Design Manual for Roads and Bridges

Road Layout
Design

CD 109
Highway link design

(formerly TD 9/93, TD 70/08)

Revision 1

Summary
This document provides requirements and advice for all aspects of highway link design to be used for both new and improved all-purpose and motorway trunk roads including connector roads.

Application by Overseeing Organisations
Any specific requirements for Overseeing Organisations alternative or supplementary to those given in this document are given in National Application Annexes to this document.

Feedback and Enquiries
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated Highways England team. The email address for all enquiries and feedback is: Standards_Enquiries@highwaysengland.co.uk

This is a controlled document.

Contents

Release notes 3

Foreword 4
Publishing information . . . 4
Contractual and legal considerations . . . 4

Introduction 5
Background . . . 5
Assumptions made in the preparation of this document . . . 5
Design principles . . . 5
General . . . 5
Connection to existing roads . . . 5
Wide single 2 + 1 roads and climbing lanes . . . 5
Coordinated link design . . . 5

Abbreviations and symbols 6

Terms and definitions 7

1. Scope 8
Aspects covered . . . 8
Implementation . . . 8
Use of GG 101 . . . 8

2. Design speed 9
Selection of design speed . . . 9
Rural roads . . . 9
Urban roads . . . 12
Harmonic mean visibility (VISI) . . . 12
Design speed related parameters and relaxations . . . 13

3. Sight distance 18
Stopping sight distance . . . 18
Full overtaking sight distance . . . 18
Obstructions to sight distance . . . 18
Relaxations . . . 19

4. Horizontal alignment 20
Road camber and superelevation . . . 20
Relaxations . . . 20
Application of superelevation . . . 21
Widening on curves . . . 21
Transitions . . . 22
Length of curve: . . . 22

5. Vertical alignment 23
Gradients . . . 23
Minimum gradient . . . 23
Vertical curves . . . 23
General . . . 23
Crest curves . . . 23
Sag curves . . . 24
Relaxations . . . 24
Crest curves . . . 24
Sag curves . . . 24

6. Wide single 2+1 roads **26**
Design principles . . . 26
Geometric standards . . . 27
Cross-section . . . 27
Lengths of overtaking lane sections . . . 29
Changeovers . . . 29
WS2+1 interfaces . . . 30
Traffic signs and road markings . . . 31

7. Climbing lanes - single carriageways **38**
Introduction . . . 38
Layout . . . 38
Layout at the start of a climbing lane . . . 38
Layout at the end of climbing lane . . . 40
Sight distance requirements . . . 45
Road markings . . . 45

8. Climbing lanes - dual carriageways and motorways **50**
Introduction . . . 50
Layout . . . 50
Lane widths . . . 50
Layout at the start of climbing lane . . . 50
Layout at the end of climbing lane . . . 51

9. Single carriageway road overtaking sections **56**
Overtaking sections . . . 56
Overtaking value . . . 56
Lengths of road over 2km . . . 56
Lengths of road less than 2 km . . . 56
Level overtaking sections . . . 56
Commencement of level overtaking sections . . . 57
Termination of level overtaking sections . . . 57
Climbing lane sections . . . 58
Commencement of climbing lane overtaking sections . . . 58
Termination of climbing lane overtaking sections . . . 58
Single lane downhill sections at climbing lanes . . . 58
Commencement of single lane downhill overtaking sections at climbing lanes . . . 58
Termination of single lane downhill overtaking sections at climbing lanes . . . 61
Dual carriageway overtaking sections . . . 61
Commencement of dual carriageway overtaking sections . . . 61
Termination of dual carriageway overtaking sections . . . 61
Wide single 2+1 roads (WS2+1) . . . 61
Commencement of WS2+1 overtaking sections . . . 61
Termination of WS2+1 overtaking sections . . . 61
Obstructions to overtaking . . . 61
Horizontal curve design . . . 62
Vertical curve design . . . 64
Changes in carriageway type . . . 65

10. Normative references **66**

11. Informative references **67**

Appendix A. Coordinated link design **68**

Release notes

Version	Date	Details of amendments
1	Mar 2020	Revision 1 (March 2020) Update to references in England National Application Annex only. Revision 0 (November 2019) CD 109 replaces TD 9/93 and TD 70/08. This full document has been re-written to make it compliant with the new Highways England drafting rules.

