Design Controls

Once the functional classification (e.g., collector, arterial, etc.) of a proposed highway has been defined, major controls affecting the design must be specified in order to guide the design process. The functional classifications of highways in rural areas include principal arterials, minor arterials, major and minor collectors, and local roads. At a minimum, the following design controls usually must be specified.

Traffic volumes

Design vehicle

Design speed

Maximum grade

Lane and shoulder widths

Traffic Volumes —The traffic data should include the current and future average daily traffic (ADT), the future design hourly volume (DHV), directional distribution, and truck percentage, as indicated in Table 2-1. On most highways, the DHV is used for design. The ADT may be used for design of minor, low-volume roads. On highways with unusual or highly seasonal fluctuations in traffic flow, the DHV should be based upon detailed analysis of the anticipated demand. For important intersections, data should be obtained to show traffic movements during morning and evening peak hours and at other times of heavy traffic. The capacity of each highway and the levels of service associated with the demand must be determined from a capacity analysis. For design purposes, the guidelines shown in Table 2-2 may provide an initial indication of the appropriate levels of service. For example, if other data are unavailable to indicate otherwise, level-of-service D would be appropriate for a rural collector highway in mountainous terrain. Estimation of actual service flow rates, level of service, and related performance measures should be done in accordance with procedures described in the latest edition of the Highway Capacity Manual (HCM).

Design Vehicles—Width and height, overhangs, and minimum turning paths at intersections are key dimensions to be noted and accommodated. Current policy (i.e. HCM) states that the vehicle that should be used in design for normal operation is the largest one that represents a significant percentage of the traffic for the design year. For design of most highways accommodating truck traffic, one of the design semitrailer combinations is typically used. When geometric configuration is constricted, such as in urban areas and at certain intersections, a design check should be made for the largest vehicle expected to ensure that it can negotiate the designated turns, particularly if pavements are curbed. In special cases, a design may have to be made to accommodate vehicles larger than the WB-15. Minimum turning paths are shown in Table 2-3. Templates are typically used to determine the location of wheel paths.

Table 2-1
Traffic elements and their relation - rural highways
(Source: Ref. 2, Table II-6)

Traffic element	Explanation and nationwide percentage or factor
Average daily traffic: ADT	Average 24-hour volume for a given year; total for both directions of travel, unless otherwise specified. Directional or one-way ADT is an average 24-hour volume in one direction of travel only.
Current traffic	ADT composed of existing trips, including attracted traffic, that would use the improvement if opened to traffic today (current year specified).
Future traffic	ADT that would use a highway in the future (future year specified). Future traffic may be obtained by adding generated traffic, normal traffic growth, and development traffic to current traffic, or by multiplying current traffic by the traffic projection factor.
Traffic projection factor	Future traffic divided by current traffic. General range, 1.5 to 2.5 for 20-year period. (Freeways may be up to 20 percent greater or 1.8 to 3.0.)
Design hour volume: DHV	Future hourly volume for use in design (two-way unless otherwise specified), usually the 30th highest hourly volume of the design year (30 HV) or equivalent, the approximate value of which can be obtained by the application of appropriate percentages to future traffic (ADT). The design hour volume, when expressed in terms of all types of vehicles, should be accompanied by factor T, the percentage of trucks during peak hours. Or, the design hour volume may be broken down to the number of passenger vehicles and the number of trucks.
Relation between DHV and ADT: K	DHV expressed as a percentage of ADT, both two-way; normal range, 12 to 18. Or, DHV expressed as a percentage of ADT, both one-way; normal range, 16 to 24.
Directional distribution: D	One-way volume in predominant direction of travel expressed as a percentage of two-way DHV. General range during design hour 50 to 80. Average, 67.
Composition of traffic: T	Trucks (exclusive of light delivery trucks) expressed as a percentage of DHV. Average 7 to 9. Where week-end peaks govern, average may be 5 to 8.

