1.3.4 CHARACTERISTICS OF CLASSIFICATIONS

The principal characteristics of each of the six groups of road classifications are described by the following figure and tables. Figure 1.3.4.1 illustrates the desirable interrelationship of the urban road classification groups. Tables 1.3.4.1 and 1.3.4.2 provide summaries of the typical characteristics of the various groups and sub-groups, for rural and urban roads respectively.

Figure 1.3.4.1 Relationship of Urban Road Classifications

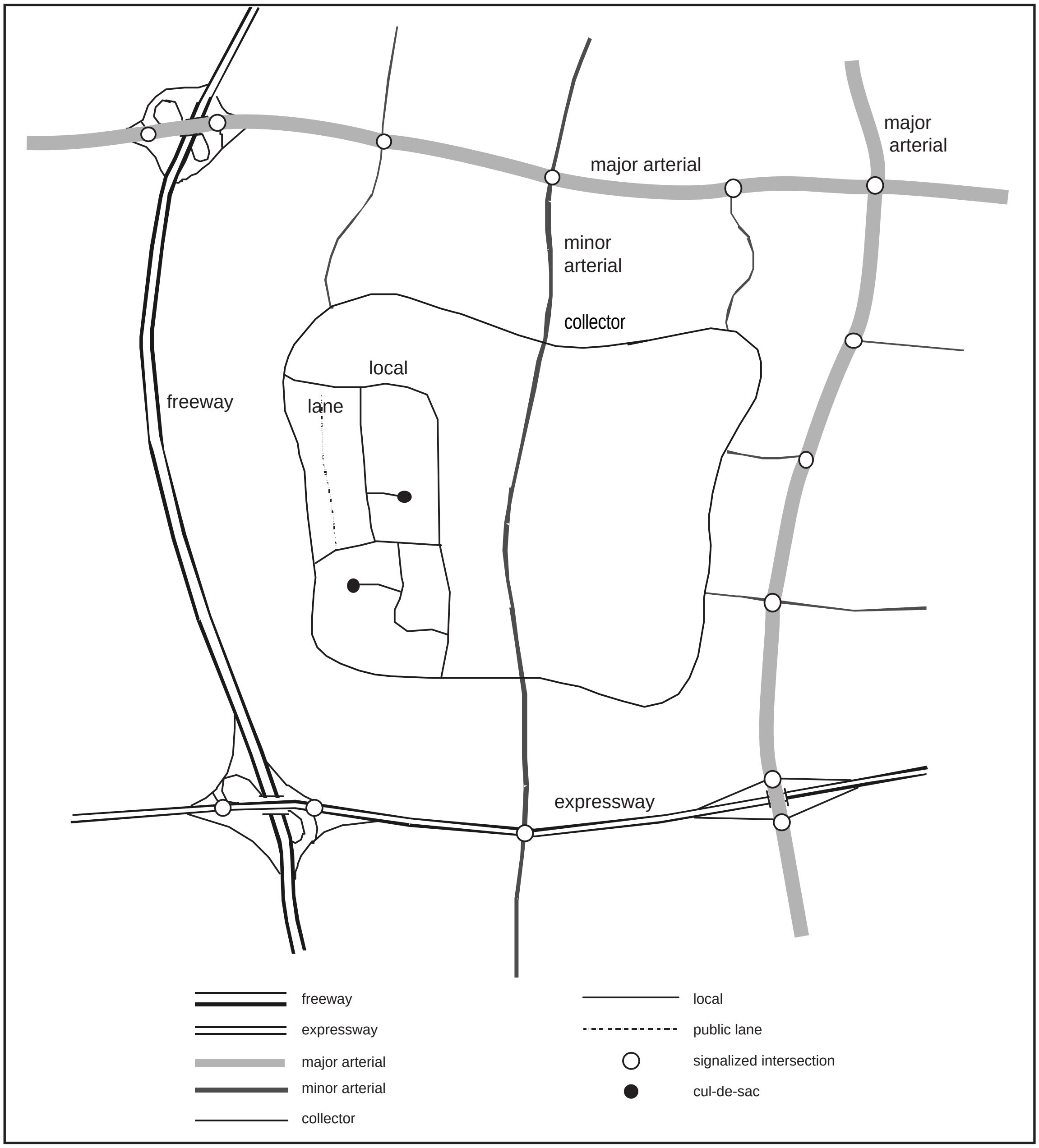


Table 1.3.4.1 Characteristics of Rural Roads

	Rural Locals	Rural Collectors	Rural Arterials	Rural Freeways
service function	traffic movement secondary consideration	traffic movement and land access of equal importance	traffic movement primary consideration	optimum mobility
land service	land access primary consideration	traffic movement and land access of equal importance	land access secondary consideration	no access
traffic volume vehicles per day (typically)	<1000 AADT	<5000 AADT	<12 000 AADT	>8000 AADT
flow characteristics	interrupted flow	interrupted flow	uninterrupted flow except at	freeflow (grade separated) major intersections
design speed (km/h)	50 - 110	60 - 110	80 - 130	100 - 130
average running speed (km/h) (free flow conditions)	50 - 90	50 - 90	60 - 100	70 - 110
vehicle type	predominantly passenger cars, light to medium trucks and occasional heavy trucks	all types, up to 30% trucks in the 3 t to 5 t range	all types, up to 20% trucks	all types, up to 20% heavy trucks
normal connections	locals collectors	locals collectors arterials	collectors arterials freeways	arterials freeways

1.4.3 OPERATING SPEED CONSISTENCY

The safety of a road is closely linked to variations in the speed of vehicles travelling on it. These variations are of two kinds:

1. Individual drivers vary their operating speeds to adjust to features encountered along the road, such as intersections, accesses and curves in the alignment. The greater and more frequent are the speed variations, the higher is the probability of collision.