Foreword

Publishing information

This document is published by Highways England.

This document supersedes TD 9/93 "Highway Link Design" and TD 70/08 "Design of Wide Single 2+1 Roads", which are withdrawn.

Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

Introduction

Background

This document sets out the design requirements and advice to be used when developing the design of a highway / road link.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 5.N] apply to this document.

Design principles

General

This document provides requirements and advice to derive the design speed and the appropriate values of geometric parameters for use in the design of the road alignment. It states the basic principles to be used for coordinating the various geometrical elements of the road design, which together form the three dimensional design of the road.

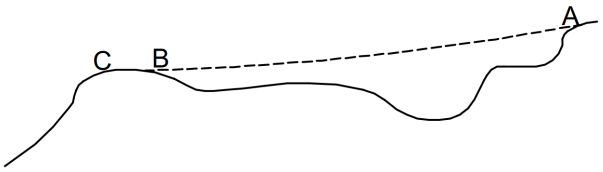
This document provides requirements for maximum and minimum levels of provision for the various design features and also identifies where relaxations from these requirements are permitted.

Connection to existing roads

Where an improved section of road rejoins an unimproved section of existing road, providing a similar standard of curvature and stopping sight distance as provided for the improvement will create a consistent standard at the interface.

The figure below shows the connection of an improvement to an existing road. The curvature and stopping sight distance at point C is adequate for the approach design speed which has increased due to the improvement between points A and B.

Connection to existing roads



Wide single 2 + 1 roads and climbing lanes

This document includes requirements and advice for the design of wide single 2 + 1 roads and climbing lanes when improving an existing carriageway or in a new build situation.

Coordinated link design

The various geometrical elements detailed in this document need to be coordinated, together with cross-section (CD 127 [Ref 1.N]) and junction layouts (CD 122 [Ref 3.N], CD 123 [Ref 2.N] and roundabouts CD 116 [Ref 4.N]), so the three-dimensional layout as a whole is appropriate in terms of traffic safety, operation and economic / environmental effects. Single carriageway design is given particular emphasis due to the problems of driver understanding and provision for overtaking. A general guide of the layout features, such as edge treatments, access treatments and junction types, that can be appropriate for various types of rural roads is given in Appendix A. It is not possible to tabulate overall layout characteristics for roads in urban areas in the same way as for rural areas, as the constraints of the existing urban fabric will result in designs tailored to meet the site-specific requirements.

Abbreviations and symbols

Abbreviations

Abbreviation	Definition
AADT	Annual average daily traffic
C/way	Carriageway
D2AP	Dual 2 lane all-purpose
D3AP	Dual 3 lane all-purpose
D2M	Dual 2 lane motorway
D3M	Dual 3 lane motorway
D4M	Dual 4 lane motorway
FOSD	Full overtaking sight distance
Km	Kilometres
Kph	Kilometres per hour
S2	Single 2 lane carriageway
TSRGD	Traffic Signs Regulations and General Directions
VRS	Vehicle Restraint System
WS2	Wide Single 2 lane carriageway
WS2+1	Wide Single 2+1 carriageway

Symbols

Symbol	Definition
Ac	Alignment constraint
B	Bendiness Degrees / km
L	Length of basic transition (metres)
Lc	Layout constraint
n	Number of observations
q	Rate of change of centripetal acceleration (metres / second^3) travelling along curve at constant speed V(kph)
R	Radius of curve (metres)
S	Superelevation %
V	Design speed kph
VW	Average verge width (averaged for both sides of the road)
VISI	Harmonic mean visibility