Highway Type	Type of Area and Appropriate Level of Service			
	Rural Level	Rural Rolling	Rural Mountainous	Urban and Suburban
Freeway	B	B	C	C
Arterial	B	B	C	C
Collector	C	C	D	D
Local	D	D	D	D

NOTE: General operating conditions for levels of service (Source: Ref. 11):
A - free flow, with low volumes and high speeds.
B - reasonably free flow, but speeds beginning to be restricted by traffic conditions.
C - in stable flow zone, but most drivers restricted in freedom to select their own speed.
D - approaching unstable flow, drivers have little freedom to maneuver.
E - unstable flow, may be short stoppages.

Table 2-2. Guide for selection of design levels of service (Source: Ref. 1, Table II-6)

Design Vehicle Type	Passenger Car	Single Unit Truck	Single Unit Bus	Articulated Bus	Semi-trailer Intermediate	Semi-trailer Combination Large	Semi-trailer Full Trailer Combination	Inter-State Semi-Trailer	Inter-State Semi-Trailer	Triple Semi-Trailer	Turnpike Double Semi-Trailer	Motor Home	Passenger Car with Travel Trailer	Passenger Car with Boat and Trailer	Motor Home and Boat Trailer
Symbol	P	SU	BUS	A-BUS	WB-12	WB-15	WB-18	WB-19*	WB-20**	WB-29	WB-35	MH	P/T	P/B	MH/B
Minimum design turning radius (m)	7.3	12.8	12.8	11.6	12.2	13.7	13.7	13.7	13.7	15.2	18.3	12.2	7.3	7.3	15.2
Minimum inside radius (m)	4.2	8.5	7.4	4.3	5.7	5.8	6.8	2.8	0	6.3	5.2	7.9	0.6	2.0	10.7

* Design vehicle with 14.6 m trailer as adopted in 1982 STAA (Surface Transportation Assistance Act).
** Design vehicle with 16.2 m trailer as grandfathered in 1982 STAA (Surface Transportation Assistance Act).

Table 2-3. Minimum turning radii of design vehicles (Source: Ref. 1, Table II-2)

Design Speed Designation – The design speed is a primary determinant of the geometric design. In order to provide better selection of potential physical design values, a distinction has been made between "rural highways and high-speed urban streets," and "low-speed urban streets". However, the latter may be appropriate for urban street designs where smaller radii and lower coefficients of friction are appropriate. As well as the selected design speed, the design will be dependent upon the traffic, highway capacity, and running speed and will reflect the following variables:

Terrain — As the terrain varies from level to mountainous, so the cost of the construction for any given speed will increase. Although difficult to define precisely, examples of level, rolling and mountainous are shown graphically in Figure 2-1. Definitions of terrain as related to highway design are given in (HCM) as follows:

"**Level terrain** is that condition where highway sight distances, as governed by both horizontal and vertical restrictions, are generally long or could be made to be so without construction difficulty or major expense.

"**Rolling terrain** is that condition where the natural slopes consistently rise above and fall below the road or street grade and where occasional steep slopes offer some restriction to normal horizontal and vertical roadway alignment.

"**Mountainous terrain** is that condition where longitudinal and transverse changes in the elevation of the ground with respect to the road or street are abrupt and where benching and side hill excavations are frequently required to obtain acceptable horizontal and vertical alignment.

"Terrain classifications pertain to the general character of a specific route corridor. Routes in valleys or passes of mountainous areas that have all the characteristics of roads or streets traversing level or rolling terrain should be classified as level or rolling. In general, rolling terrain generates steeper grades, causing trucks to reduce speeds below those of passenger cars, and mountainous terrain aggravates the situation, resulting in some trucks operating at crawl speeds."