2. Drivers travelling substantially slower or faster than the average traffic speed have a higher risk of being involved in collisions.

A designer can therefore enhance the safety of a road by producing a design which encourages operating speed uniformity.

As noted in the discussion of speed profiles in Chapter 1.2, simple application of the design speed concept does not prevent inconsistencies in geometric design. Traditional North American design methods have merely ensured that all design components meet or exceed a minimum standard, but have not necessarily ensured operating speed consistency between components.

Practices used in Europe and Australia have supplemented the design speed concept with methods of identifying and quantifying geometric inconsistencies in horizontal alignments of rural two-lane highways. This type of road typically has the most problems related to design inconsistency. These methods have not been perfected, particularly in predicting the performance of a newly designed road. Their effectiveness is greater in evaluating existing roads and identifying priority improvements to reduce collision rates.

1.4.3.1 Prediction of Operating Speeds

In order to establish consistency of horizontal alignment design for a proposed new road, it is necessary to predict operating speeds associated with different geometric elements. Limited information is generally available to assist designers with prediction of operating speeds, but the material presented in this section may help, noting the limited database used. As an alternative, some jurisdictions have local data on which to base speed predictions.

Researchers[9] collected data from five US states, measuring 85th percentile operating speeds, under free flowing traffic conditions, on long tangents and horizontal curves on rural two-lane highways. Long tangents (250 m or more) are those lengths of straight road on which a driver has time to accelerate to desired speed before approaching the next curve. The mean 85th percentile speed on long tangents was found to be 99.8 km/h on level terrain and 96.6 km/h in rolling terrain. It was noted that these speeds were probably constrained by the 90 km/h posted speed in force at the time.

On horizontal curves, the research found consistent disparities between 85th percentile speeds and inferred design speeds, with the greater disparity on tighter radius curves. The 85th percentile speed exceeded the design speed on a majority of curves in each 10 km/h increment of design speed up to a design speed of 100 km/h. At higher design speeds, the 85th percentile speed was lower than the design speed.

Using regression techniques, a relationship was found between 85th percentile speeds and the characteristics of a horizontal curve.

$$V85 = 102.45 + 0.0037L - (8995 + 5.73L) / R \qquad (1.4.1)$$

Where V85 = 85th percentile speed on curve (km/h)

L = length of curve (m)

R = radius of curvature (m)

1.4.3.2 Speed Profile Model

The findings outlined in Subsection 1.4.3.1 support the conclusion that there is no strong relationship between design speed and operating speed on horizontal curves.

Consistency of horizontal alignment design cannot therefore be assured by using design speed alone. A further check can be carried out by constructing a speed profile model, using predicted 85th percentile operating speeds for new road and measured 85th percentile speeds for existing roads.

For the predictive model, it is necessary to calculate the critical tangent length between curves as follows:

$$TL_c = \frac{2V_f^2 - V85_1^2 - V85_2^2}{25.92\,a} \qquad (1.4.2)$$

Where: TL_c = critical tangent length (m)

V_f = 85th percentile desired speed on long tangents (km/h)

$V85_n$ = 85th percentile speed on curve n (km/h)

a = acceleration/deceleration rate, assumed to be $0.85\ m/s^2$

The calculation assumes that deceleration begins where required, even if the beginning of the curve is not yet visible.

Each tangent is then classified as one of three cases, as shown on Figure 1.4.3.1, by comparing the actual tangent length (TL) to the critical tangent length (TL_c).

Having found the relationship between each tangent length (TL) and the critical tangent length (TL_c), the equations in Table 1.4.3.1 can then be used, as appropriate, to construct the speed profile model.

The speed profile model is used to estimate the reductions in 85th percentile operating speeds from approach tangents to horizontal curves, or between curves. Designers should note that the research[6,9] on which the model is based dealt only with two-lane rural highways. The same principles, however, can be applied to design of other classes of roads.

1.4.3.3 Safety

As noted in Chapter 1.2, there is evidence that the risk of a collision is lowest near the average speed of traffic and increases for vehicles travelling much faster or slower than average. While this is true in relation to the general distribution of speeds in a stream of traffic, it has also been found to apply when there is a variation in speeds caused by the effects of a reduction in speed from one geometric element to the next.

This particular form of speed variation may be experienced in situations such as the transition from a tangent to a curve, or between curves. In these cases, the previously mentioned research study[9], found that the mean collision rate increased in direct proportion to the mean speed difference caused by the transition from one geometric element to the other. The results are noted in Figure 1.4.3.2.

The numerical values from Figure 1.4.3.2 should be used with caution, because of the database used. Wherever possible, designers should use local data. However, the principles established show the effect of a lack of horizontal alignment consistency on increasing collision potential. Figure 1.4.3.2 should not be interpreted to mean that collision rate decreases as speed decreases.

Table 2.1.2.6 Superelevation and Minimum Spiral Parameters, $e_{max} = 0.06$ m/m[1]