Terms and definitions

Terms and definitions

Term	Definition
Adverse camber	A road profile where the carriageway surface slopes away from the inside of a bend, resulting in the carriageway being higher on the inside of the bend than on the outside.
Alignment constraint	The degree of constraint imparted by the road alignment.
Bendiness	The total change of direction in horizontal alignment in degrees / km measured over a minimum length of 2km.
Changeover	A carriageway layout which effects a change in the designated use of the middle lane of a WS2+1 road from one direction of traffic to the opposite direction.
Climbing lane	The nearside lane when a lane is added to a single carriageway, dual carriageway or motorway in order to improve capacity and / or safety because of the presence of a steep gradient.
Conflicting changeover	A changeover where the vehicles using the middle lane on a WS2+1 road are travelling towards each other.
Full overtaking sight distance	The sight distance required for overtaking vehicles using the opposing traffic lane on single carriageway roads.
Harmonic mean visibility	The harmonic mean of individual measurements of sight distance.
Layout constraint	The degree of constraint imparted by the road cross-section, verge width and frequency of junctions and accesses.
Link	A length of road between junctions.
Non-conflicting changeover	A changeover where the vehicles using the middle lane on a WS 2+1 road are travelling away from each other.
Non-overtaking section	Sections of a 2 lane single carriageway road which are not overtaking sections.
Overtaking lane section	A two lane section of a WS2+1 road provided in one direction to facilitate overtaking, with the opposing traffic confined to one lane.
Overtaking section	Sections of 2 lane single carriageway road where the combination of horizontal / vertical alignment, visibility, or width provision is such that clear opportunities for overtaking using the opposing lane occur.
Single lane section	A single lane section of a WS2+1 road provided in one direction running parallel to an overtaking lane section in the opposite direction.
Stopping sight distance	The distance within which drivers need to be able to see ahead to stop from a given speed as required by this document.
WS2 carriageway	A wide single carriageway road with one lane in each direction.
WS2+1 carriageway	A road with two lanes of travel in one direction and a single lane in the opposite direction as outlined in Section 6 of this document.
WS2+1 interface	The interface between a WS2+1 road and a two-lane single carriageway road (S2).

1. Scope

Aspects covered

1.1 This document provides requirements and advice for all aspects of highway / road link design and shall be used for both new and improved motorway and all-purpose trunk roads.

1.2 This document shall apply to WS2 roads where they are equal to or less than 2km in length.

Implementation

1.3 This document shall be implemented forthwith on all schemes involving highway / road link design on the Overseeing Organisations' motorway and all-purpose trunk roads according to the implementation requirements of GG 101 [Ref 5.N].