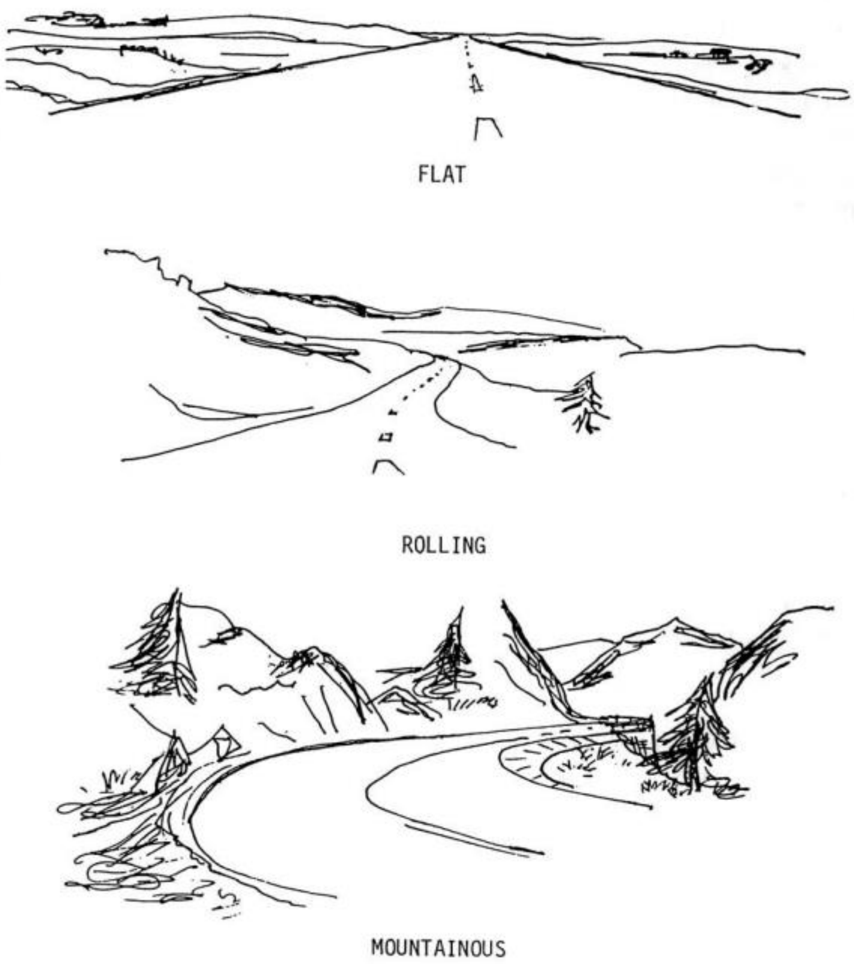

FIGURE 2-1
EXAMPLES OF TERRAIN CATEGORIES

Grades - The higher the maximum grade, the lower will be the design speed, reflecting the lower running speeds of vehicles using the highway, and commercial vehicles in particular.

Lane and Shoulder Widths — Higher values of lane increase design capacity. Designated lane widths range between 3 m and 3.6 m for highways with any significant traffic volumes. Adequate shoulders are usually necessary for safety and capacity reasons.

Example: Selection of Design Controls ~ The relationships of the above variables and design capacities are assembled in Tables 2-4, 2-5, and 2-6 for rural collector highways The design speed may be selected from these tables. For example, given the following data, determine an appropriate design speed, maximum grade, lane width, and shoulder widths:

Terrain: mountainous

ADT: 3500

Table 2-4 indicates that a minimum design speed of 60 km/h would be required, and Table 2-5 indicates a maximum grade of 10% for that design speed. The appropriate lane width would be 3.6 m with 2.4 m shoulders (Table 2-6). It should be noted that higher speeds may be justified if safety and cost considerations are adequately met.

Design Designation—In order to summarize and present the information on design controls and criteria, it is usual to indicate on the title sheet of the set of drawings describing the highway the major controls for which it is designed. This "design designation" is typified by the following example:

Control of Access	= None
ADT 1964	= None
ADT 1984	=5,000
DHV	= 500
D	= 60%
T	= 5% (assumed)
V	=60 km/h

In addition, the maximum grade and basic lane and shoulder widths may be specified.

