INST. OF TRAFFIC ENGIN.

GUIDELINES FOR DRIVEWAY DESIGN AND LOCATION

...e of Transportation Engineers Recommended Practice 1974

Guidelines

for

Driveway

Design and Location

INSTITUTE OF TRANSPORTATION ENGINEERS
ITE
1930

This report was approved as a Tentative Recommended Practice by the ITE Board of Direction on November 28, 1972. Following a period of time sufficient for the submittal of comments on its provisions, the report was reconsidered by the Technical Council and the Board. On May 17 1974, the Board of Direction approved the report as a Recommended Practice of the Institute.

The report was developed by Project Committee 5N-S in Department 5 of the ITE Technical Council. Members of the committee were; Paul C. Box, chairman; David S. Plummer; R. Clarke Bennett; Robert R. Canfield; Sam Fisher; David V. Konsa; Harry Parker; J. O. Litchford; Donald C. Morgan; Alexander T. Morris; H. Wayne Sherrell; and Earl C. Williams Jr. Special thanks go to William R. McConochie for his help in editing this report.

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The primary objective of this Recommended Practice is to establish guidelines for location and design of driveways providing access from public streets and highways to developments on abutting property. In order for the guidelines to be of maximum value, it is necessary that wide flexibility be retained in their application. Engineering judgment should override recommended dimensions if warranted by specific traffic conditions. A secondary objective of this Recommended Practice, therefore, is to provide material from prior studies to aid engineers at the municipal, county and state levels in evaluating actual traffic needs and granting variations in issuing driveway permits.

Classifications and Definitions

The following definitions and classifications apply to this Recommended Practice. They deal with various types of roadways and areas with streets of high pedestrian activity and those of lower importance to pedestrians.

Areas

An area is defined as "urban" if the abutting street has a speed limit of 40 miles per hour (mph) or less, or if at least 50 percent of the frontage on one side of the route within one half mile of the proposed driveway location has been developed with residences, business and/or industry. It is also intended that the term urban generally include developed areas within incorporated limits of municipalities and urbanized townships or counties.

All locations not included under the urban definition should be considered rural.

Streets

The term "major route" includes all marked county, state or federal routes and all urban streets a) having continuity; b) carrying substantial amounts of through traffic; and c) on which traffic is assigned the right-of-way by stop signs facing cross streets.

Land Uses

Most urban residential neighborhood business and industrial streets are of low pedestrian activity. Areas of high pedestrian activity include streets through or abutting central business districts as well as those in the same block with auditoriums, schools, libraries and secondary (community type) business districts. Under certain conditions, streets and highways adjacent to public parks and rapid transit stations may also fall into this category.

Driveway Types

1. A residential driveway is one providing access to a single family resi-

dence, to a duplex, or to an apartment building containing five or fewer dwelling units.

2. A commercial driveway is one providing access to an office, retail, or institutional building or to an apartment building having more than five dwelling units. Such buildings are customarily serviced by trucks as as incidental rather than a principal driveway use. Industrial plant driveways whose principal function is to serve administrative or employee parking lots are considered commercial driveways

3. An industrial driveway is one directly serving substantial numbers of truck movements to and from loading docks of an industrial facility, warehouse or truck terminal. A centralized retail development, such as a community or regional shopping center, may have one or more driveways specially designed, signed and located to provide access for trucks. These are classified as industrial driveways.

Methods of Measurements

1. All dimensions in this report refer to distances from (or along) *face of curb*. In the absence of a curb the measurement is considered to be from (or along) the edge of pavement.

2. Driveway angles are measured between the driveway centerline and one edge of the roadway.

Design Considerations

The efficiency and safety of a street or highway depends largely on the amount and character of interferences affecting vehicles moving along it. Major interferences are caused on most streets by vehicles entering, leaving, or crossing the road at intersecting streets and driveways. In order to minimize accidents and to assure best overall use of the facility by the general public, it is necessary to regulate vehicle movements in and out of abutting developments and cross streets.

With respect to driveways, road users have certain rights of access to abutting property as well as the right to travel on the highway with relative safety and freedom from interference. Since these various rights sometimes conflict, cities, counties and states having jurisdiction over public thoroughfares are generally given the responsibility for reconciling and, to the extent feasible, for satisfying the needs and rights of *all* road users in respect to driveway location, design and operation. When conflicts cannot be fully resolved, preference should be given to the safe and efficient use of the highway.

A number of design considerations have been established on which findings and recommendations of this Practice are based. These are listed below. When documents supporting specific principles are available for reference, they are identified.

1. Direct driveway access to abutting property represents a service to the traveling public; driveways are *not* special concessions to landowners.

2. The conflict effect of driveways is a function of traffic flow along the

street and at the driveway. Traffic from adjacent driveways and from driveways on the opposite side of the roadway may also be in conflict.

3. A low-volume driveway causes relatively little conflict on a major route, and a high-volume driveway causes little conflict on a minor route. The relationships, however, are not necessarily linear.[21]

4. Driveways are essentially "T" intersections. High activity land uses produce driveway volumes greater than those of most intersections of local streets with major routes.[19]

5. The design elements of each high-volume driveway (location, spacing, sight distance, throat width, radii, angles, deceleration and acceleration lanes and grades) should be based on expected volumes by directions of arrival and by vehicle characteristics.[37, 47]

6. In the absence of a separate left-turn lane, the left-turn *entry* movement generally causes the greatest hazard and street congestion.[19, 26, 47]

7. The left-turn *exit* movement is the most sensitive to spacing of the driveway relative to the nearest point of street traffic control (especially a signal). Such movements are also relatively hazardous.[19]

8. The right-turn entry into a driveway is the second most sensitive movement in respect to spacing from the location of street traffic control. Such movements also impede through traffic.[26]

9. Driveways along major and collector routes should be designed for curb lane access and with minimal encroachment on travel lanes disregarding present parking practices.[23]

10. In order to preclude encroachment on travel lanes, radii for right turn entry and exit should be consistent with the design vehicle's swept path requirements.[19]

11. If the radius is inadequate, encroachment will occur unless the entering or leaving vehicle temporarily occupies a substantial width of the driveway throat.[19, 47]

12. For low-volume or one-way drives, it is acceptable for vehicles to sweep across the entire throat.

13. Two-way drives represent the most practical design for many conditions; for high-volume operations, such a driveway may be considered as two adjacent one-way driveways separated by a center line.

14. If 30 feet of linear curb opening is needed for right turn entry (or exit) from a curb lane of given width and by a specific design vehicle, the access may be provided by:

a) Separate in and out drives, each with a 30-foot curb cut and a curb return of zero radius.

b) Two separate drives, each with a 30-foot curb cut, but with a 15-foot throat and a 15-foot radius on the curb return on one side.

c) A single two-way drive, with a 60-foot total curb cut, 30-foot throat and 15-foot radii on both sides.

