The Kiewit Center for Infrastructure and Transportation

Interchange Access Management

Discussion Paper #4

by

Robert Layton

Kiewit -2012/05

May 2012

The Kiewit Center for Infrastructure and Transportation
Oregon State University
111 Kearney Hall
Corvallis, OR 97331
cce.oregonstate.edu

DISCLAIMER

This discussion paper represents the viewpoints of the authors. Although prepared for the Oregon Department of Transportation (ODOT), it does not represent ODOT policies, standards, practices nor procedures.

GENERAL GOAL

This and other discussion papers were prepared for the purpose of stimulating discussion among interested individuals representing a variety of agencies and groups having an interest in Oregon's highways.

SPECIFIC OBJECTIVES

The specific objectives of this discussion paper are to:

Summarize the strategies for the effective management, design, operations, and control of interchanges and the areas around interchanges.

Identify and define the factors and criteria that affect the spacing and location of intersections and approaches in the vicinity of interchanges.

Recommend standards for intersection location, and the location and spacing of approaches.

ACKNOWLEDGEMENTS AND CREDITS

Mr. Del Huntington was project manager for ODOT. Dr. Robert D. Layton, Professor of Civil Engineering at OSU was project director for the Kiewit Center. Dr. Vergil G. Stover was consultant to TRI on this project. This discussion paper was prepared and updated by Dr. Robert Layton.

INTRODUCTION

Background

This paper draws on a draft Interchange Management Policy that was prepared in 1989 by Oregon Department of Transportation. The primary focus of this paper is interchange management within the context of access management. It does not deal with all the interchange funding, approval, design and construction issues necessary for planning and design of future interchanges.

Purpose

The purpose of this paper is to provide direction for the planning, design and access management of interchanges, particularly where they connect to the crossroads. The guidelines and standards established will be employed in the review, evaluation and design of new interchanges, modifications to existing interchanges, and upgrading cross road operation, design and access control.

Discussion Topics

Topics for discussion include the following:

1. Management strategies that should be included as a part of the Interchange Access Management policy.

2. Typical volume levels and traffic controls on which the location/ spacing criteria and standards are based.

3. The criteria and considerations that set the location and spacing standards.

4. The concern for future growth and the relevance of these standards to these conditions.

Questions to be Answered

Establishment of interchange access management standards poses several questions:

1. Should a separate set of standards be defined for 2-lane and 4-lane cross roads?
2. What management strategies are appropriately included in the policy?

3. Are the assumed volume levels appropriate for the definition of spacing and location standards?

4. Should major 2-lane cross-roads be required to meet 4-lane cross-road standards where they are like to be widened to 4 lanes?

Definitions

The following definitions are used in this policy:

Crossroad – the lower functional classification facility of the two facilities an interchange connects.

Expressway – a divided major roadway for through traffic with partial control of access and generally with interchanges at major crossroads.

Freeway – a divided major roadway with full control of access. Full control of access means that the authority to control access is exercised to give preference to through traffic by providing access connections with selected public roads only and by prohibiting crossings at grade or direct private driveway connections.

Interchange – a system on interconnecting roadways in conjunction with one or more grade separations that provides for the movement of traffic between two or more roadways or highways on different levels.

Interchange management area – the area defined by a distance along the mainline and crossroads in all directions extending beyond the end of the interchange ramp terminal intersections, or ramp or speed change lane tapers.

For crossroads it includes the crossroad on both sides of the interchange to the nearest intersection with a public street. The distance on either side should not be less than 1,320 ft. (400 m) and generally not more than 2,640 ft. (805 m).

For non-freeway mainlines in either direction it includes the shortest distance to: the nearest interchange; 1320 ft. (400 m) from the beginning or end of speed change lanes; or the nearest public road intersection. For freeway mainlines, it is the distance to the ramp or speed change lane tapers of the next interchange in either direction.

Mainline – the higher functional classification facility of the two facilities the interchange connects.

MANAGEMENT STRATEGIES

Introduction

Interchange plans are part of the long-term transportation system planning effort and must have effective strategies for 20-30 years in the future. The longer term impacts of growth and development to full build-out should also be taken into account. Interchange plans also need to consider potential need for transit, and park and ride facilities. Management strategies can use transportation system operations/control, land use, and circulation elements to achieve the intent of the interchange operation priorities.

Traffic Controls

Traffic controls that may be considered as part of management strategies include: signal phasing, intersection channelization, roundabouts, turn restrictions, traffic queue detection, traffic signal interconnection, and ramp metering.

1. Traffic signals on the cross street should be interconnected and operated to assign vehicle right of way with priority placed on moving traffic off the main highway or freeway and away from the interchange area, consistent with safety considerations.

2. Improvements may be needed to supplement the physical capacity of conflicting, yet important traffic movements through the interchange on the local facility or from the local facility to the main highway. This may require the restriction of access to properties within the interchange area or the separation of local and interchange access traffic through the construction of circulation/distribution systems discussed below.

3. Ramp metering may be necessary to ensure efficient operation on the main highway by reducing merge conflicts, eliminating the platooning effect created by ramp terminal signalization, and reducing short distance travel on the freeway where the available capacity is limited. Operations and access on the crossroad may be affected by queue spill-back from the ramp metering location.

Access Control

Access to the cross street must be controlled a sufficient distance on either side of the ramp connections to reduce conflicts and protect the ramp operations. Control may include spacing of public and private access points to the crossroad facility, and the use of a physical median barrier. Distances are provided in Attachments A and B.

The distance to the first signalized intersection should be at least 1320 ft. (1/4 mi. or 400 m) beyond a ramp intersection or a free flow ramp terminal for efficient signal coordination as shown in Attachments A and B.

Circulation/Distribution System

Development of a system of streets around the interchange shall be encouraged to circulate and distribute traffic to land uses in the area with a minimal impact on the mainline and crossroad. This system should be designed to serve traffic through a directional median opening and a right-out driveway or to direct traffic returning to the interchange to a signalized or full intersection at least 1320 ft. (1/4 mi. or 400 m) from the ramp intersections.

Land Use Controls

The comprehensive plan and zoning designations should acknowledge the function and role of the interchange and the spacing standards. Future right of way needs should also be included in the comprehensive plan.

Protective Buying and Sale of Excess Property

1. Strategies should be developed to insure property necessary for future expansion of the interchange is available and at the least relative cost. The strategies must be compatible with pertinent federal and state requirements.

2. When feasible, protective buying should be done if it is deemed more cost effective than alternatives or found to be more cost effective than buying the property in the future.

Grade Separated Crossings

Grade separated crossings, without ramps, should be used to:

1. Give local circulation additional crossings for local traffic, pedestrians and bicyclists.

2. Keep low volume intersecting roadways open for effective service.

3. Avoid having interchanges too close to each other.

4. Connect to existing or planned local connectors.

5. Provide crossing corridors that relieve traffic demand on crossings at interchanges.

6. Provide lower volume freeway crossings to enhance design of pedestrian and bicycle facilities.

Balanced Interchange Design with Ultimate Mainline Facility

The interchange design must be consistent with the plan for the mainline as expressed in the corridor plan, taking account of:

1. Level of service (LOS) operating standards.

2. The location of mainline and other interchanges that would be affected by the interchange over the planning period.

3. Future improvements in corridor plan: number of travel lanes, auxiliary lanes, high occupancy vehicles (HOV) lanes, exclusive transitways, modifications to existing interchanges, and planned new interchanges.

4. Projected LOS considering planned facilities, projected mainline traffic volumes, traffic generated by build-out of the interchange vicinity, anticipated changes in local travel resulting from the installation of a new interchange.

5. Planned surface street improvements that would relieve the freeway.

The interchange shall not be constructed or improved unless necessary supporting improvements identified in the corridor plan are in place or firmly committed to construction when needed.

Relieve Off-Ramps

1. Design, operation and management of the interchange shall give primary emphasis to off-ramp movements so traffic does not back up onto the freeway.

2. Consideration must be made for handling special events which may exceed what otherwise may be suitable design hour conditions, i.e., fairs and sporting events. Location and design of access facilities to special event land uses must take account of the potential queuing, increased delays and safety impacts, and may require larger than typical spacing standards.

Frontage Road Relocation/Closure

Frontage roads that are closer than the spacing standards for access to cross streets shall be either relocated or closed. Where feasible, local streets should be planned and built to provide for adequate access to adjacent property without interfering with the operation off the interchange ramps.

Closure of Interchange or Ramps

Certain ramps of the existing interchange or the entire interchange may be removed when the existing interchange is substandard or where better interchange facilities are already or can be developed in the area. To serve the area formerly served by the interchange, connecting roads will be provided to adjacent interchange facilities.

Local Street System

1. Interchanges shall connect to an adequate arterial street system with the necessary frontage roads, cross streets, channelization, access control, etc. In most cases the cross road should be a major or minor arterial. The connecting road design shall meet all applicable design standards.

2. The cross streets at interchanges should meet the following requirements:

    a. The cross street must have sufficient capacity in either direction for a distance of 2,640 ft. (1/2 mi. or 805 m), 1320 ft. (1/4 mi. or 402 m), or desirably from the end of the interchange ramp or speed change lane tapers to provide signal progression at level of service "C" in rural areas and "D" in urban areas. This is to assure the cross street is able to carry all the traffic that the interchange will present to it and insure adequate traffic movement away from the interchange facility.

b. The cross streets shall serve a reasonably large area, not just the area immediately around the interchange. The cross streets shall serve at least a minor arterial function in the area street system.

c. Except as provided below, no public or private access shall be allowed on the cross street for a distance of at least 590 ft. (180 m) in urban or suburban areas from a ramp intersection or ramp speed change lane taper. Where distances are less than 590 ft., access points shall generally be confined to right turns in/out. This may require construction of a physical median barrier.

Pedestrian and Bicycle Access

Urban interchanges should be designed to provide safe pedestrian and bicycle circulation across the freeway with minimum impediment. Signalized ramp terminals are preferable to free flowing ramps for safe pedestrian and bicycle operation. Where a free flowing design is used, a grade-separated path should be considered to minimize conflicts and out-of-direction travel.