Type of Terrain	Minimum Design Speeds (km/h) for Design Volumes of: ADT 0-400	ADT 400-2000	ADT over 2000
Level	60	80	100
Rolling	50	60	80
Mountainous	30	50	60

Table 2-4. Minimum design speeds (rural conditions)
(Source: Ref. 1, Table VI-I)

Type of Terrain	Rural Collectors 30	40	50	60	70	80	90	Design Speed (km/h) 100	110
					Grades (%)				
Level	7	7	7	7	7	6	6	5	4
Rolling	10	10	9	8	8	7	7	6	5
Mountainous	12	11	10	10	10	9	9	8	6
Design Speed (km/h)									

[a]Maximum grades shown for rural and urban conditions of short lengths, (less than 150 m), on one-way down grades and on low-volume rural collectors may be 2% steeper.

Table 2-5. Maximum grades (Source: Ref. 1, Table VI-3)

Design Speed (km/h)	Design Traffic Volumes: ADT Under 400	ADT 400-1500	ADT 1500-2000	ADT Over 2000
	Width of Traveled Way (m)[a]			
30	6.0[b]	6.0	6.6	7.2
40	6.0[b]	6.0	6.6	7.2
50	6.0[b]	6.0	6.6	7.2
60	6.0[b]	6.6	6.6	7.2
70	6.0	6.6	6.6	7.2
80	6.0	6.6	6.6	7.2
90	6.6	6.6	7.2	7.2
100	6.6	6.6	7.2	7.2
110	6.6	6.6	7.2	7.2
	Width of Graded Shoulder - Each Side (m)			
All Speeds	0.6	1.5[c]	1.8	2.4

[a] Where the width of the traveled way is shown to be 7.2 m, the width of traveled way may remain at 6.6 m on reconstructed highways where alinement and safety records are satisfactory.
[b] 5.4 minimum for ADT under 250.
[c] May be adjusted to achieve a minimum roadway width of 9.0 m for design speeds of 50 km/h or less.
See text for roadside barrier and offtracking considerations.

Table 2-6. Minimum width of traveled way and graded shoulders
(Source: Ref. 1, Table VI-4)

ELEMENTS OF DESIGN

Having established the major design controls, the next step is to relate them to each of the major elements of the highway design. The design of these elements, based upon the fundamental determinants of driver and vehicle characteristics and environmental conditions, includes primarily horizontal and vertical alignment and other factors such as drainage and landscaping. **Stopping Sight Distance** - Stopping sight distance for a given design speed is the minimum distance that a vehicle moving at the corresponding running speed will require to come to a safe halt. It is the sum of the distances traveled during the driver's brake reaction time and during the braking of the vehicle to a stop on a wet pavement. Stopping sight distances for various design speeds are summarized in Table2-7.

Passing Sight Distance ~ Passing sight distance is particularly important when considering safety and alignment. As described by AASHTO, "design passing sight distance is the minimum distance required to safely make a normal passing maneuver on 2-lane highways at passing speeds representative of nearly all drivers, commensurate with design speed. Passing sight distance on 2-lane highways should be provided over as high a proportion of the highway length as feasible. This proportion should be greater on highways with high volumes than on those with low volumes." See Figure 2-2 for passing sight distances for various design speeds.

Horizontal Alignment — Based upon the selected design speed and the allowable (as specified by state or other jurisdiction) superelevation rate, the minimum radius of curve, or corresponding maximum degree of curvature, may be specified. Table 2-8 indicates the key relationships between design speed, side friction factor, superelevation, minimum radius of curvature, and maximum degree of curve. Typically, establishment of the minimum radius (or degree of curve) is a basic step required before a realistic route selection can be made. For example, for a design speed of 60 km/h and maximum superelevation of 6%, the minimum radius would be 135 m, as shown in Table 2-8.

