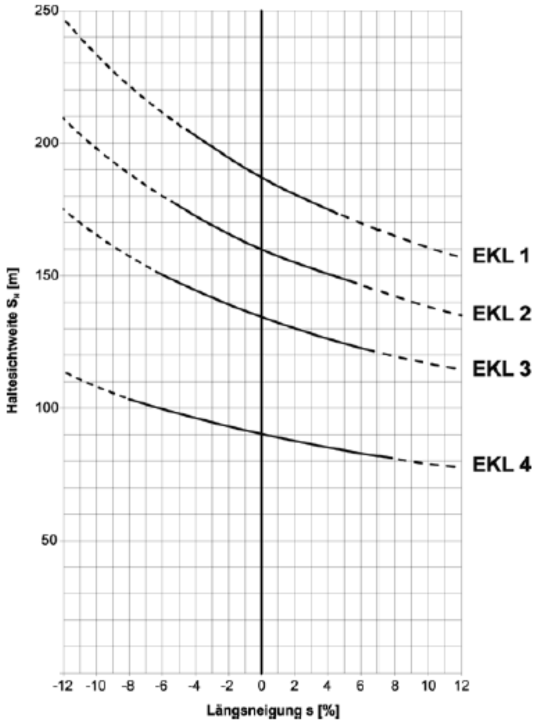
France

REF.	Text	Comments
Recommandations techniques pour la conception générale et la géométrie de la route AMÉNAGEMENT DES ROUTES PRINCIPALES (sauf les autoroutes et routes express à deux chaussées) SETRA	**4.2. Visibility requirements** The visibility distance required generally depends on the speed being practised, the reaction time, which varies according to the type of event (more or less high probability, etc.) and according to the type of reaction (to the steering wheel, to the pedals, etc.) , and the distance required for the maneuver (braking, modification of trajectory, starting, etc.). The speed V_{85} to be taken into account can legitimately be reduced at the level of the speed limit (90 km/h in the general case) except with regard to the calculation of the visibility at the level of accesses and intersections. **a) Visibility on a curve** When approaching the bend, the driver must have visibility such that he can perceive the bend and modify his behavior (trajectory, possibly speed) in time. The necessary distance can be estimated in common cases at a distance corresponding to 3 seconds traveled at the speed V_{85} practiced before the bend (at the point considered). Observation point: height 1 m, located 2 m from the right edge of the roadway. Target point: height 0 m, located on the axis of the roadway, at the start of the circular part of the bend.	They define a visibility distance for curves, which has the same meaning of the DSD, but it is probably too low to be a DSD.

Germany

REF.	Text	Comments
Richtlinien für die Anlage von Landstraßen RAL Ausgabe 2012	**5.5 Visibility** **5.5.1 Required stopping sight distance** Obstacles on the road must be recognizable at every point from a distance that drivers when driving at the planning speed applicable to the EKL, even on wet roads enables timely stopping (required stopping sight distance).	They use an "orientation" distance that may be considered as a DSD. It is 1.3 time the SSD, and it should be

REF.	Text	Comments
	Figure 23 shows the required stopping visual range as a function of the design class and the pitch. *In order to enable the driver to find out about the course of the road ahead of him in good time and thus to be able to drive without requiring increased attention, generally greater visual ranges than the required stopping visual ranges are necessary. For this reason, the existing visibility should be at least 30% above the required stopping visibility over most of the route.* It is advantageous for traffic flow and traffic safety if the need to overtake vehicles traveling at different speeds can be sufficiently satisfied. For this purpose, route sections with sufficient overtaking visibility are favorable. However, since the overtaking maneuvers on roads with very large and large driving distances should preferably be carried out in overtaking sections with safe traffic, no minimum sections of the route with sufficient overtaking visibility are explicitly required for the roads of EKL 1 and EKL 2. This also applies to EKL 3 roads, because the distances traveled on these roads are only short to medium and the dense sequence of junctions on the same plan limits overtaking opportunities in large parts of the route. This also applies to a greater extent to EKL 4 roads, where the narrow lane width also prevents overtaking.	assure over "most of the route".

REF.	Text	Comments
	 Bild 23: Erforderliche Haltesichtweite S_H in Abhängigkeit von der EKL und der Längsneigung	

Italy

REF.	Text	Comments
NORME FUNZIONALI E GEOMETRICHE PER LA COSTRUZIONE DELLE STRADE, decreto ministeriale 5 Novembre 2001	**5.1.4 Visibility distance for the lane change maneuver** The necessary space is evaluated with the following expression; in which the 9.5 seconds include the time needed to perceive and recognize the situation and to decide and carry out the one lane change maneuver (4 seconds). $D_C = 9.5 \times V = 2.6 \text{ x } v$ [m] where is it: v = vehicle speed in [m / s], or V in [km / h], punctually deduced from the diagram of speed (see par. 5.4) **5.4.2 Recognition distance** Recognition distance D_r means the maximum length of the road section by which the driver can recognize any obstacles	They consider DSD only for lane changing maneuver. They also define the “recognition distance” for the stretch preceding the curve, which set a maximum

REF.	Text	Comments
	and events. It is a function of speed and can be calculated in meters with the relation: $D_r = t \times v_p$ with: $t = 12$ s vp, expressed in m / s, is to be understood as referring to the element with the greatest radius According to this model, the appreciation of a variation in the curvature of the axis, which allows the driver to change his speed, it can only take place within the distance of recognition and therefore, to ensure traffic safety: in case of decelerations the transition distance must have a length not greater than recognition distance $D_T \leq D_r$ and furthermore, for the variation of curvature to be actually perceived it must be $D_T \leq D_v$ where D_v indicates the unobstructed viewing distance in the stretch that precedes the circular curve.	distance from which it is possible to understand the curve.

Japan

REF.	Text	Comments
https://www.mlit.go.jp/road/road_e/r1_standard_2.html		Nothing about DSD

Mexico

<table>
<tr><th>REF.</th><th>Text</th><th>Comments</th></tr>
<tr>
<td>MANUAL DE PROYECTO GEOMÉTRICO DE CARRETERAS
2018
Direccion General de Servicios Técnicos
México, Julio 2018
Tercera edición</td>
<td>

F.3.2. Decision sight distance

Stopping sight distances are often poor when drivers must make complex decisions, when information is difficult to perceive and process, or when the maneuver is unexpected or unusual. In such cases, decision sight distance should be used instead of stopping sight distance.

The decision sight distance is the minimum distance necessary for a driver, traveling at design speed, to be able to maneuver his vehicle in advance in the presence of a situation whose complexity demands greater perception-reaction times than those usually required in road. This distance is determined with the same expressions, but considering the following reaction time (t), in seconds, for stop maneuvers and changes in speed or trajectory (see Table I.5):

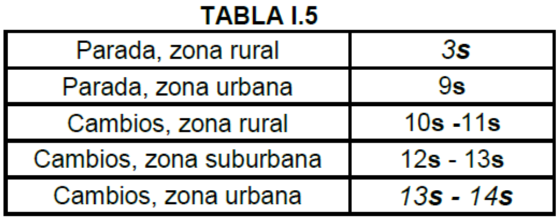


TABLA I.5

<table>
<tr><td>Parada, zona rural</td><td>3s</td></tr>
<tr><td>Parada, zona urbana</td><td>9s</td></tr>
<tr><td>Cambios, zona rural</td><td>10s -11s</td></tr>
<tr><td>Cambios, zona suburbana</td><td>12s - 13s</td></tr>
<tr><td>Cambios, zona urbana</td><td>13s - 14s</td></tr>
</table>

The resulting decision sight distances are appropriate for varying degrees of maneuver complexity. Due to the added safety and maneuverability afforded by these lengths, it is recommended that they be used only in truly troublesome locations. In the event that it is not feasible to provide these distances due to special circumstances of horizontal and vertical alignment, the possibility of using preventive signage that allows drivers to be warned about the conditions that they will find ahead on their way will be studied.