15. In most areas, pedestrian accidents involving cars entering or leaving driveways are infrequent compared with the number of vehicular collisions involving the driveways.[20]

16. Where pedestrian safety is a major factor, design 14a above is the poorest since a total of 60 feet of driveway crosses the walk in contrast to a total of 30 feet of throat for either the 14b or 14c designs. However, the degree of difference is also a function of the placement of the sidewalk within the area between the curb and the property line.

17. In areas of high pedestrian activity, designs for low speed vehicular entry and exit may be based on radii of intermediate dimensions and restricted total widths. Such designs, however may increase vehicle/vehicle conflicts and increase the number and length of delays to vehicles.

18. The differing problems indicate that two *separate* design standards are needed in urban areas: one to minimize pedestrian/vehicle driveway conflicts, and the other to minimize vehicle/vehicle conflicts.[19]

19. The lesser problems on lowvolume routes also suggest less stringent design requirements on secondary streets.

20. Because of the much higher speeds on rural highways, they require a higher level of design than urban streets.[47]

21. Most driveway design elements are directly related to the layout of the parking area, amount of reservoir space (for drive-in service facilities) type of loading facility, circulation pattern, and building placement *within* the site.[37]

22. The relationship of site plan to driveway design is so critical that review and approval of both building and driveway permits should be concurrent. This should be done even if it requires the collaboration of two separate departments.[37]

23. Land use is strongly related to traffic volume, which in turn affects driveway design; therefore, *zoning* changes should not be made without considering driveway access elements.[37]

24. No one set of regulations can be expected to apply to all access requirements (even for a single type of land use). Therefore, "controls" should be expressed as guidelines, subject to administrative variations based on engineering judgment.

Traffic Volumes

Importance of Traffic Generation Data

The potential traffic generation of specific land uses is important to highway planners and designers, zoning boards and driveway permit engineers. If generation rates are known, volumes can be calculated for use in designing access streets to service residential areas with various sizes and types of dwelling units as well as industrial, office and commercial generators. Volume data is needed particularly in calculating the number of lanes required on approaches to critical intersections.

Driveways serving commercial, industrial and high density residential developments represent an important element in the highway system. About 12 percent of the accidents on major urban routes are related directly or indirectly to vehicles entering or leaving commercial driveways. Many commercial driveways have much more traffic than the typical local street at its intersection with a major traffic route. At very high-volume driveways such as those serving regional shopping centers and major industrial developments, high-type driveway design—including left-turn bays and signalization—may be warranted. To effectively plan and design such facilities in advance of development of the generator, however, estimates are needed of future traffic volumes and turning movements.

Driveway traffic rates can be used to project total number of vehicles entering and leaving a given driveway or access street in a certain period. The turning movements that will be associated with these volumes must then be estimated separately. They are a function of the percentage of driveway traffic expected to arrive from and depart to the various sectors of the tributary area. In the case of retail operations, percentages can often be based on previous market studies of the developer. Alternatively, the engineer may use maps showing the distribution of population within the trade area, with suitable adjustments for competing retail centers along various approach routes.

If the facility is industrial or an office building, direct use of population distributions is appropriate. In these cases, the availability of mass transportation facilities and the number of persons expected to use buses or rapid transit also must be considered.

Generation Units

There are a number of units by which driving volume may be estimated. Some are more applicable to certain land uses than others. For example, studies have shown that automobile trips to an industrial plant relate poorly to either land or building area and are best related to number of employees. Employment data is usually available from management, but secondary consideration must be given to class of employee and the prevalence of car pools. Thus, a new suburban industry might have a very high proportion of cars as related to employees (the peak parking needs might be 0.8 space per employee) while a steel mill with considerable car pooling might need only half as much parking space per employee.

Traffic generation of an office building is also related to employees and their travel modes. The needs may vary widely, however, due to major differences in floor area per employee. Floor area is a known and more constant element than employment, and when possible generation is usually estimated directly from it.

In shopping centers, gross leasable area (GLA) is often a better generation unit than the number of employees or the gross square footage of the buildings.

Traffic generation of hospitals has been successfully related both to employees and to number of beds. At a medical clinic, the appropriate generation unit is the "doctor." For all schools above grade schools, the "student" is the preferred unit rather than the number of faculty members or the number of classrooms.

Certain land uses have such widely varying building sizes that they can usually best be considered as special cases. These include service stations, car washes and drive-in banks.

Residential traffic generation is directly related to number of dwelling units. Studies have found that traffic volumes vary with number of bedrooms. In apartment developments, separate identification of the number of efficiency, one-bedroom, two-bedroom and three-bedroom apartments may be desirable. Other parameters such as dollar income, age of residents and location with respect to the CBD and public transportation also affect traffic generation rates.

Various units of measurement result from a review of alternatives. For example, traffic volumes at a sit-down restaurant could be estimated on the basis of number of seats, but a more reliable index would be floor area because the latter would be harder to change operationally. This logic extends to drive-in restaurants; although the number of parking spaces might seem to be a very realistic indicator of volume, parking area is not as fixed as floor area and may not be directly related to volume.

The traffic generation potential of vacant tracts must sometimes be estimated for undeveloped areas. Such calculations are also necessary in zoning for certain classifications in the absence of specific development plans. As a general rule, however, projection of traffic volumes from land areas alone is the least accurate method for both industrial and retail uses. If developments are to be residential in nature and the number of anticipated units per acre can be estimated with reasonable confidence, it is possible to calculate volumes on the basis of estimated number of dwelling units.

Methods of Making Traffic Generation Studies

There is great variety in the type and sophistication of traffic generation studies. They range from simple counts of traffic entering and leaving driveways at anticipated peak periods of a particular facility to week-long or month-long automatic machine counts supplemented by hourly, daily or seasonal data. The more refined data is preferable, but the land use predictions may be so inaccurate that they do not justify precise calculations.

In their simplest form, peak hour traffic generation studies involve establishing relationships between vehicular volumes and number of generation units in the facility under study. For example, an office building with 100,000 square feet of gross floor area (GFA) might have 160 vehicles entering during the morning peak hour and 20 vehicles leaving. These volumes would correspond to generation rates of 1.6 per 1,000 square feet inbound and 0.2 per 1,000 square feet outbound during this peak hour. Sampling of the same hour on the various days of the week might show slight differences. Similarly, sampling during various seasons of the year might show differences due principally to summer vacation travel or seasonal hiring practices of certain offices. Obviously, abnormally severe weather, strikes and extensive vacancies in the building under study could produce major variations in the counts.

At a facility such as a drive-in restaurant, information on number of cash register transactions or dollar sales on an hourly, daily, monthly or annual basis might be used to project traffic at various hours. However, the dollar value of sales per car at a drive-in restaurant varies with time of day. Selective sampling and development of proper factors is essential, therefore, to make realistic projections of daily traffic volumes.