MULTILANE CROSS ROAD CRITERIA

Spacing Between Ramp Terminal and Nearest Major Intersection

There are a number of factors and considerations that dictate the spacing to the nearest major intersection. These include the needed distance to accommodate the weaving maneuvers from free flow off-ramp onto the cross road facility to the left turn lane at the intersection and the distance to stop safely before an event or queue. The weaving maneuvers must be completed by the time the end of the queue at the intersection is reached. Therefore, the spacing to the nearest major intersection could be the weaving distance plus the queue length at the intersection. This distance provides a comfortable operating condition. Table 1 shows the operating conditions assumed for analysis or weaving and queuing for urban, suburban and rural conditions. The volumes are assumed to be typical of the area and volume labels. These volumes are also used to determine the size of the queue generated by the traffic conditions.

Table 1. Typical Operating Conditions Assumed for Analysis

Area	Speed	Cycle	Yellow	# of Phases	Cross Road Volume, (veh/hr) / lane			Right Off-Ramp Volume (vph)		
					High	Moderate	Low	High	Moderate	Low
Urban*	35 mph (55 kph)	120^s	3^s	4	1050	900	700	900	750	600
Suburban	45 mph (70 kph)	90^s	4^s	3	800	700	600	900	750	600
Rural	55 mph (90 kph)	60^s	5^s	2	500	300	100	300	200	100

* "Urban" refers to fully developed urban.

The analysis of the weaving distance is based on the Weaving Method by Leisch, given in Figure 1. Table 2 summarizes the analysis of weaving distance. An assumption is made that 50% of the left turns at major the intersection is contributed by off-ramp traffic. The results are not very sensitive to this assumption because the weaving traffic includes the total cross road volume.

The queuing distance must also be taken into account to assure that vehicles have adequate distance to weave comfortably to the left before being trapped in the right lane by vehicles queuing back from the intersection. Otherwise, forced lane changes to avoid the queuing vehicles can result in both operations and safety problems.

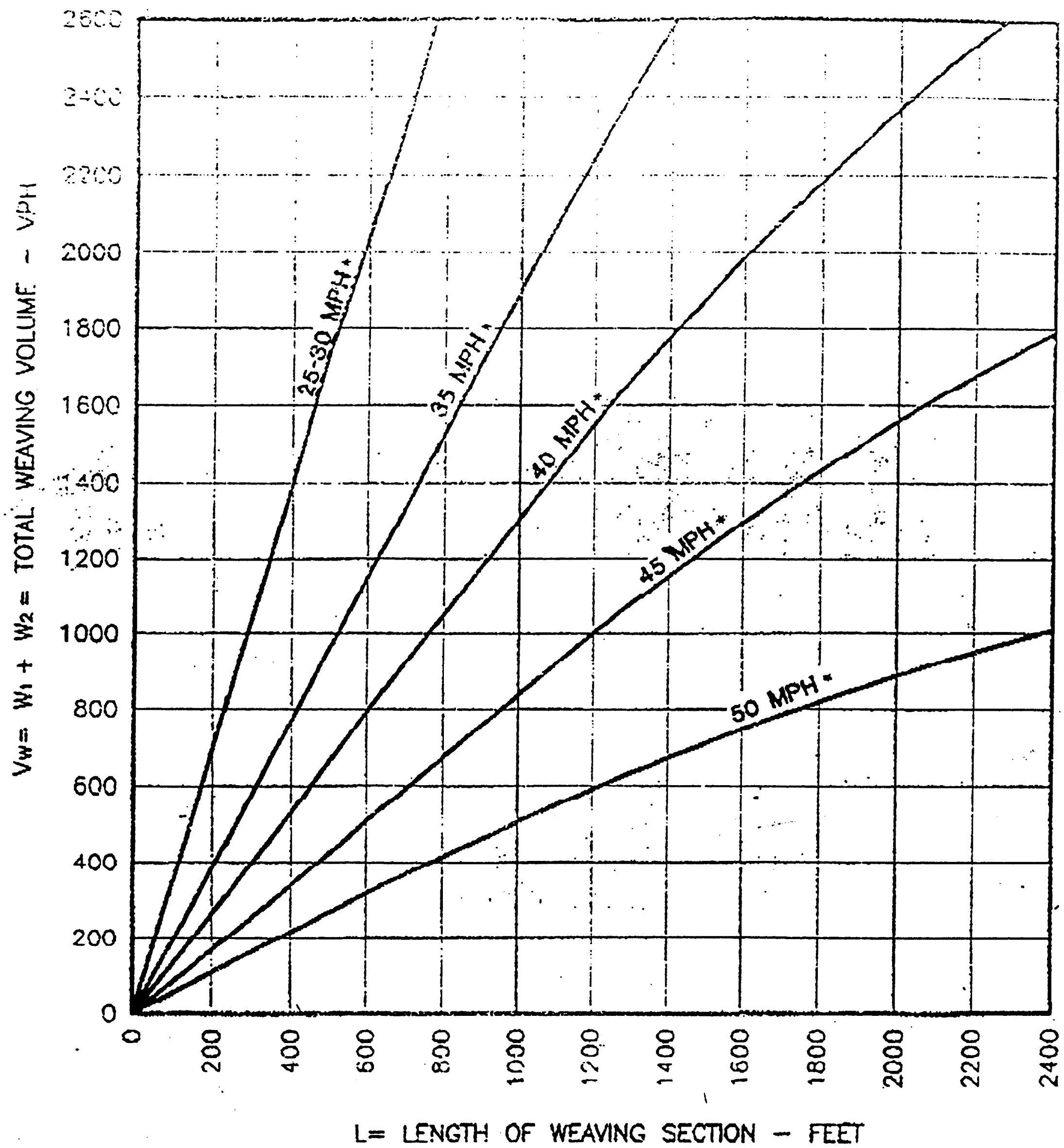
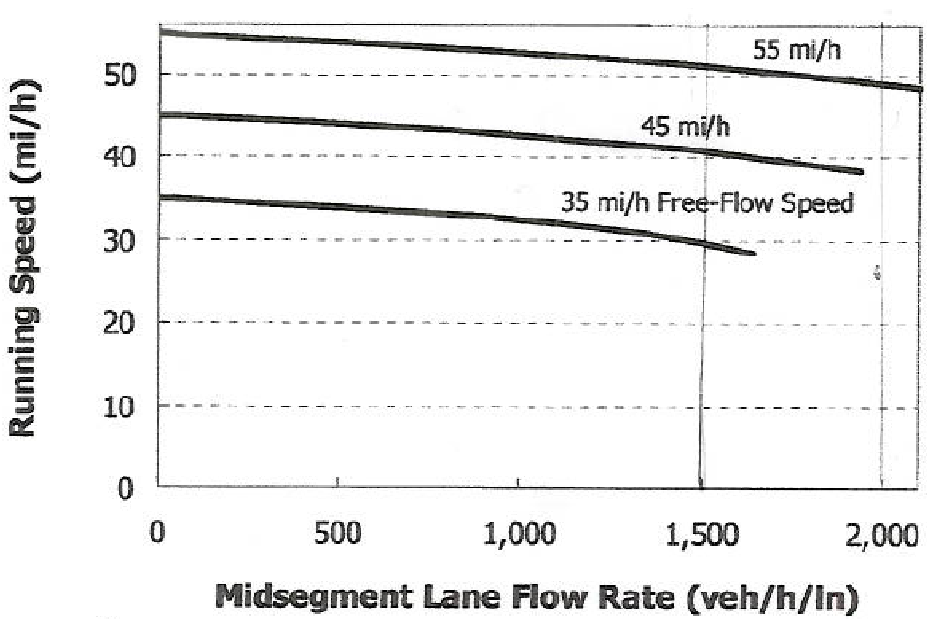


Figure 1. Analysis of Service Road Weaving Conditions
adapted from “Procedure for Analysis and Design of Weaving Sections,” FHWA Project DTFH51-82-C-00050 by Jack E. Leisch, 1982.

Table 2. Weaving Distances for Four Lane Cross Road with 10 and 20% Left Turns

Area	Volume Level	Cross Road Volume, vph/lane	Off-Ramp Volume, vph	Weaving Volumes		Weaving Distance	
				10% LT	20% LT	10% LT	20% LT
Urban (35 mph) (55 kph)	High	1050	900	2700	2400	1450	1300
	Moderate	900	750	2295	2040	1230	1100
	Low	700	600	1800	1600	950	840
Suburban (45 mph) (70 kph)	High	800	900	2250	2000	3100	2800
	Moderate	700	750	1935	1720	2700	2300
	Low	600	600	1620	1440	2100	1850
Rural (55 mph) (90 kph)	High	500	300	1170	1040	2900	2500
	Moderate	300	200	720	640	1600	1500
	Low	100	100	270	240	600	500

Stopping distance plus the queue provides another way to determine the required spacings to the next intersection from the ramp terminal. These stopping sight distances must be based on the speeds corresponding to the assumed volume conditions. Figure 2 provides estimates of these speed conditions. The figure is from the 2010 Highway Capacity Manual, showing the running speed versus the flow rate per lane.



Source: Exhibit 17-12, 2010 Highway Capacity Manual

Figure 2. Running Speed versus Flow Rate per lane

The decision sight distance has been recommended as the criteria for safety in interchange areas due to the complexity, expectancy issues, mix of traffic and volume levels. The decision sight distances are determined for the speeds corresponding to the assumed volume conditions. Then, the queue for the assumed volume conditions are added to the decision sight distance.

This queuing distance can be determined using the deterministic queuing analysis approach by:

$$Q = pqt$$

where

- q = flow rate in vehicles/sec.
- t = period of queuing, sec.
- p = randomness factor

The randomness factor recognizes the peaking or randomness of vehicles arriving at a location. A factor of 1.5 is sometimes used with high volumes as might be seen on a major arterial, with a factor of 2 used at locations where a higher degree of randomness is expected. Oregon Department of Transportation has adopted a randomness factor of 2.

The time period, t, refers to the amount of time that the vehicles are arriving at the intersection, and are not being served, i.e., not receiving a green phase. For purposes of this analysis an unblocked condition is assumed for the phasing strategy, that is, the vehicles for the through phase can arrive and be served on a green phase. Therefore, the time period is the cycle length minus the green time:

$$t = cy - G$$

where

- t = time period for queuing per cycle
- cy = cycle length, sec.
- G = green time, sec.