Design Speed (km/h)	40			50			60			70		
		A			A			A			A	
Radius (m)	e	2 lane	3&4 lane	e	2 lane	3&4 lane	e	2 lane	3&4 lane	e	2 lane	3&4 lane
7000	NC			NC			NC			NC		
5000	NC			NC			NC			NC		
4000	NC			NC			NC			NC		
3000	NC			NC			NC			NC		
2000	NC			NC			NC			RC	275	275
1500	NC			NC			RC	225	225	RC	250	250
1200	NC			NC			RC	200	200	0.023	225	225
1000	NC			RC	170	170	0.021	175	175	0.027	200	200
900	NC			RC	150	150	0.023	175	175	0.029	180	180
800	NC			RC	150	150	0.025	160	160	0.031	175	175
700	NC			0.021	140	140	0.027	150	150	0.034	175	175
600	NC	120	120	0.024	125	125	0.030	140	140	0.037	150	150
500	RC	100	100	0.027	120	120	0.034	125	125	0.041	140	150
400	0.023	90	90	0.031	100	100	0.038	115	120	0.045	125	135
350	0.025	90	90	0.034	100	100	0.041	110	115	0.048	120	125
300	0.028	80	80	0.037	90	100	0.044	100	110	0.051	120	125
250	0.031	75	80	0.040	85	90	0.048	90	100	0.055	110	120
220	0.034	70	80	0.043	80	90	0.050	90	100	0.057	110	110
200	0.036	70	75	0.045	75	90	0.052	85	100	0.059	110	110
180	0.038	60	75	0.047	70	90	0.054	85	90	0.060	110	110
160	0.040	60	75	0.049	70	85	0.056	85	90	min R = 190		
140	0.043	60	70	0.052	65	80	0.059	85	90			
120	0.046	60	65	0.055	65	75	0.060					
100	0.049	50	65	0.058	65	70	min R = 130					
90	0.051	50	60	0.060	65	70						
80	0.054	50	60	0.060	65	70						
70	0.056	50	60	min R = 90								
60	0.059	50	60									
	0.059	50	60									
	min R = 55											

Design Speed (km/h)	80			90			100		
		A			A			A	
Radius (m)	e	2 lane	3&4 lane	e	2 lane	3&4 lane	e	2 lane	3&4 lane
7000	NC			NC			NC		
5000	NC			NC			NC		
4000	NC			NC			RC	475	475
3000	NC			RC	390	400	RC	410	410
2000	RC	300	300	0.023	300	350	0.030	335	335
1500	0.024	250	250	0.029	270	275	0.029	290	290
1200	0.028	225	225	0.033	240	240	0.034	260	260
1000	0.032	200	200	0.037	225	225	0.040	235	235
900	0.034	200	200	0.039	200	200	0.043	225	225
800	0.036	175	175	0.042	200	200	0.046	210	215
700	0.039	175	175	0.045	185	195	0.050	200	210
600	0.042	175	175	0.048	175	185	0.054	190	200
500	0.046	150	160	0.052	160	175	0.059	190	190
400	0.051	135	150	0.057	160	165	0.060	190	190
350	0.054	125	140	0.059	160	160	min R = 440		
300	0.057	125	135	0.060	160	160			
250	0.060	125	125	min R = 340					
220	0.060	125	125						
200	min R = 250								

Design Speed (km/h)	110			120			130		
		A			A			A	
Radius (m)	e	2 lane	3&4 lane	e	2 lane	3&4 lane	e	2 lane	3&4 lane
7000	NC			RC			RC	710	710
5000	RC	555	555	RC	580	580	RC	600	600
4000	RC	495	495	RC	515	515	0.023	540	540
3000	0.020	430	430	0.024	450	450	0.028	465	465
2000	0.029	350	350	0.034	365	365	0.040	380	380
1500	0.036	305	305	0.042	315	315	0.049	330	335
1200	0.043	270	270	0.049	285	290	0.055	295	320
1000	0.048	245	255	0.054	260	280	0.058	280	300
900	0.051	235	250	0.057	250	270	0.060	280	300
800	0.054	220	240	0.059	250	260	min R = 950		
700	0.058	220	235	0.060	250	260			
600	0.060	220	220	min R = 750					
500	0.060	220	220						
400	min R = 600								

$e_{max} = 0.06$

Notes:

- *e* is superelevation
- *A* is spiral parameter in metres
- NC is normal cross section
- RC is remove adverse crown and superelevate at normal rate
- Spiral length, $L = A^2 / \text{Radius}$
- Spiral parameters are minimum and higher values may be used
- For 6 lane pavement: above the dashed line use 4 lane values,
- below the dashed line, use 4 lane values x 1.15.
- A divided road having a median less than 3.0 m wide may be treated as a single pavement.

Table 2.1.2.7 Superelevation and Minimum Spiral Parameters, $e_{max} = 0.08$ m/m[1]

Design (Speed km/h)	40			50			60		
Radius (m)	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane
7000	NC			NC			NC		
5000	NC			NC			NC		
4000	NC			NC			NC		
3000	NC			NC			NC		
2000	NC			NC			NC		
1500	NC			NC			RC	225	225
1200	NC			NC			RC	200	200
1000	NC			RC	170	170	0.023	175	175
900	NC			RC	150	150	0.025	175	175
800	NC			0.020	150	150	0.027	160	160
700	NC			0.023	140	140	0.030	150	150
600	RC	120	120	0.026	125	125	0.034	140	140
500	0.021	100	100	0.030	120	120	0.039	125	135
400	0.025	90	90	0.035	100	110	0.045	115	125
350	0.028	90	90	0.038	100	105	0.049	110	125
300	0.031	80	90	0.042	90	100	0.053	100	120
250	0.035	75	85	0.047	85	100	0.059	100	120
220	0.039	70	80	0.051	80	100	0.062	95	110
200	0.041	70	80	0.054	80	100	0.065	90	110
180	0.044	65	80	0.057	75	95	0.068	90	105
160	0.047	65	80	0.060	75	90	0.072	85	100
140	0.051	65	75	0.064	70	90	0.076	85	100
120	0.055	60	75	0.069	70	85	0.080	85	95
100	0.061	55	70	0.074	65	80	0.080	85	95
90	0.064	55	70	0.077	65	80	min R = 120		
80	0.067	55	65	0.080	65	75			
70	0.071	50	60	0.080	65	75			
60	0.075	50	60	min R = 80					
50	0.080	50	60						
	0.080	50	60						
	min R = 50								