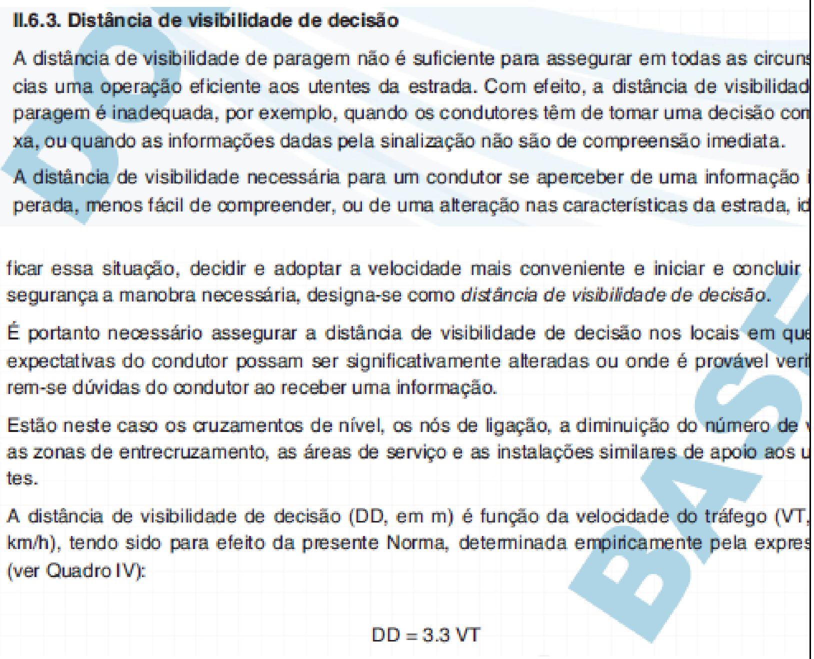
</td>
<td>They use DSD on specific locations.</td>
</tr>
</table>

Poland

REF.	Text	Comments
Dz.U. 2022 poz. 1518 Rozporządzenie Ministra Infrastruktury z	Defined DSD only for roads 2+1, regarding to visibility of the end of additional lane for overtaking. “Orientation” distance that may be considered as a DSD. It is 1.3 time the SSD”.	Based on German standard

REF.	Text	Comments
dnia 24 czerwca 2022 r. w sprawie przepisów techniczno-budowlanych dotyczących dróg publicznych		

Portugal

REF.	Text	Comments
Disposições Normativas, **Norma de Traçado,** Revisão Novembro de 2010 Documento Base Instituto de Infra-Estruturas Radoviarias IP	 **II.6.3. Distância de visibilidade de decisão** A distância de visibilidade de paragem não é suficiente para assegurar em todas as circuns cias uma operação eficiente aos utentes da estrada. Com efeito, a distância de visibilidad paragem é inadequada, por exemplo, quando os condutores têm de tomar uma decisão com xa, ou quando as informações dadas pela sinalização não são de compreensão imediata. A distância de visibilidade necessária para um condutor se aperceber de uma informação i perada, menos fácil de compreender, ou de uma alteração nas características da estrada, id ficar essa situação, decidir e adoptar a velocidade mais conveniente e iniciar e concluir segurança a manobra necessária, designa-se como *distância de visibilidade de decisão*. É portanto necessário assegurar a distância de visibilidade de decisão nos locais em que expectativas do condutor possam ser significativamente alteradas ou onde é provável veri rem-se dúvidas do condutor ao receber uma informação. Estão neste caso os cruzamentos de nível, os nós de ligação, a diminuição do número de as zonas de entrecruzamento, as áreas de serviço e as instalações similares de apoio aos u tes. A distância de visibilidade de decisão (DD, em m) é função da velocidade do tráfego (VT, km/h), tendo sido para efeito da presente Norma, determinada empiricamente pela expres (ver Quadro IV): DD = 3.3 VT	DSD is calculated as 3.3 times the traffic speed in km/h.

Spain

<table>
<tr><th>REF.</th><th>Text</th><th>Comments</th></tr>
<tr>
<td>I. DISPOSICIONES GENERALES
MINISTERIO DE FOMENTO
2217
Orden FOM/273/2016, de 19 de febrero, por la que se aprueba la Norma 3.1-IC Trazado, de la Instrucción de Carreteras.</td>
<td>

3.2.5 DECISION DISTANCE.

Decision distance is defined as the distance measured along the path followed by a vehicle so that its driver, in a road environment that may be visually congested, perceives the information provided by the signs and the existence of an unexpected situation or difficult to perceive, recognize them, assess the risk they represent, adopt an appropriate speed and trajectory and carry out the necessary maneuver safely and efficiently. The decision distance corresponds to the distance covered in ten seconds (10 s) at the design speed of the considered section and its minimum values are indicated in Table 3.4.

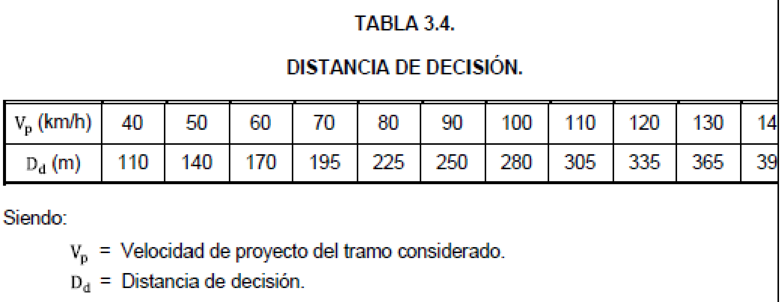


TABLA 3.4.

DISTANCIA DE DECISIÓN.

<table>
<tr><td>V_p (km/h)</td><td>40</td><td>50</td><td>60</td><td>70</td><td>80</td><td>90</td><td>100</td><td>110</td><td>120</td><td>130</td><td>14</td></tr>
<tr><td>D_d (m)</td><td>110</td><td>140</td><td>170</td><td>195</td><td>225</td><td>250</td><td>280</td><td>305</td><td>335</td><td>365</td><td>39</td></tr>
</table>

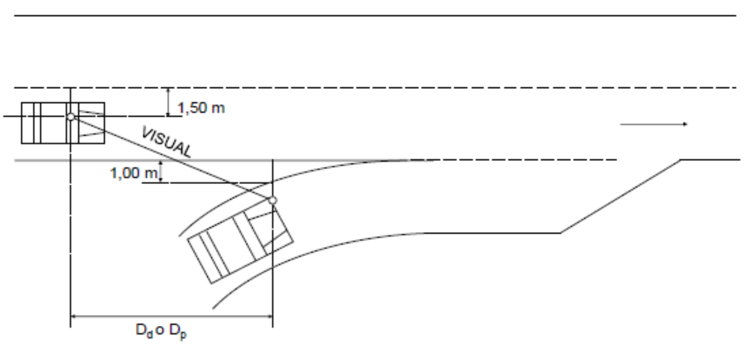
Siendo:

V_p = Velocidad de proyecto del tramo considerado.
D_d = Distancia de decisión.