It is also possible to estimate the amount of queuing based on the Poisson distribution, which is a statistical mathematical distribution used to describe the occurrence of rare, random events.

$$\Pr(n, q/t) = \frac{e^{-qt}(qt)^n}{n!}$$

where

- Pr (n,q/t) = probability of n vehicles arriving in time period, t, with volume of q
- q = flow rate, veh/sec
- t = time period, sec
- n = number of vehicles in time period

This analysis is represented by Figure 3.

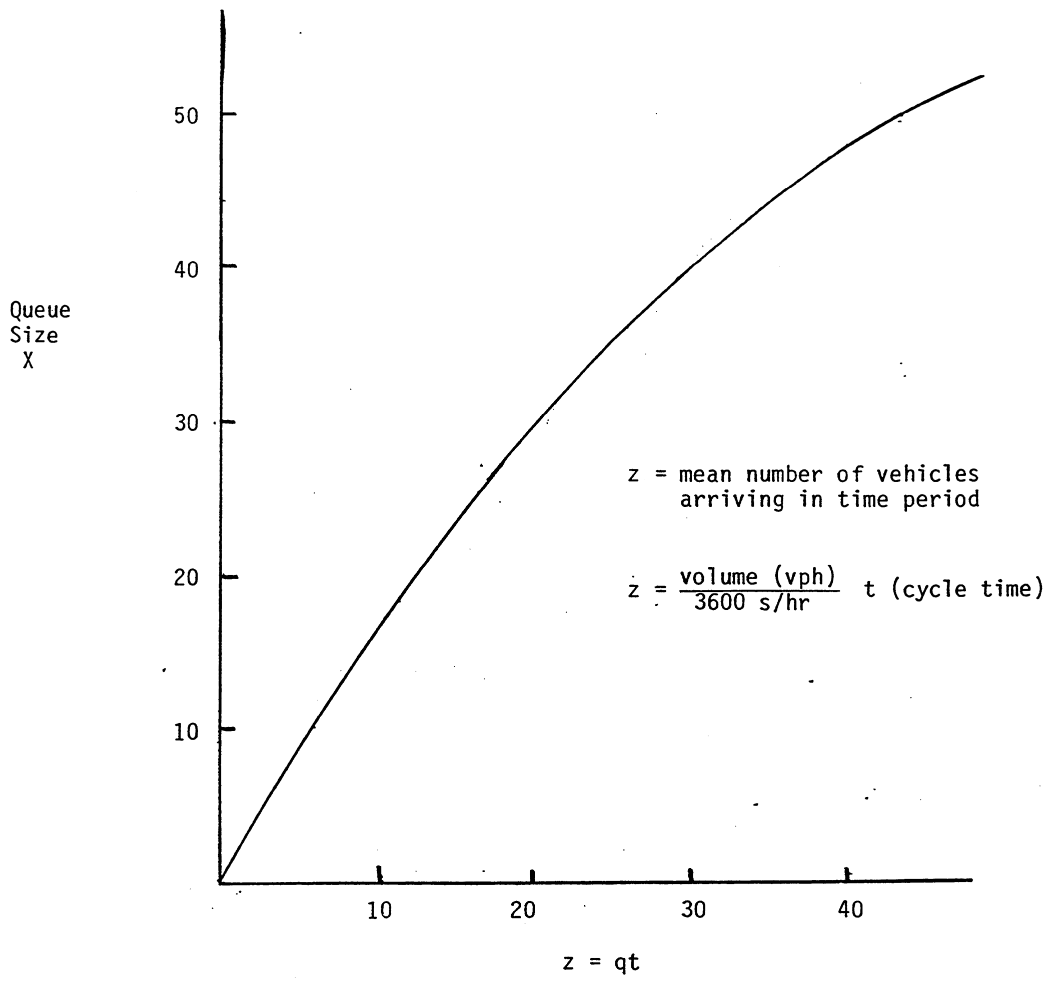


Figure 3. Queue Size Based on 95% Confidence Level Cumulative Poisson Probabilities

A comparison of the queue sizes determined for high volume shows that the use of the deterministic queuing method with a randomness factor can give very erroneous results, with a randomness factor of 2. The randomness factor only gives acceptable results for very low volumes, as seen in Tables 3 and 4.

The queuing conditions estimated from the Poisson distribution yields the most realistic results. In fact, the deterministic method with a randomness factor is attempting to approximate the results of the probabilistic based analysis using the Poisson distribution. Consequently, the queue sizes based on the Poisson distribution are used here.

Table 3. Typical Queue Sizes for Urban, Suburban and Rural Conditions by Deterministic Queuing and Probabilistic Poisson Analysis with 10% Left Turns and 10% Right Turns, Four Lane Cross Roads

Area Type	Through Volume (2 lanes) vph	Typical Ramp (2 lanes) vph	Total Queuing Volume vph	Cycle sec	Through Green sec	Left Turn Green sec	Yellow sec	Phases Φ	t sec	Queue Size, veh 1.5 qt	Queue Size, veh 2.0 qt	Queue Size, veh Poisson	Queue Length ft (m)
Urban (35 mph) (55 kph)	2100	900	2700*	120	60	13	3	4	60	24	32	24	600 (185)
	1800	750	2295*	120	60	13	3	4	60	24	32	24	600 (185)
	1400	600	1800	120	60	13	3	4	60	23	30	22	550 (170)
Suburban (45 mph) (70 kph)	1600	900	2250	90	48	10	4	3	42	20	26	21	525 (160)
	1400	750	1935	90	48	10	4	3	42	17	23	17	425 (130)
	1200	600	1620	90	48	10	4	3	42	14	19	15	375 (115)
Rural (55 mph) (90 kph)	500	300	1170	60	25	-	5	2	35	9	11	10	250 (75)
	300	200	720	60	25	-	5	2	35	5	7	7	175 (55)
	100	100	270	60	25	-	5	2	35	2	3	3	75 (25)

*Exceeds approach capacity; 950 vph/lane is assumed based on saturation flow of 1900 PCPHPL and 3 seconds lost time. This assumes intersection design or timing changes can satisfy this demand.

Table 4. Typical Queue Sizes for Urban, Suburban and Rural Conditions by Deterministic Queuing and Probabilistic Poisson Analysis with 20% Left Turns, Four Lane Cross Road

Area Type	Through Volume (2 lanes) vph	Typical Ramp (2 lanes) vph	Total Queuing Volume vph	Cycle sec	Through Green sec	Left Turn Green sec	Yellow sec	Phases Φ	t sec	Queue Size, veh 1.5 qt	Queue Size, veh 2.0 qt	Queue Size, veh Poisson	Queue Length ft (m)
Urban (35 mph) (55 kph)	1600	600	2400*	120	54	20	3	4	66	24	32	24	600 (185)
	1400	500	2040*	120	54	20	3	4	66	24	32	24	600 (185)
	1200	400	1600	120	54	20	3	4	66	22	29	23	575 (175)
Suburban (45 mph) (70 kph)	1000	400	2000	90	39	13	4	3	51	21	28	22	550 (170)
	800	300	1720	90	39	13	4	3	51	18	24	20	500 (150)
	600	200	1440	90	39	13	4	3	51	15	20	16	400 (120)
Rural (55 mph) (90 kph)	600	150	1040	60	25	-	5	2	35	8	10	9	225 (70)
	400	100	640	60	25	-	5	2	35	5	6	7	175 (55)
	200	50	240	60	25	-	5	2	35	3	3	3	75 (25)

*Exceeds approach capacity; 855 vph/lane is assumed based on saturation flow of 1900 PCPHPL and 3 seconds lost time. This assumes intersection design or timing changes can satisfy this demand.

The distances for weaving and queuing are combined to give the required spacings to the next major intersection from a free flow off-ramp terminal, if a smooth or comfortable operating condition is sought. The minimum distance to the back of the queue is taken as the weaving decision sight distance to a stop for safety or for a speed, path, or direction change, for comfortable operation. These values are given in Tables 5A and 5B.

Table 5A. Spacing to Nearest Major Intersection from a Free Flow Off-Ramp Terminal, Four Lane Cross Road, based on Decision Sight Distance and Queue

Area Type	Volume Level	Decision Sight Distance to Stop**	Queuing Distance		Spacing. ft	
			10% LT	20% LT	10%	20%
Urban (35 mph) (55 kph)	High (29 mph)	472	600*	600*	1072	1-72
	Moderate (31 mph)	510	600*	600*	1110	1110
	Low (32 mph)	530	550	575	1080	1105
Suburban (45 mph) (70 kph)	High (41 mph)	522	525	550	1047	1072
	Moderate (42 mph)	539	425	500	964	1039
	Low (43 mph)	556	375	400	931	956
Rural (55 mph) (90 kph)	High (53 mph)	507	250	275	757	783
	Moderate (53.5 mph)	514	175	175	689	689
	Low (54 mph)	521	75	75	596	596

*The urban and suburban queuing distances are based on saturation flow rate of 1900 veh/hr/lane
**The decision sight distance to the back of queue is based on speeds related to volume level, from Figure 2.

Table 5B. Spacing to Nearest Major Intersection from a Free Flow Off-Ramp Terminal, Four Lane Cross Road, based on Weaving and Queue

Area Type	Volume Level	Weaving Distance		Queuing Distance		Spacing ft (m)	
		10% LT	20% LT	10% LT	20% LT	10%	20%
Urban (35 mph) (55 kph)	High	1450	1300	600*	600*	2050 (625)	1900 (580)
	Moderate	1230	1100	600*	600*	1830 (560)	1700 (520)
	Low	950	840	550	575	1500 (460)	1415 (430)
Suburban (45 mph) (70 kph)	High	3100	2800	525	550	3625 (1105)	3350 (1040)
	Moderate	2700	2300	425	500	3125 (955)	2800 (855)
	Low	2100	1850	375	400	2475 (755)	2250 (685)
Rural (55 mph) (90 kph)	High	2900	2500	250	225	3150 (960)	2725 (830)
	Moderate	1600	1500	175	175	1775 (540)	1675 (510)
	Low	600*	650*	75	75	675 ( )	725 ( )

*The urban and suburban queuing distances are based on saturation flow rate of 1900 veh/hr/lane

The analyses performed for both 10% and 20% left turn at the major intersection, and percent of turns is not found to change the results significantly. As can be seen from Table 5A, the spacings for urban areas vary substantially from high to low volumes based on decision sight distance to a stop, but are comparable for moderate and low volumes, and all volumes for suburban. Rural spacings are roughly 50% less

A spacing of 1320 ft. should be adopted for urban areas and any developing suburban areas to provide for optimum spacing for coordinated signal progression. If the rural area also could be urbanized, a spacing of 1320 ft. should be adopted. Otherwise a spacing of 1000 ft. is suggested for suburban areas and 750 ft. for rural areas.