In practice, most traffic design for driveways should be based on both movements during the hours of peak highway traffic and also on the hours of peak traffic to and from the proposed development. Hourly volume counts are practical at driveways of commercial, industrial and residential developments where average daily traffic (ADT) counts would be impractical. Selection of seasonal peaks is largely a matter of judgment, supplemented by interviews with people knowledgeable in the operation of the particular facilities being studied.

Findings From Past Studies

The California Division of Highways[6-10] and the Maryland State Roads Commission[4] have performed major studies of traffic generation in relation to specific kinds of facilities. The Western Section of ITE made a trip generation study in 1967[11] and a report was prepared in 1970 by the Illinois Section.[5] Empirical data from over 300 generators checked in such studies are given in Table 1. While complete counts are not available for most studies, items are presented to the extent the data permitted. These include the type of area, the trip generation unit employed, and traffic volumes during street peak hours (the typical morning and evening rush hours). Also, the highest hourly volumes counted at specific facilities are given where known. They were sometimes higher than the volumes during the hours of peak traffic in the access street. Some studies yielded 24-hour data for weekdays, Saturdays and Sundays. Since information on in and out volumes during peak hours is also desirable for traffic design purposes, rates for these movements have been separately calculated wherever possible.

When several samples for a given type of development were available, averages were calculated as shown in the table.

Retail developments, offices and restaurants have rates calculated on the basis of 1,000 square feet of GFA. The most critical traffic design period is usually the PM peak hour, but the AM peak of offices and the closing hour of retail facilities may also warrant checking.

The total in plus out traffic generation of the units expressed on a floor area basis is *lowest* for a regional shopping center. The next higher value is for office buildings, followed by community-size shopping centers, grocery stores, neighborhood shopping centers, sit-down restaurants and drive-in restaurants. It is interesting to note that a neighborhood shopping center has six times the flow rate of a regional center. A drive-in restaurant has more than 60 times the generation rate of a regional shopping center.

Judgment should be applied in using the average and summarized data shown in Table 1. For example, "highest hour" traffic volumes at the

Table 1. *Driveway traffic volume rates.*

Source ref.	Type of development	Type of area	Trip generation unit	Number units in facility studied	VOLUME PER UNIT — During street peak hours — AM — IN	AM OUT	AM TOTAL	PM IN	PM OUT	PM TOTAL	Highest hourly volumes counted at facility — IN	OUT	TOTAL	24-HOUR — WEEK DAY	SAT.	SUN.
2	Motel	CBD	Room	low limit*	.01	.03	.04	.04	—	—	.05	.06	—			
2	"	"	"	top limit*	.08	.26	.34	.14	—	—	.14	.26	—			
3	"	suburb	"	500	.44	.28	.72	.24	.24	.48	.46	.28	—			
3	"	"	"	150	.20	.20	.40	.34	.14	.48	.34	.27	.48			
3	"	"	"	96	.40	.45	.85	.57	.27	.84	.57	.58	1.07			
5	"	"	"	260	—	—	.55	—	—	.48	—	—	.73			
				AVERAGE			.60			.60			.80			
1	Medical clinic	suburb	doctor	10	—	—	—	—	—	6.00	4.00	4.00	8.00	—	—	—
7	" " # 42	"	"	7	—	—	—	—	—	7.10	—	—	—	53	—	—
8	" " # 43	"	"	56	—	—	2.30	—	—	5.70	—	—	5.70	46	—	—
10	" " #105	"	"	20	—	—	—	—	—	—	2.50	5.00	7.50	52	45	—
10	" " #112	"	"	14	—	—	—	—	—	—	—	—	5.00	31	15	—
				AVERAGE						6.40			6.10	46		
6	Hospital #5	suburb	bed	87	—	—	—	—	—	—	.92	1.26	2.20	13	—	9
4	" —	"	"	107	—	—	—	—	—	—	—	—	—	19	—	—
10	" #103	"	"	142	.70	.35	1.05	—	—	—	.70	1.20	1.90	17	11	11
7	" # 30	"	"	243	—	—	.82	—	—	—	—	—	1.20	10	—	—
6	" # 18	"	"	246	—	—	.77	—	—	1.30	—	—	1.30	13	11	—
6	" # 22	"	"	319	—	—	—	—	—	1.20	—	—	1.20	9	—	—
6	" # 1B	rural	"	500	—	—	.54	—	—	.80	—	—	.80	3	—	—
5	" —	—	"	184	—	—	—	—	—	.70	—	—	1.00	—	—	—
5	" —	suburb	"	316	—	—	—	—	—	.80	—	—	1.00	—	—	—
5	" —	"	"	437	—	—	—	—	—	.70	—	—	.90	—	—	—
				AVERAGE			0.80			0.90			1.30	12		
	Shopping centers		1,000 GFA[1]													
4	regional B	—	"	500	—	—	—	—	—	—	—	—	—	44	—	—
4	" F	—	"	530	—	—	—	—	—	—	—	—	—	50	—	—
6	" #26	suburb	"	528	—	—	—	—	—	—	—	—	6.50	39	55	24
11	" A	—	"	500	—	—	—	—	—	—	—	—	—	27	33	—
11	" B	—	"	503	.40	—	—	1.40	—	—	2.30	—	—	37	53	—
11	" C	—	"	541	.26	.12	.38	.59	.86	1.50	.86	.74	1.50	18	—	—
11	" D	—	"	560	.29	.19	.48	.68	.88	1.60	.88	.73	1.60	20	—	—
11	" E	—	"	569	.54	.38	.92	1.45	1.47	2.90	2.30	1.80	4.10	43	—	—
11	" F	—	"	755	.53	.16	.69	.85	1.15	2.00	1.50	1.00	2.50	28	—	—
11	" G	—	"	811	.50	.19	.69	.93	1.16	2.10	1.50	1.00	2.50	28	—	—
				AVERAGE	0.40	0.20	0.60	1.00	1.10	2.10	1.50	1.00	3.10	33	47	