Design Speed (km/h)	Assumed Speed for Condition (km/h)	Brake Reaction Time (s)	Brake Reaction Distance (m)	Coefficient of Friction[a] f	Breaking Distance on Level (m)	Stopping Sight Distance for Design (m)
30	30-30	2.5	20.8-20.8	0.40	8.8-8.8	29.6-29.6
40	40-40	2.5	27.8-27.8	0.38	16.6-16.6	44.4-44.4
50	47-50	2.5	32.6-34.7	0.35	24.8-28.1	57.4-62.8
60	55-60	2.5	38.2-41.7	0.33	36.1-42.9	74.3-84.6
70	63-70	2.5	43.7-48.6	0.31	50.4-62.2	94.1-110.8
80	70-80	2.5	48.6-55.5	0.30	64.2-83.9	112.8-139.4
90	77-90	2.5	53.5-62.5	0.30	77.7-106.2	131.2-168.7
100	85-100	2.5	59.0-69.4	0.29	98.0-135.6	157.0-205.0
110	91-110	2.5	63.2-76.4	0.28	116.3-170.0	179.5-246.4
120	98-120	2.5	68.0-83.3	0.28	134.9-202.3	202.9-285.6

[a] Values of coefficient of friction generally approximate curves 9 and 10 (coefficient of friction for wet-PC concrete and wet-plant mixes) shown in Figure III-1A.

Table 2-7. Stopping sight distance (wet pavements)
(Source: Ref. 1, Table III-1)