The spacing for a signalized intersection, as the off-ramp terminal also yields desirable spacings, as shown in Tables 5A and 5B. It is recommended that the spacings based on decision sight distance to a stop for spacing to the nearest major intersection be adopted for safety. This is described in the discussion paper on Access Management Classification and Standard, Discussion Paper 5.

Spacing to First Approach on the Right from Off-Ramp

This is the distance from the ramp terminal to the first drive/access approach. This is shown as the distance "X" on Attachments A and B. The spacing to the first approach could be based on a number of operations or safety criteria. The three most logical criteria are presented in the following.

1. Stopping Sight Distance. The stopping sight distance to the first or second approach may be used to determine the spacing to the first approach from the off-ramp. Figure 3 demonstrates the logic behind the use of the stopping sight distance for the right turn conflict. With the single right turn conflict it is assumed that the driver must have enough distance once entering the roadway to see operations and vehicles at the next drive with enough distance to stop. The double right turn conflict assumes drivers are keeping track of conditions at two drives. With the driver arriving on the cross road from the off-ramp or passing the ramp terminal, the single right turn conflict criteria, or stopping sight distance to the first drive is logical. This is based on the stopping sight distance from the 2004 AASHTO Greenbook.

2. Minimum Access Spacing to Maximum Egress Capacity. This criteria uses 1.5 times the distance to accelerate from 0 to through traffic speed, based on the acceleration data from the 1990 AASHTO Greenbook, p. 749, shown in Figure 4. These criteria are based on research performed by Major and Buckley[1] which reported that driveways spaced at distances greater than 1.5 times the distance required to accelerate from zero to the speed of through traffic will reduce delay to vehicles entering the traffic stream and will improve the traffic absorption characteristics of the traffic stream. Spacings based on acceleration distances for passenger cars on level grades are given in Table 7.

[1] I.T. Major and D.J. Buckley, "Entry to a Traffic Stream," Proceedings of the Australian Road Research Board, 1962.

Table 6. Stopping Sight Distances

Area	Speed mph (kph)	Sight Distance ft (m)
Urban	35 (55)	250 (75)
Suburban	45 (70)	360 (105)
Rural	55 (90)	495 (160)

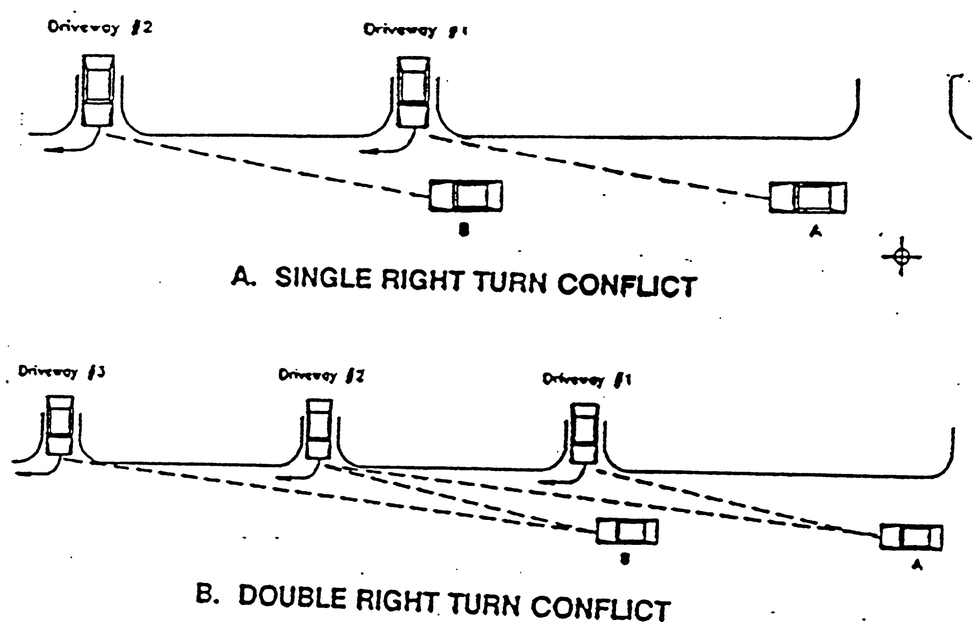


Figure 3. Schematic Illustration of the Right Turn Conflict Overlap

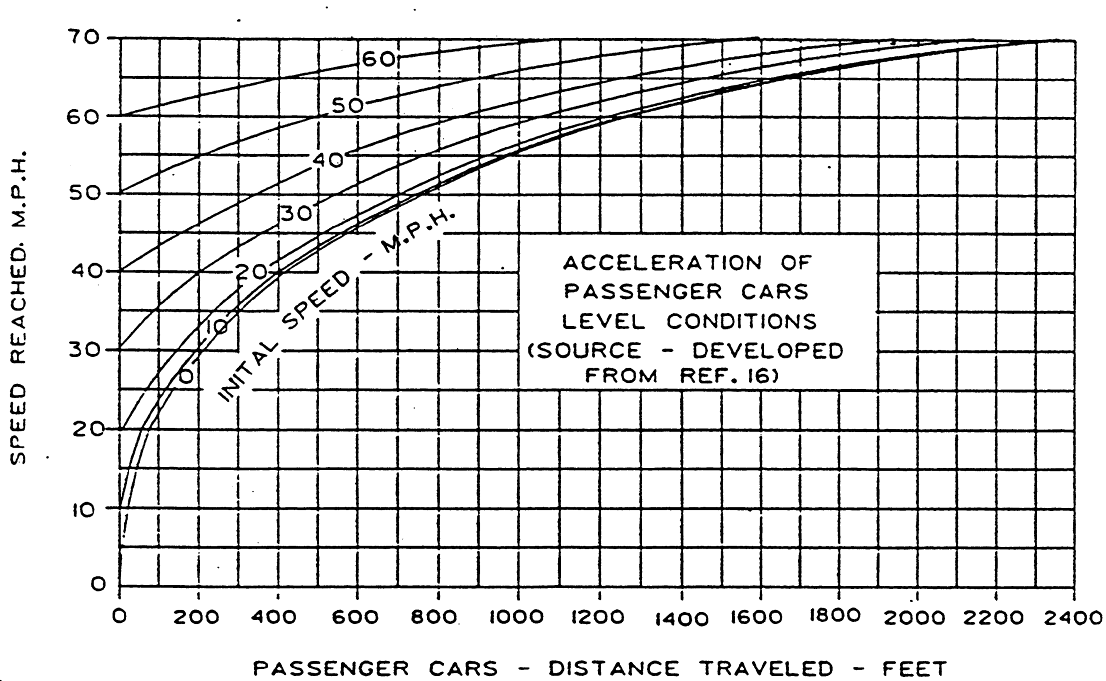


Figure 4. Acceleration of Passenger Cars on Level Terrain

Table 7. Minimum Access Spacing to Provide Maximum Egress Capacity

Area	Speed	1 × Acceleration Distance	1.5 × Acceleration Distance
Urban	35 mph (55 kph)	300 ft. (90 m)	450 ft. (135 m)
Suburban	45 mph (70 kph)	575 ft. (175 m)	860 ft. (360 m)
Rural	55 mph (90 kph)	1000 ft. (305 m)	1500 ft. (455 m)

Table 8. Decision Sight Distance Criteria

Area	Speed	Stop	Speed/Path/Direction Δ
Urban	35 mph (50 kph)	590 ft.	720 ft.
Suburban	45 mph (70 kph)	590 ft.	800 ft.
Rural	55 mph (90 kph)	535 ft.	865 ft.

Based on 2004 AASHTO Policy on Geometric Design

3. Decision Sight Distance Criteria. These criteria are based on the 2004 AASHTO Greenbook on decision sight distance. This provides the driver with adequate sight distance to perceive and react to unexpected, unusual, and/or complex conditions. The decision sight distance varies with the area character and the type of maneuver required to negotiate the location properly. The maneuvers include (1) stopping on rural, suburban or urban roads and, (2) a speed, path, and/or direction change on urban, suburban or rural roads.

   Decision sight distance provides an increase in perception-reaction time as the situation complexity increases, therefore, the perception-reaction time is longer for urban areas with the increased complexity of traffic operations and land use. The spacing to the first drive or access road must at a minimum meet the decision sight distance criteria for stopping.

   The operations on cross roads in the vicinity of on-ramps and off-ramps are complex and often unlike the operation throughout the rest of the road/street system. Drivers are exiting or entering a facility that is higher speed, access controlled and often divided. The entrances and exits are presented in many different configurations; therefore, drivers must discern the appropriate entries or exits from other drives and approach facilities. This requires greater perception-reaction time to sort out the more complex situation. Further, driver's expectations on freeways and expressways are quite different than on surface streets and two lane roadways. The driver anticipates fewer distractions and access points along the freeways and expressways.

4. Intersection Sight Distance Criteria. These criteria are taking account of the distance that a driver must be able to see a vehicle upstream of the approach road, and be able to enter the roadway safely. This criteria is not really relevant to spacing to the first approach because is measures how far upstream of the approach that a vehicle is visible so a vehicle in the approach can enter the major roadway. It is not concerned with the operation on the major roadway.

5. Weaving Distance Criteria. Weaving operations require long distances to be accomplished smoothly and safely. A free flow off-ramp terminal followed by an approach road generates a weaving section. The off-ramp vehicles must weave with the vehicles exiting at the approach road. They then must decelerate to the entrance speed of the approach. The necessary weaving distances and braking distances are shown in Table 10.

   The braking distances are based on the AASHTO criteria for safe stopping distance, which corresponds to maximum comfortable deceleration rates.

6. Recommended Spacings to First Approach. Based on the five criteria reviewed, a distance to the first approach of 590 ft. may be accepted in urban and suburban areas. Rural areas can use a spacing of 535 ft. However, rural areas that may develop into urban conditions should use spacing to the first approach of 590 ft.