3.2.6 DECISION VISIBILITY.

The distance in a straight line between the position of a moving vehicle (defined by the driver's point of view) and the element that the driver must observe measured on the axis of the road will be considered decision visibility. Side signs, banners and immediate exit gates must be perceived at a distance greater than the minimum values of the decision distance indicated in Table 3.4. The distance between the driver's point of view and the geometric center of the immediate exit signs will be measured in a straight line. The front left corner of a light vehicle (car) located in the characteristic section of one meter (1.00 m) in the center of the acceleration lane of a connecting branch or a junction turning lane, must be warned by drivers of vehicles traveling on the basic lanes of a junction at stopping distance (minimum) or decision distance (desirable) (Figure 3.2)

</td>
<td>DSD is considered as 10 s long. Under specific conditions, this length must be improved (but it is not specified how much).</td>
</tr>
</table>

REF.	Text	Comments
	FIGURA 3.2. VISIBILIDAD DE DECISIÓN O PARADA RESPECTO DE UN VEHÍCULO SITUADO EN EL INICIO DE UN CARRIL DE ACELERACIÓN.  If this decision-making visibility is not available on the approach to a junction, drivers' perception will be improved by reducing the posted speed on the section or by implementing driving aids.	

USA

REF.	Text	Comments
AASHTO GREEN BOOK 2018, 3.2.3 Decision Sight Distance	3.2.3 Decision Sight Distance Stopping sight distances are usually sufficient to allow reasonably competent and alert drivers to come to a hurried stop under ordinary circumstances. However, greater distances may be needed where drivers must make complex or instantaneous decisions, where information is difficult to perceive, or when unexpected or unusual maneuvers are needed. Limiting sight distances to those needed for stopping may preclude drivers from performing evasive maneuvers, which often involve less risk and are otherwise preferable to stopping. Even with an appropriate complement of standard traffic control devices in accordance with the Manual on Uniform Traffic Control Devices (MUTCD), stopping sight distances may not provide sufficient visibility distances for drivers to corroborate advance warning and to perform the appropriate maneuvers. It is evident that there are many locations where it would be prudent to provide longer sight distances. In these circumstances, decision sight distance provides the greater visibility distance that drivers need. Decision sight distance is the distance needed for a driver to detect an unexpected or otherwise difficult-to-perceive information source or	They consider DSD for specific locations

REF.	Text	Comments
	condition in a roadway environment that may be visually cluttered, recognize the condition or its potential threat, select an appropriate speed and path, and initiate and complete complex maneuvers. Because decision sight distance offers drivers additional margin for error and affords them sufficient length to maneuver their vehicles at the same or reduced speed, rather than to just stop, its values are substantially greater than stopping sight distance. Drivers need decision sight distances whenever there is likelihood for error in either information reception, decision making, or control actions. Examples of critical locations where these kinds of errors are likely to occur, and where it is desirable to provide decision sight distance in- clude interchange and intersection locations where unusual or unexpected maneuvers are need- ed, changes in cross section such as toll plazas and lane drops, and areas of concentrated demand where there is apt to be "visual noise" from competing sources of information, such as roadway elements, traffic, traffic control devices, and advertising signs. The decision sight distances in Table 3-3 may be used to (1) provide values for sight distances that may be appropriate at critical locations, and (2) serve as criteria in evaluating the suitability of the available sight distances at these locations. Because of the additional maneuvering space provided, decision sight distances should be considered at critical locations or critical decision points should be moved to locations where sufficient decision sight distance is available. If it is not practical to provide decision sight distance because of horizontal or vertical curvature or if relocation of decision points is not practical, special attention should be given to the use of suitable traffic control devices for providing advance warning of the conditions that are likely to be encountered.	

REF.	Text	Comments

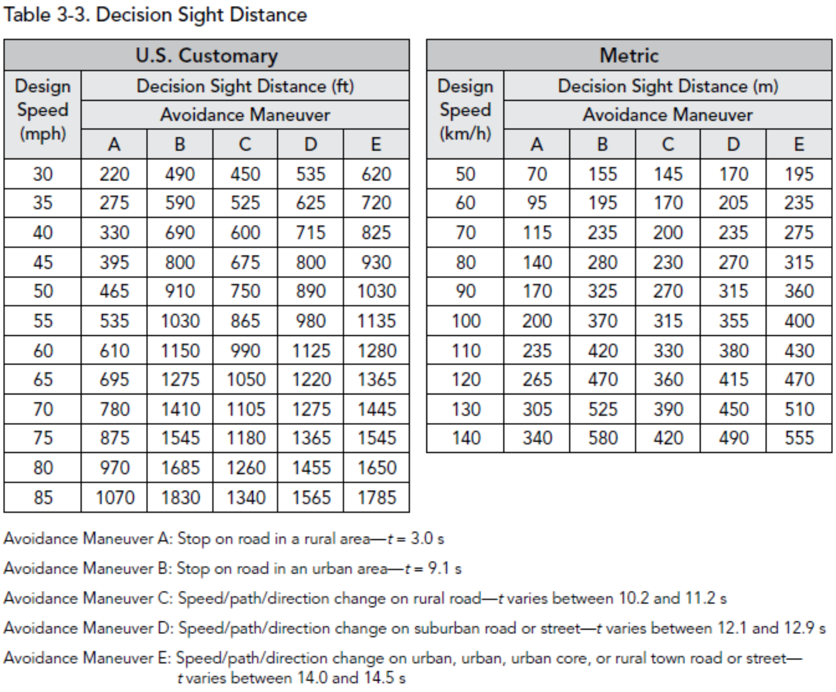


Table 3-3. Decision Sight Distance

U.S. Customary					
Design Speed (mph)	Decision Sight Distance (ft)				
	Avoidance Maneuver				
	A	B	C	D	E
30	220	490	450	535	620
35	275	590	525	625	720
40	330	690	600	715	825
45	395	800	675	800	930
50	465	910	750	890	1030
55	535	1030	865	980	1135
60	610	1150	990	1125	1280
65	695	1275	1050	1220	1365
70	780	1410	1105	1275	1445
75	875	1545	1180	1365	1545
80	970	1685	1260	1455	1650
85	1070	1830	1340	1565	1785

Metric					
Design Speed (km/h)	Decision Sight Distance (m)				
	Avoidance Maneuver				
	A	B	C	D	E
50	70	155	145	170	195
60	95	195	170	205	235
70	115	235	200	235	275
80	140	280	230	270	315
90	170	325	270	315	360
100	200	370	315	355	400
110	235	420	330	380	430
120	265	470	360	415	470
130	305	525	390	450	510
140	340	580	420	490	555

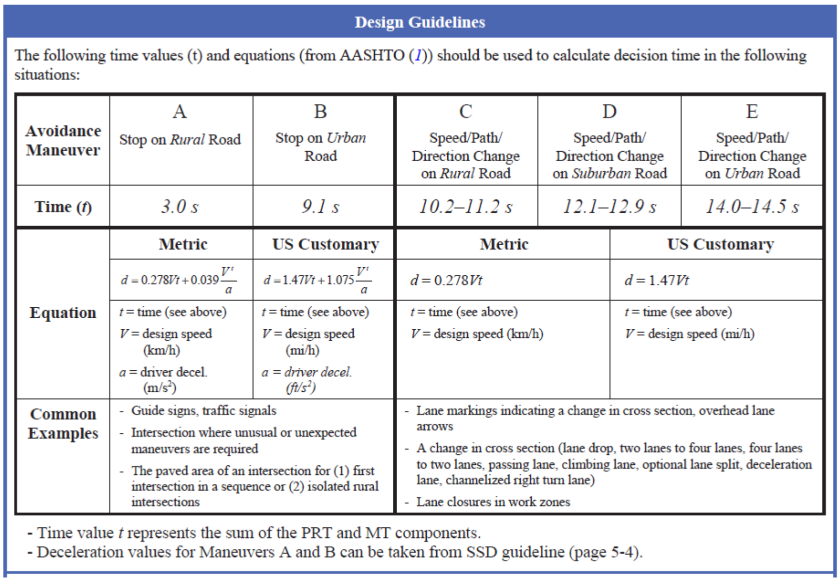
Avoidance Maneuver A: Stop on road in a rural area—*t* = 3.0 s