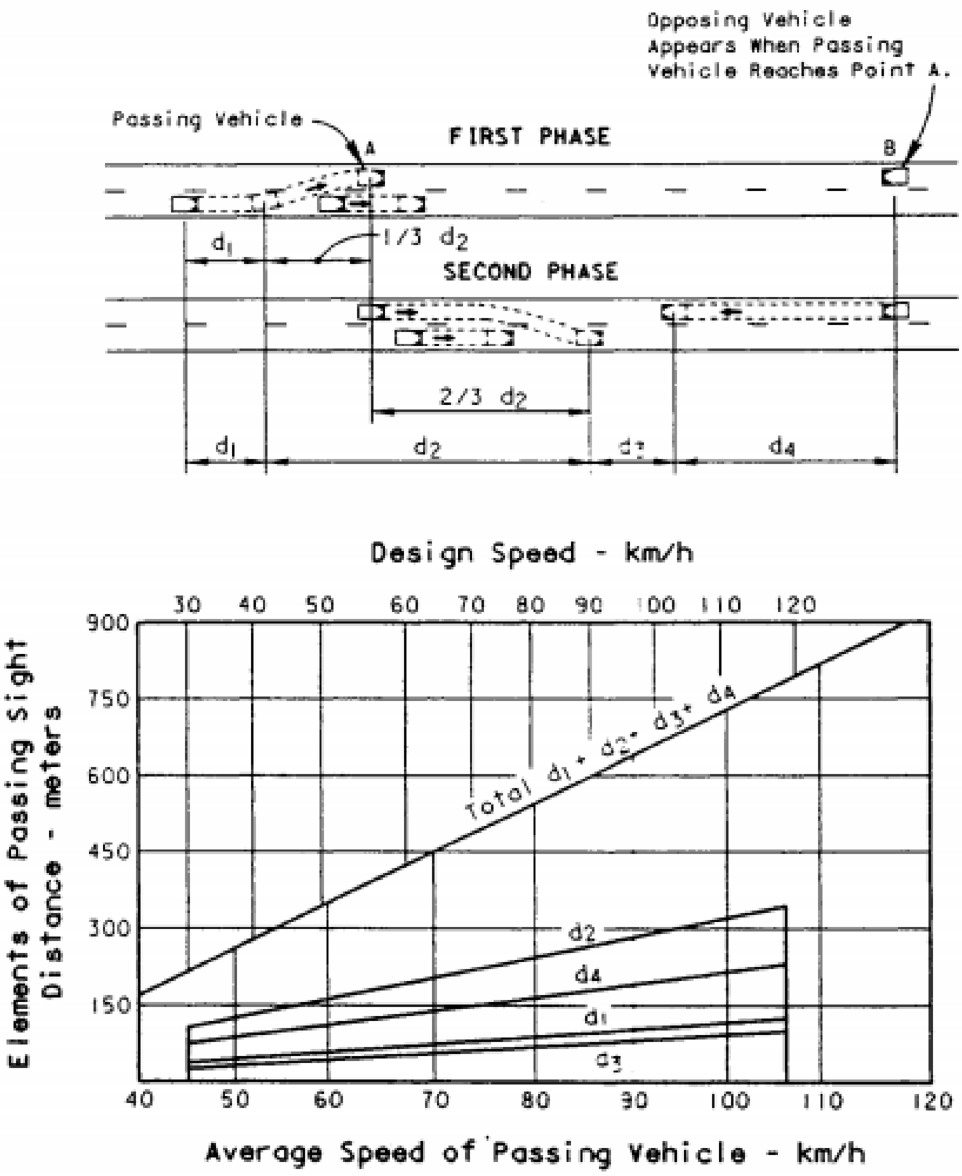

**Figure 2-2. Elements of and total passing sight distance - two-lane highways
(Source: Ref. 1, Figure III-2)**

Design Speed (km/h)	Maximum e %	Limiting Values of f	Total (e/100+f)	Calculated Radius (meters)	Rounded Radius (meters)
30	4.00	0.17	0.21	33.7	35
40	4.00	0.17	0.21	60.0	60
50	4.00	0.16	0.20	98.4	100
60	4.00	0.15	0.19	149.2	150
70	4.00	0.14	0.18	214.3	215
80	4.00	0.14	0.18	280.0	280
90	4.00	0.13	0.17	375.2	375
100	4.00	0.12	0.16	492.1	490
110	4.00	0.11	0.15	635.2	635
120	4.00	0.09	0.13	872.2	870
30	6.00	0.17	0.23	30.8	30
40	6.00	0.17	0.23	54.8	55
50	6.00	0.16	0.22	89.5	90
60	6.00	0.15	0.21	135.0	135
70	6.00	0.14	0.20	192.9	195
80	6.00	0.14	0.20	252.0	250
90	6.00	0.13	0.19	335.7	335
100	6.00	0.12	0.18	437.4	435
110	6.00	0.11	0.17	560.4	560
120	6.00	0.09	0.15	755.9	755
30	8.00	0.17	0.25	28.3	30
40	8.00	0.17	0.25	50.4	50
50	8.00	0.16	0.24	82.0	80
60	8.00	0.15	0.23	123.2	125
70	8.00	0.14	0.22	175.4	175
80	8.00	0.14	0.22	229.1	230
90	8.00	0.13	0.21	303.7	305
100	8.00	0.12	0.20	393.7	395
110	8.00	0.11	0.19	501.5	500
120	8.00	0.09	0.17	667.0	665
30	10.00	0.17	0.27	26.2	25
40	10.00	0.17	0.27	46.7	45
50	10.00	0.16	0.26	75.7	75
60	10.00	0.15	0.25	113.4	115
70	10.00	0.14	0.24	160.8	160
80	10.00	0.14	0.24	210.0	210
90	10.00	0.13	0.23	277.3	275
100	10.00	0.12	0.22	357.9	360
110	10.00	0.11	0.21	453.7	455
120	10.00	0.09	0.19	596.8	595
30	12.00	0.17	0.29	24.4	25
40	12.00	0.17	0.29	43.4	45
50	12.00	0.16	0.28	70.3	70
60	12.00	0.15	0.27	105.0	105
70	12.00	0.14	0.26	148.4	150
80	12.00	0.14	0.26	193.8	195
90	12.00	0.13	0.25	255.1	255
100	12.00	0.12	0.24	328.1	330
110	12.00	0.11	0.23	414.2	415
120	12.00	0.09	0.21	539.9	540

NOTE: In recognition of safety considerations, use of e_{max} = 4.00 % should be limited to urban conditions.

Table 2-8. Maximum degree of curve and minimum radius determined for limiting values of e and f, rural highways and high-speed urban streets (Source: Ref. 1, Table III-6)