Table 10. Weaving Distance from Off-Ramp Terminals to First Approach

Area Type	Volume Level	Typical Ramp Volume vph	Weaving Volume vph	Weaving Distance ft. (m)	Braking Distance to 10 mph (15 kph) ft. (m)	Spacing to First Approach ft. (m)
Urban (35 mph) (55 kph)	High	900	901	460 (140)	110 (35)	570 (175)
	Moderate	750	751	400 (120)	110 (35)	510 (155)
	Low	600	601	310 (95)	110 (35)	420 (130)
Suburban (45 mph) (70 kph)	High	900	901	1100 (335)	207 (65)	1307 (400)
	Moderate	750	751	900 (275)	207 (65)	1107 (340)
	Low	600	601	700 (215)	207 (65)	907 (275)
Rural (55 mph) (90 kph)	High	300	301	850 (260)	325 (100)	1175 (360)
	Moderate	200	201	500 (150)	325 (100)	825 (250)
	Low	100	101	300 (90)	325 (100)	625 (190)

TWO LANE CROSS ROAD CRITERIA

Rationale for Same Spacing to First Approach from Free Flow and Signalized Ramp Terminals

A primary criterion for determination of the spacing to the first approach after a free flowing ramp terminal or a signalized intersection is decision sight distance for a speed path or direction change, as defined by the AASHTO Policy on Geometric Design. Decision sight distance should always be provided.

Decision sight distance should be used where the traffic conditions are complex, unexpected and change significantly from other nearby conditions. This is true for both free flowing ramp terminals and signalized intersections. On free flowing ramp terminals, the vehicles are coming directly off the freeway into a more complex setting. The need to use decision sight for a speed path or direction change for spacing to the first approach from free flowing ramp terminals is supported by the added complexity on the surface streets, the transition in operations from high speed to low speeds in a short time period and the differences in driver expectancy on freeways versus surface streets.

Signalized ramp terminals present a similar set of conditions;

- There is likely to be a mix of local traffic (familiar drivers) and unfamiliar drivers creating different expectations.

- Vehicles traveling through the signalized intersection on the cross street are traveling through a complex situation; the conflict with vehicles slowing, turning and, at times, stopping at the access drive, are superimposed on intersection conflicts if the approach is too close to the signalized intersection.

- The speeds of some vehicles through the intersection are not slowed by the signals, so the operation is similar to those for vehicles on the free-flow exit ramp.

- Some vehicles passing through the signalized intersection are also recent freeway drivers; that is, left turns from the other off-ramp, so their conditioning and expectancy is for high speed travel with limited access conflicts.

Further, all of the analysis and evaluation is based on passenger car operations, and trucks compound the operational effects and further limit site distance. Consequently, any reduction in the spacing below the decision sight distance would be too restrictive.

Spacing to First Median Opening from Off-Ramp Terminal

The location of first median opening or access to a left approach, from a free flow off-ramp is based on the distance required for an off-ramp vehicle to weave to the median opening. The slowing of vehicles as they enter the turn bay or median opening impacts operations and safety. However, little of the slowing is taken into account in the weaving operations. The required weaving distances are shown in Table 11, based on typical volume conditions and vehicles entering the intersection area for the various area types. The weaving distances are shown from Figure 1.

Table 11. Minimum Weaving Distance to First Median Opening and First Drive/Access on Left, Four Lane Cross Road

Area Type	Volume Level	Through Volume (2 lanes), vph	Typical Ramp Volume, vph	Total Weaving Volume, vph	Weaving Distance, ft. (m)
Urban (35 mph) (55 kph)	High	2000	900	2101	1110 (340)
	Moderate	1800	750	1801	950 (290)
	Low	1400	600	1401	730 (225)
Suburban (45 mph) (70 kph)	High	1600	900	1601	830 (255)
	Moderate	1400	750	1401	730 (225)
	Low	1200	600	1201	620 (190)
Rural (55 mph) (90 kph)	High	1000	300	1001	520 (160)
	Moderate	600	200	601	310 (95)
	Low	200	100	201	100 (30)

After the weaving maneuver is accomplished, the vehicle must decelerate to a stop in the median opening. The stopping distances in Table 12 are found using deceleration rates corresponding to those for safe stopping.

Table 12. Stopping Distances

Area Type	Coefficient of Friction	Deceleration Rate ft/sec^2 (m/sec^2)	Braking Distance ft (m)
Urban (35 mph/55 kph)	.35	11.2 (3.4)	118 (35)
Suburban (45 mph/70 kph)	.35	11.2 (3.4)	194 (56)
Rural (55 mph/90 kph)	.35	11.2 (3.4)	290 (93)

where braking distance is calculated from;

$$\text{Braking Dist (ft.)} = \frac{V^2}{30f} = \frac{V^2}{30\frac{a}{32.2}} \qquad \text{(U.S. Customary)}$$

$$\text{Braking Dist (m)} = \frac{V^2}{254f} = \frac{V^2}{254\frac{a}{9.81}} \qquad \text{(Metric)}$$

These stopping distances should be viewed as minimum because the deceleration rate is the maximum comfortable deceleration rate. The minimum required spacing to the first median opening is the sum of the weaving distance and the stopping distance. However, the minimum spacing should not be less than the decision sight distance for a speed, path, or direction change. Table 13 summarizes these results.

The median opening should serve adequately as an area develops, from rural to suburban, and ultimately, to urban. A distance of 600 ft. could serve typical urban and suburban locations up to high volume conditions. Rural locations could have a spacing of 550 ft. This is roughly 1/8 mile, which fits well within other requirements of both intersection and median spacings.

Table 13. Minimum Spacing to the First Median Opening and Drive/Access on Left

Area Type	Volume Level	in Feet: Weaving Distance	Braking Distance	Queuing* Distance	DSD to Stop**	Weaving Based*** Min. Spacing	DSD Based**** Spacing
Urban (35 mph)	High (29 mph)	1110	118	75	472	1303	547
	Moderate (31 mph)	950	118	75	510	1143	585
	Low (32 mph)	730	118	75	530	923	605
Suburban (45 mph)	High (41 mph)	830	194	50	522	1074	572
	Moderate (42 mph)	730	194	50	539	974	589
	Low (43 mph)	620	194	50	556	864	606
Rural (55 mph)	High (53 mph)	520	290	25	507	835	532
	Moderate (53.5 mph)	310	290	25	514	625	539
	Low (54 mph)	100	290	25	521	415	546

* Assume a queue of 3 veh - urban, 2 veh - suburban and 1 veh – rural
** DSO based speeds related to volume level from Figure 2
*** Based on weaving
**** Based on decision sight distance

Spacing Between Nearest Approach and a Free Flow On-Ramp Terminal

The two primary criteria to evaluate spacing for the last approach road before the on-ramp are decision sight distances for speed path or direction change and the weaving distance from the approach road to the ramp. It should include the weaving distance plus the deceleration distance, when vehicles are required to stop or slow. The situation where vehicles must be able to weave before the back of a queue must also be considered. The spacing criteria that result are comparable to the first approach from the off-ramp, so a median must be located between the two approaches if both are located at the minimum; otherwise a four-legged intersection is created.

A primary concern in the location of the last approach before on-ramp is the necessary decision sight distance to a stop or for a speed, path or direction change in a complex situation. Since the approach interrupts the drivers attention, the drive should be placed at least that distance for safety upstream of the taper to the on-ramp In very complex donations, the decision sight distance for a speed, path or direction change could be used for multilane cross roads. These are shown in Table 14.

Table 14. Decision Sight Distance to a Stop or for Speed/Path or Direction Changes

Area	Typical Speed	Decision Sight Distance, ft.	
		to Stop	Speed/Path/or Direction Change
Urban	35 mph	590	720
Suburban	45 mph	590	800
Rural	55 mph	535	865

Another important effect is the weaving between vehicles entering from the approach and the vehicles destined for the on-ramp. This effect examines a comfortable operating condition. The effect is difficult to analyze because both typical on-ramp volumes and volumes from the approach must be known. The higher these volumes, the greater the effect of the weaving operations. The vehicles in the left lane can be assumed not be involved in the weave unless they are on-ramp vehicles. Using typical volume conditions, the required weaving distances can be estimated as shown in Table 15. For purposes of this analysis, assume 50 vehicles/hr from the access.

Table 15. Required Weaving Distances Between an On-Ramp and the Nearest Access/Drive

Area Type	Through Volume vphpl	Typical Ramp Volume vph	Access Volume vph	Total Weaving Volume vph	Weaving Distance ft. (m)
Urban (35 mph)	1050	900	50	1025	550 (168)
	900	750	50	875	450 (137)
	700	600	50	700	350 (107)
Suburban (45 mph)	800	900	50	900	1100 (335)
	700	700	50	750	900 (274)
	600	600	50	60	750 (229)
Rural (55 mph)	500	300	50	450	900 (274)
	300	200	50	300	600 (183)
	100	100	50	150	300 (91)

These primary control of decision sight distances should be provided for safety, based on decision sight distance for speed, path or direction change, Table 14, for multilane highways. The weaving distances in Table 15 provide smooth, comfortable operating conditions. For signalized ramp terminals, the spacing from the nearest upstream access point is estimated better from the decision sight to stop plus the queue upstream of the on ramp terminal intersection. The analysis for this is given in Table 16.

Spacing Between Nearest Approach and a Signalized On-Ramp Terminal

The condition with a signalized intersection requires distance to weave to the back of a potential queue. Table 16 shows the spacing requirements based on typical volume and signal timing.

Table 16. Calculations for Z Distance to Signalized On-Ramp

Area Type	Volume Level	Total Queuing Volume	Speed at Volume	Queue Distance	DSD to Stop	
Urban (35 mph)	High	2400*	29 mph	575 ft. (23 vh)	472	1047
	Moderate	2400*	31 mph	575 ft. (23 vh)	510	1085
	Low	1600	32 mph	550 ft. (22 vh)	530	1080
Suburban (45 mph)	High	2000*	41 mph	575 ft. (23 vh)	522	1097
	Moderate	1720	42 mph	575 ft. (23 vh)	539	1114
	Low	1440	43 mph	500 ft. (20 vh)	556	1056
Rural (55 mph)	High	1040	53 mph	325 ft. (13 vh)	507	832
	Moderate	640	53.5 mph	225 ft. (9 vh)	514	739
	Low	240	54 mph	100 ft. (4 vh)	521	621

* Exceeds approach capacity, 855 vph/lane is assumed based on saturation flow of 1900 pcphpl and 3 seconds lost. This assumes intersection design or turning changes can satisfy this demand.