Avoidance Maneuver B: Stop on road in an urban area—*t* = 9.1 s

Avoidance Maneuver C: Speed/path/direction change on rural road—*t* varies between 10.2 and 11.2 s

Avoidance Maneuver D: Speed/path/direction change on suburban road or street—*t* varies between 12.1 and 12.9 s

Avoidance Maneuver E: Speed/path/direction change on urban, urban, urban core, or rural town road or street—*t* varies between 14.0 and 14.5 s



Design Guidelines

The following time values (t) and equations (from AASHTO (*1*)) should be used to calculate decision time in the following situations:

Avoidance Maneuver	A Stop on *Rural* Road	B Stop on *Urban* Road	C Speed/Path/ Direction Change on *Rural* Road	D Speed/Path/ Direction Change on *Suburban* Road	E Speed/Path/ Direction Change on *Urban* Road
Time (*t*)	*3.0 s*	*9.1 s*	*10.2–11.2 s*	*12.1–12.9 s*	*14.0–14.5 s*
Equation	**Metric**	**US Customary**	**Metric**	**US Customary**	
	$d = 0.278Vt + 0.039\frac{V'}{a}$	$d = 1.47Vt + 1.075\frac{V'}{a}$	$d = 0.278Vt$	$d = 1.47Vt$	
	t = time (see above) V = design speed (km/h) a = driver decel. (m/s^2)	t = time (see above) V = design speed (mi/h) a = *driver decel. (ft/s^2)*	t = time (see above) V = design speed (km/h)	t = time (see above) V = design speed (mi/h)	
Common Examples	- Guide signs, traffic signals - Intersection where unusual or unexpected maneuvers are required - The paved area of an intersection for (1) first intersection in a sequence or (2) isolated rural intersections		- Lane markings indicating a change in cross section, overhead lane arrows - A change in cross section (lane drop, two lanes to four lanes, four lanes to two lanes, passing lane, climbing lane, optional lane split, deceleration lane, channelized right turn lane) - Lane closures in work zones		

- Time value *t* represents the sum of the PRT and MT components.
- Deceleration values for Maneuvers A and B can be taken from SSD guideline (page 5-4).

ANNEX D – MAXIMUM AND MINIMUM GRADES, CRITICAL LENGTHS OF GRADES

Austria

REF.	Maximum grades

RVS 03.03.23

The following maximum longitudinal inclinations are recommended (Tab. 1 RVS 03.03.23):

- Motorways and Expressways: ≤ 4%
- major roads: ≤ 6%
- regional roads (with greater traffic importance) ≤ 8%
- regional roads (with less traffic importance) ≤ 10%

Absolutely maximum longitudinal inclination: 12%

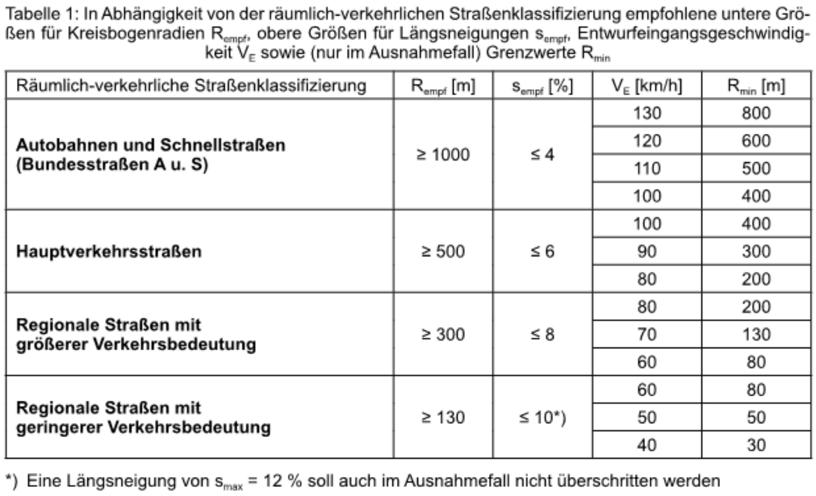


Tabelle 1: In Abhängigkeit von der räumlich-verkehrlichen Straßenklassifizierung empfohlene untere Größen für Kreisbogenradien R_{empf}, obere Größen für Längsneigungen s_{empf}, Entwurfeingangsgeschwindigkeit V_E sowie (nur im Ausnahmefall) Grenzwerte R_{min}

Räumlich-verkehrliche Straßenklassifizierung	R_{empf} [m]	s_{empf} [%]	V_E [km/h]	R_{min} [m]
Autobahnen und Schnellstraßen (Bundesstraßen A u. S)	≥ 1000	≤ 4	130	800
			120	600
			110	500
			100	400
Hauptverkehrsstraßen	≥ 500	≤ 6	100	400
			90	300
			80	200
Regionale Straßen mit größerer Verkehrsbedeutung	≥ 300	≤ 8	80	200
			70	130
			60	80
Regionale Straßen mit geringerer Verkehrsbedeutung	≥ 130	≤ 10*)	60	80
			50	50
			40	30

*) Eine Längsneigung von s_{max} = 12 % soll auch im Ausnahmefall nicht überschritten werden

Source: "RVS 03.03.23 Linienführung und Trassierung" of the "Österreichische Forschungsgesellschaft Straße-Schiene-Verkehr (FSV)" (status: 01.08.2014)

The maximum permitted cross slope also depends on the maximum speed and the arc radius (Tab. 6 RVS 03.03.23). The highest value in the table is 7%.

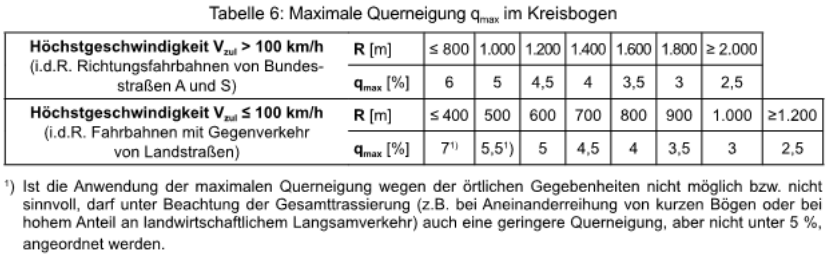


Tabelle 6: Maximale Querneigung q_{max} im Kreisbogen

Höchstgeschwindigkeit V_{zul} > 100 km/h (i.d.R. Richtungsfahrbahnen von Bundesstraßen A und S)	**R** [m]	≤ 800	1.000	1.200	1.400	1.600	1.800	≥ 2.000	
	q_{max} [%]	6	5	4,5	4	3,5	3	2,5	
Höchstgeschwindigkeit V_{zul} ≤ 100 km/h (i.d.R. Fahrbahnen mit Gegenverkehr von Landstraßen)	**R** [m]	≤ 400	500	600	700	800	900	1.000	≥1.200
	q_{max} [%]	7¹⁾	5,5¹⁾	5	4,5	4	3,5	3	2,5

[1]) Ist die Anwendung der maximalen Querneigung wegen der örtlichen Gegebenheiten nicht möglich bzw. nicht sinnvoll, darf unter Beachtung der Gesamttrassierung (z.B. bei Aneinanderreihung von kurzen Bögen oder bei hohem Anteil an landwirtschaftlichem Langsamverkehr) auch eine geringere Querneigung, aber nicht unter 5 %, angeordnet werden.