Source ref.	Type of development	Type of area	Trip generation unit	Number units in facility studied	VOLUME PER UNIT: During street peak hours, AM, IN	AM OUT	AM TOTAL	PM IN	PM OUT	PM TOTAL	Highest hourly Volumes counted at facility IN	OUT	TOTAL	24-HOUR WEEK DAY	SAT.	SUN.
	Shopping centers		1,000 GFA													
4	community A	—	"	295										61		
4	" C	—	"	157										81		
4	" D	—	"	189										40		
4	" E	—	"	366										53		
4	" G	—	"	87										71		
4	" H	—	"	341										58		
4	" I	—	"	325										44		
3	" —	suburb	"	127				3.10	3.30	6.40	4.40	4.20	8.60	—		
3	" —	"	"	295				2.00	2.20	4.20	2.00	2.20	4.20	—		
3	" —	"	"	165				2.10	2.20	4.30	2.90	2.50	5.40	—		
3	" —	"	"	127				2.50	2.80	5.30	3.80	3.70	7.50	—		
3	" —	"	"	106				2.40	2.30	4.70	—	—	—	—		
3	" —	"	"	72				4.90	3.30	8.20	4.70	4.70	9.40	—		
				AVERAGE				2.80	2.70	5.50	3.50	3.50	7.00	58		
	Shopping centers		1,000 GFA													
6	neighborhood #3	suburb	"	83										84		
5	"	"	"	33	1.40	1.20	2.60	8.00	6.80	14.80	8.00	7.30	15.30			
5	"	"	"	26	0.40	.30	.70	1.40	1.70	3.10	1.70	2.00	3.70			
5	"	"	"	15	1.90	1.60	3.50	7.70	6.50	14.20	7.70	6.50	14.20			
5	"	"	"	7	.30	.30	.60	11.60	11.60	23.20	12.70	12.70	25.40			
				AVERAGE	1.00	0.80	1.80	7.20	6.60	14.00	7.50	7.10	14.50			
5	Grocery stores	suburb	1,000 GFA	10	.50	.50	1.00	4.00	4.00	8.00	4.50	4.50	9.00			
5	" "	outlying	"	3	—	—	—	—	—	20.00	—	—	20.00			
5	" "	"	"	14	—	—	—	6.30	6.70	13.00	6.30	6.70	13.00			
5	" "	suburb	"	12	.80	.20	1.00	3.70	4.30	8.00	5.50	5.50	11.00			
5	" "	outlying	"	28	—	—	—	—	—	—	—	—	16.00			
				AVERAGE	0.60	0.40	1.00	4.70	5.00	12.00	5.40	5.50	13.80			

*Volumes for lower and upper limits of range found for several facilities. [1]per 1,000 Square Feet Gross Floor Area.

Table 1, *continued.*

Source ref.	Type of development	Type of area	Trip generation unit	Number units in facility studied	VOLUME PER UNIT: During street peak hours, AM IN	AM OUT	AM TOTAL	PM IN	PM OUT	PM TOTAL	Highest hourly Volumes counted at facility IN	OUT	TOTAL	24-HOUR WEEK DAY	SAT.	SUN.
	Restaurant															
5	sit down	urban	1,000 GFA	1	—	—	—	—	—	—	—	—	56.00			
5	" "	"	"	7	—	—	—	—	—	—	—	—	9.00			
3	" "	suburb	"	3	—	—	—	11.90	7.50	19.40	13.50	10.30	23.80			
3	" "	"	"	3	—	—	—	10.40	9.60	20.00	10.40	9.60	20.00			
3	" "	"	"	1	—	—	—	19.20	20.00	39.20	36.00	28.00	64.00			
3	" "	"	"	3	33.00	38.00	71.00	12.00	9.00	21.00	33.00	38.00	71.00			
				AVERAGE				13.00	12.00	25.00	23.00	21.00	44.00			
	Restaurant															
5	drive-in	urban	1,000 GFA	1									241			
5	" "	"	"	1									156			
5	" "	"	"	2									94			
5	" "	"	"	2									71			
5	" "	"	"	3									60			
3	" "	suburb	"	1	—	—	—	—	—	—	260	287	547			
3	" "	"	"	1	—	—	—	55	45	100	156	104	260			
3	" "	"	"	1	—	—	—	24	24	48	69	63	132	1160	1140	720
3	" "	"	"	1	—	—	—	—	—	256	—	—	424	3260	3460	2300
				AVERAGE						134			220			
3	Car wash	suburb	each	1				36	36	72	57	57	114			
3	" "	"	"	1									47			
3	" "	"	"	1									58			
3	" "	"	"	1									48			
3	" "	"	"	1	—	—	—	—	—	60	—	—	60			
				AVERAGE						66			65			
3	Bank, drive-in	suburb	each	1				130	140	270	150	160	310			
3	" "	"	"	1				200	200	400	200	200	400			
3	" "	"	"	1				180	180	360	190	190	380			
				AVERAGE				170	170	340	180	180	360			
5	Service stations	suburb	each	13[2]	—	—	22	—	—	—	—	—	—			
5	" "	"	"	16[2]	—	—	—	—	—	23	—	—	—			
5	" "	"	"	5[2]	—	—	—	—	—	—	—	—	28			
				AVERAGE			22			23			28			

Source ref.	Type of development	Type of area	Trip generation unit	Number units in facility studied	VOLUME PER UNIT: During street peak hours, AM IN	AM OUT	AM TOTAL	PM IN	PM OUT	PM TOTAL	Highest hourly Volumes counted at facility IN	OUT	TOTAL	24-HOUR WEEK DAY	SAT.	SUN.
3	Auto dealers	suburb	each	1	23	10	33	33	34	67	—	—	—			
3	" "	"	"	1	39	33	72	41	48	89	49	53	102			
3	" center	"	"	1	—	—	19	—	—	126	—	—	126			
				AVERAGE			41			94			114			
5	Offices	suburb	1,000 GFA	157	—	—	—	—	—	2.70						
3	"	"	"	117	1.60	.20	1.80	.40	1.60	2.00						
				AVERAGE						2.30						
	Industrial															
12	" mixed	suburb	employee	22[3]	.27	.05	.30	.06	.28	.30						
4	" park	"	"	1000	—	—	—	—	—	—	—	—	—	4.40		
4	" "	"	"	2200	—	—	—	—	—	—	—	—	—	2.20		
7	" "	"	"	30	—	—	1.30	—	—	—	—	—	2.00	7.50		
10	" "	"	"	570	—	—	.70	—	—	.80	—	—	—	7.10	3.30	1.30
10	" "	"	"	280	—	—	.60	—	—	.50	—	—	—	3.90	1.30	—
10	" "	"	"	140	—	—	.50	—	—	.40	—	—	—	3.70	—	2.10
10	" "	"	"	550	—	—	.60	—	—	.50	—	—	—	2.20	1.20	1.00
10	" "	"	"	120	—	—	.90	—	—	—	—	—	—	4.30	—	—
10	" "	"	"	410	—	—	.50	—	—	.70	—	—	—	2.90	.70	—
10	" "	"	"	100	—	—	.50	—	—	.80	—	—	—	4.40	—	—
7	" "	"	"	960	.53	.19	.70	—	—	—	.18	.49	.70	4.70	—	—
7	" "	"	"	290	—	—	1.00	—	—	.90	—	—	—	4.50	—	—
7	" "	"	"	300	.93	.16	1.10	.36	.59	.90	—	—	—	4.00	—	—
7	" "	"	"	5170	—	—	—	—	—	.30	—	—	.40	1.90	—	—
9	" "	"	"	130	—	—	—	—	—	—	—	—	.60	2.90	—	—
9	" "	"	"	150	.19	.19	.40	.13	.38	.50	—	—	—	4.10	—	—
9	" "	"	"	200	.39	.07	.50	.12	.43	.50	—	—	—	2.20	—	—
10	" "	"	"	370	—	—	.50	—	—	.60	—	—	—	2.40	1.50	—
				AVERAGE	0.31	0.06	0.50	0.08	0.30	0.40	—	—	0.90	3.90	1.60	1.50

[2]number of different stations sampled for time shown. [3]number of different facilities studied.