From the analysis in Table 16 for urban and suburban areas, the spacing to the signalized ramp terminal from the nearest upstream access point should be 1100 ft, and for the rural area, 800 ft.

The resulting spacings at signalized ramp terminals are longer than at free flow ramps; however, the location of approaches from the centerline of the freeway is comparable for both cases since the free flow ramp terminal must be located farther from the freeway. Spacing recommendations are 990 ft. (300 m) for fully developed urban areas and 1320 ft. (400 m) for suburban and rural areas.

Spacing to Nearest Major Intersection with Two Lane Cross Road

Driver expectancy is a major concern with two lane cross roads because the drivers present have varying levels of expectations. The drivers exiting from the freeway/expressway have higher levels of expectations based on the higher levels of speeds, design, operations, and access control that they have been experiencing. The drivers on the two lane cross road naturally have lesser expectations. The mix of drivers, complexity of the interchange area, and uniqueness of the operations, ramp layouts and design elements requires more time for drivers to perceive and react properly. Consequently, decision sight distance must be provided and is a major factor in assuring smooth operations and safety.

A second major factor is the queuing distance required to accommodate all of the vehicles waiting to enter the nearest intersection. With a two lane facility near an intersection, queuing must be accommodated in one lane for all vehicles entering the intersection from the interchange, unless a wider section of roadway with turn lanes is provided at the intersection. Obviously, weaving is not an issue.

The sight distance to the back of queue must use the decision sight distance for a stop condition rather than stopping sight distance because the conditions are complex, unexpected and somewhat unique. The operations around interchange ramps may be different than those experienced on typical roads and streets. The decision sight distance for a stop condition is given in Table 17.

Table 17. Decision Sight Distance for the Stop Condition*

Area	Speed	Decision Sight Distance
Urban	35 mph	590 ft.
Suburban	45 mph	590 ft.
Rural	55 mph	535 ft.

*Based on 2004 AASHTO Policy on Geometric Design

The analysis of queuing conditions for two lane cross roads uses the same assumptions for volume and operating conditions assumed previously for multilane highways. The results of the queuing analysis are based on the Poisson distribution and are summarized in Table 18.

Table 18. Queue Size for Two Lane Road for Urban, Suburban and Rural Conditions by Deterministic Queuing and Probabilistic Poisson Analysis

Area Type	Through Level	Through Volume vph	Typical Ramp Volume vph	Total Queuing Volume* sec	Cycle sec	Through Green sec	Yellow sec	Phases Φ	t sec	Queue Size, veh 1.5 qt	Queue Size, veh 2.0 qt	Queue Size, veh Poisson	Queue Length ft. (m)
Urban (35 mph) (55 kph)	High	800	600	1050	120	65	3	3	55	24	32	24	600 (185)
	Moderate	700	500	900	120	65	3	3	55	21	28	22	550 (170)
	Low	600	400	750	120	65	3	3	55	17	23	19	475 (145)
Suburban (45 mph) (70 kph)	High	800	600	1050	90	48	4	3	42	18	24	21	525 (160)
	Moderate	700	500	900	90	48	4	3	42	16	21	18	450 (135)
	Low	600	400	750	90	48	4	3	42	13	18	14	350 (105)
Rural (55 mph) (90 kph)	High	500	300	600	60	25	5	2	35	9	12	10	250 (75)
	Modreate	300	200	375	60	25	5	2	35	5	7	7	175 (55)
	Low	100	100	150	60	25	5	2	35	2	3	3	75 (25)

* Assumes 25% left turns which are accommodated by a separate left turn bay. This result is insensitive to the % of left turns assumed. For example, if 35% left turns is assumed, a queue size from the Poisson distribution of 24 vehicles also results for the high volume level with urban conditions.

In summary, the spacing to the next major intersection is determined from the sum of the decision sight distance to stop and the queuing distance, based on the Poisson distribution. These results are shown in Table 19.

Table 19. Spacing to Nearest Major Intersection from Free Flow Off-Ramps for Two Lane Cross Roads

Area Type	Volume Level	Decision Sight Distance to Stop* ft.	Queuing Distance (Poisson based) ft. (m)	Spacing ft.
Urban (35 mph) (55 kph)	High	472	600 (185)	1072
	Moderate	510	550 (170)	1060
	Low	530	475 (145)	1005
Suburban (45 mph) (70 kph)	High	522	525 (160)	1047
	Moderate	539	450 (135)	989
	Low	556	350 (105)	906
Rural (55 mph) (90 kph)	High	507	250 (75)	757
	Moderate	514	175 (55)	689
	Low	521	75 (25)	596

* DSD is based on speeds related to volume level from Figure 2

Spacing to First Approach on Right from Free Flow Off-Ramp

The conditions are very similar to those experienced on a multilaned cross road for the first drive on the right; consequently, a criteria similar to that applied for multilaned cross roads should be used. However, there are two separate cases that must be considered: right turns in and right turns out only; and left turns into the drive from the major facility. No four-legged unsignalized intersections may be placed between ramp terminals and the first major signalized intersection.

1. Right In / Right Out Only. This condition occurs when only right turns into an approach and out of an approach are permitted. This implies that no major impact on the speeds and operations on the major facility will be allowed. Unfortunately, right in and right out designs that use only islands on the approach, "lamb chop designs", often are not effective in controlling the paths of vehicles entering and leaving the approach. Consequently, this criterion is defined assuming a non-traversable median, or barrier, between the lanes on the major facility. The other constraint assumed in the definition of this criterion is that no major slowing of vehicles on the major facility may occur, as would occur with poorly design driveway approaches across a sidewalk. Examples of poor driveway design are steep "dust pan" driveways or locations where the site design of the adjacent property places activities too close to the highway right of way, causing queuing or heavy deceleration.

   The major controls on this distance between the freeway off-ramp and the first approach to the right are the decision sight distance to a stop as previously defined and the intersection sight distance for the right turn maneuver.

   a. Decision Sight Distance Criteria. The decision sight distances to a stop condition are given previously in Table 17, ranging from 535 ft. in rural conditions to 590 ft. in suburban conditions, with 590 ft. for urban conditions. The decision sight distance to stop is greater than stopping sight distance, so the stopping sight distance is not a controlling condition.

b. Intersection Sight Distance Criteria. Intersection sight distance is not a relevant criteria for spacing to the first approach because it applies to how far upstream a vehicle can be seen from the approach. It doesn't apply to traffic operating on the major facility.

c. Minimum Access Spacing to Maximum Egress Capacity. This criteria, based on research performed by Major and Buckley,[2] locates driveways at distances greater than 1.5 times the distance required to accelerate from zero to the speed of through traffic to reduce delay and improve the traffic absorption characteristics of the traffic stream. Spacings based on acceleration distances for passenger cars on level grades are given in Table 20.

Table 20. Minimum Access Spacing to Provide Maximum Egress Capacity

Area	Speed	1 × Acceleration Distance	1.5 × Acceleration Distance
Urban	35 mph (55 kph)	300 ft. (90 m)	450 ft. (135 m)
Suburban	45 mph (70 kph)	575 ft. (175 m)	860 ft. (260 m)
Rural	55 mph (90 kph)	1000 ft. (305 m)	1500 ft. (455 m)

2. Recommended Spacing to First Approach on the Right. Values of 590 ft. for urban, 590 ft. for suburban, and 535 ft. for rural would meet all the above criteria and observed behavior for both right turns and left turns from the major facility, except the Maximum Egress Capacity spacing for rural areas where capacity is not typically a problem. However, since a major cross road in an urban area is likely to be widened to four or more lanes, the spacing for four lane cross roads is recommended, that is, 750 ft. (230 m). In both developing urban and rural areas, a spacing of 1320 ft. (400 m) is recommended.

[2] I.T. Major and D.J. Buckley, "Entry to a Traffic Stream," Proceedings of the Australian Road Research Board, 1962.

Spacing to First Approach on Left from Free Flow Off-Ramp

The conditions for this spacing are similar for the first drive on the right. The driver must have adequate time/distance to discern the vehicle is stopping, or is stopped to turn left. This distance must be adequate to provide the decision sight distance for the stopping condition. The decision sight distance for change in speed, path, or direction cannot be used since the left turning vehicle could be blocking the lane. The volume of vehicles on the major facility and the number of left turns expected into any approach are not likely to generate a long queue. Table 21 shows the expected queue lengths with 1 to 5% of the lane volume turning left, yielding 1 to 3 vehicles in queue. The left turning vehicles do not generate a long queue.

Table 21. Queue Size for Left Turning Vehicles

Approach Volume	Turning Volume		Capacity	Average Delay[3], sec		95% Queue Size		Length ft. (m)
	1%	5%		1%	5%	1%	5%	
1050	11	53	530	7	7.5	3	3	75 (23)
900	9	45	640	5.5	6	2	2	50 (15)
800	8	40	620	5.5	6	2	2	50 (15)
700	7	35	730	5	5	1	1	25 (8)

The spacing to the first drive on the left from the end of the off-ramp can then be estimated from the decision sight distance for stopping plus the queue length expected. This yields the distances given in Table 22. This yields values for the spacing for first drive on the left are slightly larger than the decision sight distance for stopping. Again, no four-legged unsignalized intersections may be placed between ramp terminals and the first major signalized intersection.

[3] "The 1994 Update, Highway Capacity Manual," Chapter 10 Unsignalized Intersections, Transportation Research Board, Washington, DC, 1995.