Source: "RVS 03.03.23 Linienführung und Trassierung" of the "Österreichische Forschungsgesellschaft Straße-Schiene-Verkehr (FSV)" (status: 01.08.2014)

There is also a limit to the upward slant. Therefore, with high longitudinal gradients, the maximum transverse gradient is additionally limited (Tab.7 RVS 03.03.23)

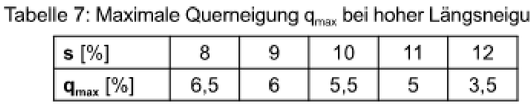


Tabelle 7: Maximale Querneigung q_{max} bei hoher Längsneigung s

s [%]	8	9	10	11	12
q_{max} [%]	6,5	6	5,5	5	3,5

Source: "RVS 03.03.23 Linienführung und Trassierung" of the "Österreichische Forschungsgesellschaft Straße-Schiene-Verkehr (FSV)" (status: 01.08.2014)

REF.	Minimum grades
RVS 03.03.23	The cross fall must not be less than 2,5% If the cross fall is ≥ 2.5% at any point, a longitudinal slope of 0% is also permissible. Otherwise the longitudinal slope must be at least 0,3% In twisting areas there are special regulations
REF.	**Critical lengths of grades**
-	-
REF.	**Grades in junctions, Intersections and roundabouts**
RVS 03.05.12 RVS 03.05.13 RVS 03.05.14	**JUNCTIONS:** longitudinal inclination of the higher-level road in the junction area max. 4% longitudinal inclination of the lower-level road in the junction area max. 6% (in accordance with RVS 03.05.12) **ROUNDABOUTS:** Cross fall of the circular lane between 1.5 - 4% (usually 2.5% to the outside) Max. Longitudinal inclination of the entrances and exits (arms of the roundabout): 4%

Australia

<table>
<tr><th>REF.</th><th>Maximum grades</th></tr>
<tr><td>Austroads Guide to Road Design Part 3 (Section 8.5.3)</td><td>General maximum grades dependent on operating speed and terrain type.

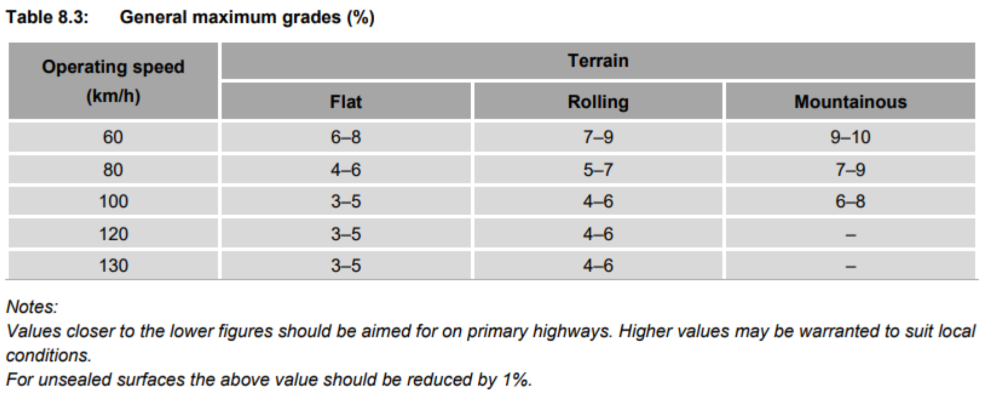



Table 8.3: General maximum grades (%)
<table>
<tr><th>Operating speed (km/h)</th><th colspan="3">Terrain</th></tr>
<tr><th></th><th>Flat</th><th>Rolling</th><th>Mountainous</th></tr>
<tr><td>60</td><td>6–8</td><td>7–9</td><td>9–10</td></tr>
<tr><td>80</td><td>4–6</td><td>5–7</td><td>7–9</td></tr>
<tr><td>100</td><td>3–5</td><td>4–6</td><td>6–8</td></tr>
<tr><td>120</td><td>3–5</td><td>4–6</td><td>–</td></tr>
<tr><td>130</td><td>3–5</td><td>4–6</td><td>–</td></tr>
</table>
Notes:
Values closer to the lower figures should be aimed for on primary highways. Higher values may be warranted to suit local conditions.
For unsealed surfaces the above value should be reduced by 1%.</td></tr>
<tr><th>REF.</th><th>Minimum grades</th></tr>
<tr><td>Austroads Guide to Road Design Part 3</td><td>Minimum grade depends on type of longitudinal drainage being provided.</td></tr>
</table>

(Section 8.5.6)

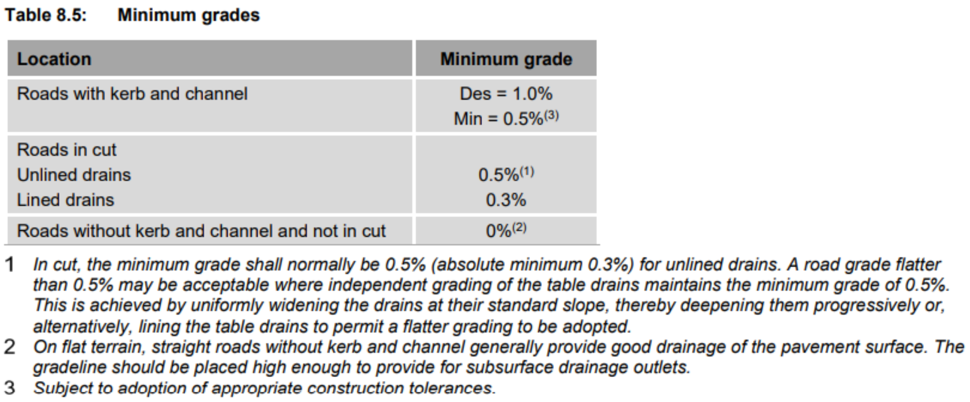


Table 8.5: Minimum grades

Location	Minimum grade
Roads with kerb and channel	Des = 1.0% Min = 0.5%⁽³⁾
Roads in cut Unlined drains Lined drains	 0.5%⁽¹⁾ 0.3%
Roads without kerb and channel and not in cut	0%⁽²⁾

1 *In cut, the minimum grade shall normally be 0.5% (absolute minimum 0.3%) for unlined drains. A road grade flatter than 0.5% may be acceptable where independent grading of the table drains maintains the minimum grade of 0.5%. This is achieved by uniformly widening the drains at their standard slope, thereby deepening them progressively or, alternatively, lining the table drains to permit a flatter grading to be adopted.*
2 *On flat terrain, straight roads without kerb and channel generally provide good drainage of the pavement surface. The gradeline should be placed high enough to provide for subsurface drainage outlets.*
3 *Subject to adoption of appropriate construction tolerances.*

Required cross fall depends on pavement type being provided.