Use of GG 101

1.4 The requirements contained in GG 101 [Ref 5.N] shall be followed in respect of activities covered by this document.

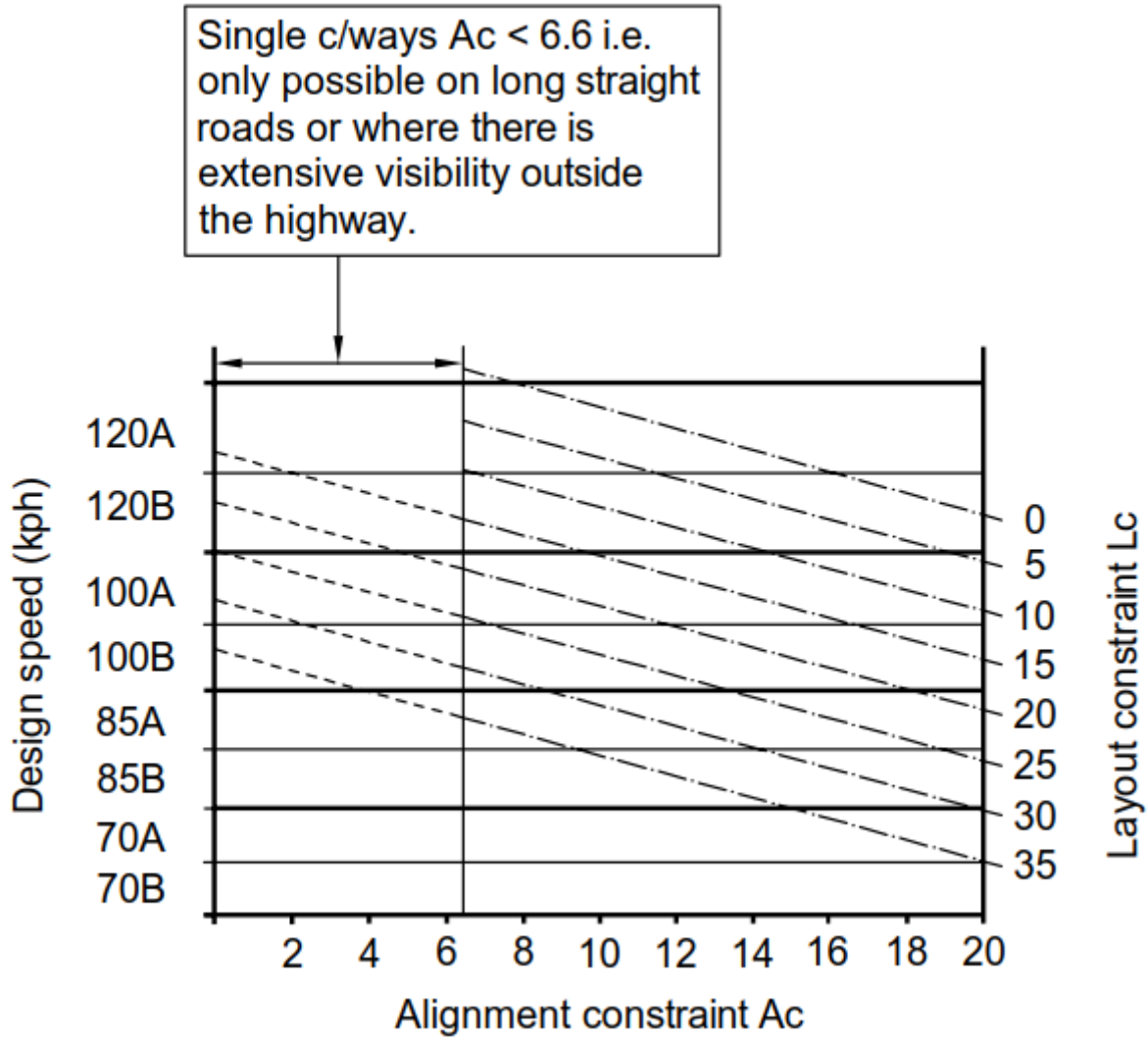
2. Design speed

Selection of design speed

Rural roads

2.1 For new rural roads, design speed shall be derived from Figure 2.1 using alignment constraint (Ac) and layout constraint (Lc).

Figure 2.1 Selection of design speed (rural roads)



NOTE 1 *In Figure 2.1 the design speeds are arranged in bands (i.e. 120kph, 100kph, 85kph, etc). Suffixes A and B indicate the higher and lower categories of each band.*

NOTE 2 *As an example using Figure 2.1 to derive a design speed, an Ac value of 12 and and Lc value of 15 would give a design speed of 100A.*

2.2 Alignment constraint (Ac) shall be calculated using Equation 2.2a and Equation 2.2b for dual carriageways and single carriageways respectively:

Equation 2.2a Dual carriageways

$$Ac = 6.6 + \frac{B}{10}$$

Equation 2.2b Single carriageways

$$Ac = 12 - \frac{\text{VISI}}{60} + \frac{\text{2B}}{45}$$

where:

B = Bendiness degrees / km.