Table 22. Distance to the First Approach on the Left from Free Flow Off-Ramps

Area Type	Volume Level	Decision Sight Distance to Stop ft.	Queuing Distance (Poisson based) ft. (m)	Spacing ft.
Urban (35 mph) (55 kph)	High	590	75 (23)	665
	Moderate	590	50 (15)	640
	Low	590	25 (8)	615
Suburban (45 mph) (70 kph)	High	590	75 (23)	665
	Moderate	590	50 (15)	640
	Low	590	25 (8)	615
Rural (55 mph) (90 kph)	High	535	25 (8)	560
	Moderate	535	25 (8)	560
	Low	535	25 (8)	560

The first approach on the left from an off-ramp is also the approach upstream of the on-ramp. A spacing equal to the decision sight distance to a stop must be provided. These criteria require longer spacings for suburban and rural conditions, thus should control the spacings at 660 ft. for suburban and urban conditions, and 560 ft. for rural conditions, at a minimum.

Table 23. Decision Sight Distances to Stop and for Speed, Path and Direction Changes

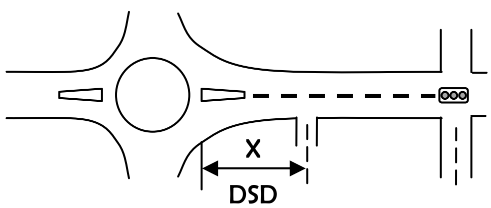
Area	Speed	Decision Sight Distance	
		to Stop	to Change Speed/Path/Direction
Urban	35 mph (55 kph)	590 ft.	720 ft.
Suburban	45 mph (70 kph)	590 ft.	800 ft.
Rural	55 mph (90 kph)	535 ft.	865 ft.

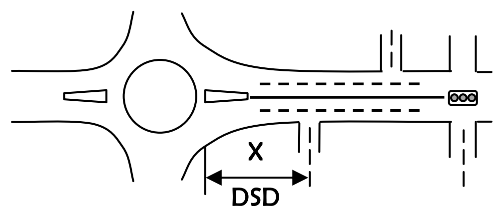
Where the major cross road in an urban or suburban area is likely to be widened to four or more lanes, the spacing for four lane urban cross roads is recommended, that is 800 ft. for “fully developed” urban.

Typical Spacing Standards for Roundabout Diamond Interchanges

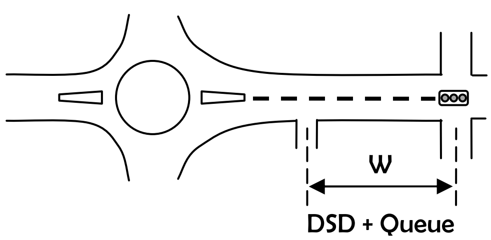
The use of roundabouts to serve the interchanging of traffic on the crossroad can have beneficial access management impacts. The speeds in the roundabout are controlled to 25-35 mph. Therefore, the spacing to the first access point is reduced. A roundabout could be used at the first access point near the interchange, with compatible operations. The first access point could be supplemented with an access point on the opposite side of the crossroad, both served by a roundabout.

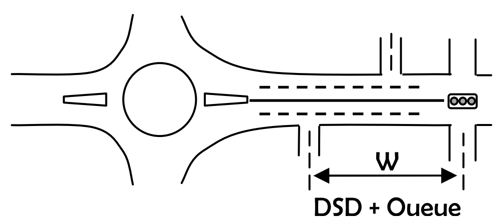
- *Spacing to first driveway from the terminal roundabout* – if the first driveway is a right-in, right-out or a similar design, it can be placed at the decision sight distance to a stop for a speed of 25, 30 or 35 mph. If a roundabout is used to serve the access point, or access points, it can be located very close to the ramp terminal roundabout, as long as queues from the access point roundabout do not inundate the ramp terminal.



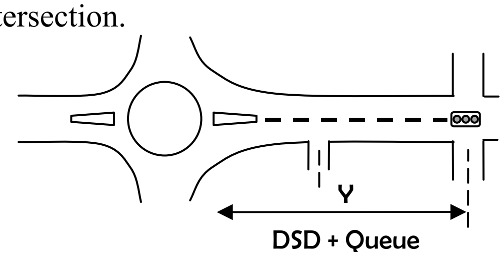


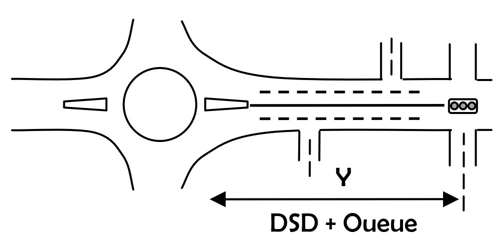
- *Spacing to the first signalized intersection from the last driveway* – the minimum distance to the first signalized intersection from the last driveway should be the decision sight distance to stop plus queuing at the intersection.



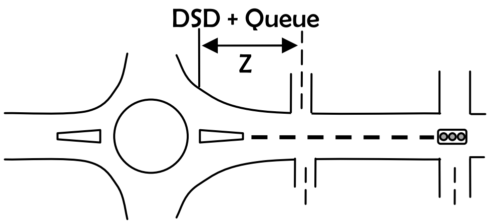


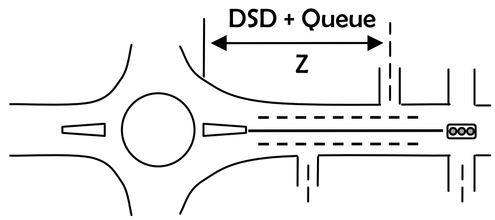
- *Spacing to the first intersection from the terminal roundabout* – the spacing to the first intersection for roundabout control should assure decision sight distance from the upstream roundabout, based on the roundabout design speed, plus the queue that may be experienced at the intersection. If there were an intermediate access point, the spacing would include the spacing to the first access point plus the decision sight distance to top plus queuing at the intersection.



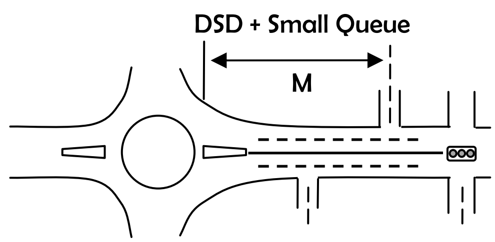


- *Spacing to the last driveway upstream of the terminal roundabout* – the use of a roundabout at the ramp terminals would reduce the spacing and would be the decision sight distance to stop plus the largest expected queue that could develop upstream of the roundabout.





- *Spacing to the first median opening from the terminal roundabout* – the distance to the first median opening from the off-ramp for multilane crossroads should be the decision sight distance to stop plus a few queued vehicles. Two-lane crossroads would typically not have a median so decision sight distance to a stop behind the expected left turning queue length should be provided. This should also provide acceptable spacing if a median with an opening is used on a two-lane roadway.



Typical spacing standards are given in Table 24.

Table 24. Typical Spacing Standards for Roundabout Terminals with Two- and Four-Lane Crossroads

Type of Area	Arterial Width	Design Speed	Spacing Dimension, ft				
			X	W	Y	Z	M
Urban (35 mph)	2 Lane	25 mph	400	1000	1000	400	-
		30 mph	490	1090	1090	400	-
		35 mph	590	1140	1140	400	-
	4 Lane	25 mph	400	1000	1000	450	475
		30 mph	490	1090	1090	450	565
		35 mph	590	1140	1140	450	665
Suburban (45 mph)	2 Lane	25 mph	400	925	925	460	-
		30 mph	490	915	915	460	-
		35 mph	590	965	965	460	-
	4 Lane	25 mph	400	925	925	510	340
		30 mph	490	915	915	510	400
		35 mph	590	965	965	510	475
Rural (55 mph)	2 Lane	25 mph	280	530	530	545	-
		30 mph	350	525	525	545	-
		35 mph	425	500	500	545	-
	4 Lane	25 mph	280	530	530	545	205
		30 mph	350	525	525	545	245
		35 mph	425	500	500	545	300
Criteria		Roundabout design speed	DSD to stop for Round. design speed	DSD to stop from Round. design speed + queuing	DSD to stop + queue at intersection	DSD to stop + queue at roundabout	DSD to stop + queue of 3, 2 & 1 vehicles

* = Y must be ≥X+W if a driveway is allowed between ramp terminal and first major intersection

X = Distance to first driveway on the right; right in/right out only

W = Distance from last driveway to first major intersection

Y = Distance to first major intersection

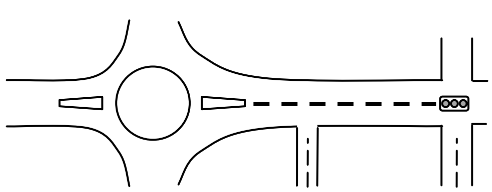
Z = Distance between the last driveway and the start of the taper for the on-ramp

M = Distance to first directional median opening. No full median openings are allowed in non-traversable medians to the first major intersection

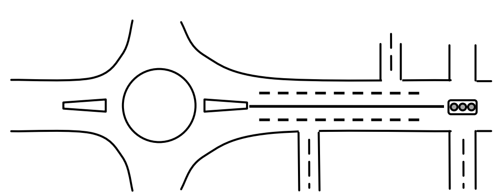
Notes:

(1) No four-legged intersections may be placed between ramp terminals and the first major intersection.

(2) Distance to last approach before the terminal roundabout, Z, can be reduced significantly if an entry bypass lane is provided.



Two Lane Crossroad



Four Lane Crossroad

Roundabouts are an attractive strategy for improving spacing requirements; however, there are factors that should be taken into account before electing this strategy.