Table 1, *continued.*

Source ref.	Type of development	Type of area	Trip generation unit	Number units in facility studied	VOLUME PER UNIT: During street peak hours, AM, IN	AM OUT	AM TOTAL	PM IN	PM OUT	PM TOTAL	Highest hourly Volumes counted at facility, IN	OUT	TOTAL	24-HOUR, WEEK DAY	SAT	SUN
6	Warehouse	suburb	employee	50	—	—	1.50	—	—	1.20	—	—	—	10.50		
6	"	"	"	250	—	—	.80	—	—	.70	—	—	—	6.40		
6	"	"	"	30	—	—	2.10	—	—	—	—	—	—	15.70		
				AVERAGE			1.50			1.00				10.10		
9	Adm., research	suburb	employee	60	—	—	.50	—	—	1.00	—	—	—	3.50		
9	" "	"	"	180	—	—	.40	—	—	.50	—	—	—	2.40		
9	" "	"	"	40	—	—	1.40	—	—	.80	—	—	—	5.30		
				AVERAGE			.80			.80				3.70		
7	High schools	suburb	student	690	—	—	.50	—	—	—	—	—	—	1.70	—	—
7	" "	"	"	1290	.14	.05	.20	—	—	—	—	—	—	1.10	—	—
7	" "	"	"	2050	—	—	.30	—	—	—	—	—	—	1.10	—	—
10	" "	"	"	1200	.27	.09	.40	—	—	—	—	—	—	2.10	1.20	40
10	" "	"	"	2850	.21	.08	.30	—	—	—	—	—	—	1.10	.60	20
				AVERAGE	0.21	.07	0.30							1.40	.90	.30
4	Colleges	suburb	student	1350										2.70		
4	"	"	"	1850										2.90		
4	"	"	"	3310										1.90		
7	"	"	"	12000	—	—	.13	—	—	—	—	—	—	1.40		
8	"	"	"	5300	.14	.02	.16	.02	.06	.09	—	—	—	1.40		
8	"	"	"	900	.15	.05	.20	.10	.20	.30	.19	.25	.44	2.70		
8	"	"	"	5370	.19	.03	.22	.06	.16	.22	—	—	—	2.60		
8	"	"	"	14300	.13	.01	.14	.03	.02	.05	—	—	—	1.10		
8	"	"	"	2150	.19	.02	.21	.01	.06	.07	—	—	—	1.60		
9	"	"	"	700	.19	.06	.25	.09	.18	.27	—	—	—	2.60		
10	"	urban	"	11000	.18	.03	.21	.04	.17	.21	—	—	—	1.90		
				AVERAGE	0.17	.03	.20	.05	.12	.17				2.10		

Source ref.	Type of development	Type of area	Trip generation unit	Number units in facility studied	VOLUME PER UNIT: During street peak hours, AM IN	AM OUT	AM TOTAL	PM IN	PM OUT	PM TOTAL	Highest hourly Volumes counted at facility IN	OUT	TOTAL	24-HOUR WEEK DAY	SAT.	SUN.
4	Apartments	suburb	D.U.[4]	13[3]										7.70		
5	"	"	"	7	.08	.49	.57	.46	.23	.69						
6	"	urban	"	190	—	—	.31	—	—	.37	—	—	—	3.00		
9	"	suburb	"	990	—	—	—	.35	.21	.56	—	—	—	5.40		
9	"	"	"	120	—	—	.67	—	—	.83	—	—	—	3.40		
10	"	"	"	300	—	—	.70	—	—	1.10	—	—	—	7.90	8.40	7.10
10	"	"	"	180	—	—	.77	—	—	.93	—	—	—	7.00	7.60	6.20
10	"	"	"	150	—	—	.55	—	—	.96	—	—	—	6.90	4.40	4.30
10	"	"	"	140	—	—	.57	—	—	.57	—	—	—	5.10	5.30	4.90
10	"	"	"	220	—	—	1.00	—	—	1.64	—	—	—	5.90	8.10	5.80
10	"	"	"	100	—	—	.69	—	—	.79	—	—	—	6.50	6.70	6.60
10	"	"	"	70	—	—	.42	—	—	.71	—	—	—	4.80	5.80	—
10	"	"	"	130	—	—	.63	—	—	.79	—	—	—	7.10	7.50	6.90
10	"	"	"	100	—	—	.63	—	—	1.05	—	—	—	6.90	7.30	6.20
11	"	urban	"	590	.11	.33	.44	.35	.13	.48	—	—	—	5.10	—	—
				AVERAGE			.60			.78				6.70	6.80	6.00
11	Apartments	high rise	D.U.	560	.03	.16	.19	.17	.08	.25	—	—	—	3.00		
11	"	" "	"	50	.10	.35	.45	.31	.19	.50	—	—	—	4.20		
2	"	CBD	"	low limit*	.02	.18	.20	.12	.03	.15						
2	"	"	"	top limit*	.05	.25	.30	.24	.14	.38						
				AVERAGE	.05	.24	.30	.21	.11	.32						
4	Single family	suburb	D.U.	84[3]	—	—	.90	—	—	1.00	—	—	—	8.60		
5	" "	"	"	5[3]	.23	.58	.81	.60	.40	1.00						
11	" "	"	"	19[3]	.18	.63	.81	.68	.45	1.13	—	—	—	9.70	10.00	8.70
11	" "	"	"	15[3]	—	—	—	—	—	—	—	—	—	8.30	—	—
				AVERAGE	.19	.62	.80	.67	.44	1.00				8.70	10.00	8.70

*Volumes for lower and upper limits of range found for several facilities. [3]number of different facilities studied. [4]Dwelling Unit.

various drive-in restaurants ranged from 60 to 547. The "average" of 220 vehicles per hour is substantially different from either the highest or the lowest. Such variations exist partially because of differences in the generation rates of various drive-in restaurants and also because peak conditions were probably not observed at all of the facilities studied. Substantial data was available for two drive-in restaurants, but the ratio of their peak traffic is more than three-to-one when expressed on a floor area basis. A more meaningful relationship might be found by comparing land areas. Even this yields substantial differences, however, due to landscaped setbacks and differences in the efficiency of parking layouts.

It is interesting to compare service station traffic with that of neighborhood shopping centers. If expressed on the basis of land area, a neighborhood shopping center generates about five times as much traffic as a typical service station. Ironically, many zoning codes would permit a neighborhood shopping center at a given site but would prohibit a service station or require a special use permit because of anticipated "traffic problems."