VISI = Harmonic mean visibility (metres) (see harmonic mean visibility section below).

NOTE *Bendiness is calculated by dividing the sum of the change in direction (in degrees) of a road by the length (in km) over which it occurs. For example, a 3km length of road with a total change in direction of 180 degrees would have a bendiness of 60 degrees / km.*

2.3 Layout constraint (Lc) shall be derived using Table 2.3.

Table 2.3 Layout constraint (Lc)

Road type	S2				WS2		WS2+1		D2AP		D3AP	D2M	D3M	D4M
Carriageway width (excluding hard strips and hard shoulder)	6 metres		7.3 metres		10 metres		11.5 metres		Dual 7.3 metres		Dual 11 m-etres	Dual 7.3 metres & hard shoulder	Dual 11 metres & hard shoulder	Dual 14.7 metres & hard shoulder
Frequency of commercial accesses, lay-bys and junctions	H	M	M	L	M	L	M	L	M	L	L	L	L	L
Standard verge width	29	26	23	21	19	17	19	17	10	9	6	4	0	0
1.5 metre verge	31	28	25	23	-	-	-	-	-	-	-	-	-	-
0.5 metre verge	33	30	-	-	-	-	-	-	-	-	-	-	-	-
L = Low number of commercial accesses, lay-bys and junctions, less than or equal to 5 per km														
M = Medium number of commercial accesses, lay-bys and junctions, between 6 to 8 per km														
H = High number of commercial accesses, lay-bys and junctions, greater than or equal to 9 per km														

NOTE 1 *Layout constraint (Lc) measures the degree of constraint provided by the road cross-section, verge width, and frequency of junctions, lay-bys and commercial accesses.*

NOTE 2 *Values of Lc are obtained from Table 2.3 by reading along the appropriate verge width rows and down the road type columns corresponding to the appropriate frequency of commercial accesses, lay-bys and junctions. The appropriate value of Lc is denoted by the number read at the intersection of the verge width row and the road type column.*

2.4 For road improvements of up to 2km in length on existing rural roads, the design speed shall be derived using Figure 2.1 with the value of Ac calculated for a minimum road length of 2 km incorporating the section of road improvement.

Urban roads

2.5 On urban roads, design speeds shall be selected with reference to the speed limits for the road, as shown in Table 2.5.

Table 2.5 Urban roads speed limit/design speed relationship

Speed limit		Design speed
Mph	**Kph**	**Kph**
30	48	60B
40	64	70A
50	80	85A
60	96	100A

NOTE *Design speeds are higher than the speed limit and therefore permit a small margin for vehicle speeds in excess of the speed limit.*

Harmonic mean visibility (VISI)

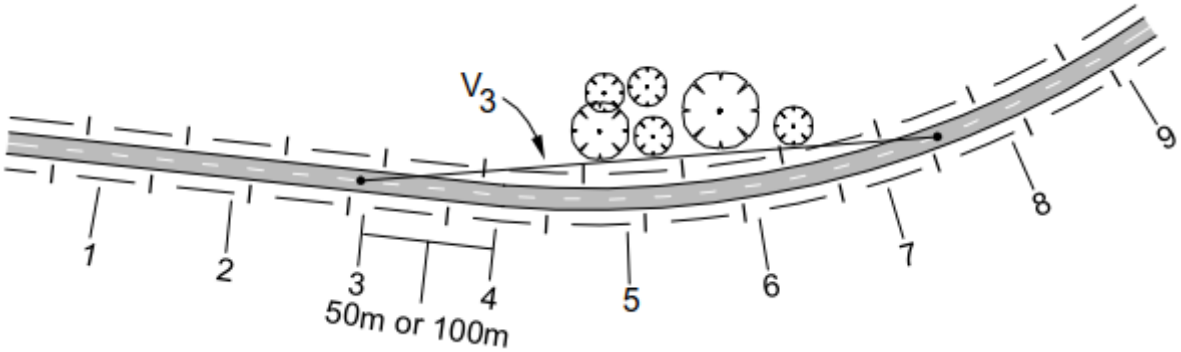
2.6 The harmonic mean visibility (VISI) shall be measured over a minimum length of 2km.