1. Roundabouts do not support coordinated signal timing

2. Unbalanced volumes can leave some approaches poorly served

3. Pedestrians and bicyclists have some difficulties with roundabouts

Variance Spacing Standards

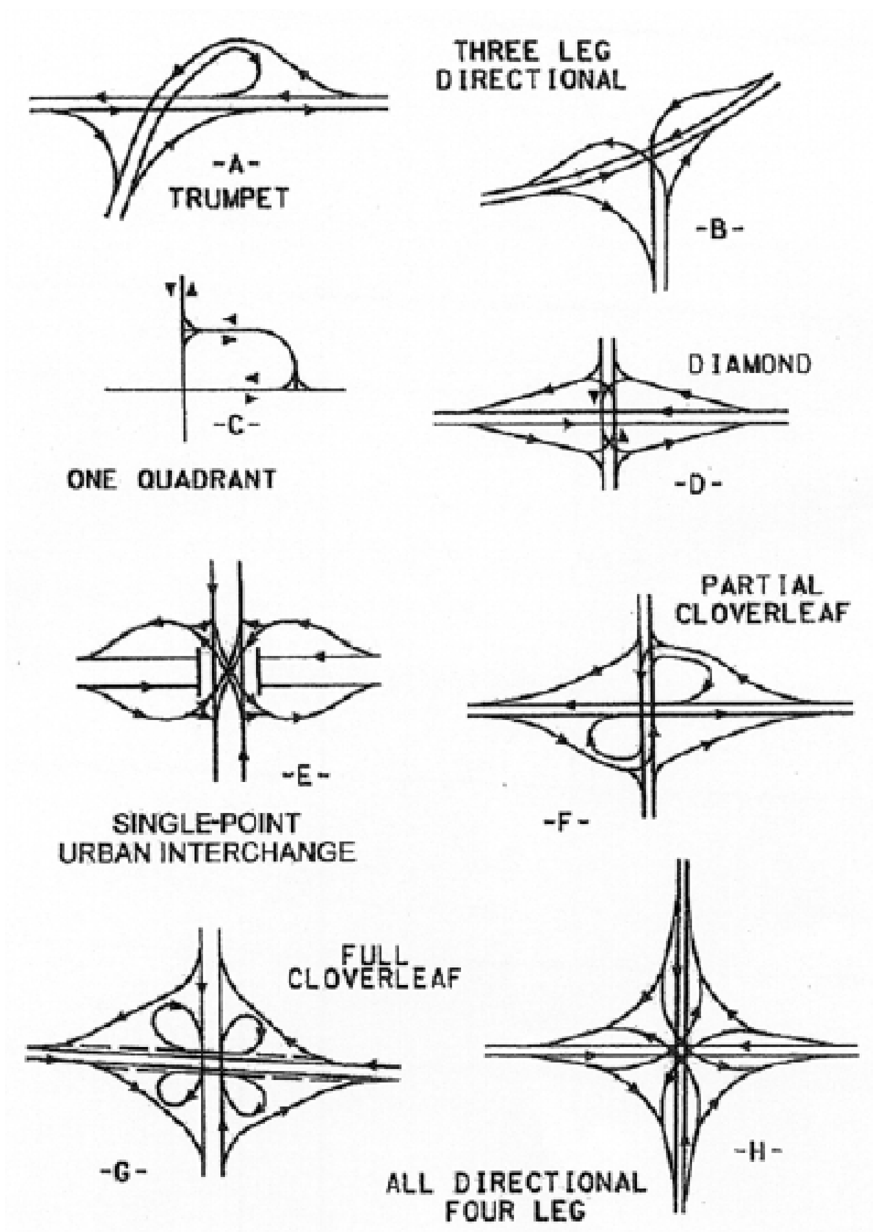
There are situations where it is impossible to achieve the desired spacing standards due to land use, topographic or existing roadway network constraints. Under those conditions, variances may be permitted on the spacing standards. These variances should only be allowed if an engineering study proves they are warranted.

The use of stopping sight distance rather than decision sight distance is the primary change in the determination of the spacing standards. Stopping sight distance is based on the safe stopping distance to a single hazard in the middle of the roadway. Thus, the variance should only be allowed where conditions are simple and straight forward.

The proposed variance standards are shown in Table 25 together with the basis of the criteria.

Table 25. Variance Spacing Standards for Ramp Terminals with Two- and Four-Lane Crossroads

Type of Area	Arterial Width	Spacing Dimension, ft					
		X	W	Y	Y′	Z	M
Urban (35 mph)	2 Lane	250	850 SSD + 600’	850	-	325 SSD + 3 veh	325
	4 Lane	250	850 SSD + 600’	850	-	325 SSD + 3 veh	
Suburban (45 mph)	2 Lane	360	860 SSD + 500’	860	-	410 SSD + 2 veh	410
	4 Lane	360	860 SSD + 500’	860	-	410 SSD + 2 veh	
Rural (55 mph)	2 Lane	495	670 SSD + 175’	670	-	520 SSD + 1 veh	520
	4 Lane	495	670 SSD + 175’	670	-	520 SSD + 1 veh	
Criteria		SSD	SSD + Queue	SSD + Queue	No Signal Progress	SSD + Small Queue	SSD + Small Queue



Source: "Policy on Geometric Design of Streets and Highways," AASHTO, 2004

Figure 5. Interchange Forms

Appendix A

Table A1. Typical Spacing Standards for Signalized Ramp Terminals with Two- and Four-Lane Crossroads

Type of Area	Arterial Width	Spacing Dimension, ft					
		X	W	Y*	Y^1	Z	M
Urban, 35 mph	2 Lane	590	1100	1100**	1320	660	--
	4 Lane	590	1100	1100**	2640	750	600
Suburban, 45 mph	2 Lane	590	1100	1100**	1320	660	--
	4 Lane	590	1100	1100**	2640	800	600
Rural, 55 mph	2 Lane	535	750	750**	1320	560	--
	4 Lane	535	750	750**	2640	865	550
Criteria		DSD	DSD + Queue	DSD + Queue	Signal Progress	DSD + Queue	DSD + Small Queue

* = Y must be ≥X+W if a driveway is allowed between ramp terminal and first major intersection

** = If the area could be fully developed urbanized, use 1320' for urban, suburban and rural, or 2640' for future coordinated multilane arterial

X = Distance to first driveway on the right; right in/right out only

W = distance from last driveway to first major intersection

Y = Distance to first major intersection

Y^1 = Distance to first major intersection in coordinated signal network for two-way progression

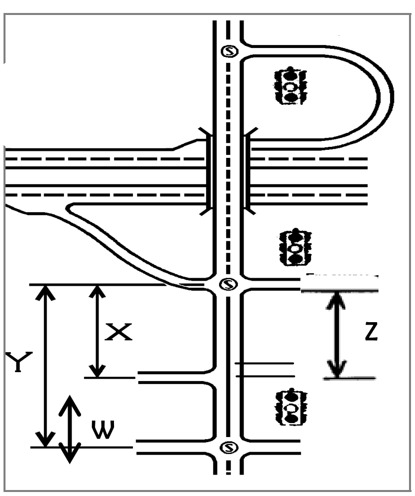
Z = Distance between the last driveway road to the on-ramp signalized intersection

M = Distance to first directional median opening for left turns from crossroad. No full median openings are allowed in non-traversable medians to the first major intersection

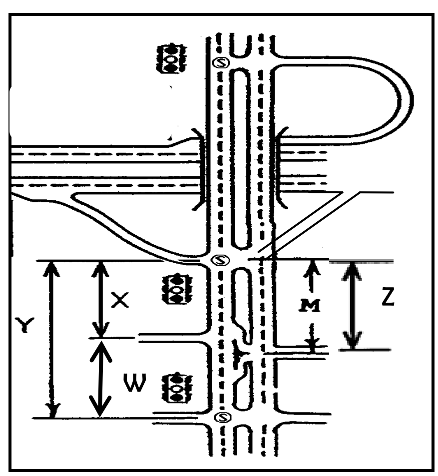
Notes:

(1) No four-legged intersections may be placed between ramp terminals and the first major intersection.

(2) Distance to last approach before on-ramp, Z, can be reduced significantly if an added free right turn lane is provided.



Two Lane Crossroad



Four Lane Crossroad

Table A2. Typical Spacing Standards Applicable to Free Flow Ramp Terminals with Two-and Four-Lane Crossroads

Type of Area	Arterial Width	Spacing Dimension, ft					
		X	W	Y*	Y[1]	Z	M
Urban, 35 mph	2 Lane	590	1100	1100**	1320	1100	--
	4 Lane	590	1100	1320**	2340	1100	600
Suburban, 45 mph	2 Lane	590	1100	1100**	1320	1100	--
	4 Lane	590	1100	1100**	2640	1100	600
Rural, 55 mph	2 Lane	535	750	750**	1320	800	--
	4 Lane	535	750	750**	2640	800	550
Criteria		DSD	DSD + Queue	DSD + Queue	Signal Progress	DSD	DSD + Small Queue

* = Y must be ≥X+W if a driveway is allowed between ramp terminal and first major intersection

** = If the area could be fully developed urbanized, use 1320' for urban, suburban and rural, or 2640' for future coordinated multilane arterial

X = Distance to first driveway on the right; right in/right out only

W = Distance from last driveway to first major intersection

Y = Distance to first major intersection

Y^1 = Distance to first major intersection in coordinated signal network for two-way progression

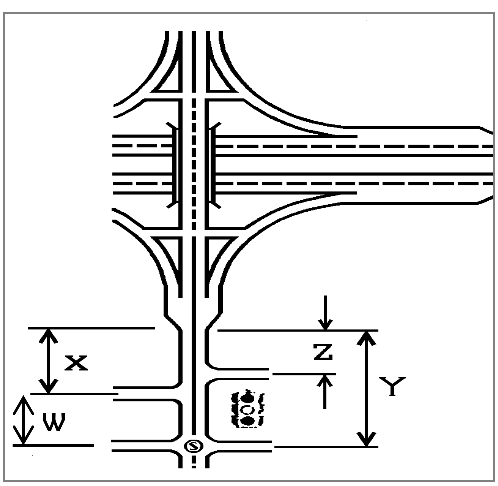
Z = Distance between the last driveway road and the start of the taper for the on-ramp

M = Distance to first directional median opening. No full median openings are allowed in non-traversable medians to the first major intersection

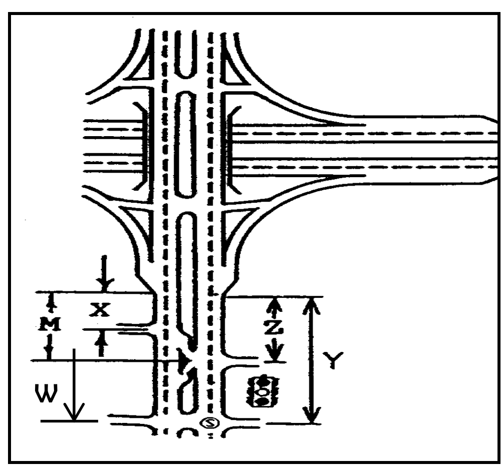
Notes:

(1) No four-legged intersections may be placed between ramp terminals and the first major intersection.

(2) Distance to last approach before on-ramp, Z, can be reduced significantly if an added free right turn lane is provided.



Two Lane Crossroad



Four Lane Crossroad