Design (Speed km/h)	70			80			90		
Radius (m)	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane
7000	NC			NC			NC		
5000	NC			NC			NC		
4000	NC			NC			NC		
3000	NC			NC			RC	390	400
2000	RC	270	275	0.021	300	300	0.026	300	300
1500	0.021	255	260	0.027	250	250	0.032	270	275
1200	0.026	220	225	0.032	225	225	0.038	240	240
1000	0.029	200	200	0.036	200	200	0.043	225	225
900	0.032	180	180	0.039	200	200	0.046	200	220
800	0.035	175	175	0.042	175	195	0.049	200	220
700	0.038	165	165	0.046	175	190	0.053	185	200
600	0.042	150	160	0.050	165	185	0.058	175	200
500	0.048	140	150	0.056	150	175	0.064	160	200
400	0.054	125	150	0.063	135	165	0.071	160	185
350	0.058	120	150	0.067	125	160	0.075	160	175
300	0.063	120	140	0.072	125	150	0.080	160	175
250	0.069	110	135	0.078	125	150	0.080	160	175
220	0.073	110	125	0.080	125	150	min R = 300		
200	0.075	110	125	min R = 230					
180	0.078	110	120						
160	0.080	110	120						
140	min R = 170								

Design (Speed km/h)	100			110			120			130		
Radius (m)	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane	e	A 2 lane	A 3&4 lane
7000	NC			RC			RC			RC	710	710
5000	RC			RC	555	555	RC	580	580	0.021	600	600
4000	RC	480	480	RC	495	495	0.021	515	515	0.026	540	540
3000	RC	410	410	0.023	430	430	0.028	450	450	0.033	465	465
2000	0.030	335	335	0.035	350	350	0.040	365	365	0.047	380	380
1500	0.033	290	290	0.042	305	305	0.050	315	330	0.058	330	365
1200	0.040	260	260	0.050	270	285	0.059	285	320	0.067	295	350
1000	0.047	240	240	0.057	250	280	0.066	260	310	0.074	280	340
900	0.051	225	240	0.062	235	275	0.071	250	300	0.078	280	330
800	0.055	210	235	0.066	220	270	0.075	250	295	0.080	280	330
700	0.061	200	230	0.072	220	260	0.079	250	285	0.080	280	300
600	0.067	190	225	0.77	220	250	0.080	250	285	min R = 830		
500	0.073	190	215	0.80	220	250	min R = 670					
400	0.080	190	200	min R = 530								
350	0.080	190	200									
300	min R = 390											

$e_{max} = 0.08$

Notes:
- *e* is superelevation
- *A* is spiral parameter in metres
- NC is normal cross section
- RC is remove adverse crown and superelevate at normal rate
- Spiral length, $L = A^2$ / Radius
- Spiral parameters are minimum and higher values may be used
- For 6 lane pavement: above the dashed line use 4 lane values,
- below the dashed line, use 4 lane values x 1.15.
- A divided road having a median less than 3.0 m wide may be treated as a single pavement.

Figure 2.1.2.12 Lateral Clearance for Range of Lower Values of Stopping Sight Distance[2]