2.6.1 Measurements of sight distance should be taken in both directions at regular intervals (50 metres for sites of restricted visibility, 100 metres for sites with unrestricted visibility).

2.7 Sight distance shall be measured from an eye height of 1.05 metres to an object height of 1.05 metres, with both measurements taken above the centre line of the road surface.

2.8 Sight distance shall be the true sight distance available at any location, including any sight distance available across verges and outside of the highway boundary or across embankment slopes or adjoining land, as shown in Figure 2.8.

Figure 2.8 Measurement of harmonic mean visibility



2.8.1 The harmonic mean visibility for new roads should be calculated using Equation 2.8.1.

Equation 2.8.1 Formula for calculating harmonic mean visibility

$$VISI = \frac{n}{\frac{1}{V_1} + \frac{1}{V_2} + \frac{1}{V_3} \ldots + \frac{1}{V_n}}$$

where:

n =	Number of observations.
V_1 =	Sight distance at point 1, etc.

2.8.2 The harmonic mean visibility for existing roads should be calculated using an empirical relationship given in Equation 2.8.2.

Equation 2.8.2 Empirical relationship

$$\mathrm{Log}_{10} VISI = 2.46 + \frac{\mathrm{VW}}{25} - \frac{B}{400}$$

where:

VW =	Average verge width (averaged for both sides of the road)
B=	Bendiness (degree per km - minimum length of 2 km)

NOTE 1 Equation 2.8.2 is applicable up to VISI = 720 metres.

NOTE 2 On long straight roads, or where sight distance is available outside of the highway boundary, the relationship between the average verge width and bendiness can result in values of harmonic visibility calculated using Equation 2.8.1 being significantly underestimated.

2.8.3 For preliminary route analysis, where detailed measurements of sight distance are not available, the following typical values should be used:

1) VISI = 700 metres for long virtually straight roads, or where the road is predominantly on embankment affording high visibility across embankment slopes or adjoining level land;
2) VISI = 500 metres where a new road is designed with continuous overtaking visibility, with large crest K values and wide verges for visibility;
3) VISI = 300 metres where a new road is designed with frequent overtaking sections, but with stopping sight distance provision at all sharp curves;
4) VISI = 100 - 200 metres where an existing single carriageway contains sharp bends, frequent double white line sections and narrow verges.

NOTE The empirical relationship provided by Equation 2.8.2 can be used for the preliminary analysis of existing routes if values of bendiness (B) are available.

Design speed related parameters and relaxations

2.9 Designs shall provide at least the desirable minimum values for stopping sight distance, horizontal curvature, vertical crest curvature and sag curvature as shown in Table 2.10, except for the following situations:

1) where a relaxation is permitted by sections 2, 3, 4 or 5 of this document;
2) the design of a vertical crest curve on a 2 lane single carriageway road (see Section 9).

2.9.1 Design parameters should meet or exceed desirable minimum values except where particular circumstances relating to 2 lane single carriageways roads exist (see Section 9).

NOTE Requirements and advice on the application of relaxations below desirable minimum is provided in GG 101 [Ref 5.N].

2.9.2 Interfaces between sections of road with different design speeds should be designed so as not to suddenly present the driver with low radius horizontal curves, sharp crests or shorter sight distances.

2.10 Minimum geometric parameters for full overtaking sight distance (FOSD) and overtaking crest K values that shall be used for the corresponding design speed are shown in Table 2.10.