Generation factors for community and regional shopping centers should also be modified on the basis of engineering judgment. The factors shown in Table 1 are related primarily to weekday traffic. Heavy weekend traffic at shopping centers should be considered in estimating the peak volume likely to use a driveway.

Despite its limitations, the data in Table 1 is considered reliable enough to enable an engineer to estimate typical volumes or to check the calculations of other engineers.

Based on Table 1, various land uses may be classified as follows:

Low traffic generators:
Farms
Homes for the elderly
Single family, duplex and small apartments (five units or less)

Medium traffic generators:
Apartments (over five units in a single building)
Automobile dealers
Drug stores
Libraries
Medical clinics
Motels
Office buildings (small)
Restaurants, sit-down
Schools, elementary and junior high
Service stations

High traffic generators:
Apartments, multibuilding projects
Banks, drive-in

Car washes
Colleges and universities
Factories
High schools
Hospitals
Office buildings, over 50,000 square feet
Restaurants, drive-in
Shopping centers, all sizes
Theaters, auditoriums.

Studies of the hourly variations of driveway traffic were made in North Carolina at 87 commercial developments along state highways. The hourly percentages of total traffic counted during a 10-hour business day are shown in Table 2 for several types of commercial use. It may be noted that some of the land uses had the highest hourly traffic volume during the evening rush.

There are also month-to-month variations depending on whether the traffic generator is seasonal or recreational, as may be the case with a motel or restaurant, or part-year as is the case with most high schools and colleges. Industrial plants and office buildings are affected by vacations, their volumes dipping during summer months. A car wash generates higher volumes

Table 2. *Frequency distributions of commercial driveway volumes along North Carolina State highways.*

	Percentage of 10-Hour Total Volume						
Hour beginning	Service stations	Grocery and grocery service station comb.	Supermarkets	Restaurants	Cafes and drive-ins	Furniture and equipment	Misc.
0700	7.1%	4.2%	6.7%	5.7%	4.4%	4.4%	3.4%
0800	8.7	7.2	8.7	7.4	6.1	8.5	7.0
0900	9.2	7.4	4.8	8.6	7.2	9.7	8.7
1000	10.9	12.9	7.2	8.9	8.7	11.3	13.4
1100	9.7	9.9	10.6	10.9	10.9	11.1	11.5
1200	11.5	13.9	15.0	18.1	18.0	11.0	10.9
1300	10.4	11.4	8.8	14.2	12.6	11.4	11.3
1400	9.9	10.8	11.9	9.8	11.0	8.5	8.6
1500	10.6	10.8	9.5	9.0	11.5	15.0	11.9
1600	12.0	11.5	16.8	7.4	9.6	9.1	13.3
TOTAL	- - - - - - - 100% - - - - - - - - - -						
Number Sampled	20	22	7	6	12	9	11

Source: Adapted from Table 13, "The Effect of Commercial Roadside Development on Traffic Operations," North Carolina State College, Project ERD-110B.

during winter months than in the summer. Shopping centers peak in December and just before Easter.

The term "generation" as used in this manual and in most studies of the relationship of traffic volumes to land use is a misnomer in many cases. The traffic using driveways and streets connected with residential and industrial developments is actually generated and added to the highway system. Part of the traffic entering and leaving driveways of retail and service facilities, however, was *already* on the street system. In studies of service stations, less than 50 percent of the traffic using the driveways during rush hours was actually generated; i.e., went toward its point of origin when it left the station.[19] Weekday studies of community shopping centers by the same researcher resulted in similar findings.

Studies in which direction of approach and departure of each shopper is traced have limitations. The return route may differ from the route used to the facility, but the trip may actually have been generated nonetheless. In any case, the data of Table 1 and 2 relate to *driveway volume* estimates, and these are of primary interest to the engineer responsible for issuing or approving driveway permits.

Traffic at Successive Entrances

Large facilities are sometimes served by several successive driveways along a major traffic route. With this condition, even after general directions of arrival and departure have been carefully estimated, and total daily traffic has been allocated to in- and out-movements by hours of the day, the volumes expected to use each access point will still be unknown. If accessibility is equal (both right and left turns permitted to both inbound and outbound vehicles at all driveways), and complete and convenient internal circulation is possible, most drivers entering from a given direction will tend to use the closest driveway. At one large community shopping center in Wisconsin, for example, 62 percent of the vehicles from one direction were found to enter at the first driveway while 88 percent of the arrivals from the opposite direction entered at their closest driveway. In a study at a regional shopping center in New York, 36 percent of entering drivers used the heaviest driveway. Studies at other regional shopping centers have found examples of near-equality in entering volumes at some driveways and extreme differences at others. The data show clearly that as congestion increases on certain days and in the busier hours, users shift to less congested access points. Thus, in making peak hour estimates for design purposes, it may be appropriate to load the first contact point with somewhat more than its proportionate share and distribute the balance downstream to successive driveways. A suggested distribution is 50-60 percent at the first driveway; 20-30 percent at the seond; and 10-20 percent at the third.

Estimating Driveway Traffic

The Shirlington House apartment complex in a Virginia suburb of Washington, D.C., may be used to illustrate the application of traffic genera-

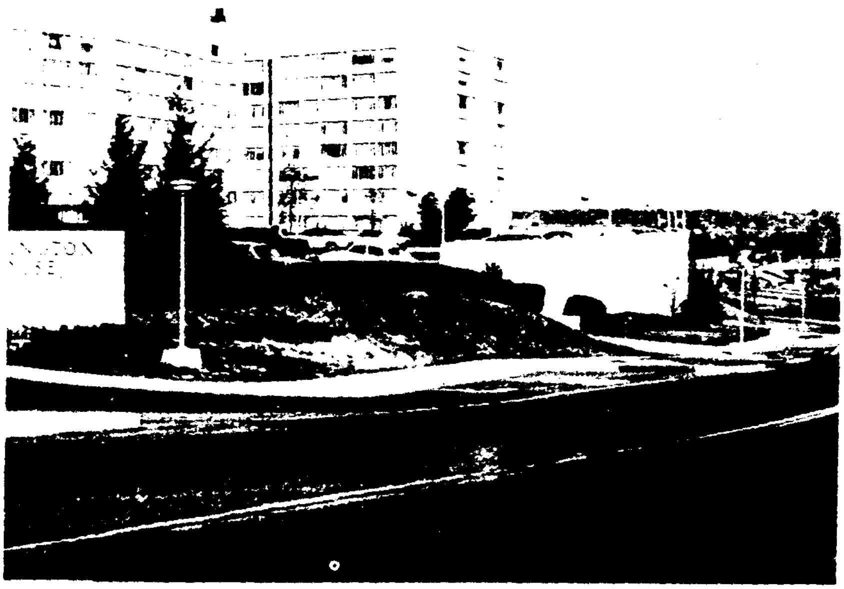


Figure 1. *View of access points to Shirlington House garages and surface lots.*

tion data. The development has 436 dwelling units, 85 percent of which have one bedroom. This characteristic of the development would indicate few school-age children and little trip orientation toward schools. Bus service is available and car pooling is prevalent. Figure 1 is a view looking north toward Washington. The nearest freeway interchange connecting directly to Washington is also in this direction. The nearest community and neighborhood shopping centers are in the vicinity of the interchange.