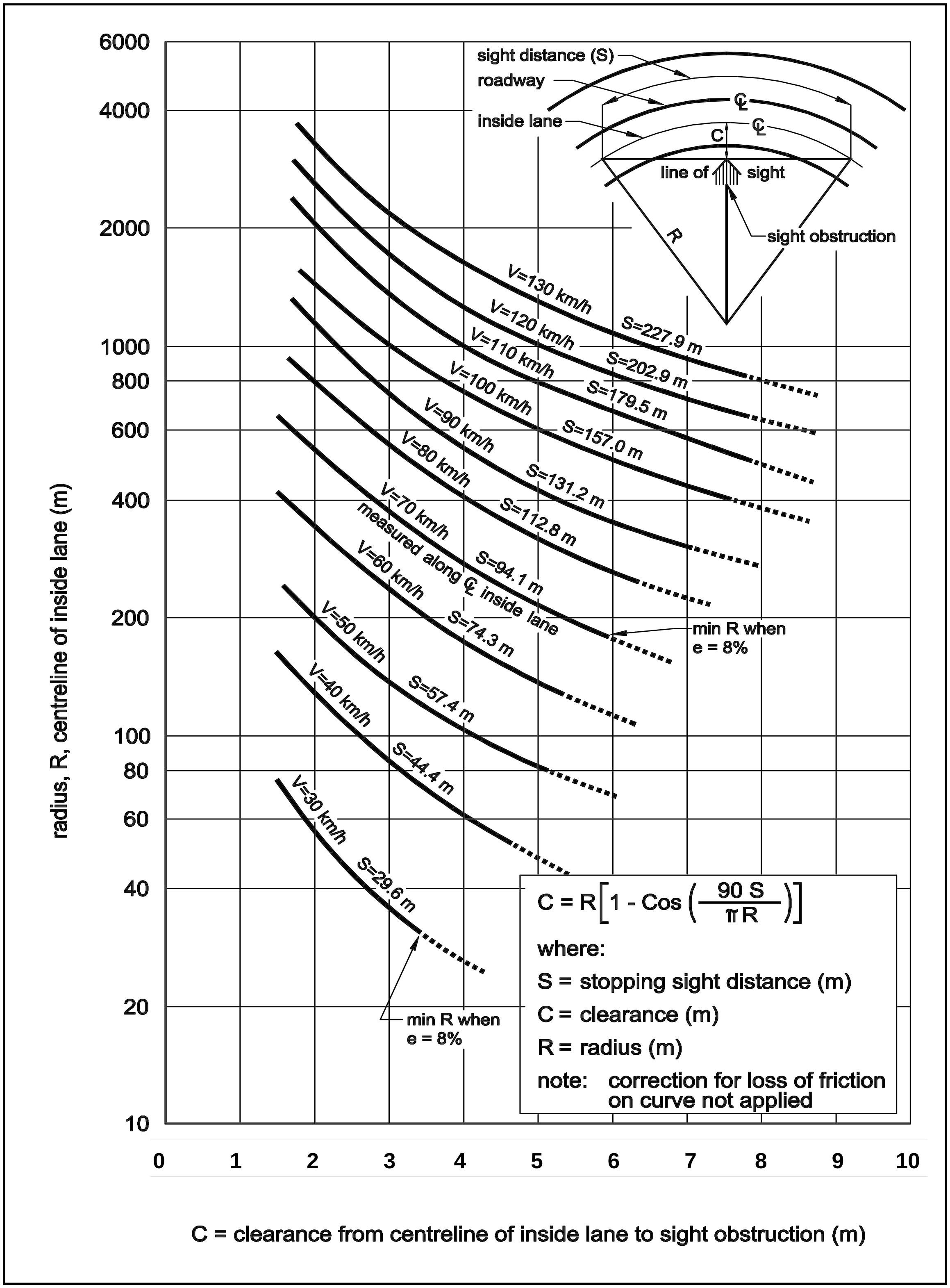


Figure 2.1.2.13 Lateral Clearance for Passing Sight Distance[2]

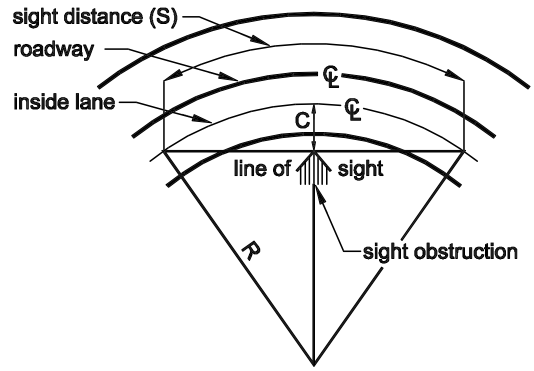
$$C = R\left[1 - \cos\left(\frac{90\,S}{\pi R}\right)\right]$$

where:

S = passing sight distance (m)

C = clearance (m)

R = radius (m)



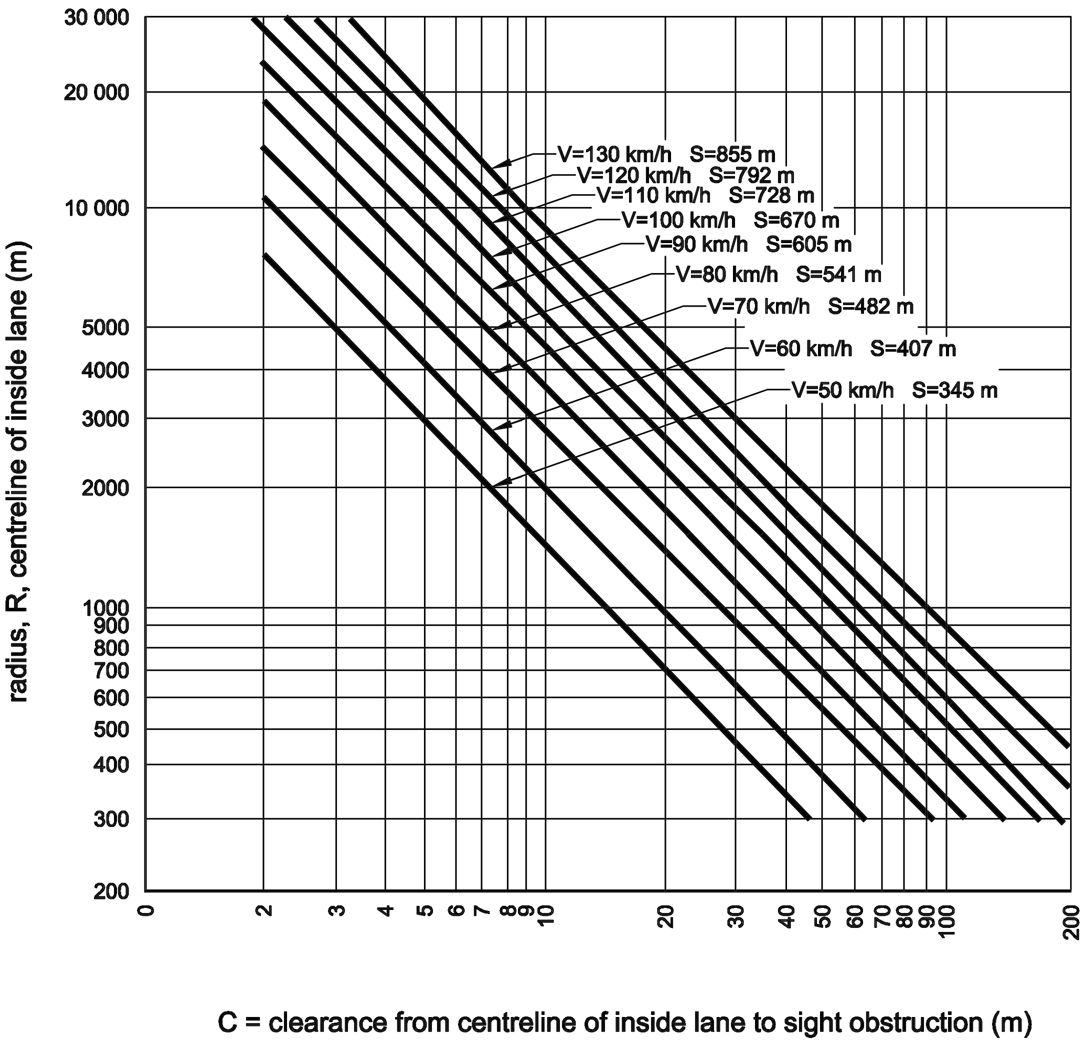


Figure 2.1.8.3 Performance Curves for Heavy Trucks, 180 g/W, Decelerations & Accelerations[7]