Table 2.10 Design speed related parameters

Design speed kph	120	100	85	70	60	50	V2/R
Stopping sight distance (metres)							
Desirable minimum	295	215	160	120	90	70	-
One step below desirable minimum	215	160	120	90	70	50	-
Horizontal curvature (metres)							
Minimum R* with adverse camber and without transitions	2880	2040	1440	1020	720	520	5
Minimum R* with superelevation of 2.5%	2040	1440	1020	720	510	360	7.07
Minimum R* with superelevation of 3.5%	1440	1020	720	510	360	255	10
Desirable minimum R (superelevation 5%)	1020	720	510	360	255	180	14.14
One step below desirable Minimum R (superelevation 7%)	720	510	360	255	180	127	20
Two steps below desirable minimum radius (superelevation 7%)	510	360	255	180	127	90	28.28
Vertical curvature							
Desirable minimum* crest K value	182	100	55	30	17	10	-
One step below desirable min crest K value	100	55	30	17	10	6.5	-
Desirable minimum sag K value	37	26	20	20	13	9	-
Overtaking sight distances							
Full overtaking sight distance FOSD (metres)	-	580	490	410	345	290	-
FOSD overtaking crest K value	-	400	285	200	142	100	-
* Not recommended for use in the design of single carriageways (see Section 9)							
The V^2/R values shown above simply represent a convenient means of identifying the relative levels of design parameters, irrespective of design speed.							

NOTE 1 The limit for relaxations is defined by a given number of design speed steps below a specific bench mark, usually the desirable minimum. Relaxations vary according to the type of road - motorway or all-purpose, and whether the design speed is band A or band B. Details for permitted relaxations are given in:

1) Section 3 for stopping sight distance;

2) Section 4 for horizontal alignment; and

3) section 5 for vertical alignment.

NOTE 2 GG 101 [Ref 5.N] provides requirements and advice on recording the decision process when applying relaxations.

NOTE 3 When preparing design options that include relaxations, a number of site specific factors need to be assessed, including, whether the site is:

1) isolated from other relaxations;

2) isolated from junctions;

3) one where drivers have desirable minimum stopping sight distance;

4) subject to momentary visibility impairment only;

5) subject to low traffic volumes;

6) on geometry that is readily understandable to road users;

7) on a road with no frontage access;

8) one where traffic speeds are reduced locally due to adjacent road geometry (e.g. uphill sections, approaching roundabouts and priority junctions where traffic has to give way or stop, etc), or speed limits.

NOTE 4 The safety risk of using a relaxation in the design can be mitigated by providing:

1) collision prevention measures;

2) specific warning signs and road markings.

2.11 Values for stopping sight distance, horizontal curvature and vertical curvature shall not be less than those given in Table 2.10 for 50kph design speed regardless of permitted relaxations.

2.12 Except for stopping sight distance relaxations of up to 1 design speed step below desirable minimum coincident with horizontal curvature relaxations of up to 1 design speed step below desirable minimum, relaxations shall not be used in combination.

2.13 The relaxations below desirable minimum in stopping sight distance, desirable minimum vertical curvature for crest curves and sag curves, described in Sections 3 and 5 of this document respectively, shall not be used on the immediate approaches to junctions.

NOTE For the purposes of this document the immediate approaches to a junction are defined as:

1) for minor road approaches at at-grade priority junctions without diverge and merge tapers, those lengths of carriageway on the minor roads between a point 1.5 times the desirable minimum stopping sight distance upstream of the stop line or give way line and the stop line or give way line itself;

2) for major road approaches at at-grade priority junctions without diverge and merge tapers, those lengths of carriageway on the mainline between a point 1.5 times the desirable minimum stopping sight distance from the centre line of the minor road and the centre line itself;

3) for at-grade junctions with a diverge taper the length of carriageway from a point 1.5 times the desirable minimum stopping sight distance upstream of the start of the diverge taper to a point level with the minor road centre line;

4) for at-grade junctions with a diverge auxiliary lane the length of carriageway from a point 1.5 times the desirable minimum stopping sight distance upstream of the start of the auxiliary lane taper to a point level with the minor road centre line;