Given such conditions during the zoning, design and planning stages, a local municipal traffic engineer might logically postulate that 80 percent of PM peak hour traffic would be southbound. Furthermore, should the actual directional split be 70 or 90 percent southbound, rather than 80 percent, it would not make any significant difference.

Due to the one-bedroom nature of the development, together with the bus service and car pool potentials, the traffic generation rate should be lower than average for apartment buildings. The study of 990 suburban apartments referenced in Table 1 found a rate of 0.35 cars inbound per dwelling unit, and 0.21 cars outbound during the PM rush hour. If these factors were multiplied by the number of dwelling units at Shirlington House, estimated PM peak hour volume for the development would be 150 vehicles inbound and 90

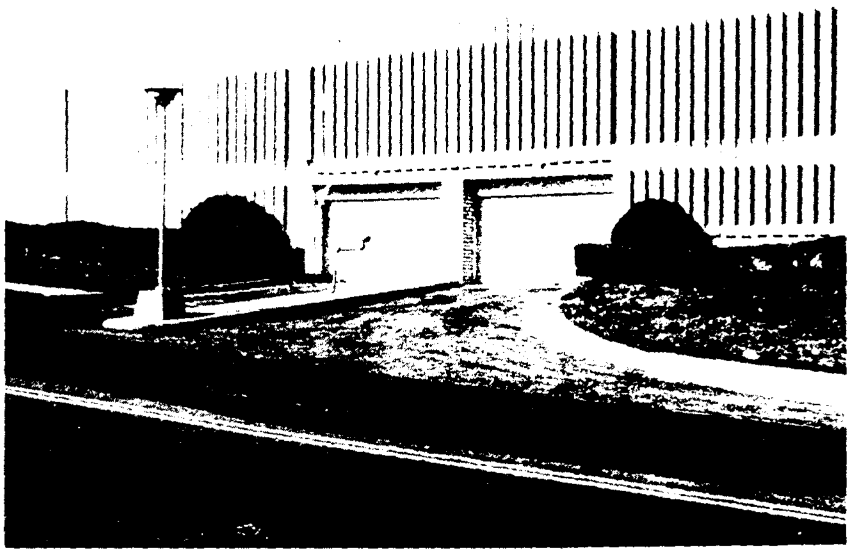


Figure 2. *Shirlington House garage access channelization.*

vehicles outbound. If 80 percent of total traffic was from the north, about 120 vehicles would be expected to come from that direction; these would represent the total peak hour right turn entry.

During site design, the developers planned approximately 360 parking spaces in two garages, each with a single entry-exit driveway and a 240-space open parking lot also serviced by a single driveway (to the extreme left in Figure 1). If arrival volumes were distributed in proportion to the capacity of each parking facility, the estimated volume of inbound right turns would be 36 vehicles per hour at each garage driveway and 48 vehicles at the driveway to the open lot.

The site could also be considered in terms of a higher traffic generation rate. If the average for all apartment complexes studied were used (0.78 per dwelling unit) and a higher proportion of entering-to-leaving, such as two-to-one, were also used, the peak inbound flow would be estimated at 230 vehicles per hour. With an 80-20 directional split, 180 southbound cars would enter the driveways, with 54 arriving for entry by right turns at each garage drive and 72 at the open lot drive. However, these differences in estimated volumes would have little effect on design.

As actually developed, Shirlington House illustrates unusually good driveway design. Deceleration lanes are provided at each entrance, together with channelizing islands and adequate radii at entrance and exit drives (Figure 2).

Typical steps in making volume projections for individual access points of a proposed development were shown by the foregoing example. These are summarized below:

1. Identify the important characteristics of the development as related to traffic during the critical hour (or hours).
2. Make counts of turning movements at an existing project with similar characteristics, and calculate the generation rate in terms of an appropriate unit.
3. If a similar development is not available for study, use data from appropriate studies of other projects such as those in Table 1.
4. Calculate peak hour inbound and outbound flows for the proposed land use.
5. Estimate directional splits and calculate turning movements.
6. Assign appropriate volumes to individual access points.
7. Evaluate the potential conflicts with street traffic, particularly as related to left turn entering and leaving movements, and assess need for roadway improvements adjacent to the site.
8. Visualize "downstream" traffic impacts at critical intersections, and assess need for improvements.

With such data in hand, the traffic engineer can give his planning board an appraisal of the traffic effect of a new development. Right-of-way dedications and payment for street improvements are best negotiated before rezoning or granting a building permit. Even where a zoning change is not involved, knowledge of probable traffic volumes is very useful in chosing driveway locations and in preparing designs. In planning and designing major thoroughfares, it is usually desirable to consolidate access points. Turning volumes may need to be projected for undeveloped parcels of land. Need for detailed knowledge of traffic generation rates exists, therefore, in all phases of engineering.

Design Elements

Radii and Width

A critical element of driveway design is the radius of the curb return or amount of flare of the curbing connecting the edge or throat of a driveway with the edge of the nearest travel lane. The radius should be related to the swept path of a vehicle making a right turn in or out considering the width of the adjacent street lane and the width of the driveway. Figure 3 shows the path of a passenger car entering driveways of two different designs, both with 30-foot throats, measured at a point 15 feet from the curbing. A 12-foot roadway lane has been assumed, with the vehicle beginning its turn from the outer edge of the lane. In the upper portion of this figure, a flare of only two