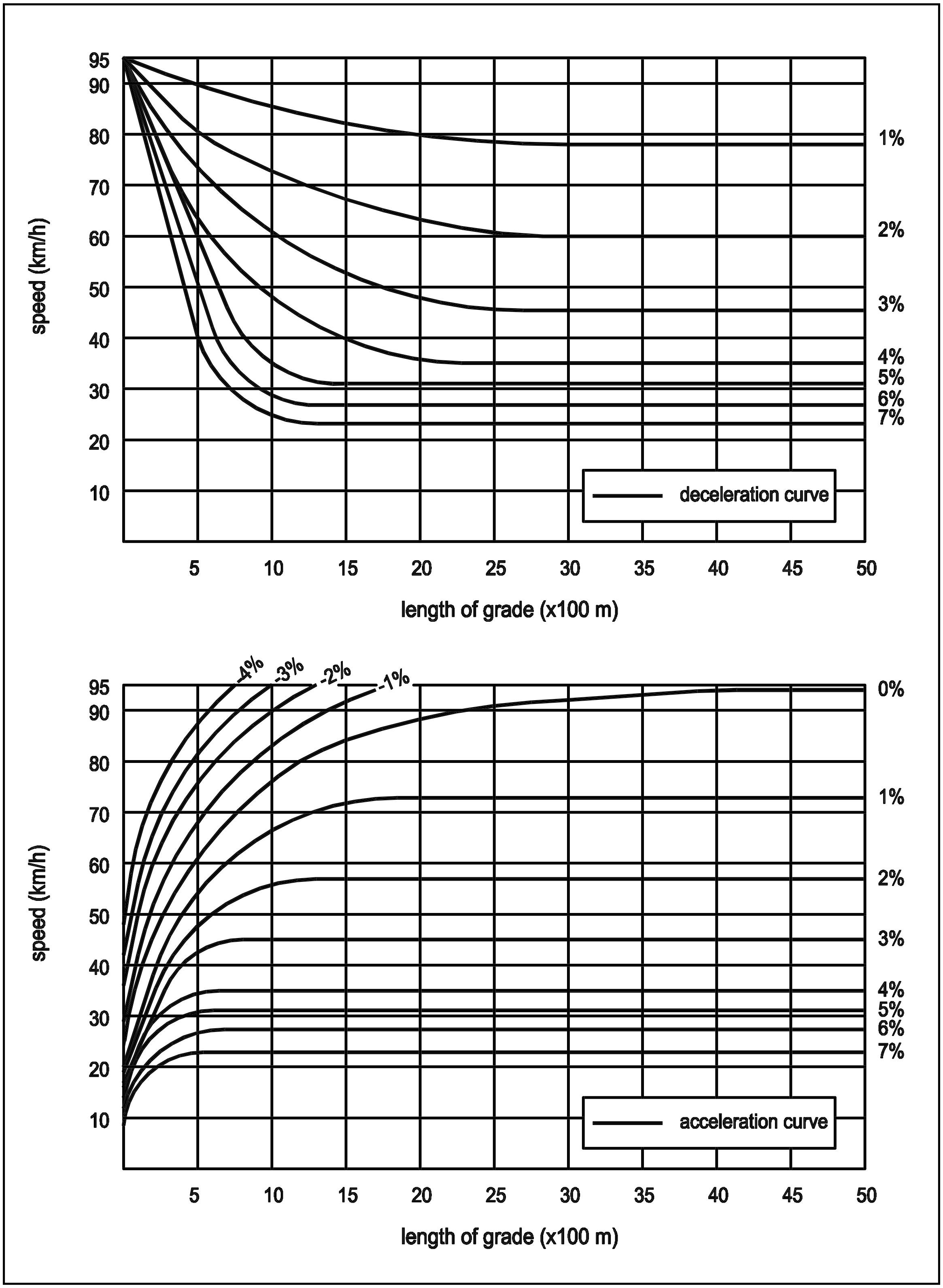
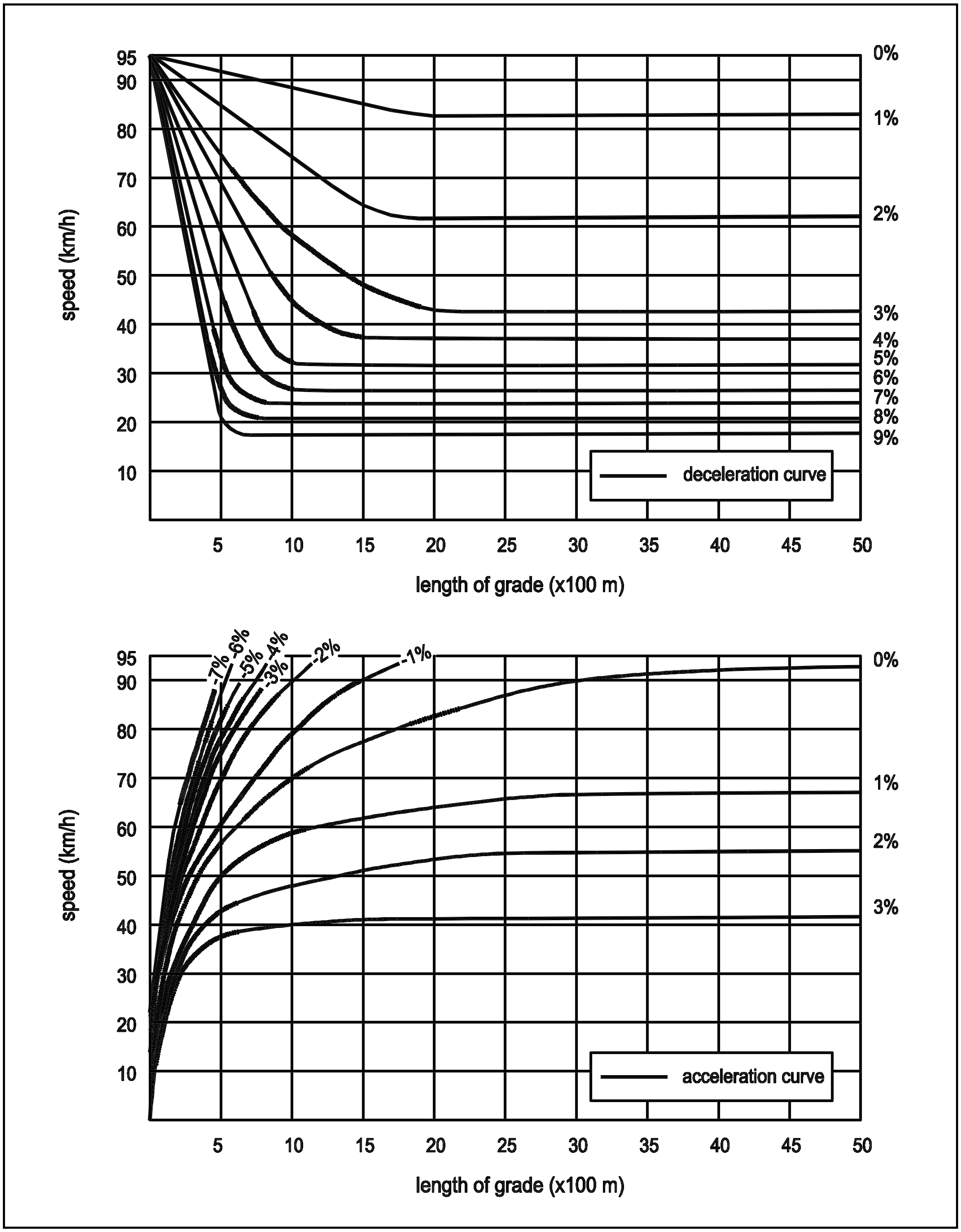