Austroads Guide to Road Design Part 3 (Section 4.2.2)

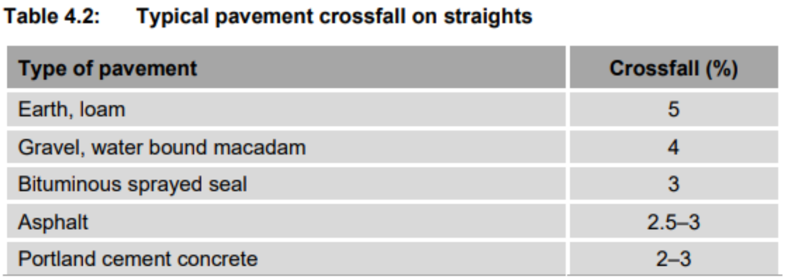


Table 4.2: Typical pavement crossfall on straights

Type of pavement	Crossfall (%)
Earth, loam	5
Gravel, water bound macadam	4
Bituminous sprayed seal	3
Asphalt	2.5–3
Portland cement concrete	2–3

REF. | **Critical lengths of grades**

Austroads Guide to Road Design Part 3 (Section 8.5.4)

Maximum length of steep grades applies.

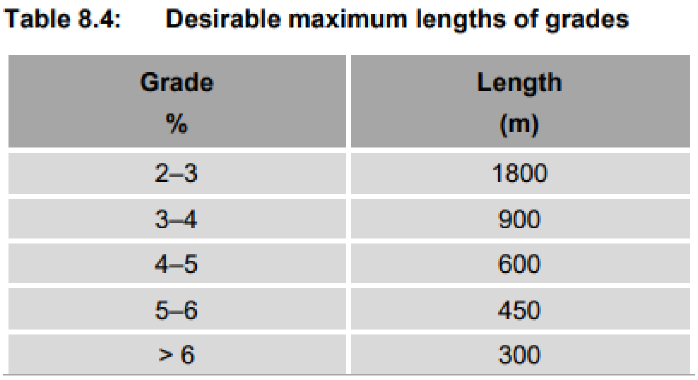


Table 8.4: Desirable maximum lengths of grades

Grade %	Length (m)
2–3	1800
3–4	900
4–5	600
5–6	450
> 6	300

REF. | **Grades in junctions, Intersections and roundabouts**

Austroads Guide to Road Design Part 4A (Section 2.2.2)

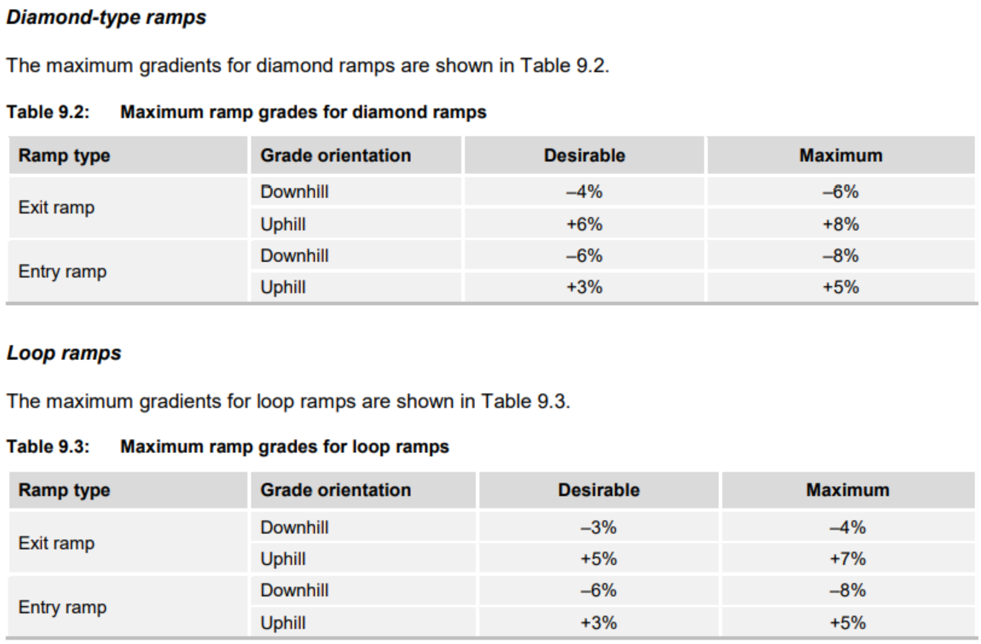
<u>JUNCTIONS:</u>

Desirable and maximum grades dependent on several factors.

For access roads to junctions where access gradients of more than 3% are required, the road should preferably be constructed with a gradient of 3% (maximum 4%) or less for a minimum distance of 10m from the edge of the channel or curb.

Austroads Guide to Road Design Part 4A (Section 2.2.4)	Minimum and maximum cross falls through intersections provided. In general the cross fall adopted for turning roadways where vehicles can turn at moderate speed should desirably not exceed +7% or –3%. For a turn executed at very slow speed (say < 10 km/h), the desirable maximum adverse cross fall (i.e. the vector sum) is –5%.
	ROUNDABOUTS:
Austroads Guide to Road Design Part 4B (Section 4.10.1)	Minimum and maximum cross falls of the circulating carriageway provided. As a general design practice, a maximum pavement cross fall or superelevation of 2.5 to 3% should be adopted for the circulating carriageway. On circulating carriageways with varying cross fall, the superelevation should stay within the range of ± 4%. Grades on the circulating roadway greater than 4% should be avoided. Where the general slope of the land is greater than 4%, it will be necessary to 'bench' the area for the roundabout, using a desirable maximum grade of 3% with an absolute maximum grade of 4%.
Austroads Guide to Road Design Part 4B (Section 4.10.2)	Maximum approach grades provided. Generally, it is desirable that the gradient on approaches to roundabouts be limited to 3 to 4% and should not exceed 6%. While the gradient may extend along part of the length of the entry curve it is essential that: • On an uphill approach a flat area (say 2–3% maximum) is provided on the immediate approach to the roundabout to accommodate the length of one design vehicle. This flat area will assist heavy vehicles to start up and move into gaps, ensure that capacity is not unduly compromised, and also assist with respect to sight distance. • On a downhill approach a sag curve will be required to match the higher gradient to a 3% positive superelevation on the roundabout.
	INTERCHANGES:
Austroads Guide to Road Design	Minimum cross fall provided for Diamond interchanges. For both types of interchanges, the following additional criteria need to be considered: • The cross fall on the minor road may be reduced to a minimum of 2% at ramp terminals to reduce the impact of adverse cross fall on the turning movements. The cross fall on the minor road bridge structure may be reduced to match that at the ramp terminal where a suitable profile on the minor road cannot be achieved. The impact on drainage spread widths should be considered before reducing cross fall on the bridge. In general a higher cross fall on the bridge will result in less drainage facilities being required. • The maximum upgrade for at least the last 30 m from the intersecting edge of pavement for an exit ramp should be limited to 3%

<table>
<tr>
<td>Part 4C (Section 9)

Austroads Guide to Road Design Part 4C (Section 9.3)</td>
<td>
<p>Maximum grade at Diamond interchange ramps and Loop ramps dependent on grade orientation and ramp type.</p>
<p>It is recommended that the preferred maximum gradient is 3% with an absolute maximum of 5%</p>