Figure 2.1.8.4 Performance Curves for Heavy Trucks, 200 g/W, Decelerations & Accelerations[7]



and limitations. When a design is incompatible with the attributes of a driver, the chances for driver error increases. Inefficient operation and collisions are often a result.[3]

In general, traffic volume is the most significant contributor to intersection collisions. Typically, as traffic volumes increase, conflicts increase, and therefore the number of collisions increase.[5] Severity of collisions varies only slightly among rural, suburban and urban intersections; the percent of severe collisions is approximately 5% higher for rural intersections.[5]

Other elements related to intersection collision rates include geometric layout and traffic control.[3] As previously noted, traffic control measures are not addressed in this document. The relationship of specific geometric elements and safety is described below:

Type of Intersection

In rural settings, four-legged intersections typically have higher collision rates than T-intersections (three-legged) for stop and signal controls.[7]

In urban settings, very little difference in collision rates between four-legged and T-intersections was found for low volume intersections (Average Daily Traffic under 20 000); however, for larger volumes, the four-legged intersection was found to have the higher collision rate.[8]

Sight Distance

In both an urban and a rural setting, studies have shown that the collision rate at most intersections will generally decrease when sight obstructions are removed, and sight distance increased.[3]

Channelization

In a rural environment, it was found that left-turn lanes would reduce the potential of passing collisions.[9]

In an urban setting, it was found that multi-vehicle collisions decrease when lane "dividers" (raised reflectors, painted lines, barriers or medians) are used; however the use of left-turn lanes was not considered effective as a collision countermeasure but was considered effective as a means of increasing capacity.[8]

Cross Section

Safety considerations for cross section elements, such as lane width, are addressed in Chapter 2.2.

2.3.1.7 Intersection Spacing Considerations

Both rural road and urban road network spacing is often predicated on the location of the original road allowances prior to urban development. The systems of survey employed in the layout of original road allowances vary from region to region across Canada. As rural areas urbanize, the development of major roads generally occurs along these original road allowances, and consequently road networks vary from region to region. As examples, the land survey system in Ontario has created a basic spacing between major roads of 2.0 km, whereas the land survey system in the prairie provinces has resulted in a 1.6 km grid.

As development occurs, this spacing is often reduced. In areas of commercial or mixed use development, the traffic generated by employment and retail shopping may result in a reduced arterial spacing. In downtown areas, this spacing could be reduced further as determined by the traffic needs and the characteristics of the road network.

The spacing of intersections along a road in both an urban and rural setting has a large impact on the operation, level of service, and capacity of the roadway. Ideally, intersection spacing along a road should be selected based on function, traffic volume and other considerations so that roads with the highest function will have the least number (greatest spacing) of intersections (the relationship of road classification and the preferred functional hierarchy of circulation is described in Chapter 1.3 of this Guide). However, it is often not always possible to provide ideal intersection spacing, especially in an urban setting. As such, the following should be considered:

Arterials

Along signalized arterial roads, it is desirable to provide spacing between signalized intersections consistent with the desired traffic progression speed and signal cycle lengths. By spacing the intersections uniformly based on known or assumed running speeds and appropriate cycle lengths, signal progression in both directions can be achieved. Progression allows platoons of vehicles to travel through successive intersections without stopping. For a progression speed of about 50 km/h and a cycle length of 60 s, the corresponding desired spacing between signalized intersections is approximately 400 m. As speeds increase the optimal intersection spacing increases proportionately. Further information on the spacing of signalized intersections is provided in the Subsection 2.3.1.8.

A typical minimum intersection spacing along arterial roadways is 200 m, generally only applicable in areas of intense existing development or restrictive physical controls where feasible alternatives do not exist. The 200 m spacing allows for minimum lengths of back to back storage for left turning vehicles at the adjacent intersections.

The close spacing does not permit signal progression and therefore, it is normally preferable not to signalize the intersection that interferes with progression along a major arterial. Intersection spacing at or near the 200 m minimum is normally only acceptable along minor arterials, where optimizing traffic mobility is not as important as along major arterials.