<p><i>Diamond-type ramps</i></p>
<p>The maximum gradients for diamond ramps are shown in Table 9.2.</p>
<p>Table 9.2: Maximum ramp grades for diamond ramps</p>
<table>
<tr><th>Ramp type</th><th>Grade orientation</th><th>Desirable</th><th>Maximum</th></tr>
<tr><td>Exit ramp</td><td>Downhill</td><td>–4%</td><td>–6%</td></tr>
<tr><td></td><td>Uphill</td><td>+6%</td><td>+8%</td></tr>
<tr><td>Entry ramp</td><td>Downhill</td><td>–6%</td><td>–8%</td></tr>
<tr><td></td><td>Uphill</td><td>+3%</td><td>+5%</td></tr>
</table>
<p><i>Loop ramps</i></p>
<p>The maximum gradients for loop ramps are shown in Table 9.3.</p>
<p>Table 9.3: Maximum ramp grades for loop ramps</p>
<table>
<tr><th>Ramp type</th><th>Grade orientation</th><th>Desirable</th><th>Maximum</th></tr>
<tr><td>Exit ramp</td><td>Downhill</td><td>–3%</td><td>–4%</td></tr>
<tr><td></td><td>Uphill</td><td>+5%</td><td>+7%</td></tr>
<tr><td>Entry ramp</td><td>Downhill</td><td>–6%</td><td>–8%</td></tr>
<tr><td></td><td>Uphill</td><td>+3%</td><td>+5%</td></tr>
</table>
</td>
</tr>
</table>

Belgium

REF.	**Maximum grades**
[1]	The maximal longitudinal slopes are deduced from: • the relation between longitudinal slope and transversal slope • the maximal transversal slope The result shows: • 120km/h: max 4% • 90km/h: max 6% • 50 km/h: max 8%
REF.	**Minimum grades**
[1]	Cross fall min 2,5%
REF.	**Critical lengths of grades**

[1]	Slow vehicles lane added for high slopes (in function of local circumstances)
REF.	**Grades in junctions, Intersections and roundabouts**
[1]	-

Canada

REF.	**Maximum grades**
[1]	Max slope: • motorways 5-7% • primary and secondary 7% • collector and local roads 10% The desirable maximum gradient ranges from 3% to 13% depending on the design designation
REF.	**Minimum grades**
[1]	Level grades (0%) on uncurbed rural highways are acceptable for short distances, if the roadway surface is adequately crowned to drain the surface laterally. A 2% crown is standard for paved roadways. A 3% crown is standard for gravel surfaces. In urban applications, the minimum grade should be 0.5%. An absolute minimum of 0.35% may be considered in a retrofit situation where it means the retention, rather than the removal, of existing pavement. A minimum grade of 0.6% should be maintained along curb returns and a minimum of 1.0% towards the curb line within the limits of an intersection (i.e., the resultant slope of the cross fall and longitudinal gradient should be a minimum of 1%).
REF.	**Critical lengths of grades**
[1]	The length of the slopes is problematic for heavy vehicles. The speed of heavy vehicles varies according to the steepness of the slope and its length. A slow-moving auxiliary lane may be required if the speed differential between automobiles and slow-moving vehicles exceeds 15 km/h.
REF.	**Grades in junctions, Intersections and roundabouts**
[1]	**INTERSECTIONS**: Longitudinal slope from 5% to 10% The desirable maximum grade through intersections on lower speed roadways (design speed ≤ 70 km/h), in an urban environment, is 4 percent.

	Higher speed roadways (design speed > 70 km/h) should be limited to a 3% desirable maximum grade through intersections.

Chile

RDS	**Maximum grades**
[1]	-
RDS	**Minimum grades**
[1]	-
RDS	**Critical lengths of grades**
[1]	-
RDS	**Grades in junctions, Intersections and roundabouts**
[1]	-

Czechia

REF.	**Maximum grades**
[1]	maximal longitudinal slope (its range 3% - 12% depends on road category and kind of terrain)
REF.	**Minimum grades**
[1]	minimal longitudinal slope 0,5%
REF.	**Critical lengths of grades**
[1]	min. length
REF.	**Grades in junctions, Intersections and roundabouts**
[1]	**<u>JUNCTIONS:</u>** maximum longitudinal slope (recommended max. 3% for intersection space) max. longitudinal slope of arms 4% **<u>ROUNDABOUTS:</u>** • max. recommended longitudinal slope of the roundabout space: 6%, • max. cross slope of ring road belt 3,5%, recommended max. total slope of ring road belt 5% • max. longitudinal slope of arms 4%,

France

REF.	**Maximum grades**
technical guide ICTAAL	**<u>RURAL MOTORWAYS:</u>** • 130 km/h (ICTAAL L1): maximum gradient = 5 %

technique guide ARP	- 110 km/h: maximum gradient = 6% **URBAN STRUCTURING ROADS (IE URBAN MOTORWAYS):** - 90 km/h (VSA 90): maximum gradient = 6% - VSA 110: maximum gradient = 6% **MAJOR ROADS:** - maximum gradient = 6% (category R1) For a road developing in hilly terrain or in the presence of site-related constraints (category R2), the maximum gradient of 7% may be tolerated but only where necessary and in the knowledge that this could alter the safety level
REF.	**Minimum grades**
[1]	There is no minimum gradient but the combination of the vertical alignment and the superelevation must ensure a sufficient resultant gradient for the drainage of surface water on the carriageway. This is critical where the vertical gradient is low (<1%) and the superelevation orientation is changing - on rural motorways, the resultant gradient must be at least 0.5 % at all points on the carriageway - on urban structuring roads (urban motorways), the resultant gradient must be at least 1 % at all points on the carriageway - on major roads , the resultant gradient must be at least 1 % at all points on the carriageway. A value of 0.5% can be tolerated in case of constraints, but with a particular vigilance during the construction phase.
REF.	**Critical lengths of grades**
[1]	On descending gradients, the difference in level D of the section in which there is a slope greater than 3% will be adopted as the risk indicator. A section where critical length exceeds 130 m is defined as a steep slope, which should be avoided; failing that, and in order to encourage users – especially HGV drivers – to adopt suitable driving behaviour for steep slopes, it is preferable: - to prohibit the use of long straight sections of road and lengthy bends, and instead to use short straight sections and bends with radii in the region of 1.5 Rdn;

	• to introduce an abrupt steep gradient instead of gradually steepening slopes; • to avoid a more gradual slope in the middle of a steep slope; • to avoid placing unique points (interchanges, non-superelevated bends, etc.) in the middle of a steep slope. On rural motorways, it is recommended to provide a slow-moving lane where critical length exceeds 130 m.
REF.	**Grades in junctions, Intersections and roundabouts**
[1]	**INTERCHANGES ON RURAL MOTORWAYS:** • maximum gradient = 6% **INTERCHANGES ON URBAN STRUCTURING ROADS:** • maximum gradient = 6% **ROUNDABOUTS:** the recommendations are mainly on the grade of the major road where the roundabout is installed: • installing a roundabout on a roadway with a grade lower than 3% is generally not a problem → *recommended value* • Between 3% and 6%, some designs can adversely affect safety, notably by impairing the stability of trucks (steep banking, high entrance speed, etc.). → *must be avoided but can be admitted* • If the grade is higher than 6%, it is generally acknowledged that this type of facility can create some serious problems. However, under the same conditions, another type of at grade intersection does not always perform better and offers a lower level of safety. The use of a roundabout can therefore not be excluded in principle at grades of 6% or higher, through the modification of existing roads. In the case of a new facility, giving up the roundabout solution should not lead to the acceptance of another type of intersection, but to the elimination or relocation of the intersection, or to a modification of its vertical profile. → *a roundabout on a grade higher than 6% is strongly discouraged and can lead to safety issues. However, this solution generally provides a better safety level than other at-grade junctions and therefore cans not be excluded on existing roads, to improve an at grade junction that cannot be eliminated or relocated*

Italy

REF.	**Maximum grades**

[1]	max slope for motorways: 6%, max for local roads 10%
REF.	**Minimum grades**
[1]	-
REF.	**Critical lengths of grades**
[1]	-
REF.	**Grades in junctions, Intersections and roundabouts**
[1]	**JUNCTIONS:** Long. Slope from 5% to 10% according to road classes **AT GRADE INTERSECTIONS:** Max slope of the incoming roads.

Japan

REF.	**Maximum grades**
[1]	Depends on road classification and design speed. Maximum between 2 and 12 %; higher values for certain exceptions. e.g. max. 2% for Regular motor vehicle roads with design speed 120km/h; with exception max. 5% A climbing lane, if necessary, shall be provided to the carriageway of the regular motor vehicle roads where grades exceed 5% (or 3% when the design speed is no less than 100 km per hour on other regular motor vehicle roads than national expressways and national highways).
REF.	**Minimum grades**
[1]	-
REF.	**Critical lengths of grades**
[1]	-
REF.	**Grades in junctions, Intersections and roundabouts**
[1]	-

Mexico

REF.	**Maximum grades**
[1]	Max slope: • motorways: 6%,

	• regional roads: 7% • local roads: 12%
REF.	**Minimum grades**
[1]	-
REF.	**Critical lengths of grades**
[1]	-
REF.	**Grades in junctions, Intersections and roundabouts**
[1]	-

Poland

REF.	**Maximum grades**
[1]	max 4% (motorway Vd(design speed)=120 km/h), max 12% (Vd(design speed)=120 km/h)
REF.	**Minimum grades**
[1]	longitudinal slope: • min. 0% (urban) • 0,3% (rural)
REF.	**Critical lengths of grades**
[1]	-
REF.	**Grades in junctions, Intersections and roundabouts**
[1]	**INTERSECTIONS AND ROUNDABOUTS:** Max. longitudinal slope • Major road 6% (rural) and 4% (urban) • Minor road 3% for 20m from the edge of intersection

Portugal

REF.	**Maximum grades**
[1]	-
REF.	**Minimum grades**
[1]	-
REF.	**Critical lengths of grades**
[1]	-
REF.	**Grades in junctions, Intersections and roundabouts**

[1]	**JUNCTIONS:** Long. Slope from max. 6%. **INTERSECTIONS & ROUNDABOUTS:** Long. Slope from max. 6%

Spain

REF.	**Maximum grades**
[1]	-
REF.	**Minimum grades**
[1]	-
REF.	**Critical lengths of grades**
[1]	-
REF.	**Grades in junctions, Intersections and roundabouts**
	INTERCHANGES & INTERSECTIONS: recommended slope for legs 3%, max. 6%. **ROUNDABOUTS:** Legs slope inferior to 2% recommended §4.6.2.4.

South Africa

<table>
<tr><th>REF.</th><th>Maximum grades</th></tr>
<tr><td>[1]</td><td>Varies based on existing terrain and design speed as follows:

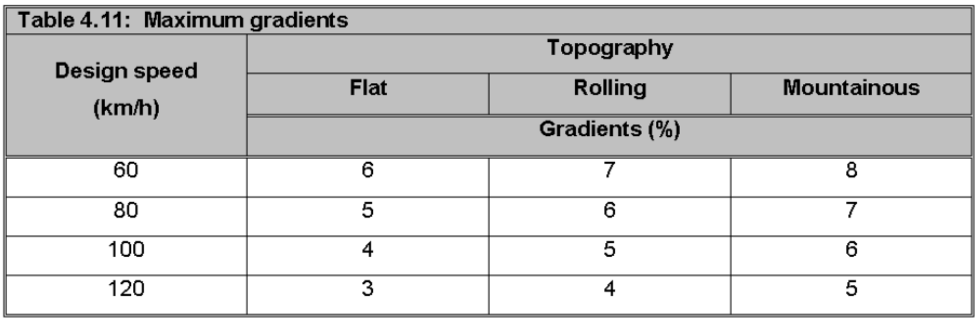
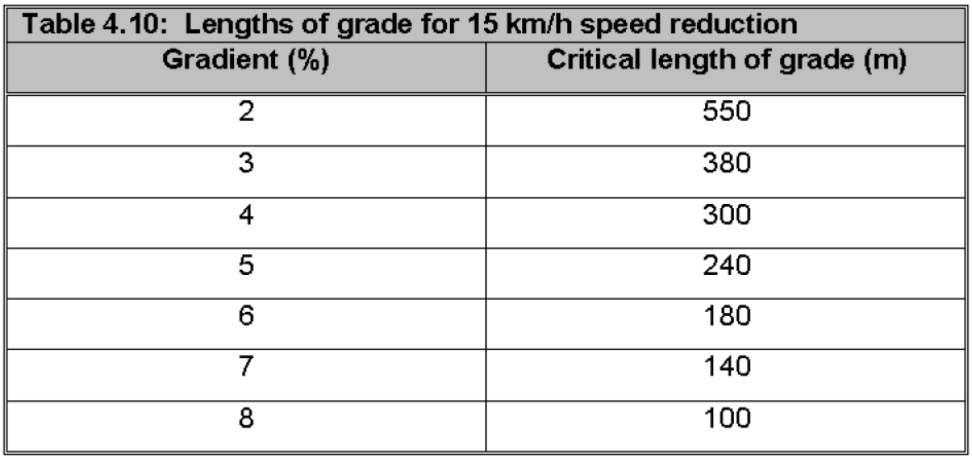



Table 4.11: Maximum gradients
<table>
<tr><th rowspan="3">Design speed (km/h)</th><th colspan="3">Topography</th></tr>
<tr><th>Flat</th><th>Rolling</th><th>Mountainous</th></tr>
<tr><th colspan="3">Gradients (%)</th></tr>
<tr><td>60</td><td>6</td><td>7</td><td>8</td></tr>
<tr><td>80</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>100</td><td>4</td><td>5</td><td>6</td></tr>
<tr><td>120</td><td>3</td><td>4</td><td>5</td></tr>
</table></td></tr>
<tr><th>REF.</th><th>Minimum grades</th></tr>
<tr><td>[1]</td><td>Longitudinal grade: min. 0,5% to allow side drains to operate without siltation</td></tr>
<tr><th>REF.</th><th>Critical lengths of grades</th></tr>
</table>

<table>
<tr><td>[1]</td><td>Defined as the maximum length of grade on which a loaded truck can operate without an “unreasonable” reduction in speed. A speed reduction of 15km/h is considered “unreasonable”. Based on the design truck the following table applies:

<table>
<tr><th colspan="2">Table 4.10: Lengths of grade for 15 km/h speed reduction</th></tr>
<tr><th>Gradient (%)</th><th>Critical length of grade (m)</th></tr>
<tr><td>2</td><td>550</td></tr>
<tr><td>3</td><td>380</td></tr>
<tr><td>4</td><td>300</td></tr>
<tr><td>5</td><td>240</td></tr>
<tr><td>6</td><td>180</td></tr>
<tr><td>7</td><td>140</td></tr>
<tr><td>8</td><td>100</td></tr>
</table>
</td></tr>
<tr><th>REF.</th><th>Grades in junctions, Intersections and roundabouts</th></tr>
<tr><td>[1]</td><td>**<u>JUNCTIONS:</u>**
Longitudinal slope max. = 8%, however max resultant grade (combination of long grade and cross fall) = 8%.

<u>INTERSECTIONS & ROUNDABOUTS</u>:
• Minor roads max. = 20%
• Major roads max. = 8%</td></tr>
</table>

World Road Association (PIARC)

La Grande Arche, Paroi Sud, 5e étage, F-92055 La Défense cedex