Where intersection spacing along an arterial does not permit an adequate level of traffic service, a number of alternatives can be considered to improve traffic flow. These include: conversion from two-way to one-way operation, the implementation of culs-de-sac for minor connecting roads, and the introduction of channelization to restrict turning movements at selected intersections to right turns only.

On divided arterial roads, a right-in, right-out intersection without a median opening may be permitted at a minimum distance of 100 m from an adjacent all-directional intersection. The distance is measured between the closest edges of pavement of the adjacent intersecting roads.

In retrofit situations, the desired spacing of intersections along an arterial is sometimes compromised in consideration of other design controls, such as, the nature of existing adjacent development and the associated access needs.

Collectors

The typical minimum spacing between adjacent intersections along a collector road is 60 m.

Locals

Along local roads, the minimum spacing between four-legged intersections is normally 60 m. Where the adjacent intersections are three-legged a minimum spacing of 40 m is acceptable.

Cross Roadway Intersection Spacing Adjacent to Interchanges

The upper half of Figure 2.3.1.6 indicates the intersection spacing along an arterial crossing road approaching a diamond interchange. The suggested minimum distance between a collector road and the nearest ramp, as measured along the arterial cross road, is 200 m (dimension A_c on Figure 2.3.1.6). In the case of an arterial/arterial cross road intersection, this minimum offset distance from the ramp is normally increased to 400 m (dimension A_a on Figure 2.3.1.6). The same dimensions apply to arterial cross roads approaching parclo-type interchanges as shown on the lower half of Figure 2.3.1.6.

Ramp Intersection Spacing at Interchanges

The upper half of Figure 2.3.1.6, as well as Figure 2.3.1.7, illustrate the suggested and minimum intersection spacing and lane configurations on the cross road at a typical diamond interchange. The two different channelization treatments illustrate the following

Figure 2.3.8.6 Left-Turn Lane Designs Along Four-Lane Undivided Roadways, No Median

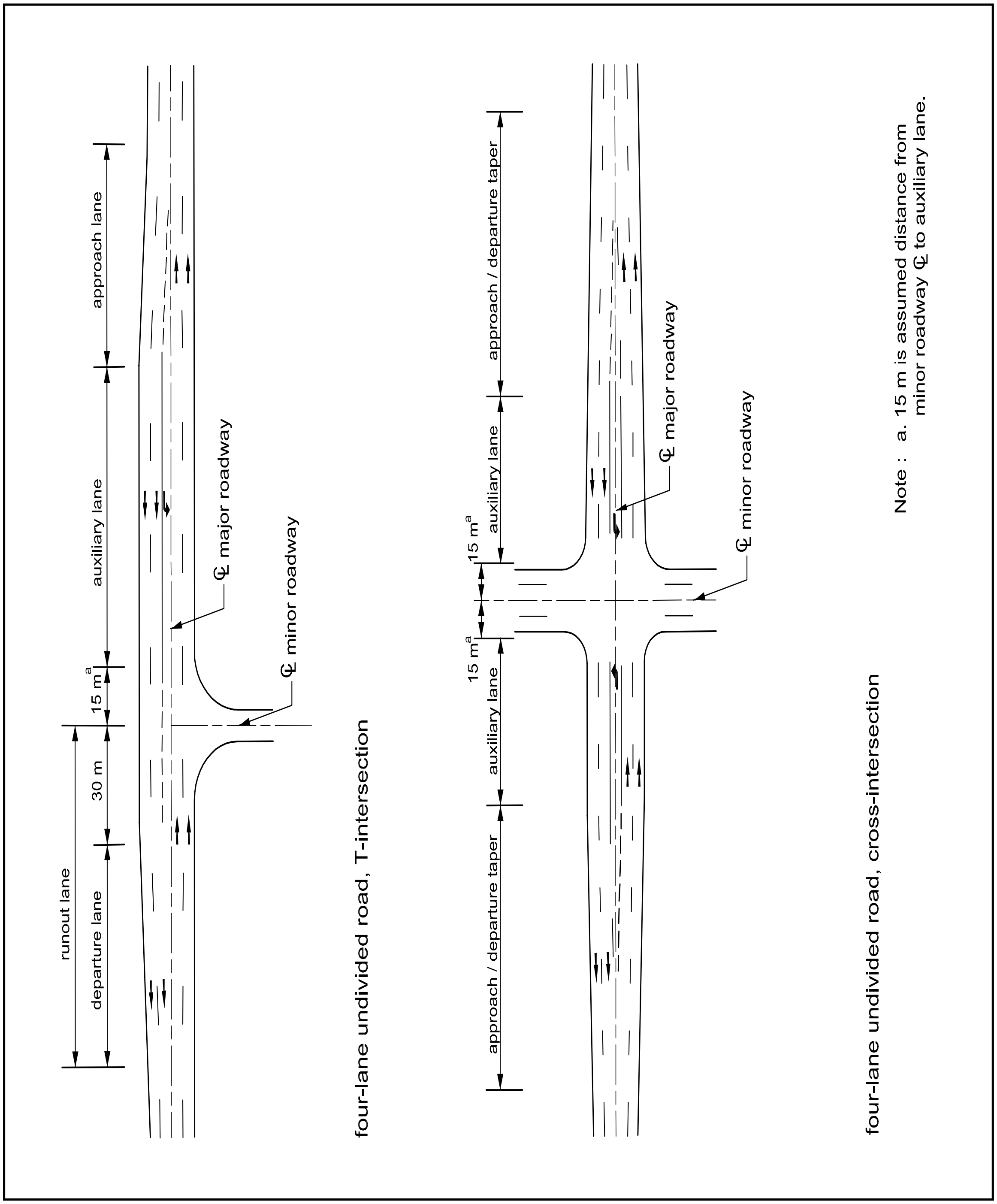


Figure 2.3.8.7 Introduced Raised Median