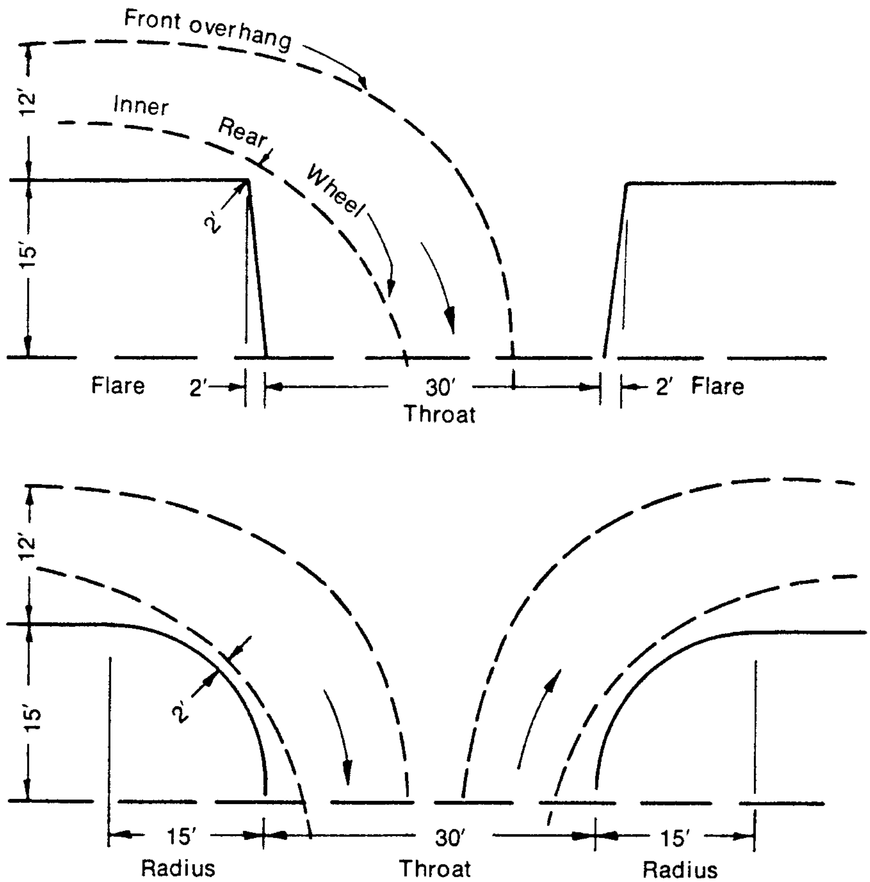


Figure 3. *Swept path of passenger car turns to and from 12-foot curb lane.*

feet has been used. Obviously, a vehicle would occupy a substantial portion of the throat in entering the driveway, and a vehicle exiting from the driveway would be in direct conflict with an entering vehicle. If an exiting vehicle were waiting in the driveway, the entering vehicle would have to stop in the traveled lane until the other vehicle was able to leave. The potentials for congestion and accidents might be serious, depending on general traffic conditions.

Operation at a two-way driveway with a 30-foot throat is greatly improved if the radii of the curb returns on both sides of the driveway are adequate, as illustrated in the lower part of Figure 3. In this case, a vehicle is able to enter or leave by a right turn without lane encroachment at a speed which minimizes interference with through vehicles, and without conflicting with other vehicles entering or leaving the driveway.

The swept path diagram shows that a 15-foot flare would give operational results equally as effective as a curb return with a 15-foot radius. For single-family residential driveways, flares are probably just as good as the five- to seven-foot radii normally used. On the larger swept path radii needed for commercial and industrial driveways, however, the curved area of paving reduces the total cost of a driveway and looks better. It may also facilitate turning movements.

In the Recommended Guidelines section of this Recommended Practice, the minimum radii range is from 5 to 25 feet, depending on type of area and land use served. The maximum radii range is from 15 to 50 feet. A three-centered curve may be used for industrial driveways.

These values apply on the side of the driveway used for entry or exit by right-turning vehicles. For a one-way driveway, the proper radius for the side *not* used for right turn entry (or exit) is established by the swept path needs of a vehicle entering by a left turn from the far side of the street (or exiting by a left turn onto the far side). Except for very narrow streets or for large vehicles, the "off-side" radii may be small.

Since parking may be prohibited in the future along any major thoroughfare, and a curb lane adjacent to a given driveway may be clear at times on *any* street, it is good practice to design driveways (other than single-family residential driveways on local streets or low-volume collectors) for entry from the curb lane without encroachment onto adjacent lanes or beyond the centerline.

The radius used at a given driveway is meaningful only when related to the width of throat. This throat is basically a point of narrowest controlled width. When the distance between curb line and right-of-way is equal to or greater than the design radius, the throat width may conveniently be measured along either the property line or the end of the radius. In many cases —especially in urban areas—the proper radius will be greater than the distance between curb line and property line. In such cases, if a raised barrier curbing extends into private property, the throat width may appropriately be measured at the end of the radius even though this may be on private property.

It is recommended that, as a general rule, the widths of two-way driveways be measured parallel to the roadway. One-way driveways may be measured at right angles to the driveway if it is constructed on a skew. When a center channelizing island is used in a two-way driveway to restrict entries to right turns in and right turns out, it is also appropriate to measure the width separately and at right angles between the curbing of the channelizing island and the driveway curb return. In this type of design, radii and total width of driveway at the throat are necessarily somewhat greater than for a two-way driveway without a channelizing island due to the need for lateral clearance between faces of the barrier curbs.

The design guidelines for the minimum width of driveways, measured at the throat or at another control point, range from 10 to 20 feet. For commercial driveways, this minimum width is based on one-way operation. Maximum widths range from 30 to 40 feet, depending on type of area, land use served, and degree of pedestrian activity. These widths assume two-way operation. The use of channelizing islands in any of these driveways, however, should automatically produce variations for such additional widths as necessary to assure efficient and safe traffic movements.

Where public sidewalks abut the curb in an urban area, it may be difficult to make the edge of the driveway visually apparent if the sidewalk is warped down into the driveway rather than using a stepdown curb along the edge of the drive. While most driveways will function satisfactorily with warped sidewalks, thus avoiding pedestrian inconvenience, use of step-down curbs warrants consideration for special circumstances, since curbs have the important secondary advantage of notifying the pedestrian that he is in a *zone of conflict*.

If step-down curbs are used, sidewalk ramps for use by persons in wheelchairs and other physically handicapped persons should be considered. In areas where there are many pedestrians (e.g., central business districts; the vicinity of high-rise apartments; or near places of public assembly) curb ramps should be considered. Ramps may be needed in the vicinity of major office buildings, especially those housing medical services. Ramps should be designed to fit the needs at each particular location. Usually they should be about 4 feet wide with rounding near the curb. They should have a nonslip surface and a slope not steeper than about 12:1. They should be designed so as not to interfere with storm drainage. Other helpful details can be found in USASI Standard A117.1-1961, "American Standard Specifications for Making Buildings Accessible to, and Usable by, the Physically Handicapped."

Angles

As with other geometric design elements of driveways, the angle between the driveway centerline and roadway edge should be based primarily on safety requirements. The speed at which a vehicle can enter or leave a public roadway is affected by the angle of approach or departure. If a desirable angle cannot be used because of lot size, physical obstructions or other limitations, the design speed can be increased by altering radii, width or grade of the driveway. Also, the main roadway may be modified by adding acceleration or deceleration lanes designed in accordance with AASHTO* standards.

The choice between 90-degree ("T" driveways) and angled driveways is most often dictated by direction of travel and ease of turning into or out of the public street. Angled or one-way driveways are appropriate on one-way streets or streets divided by medians which limit movements to right turns in and out. A pair of such driveways may be widely separated or consist merely of two one-way driveways separated by a triangular island. Figure 4 shows

*American Association of State Highway and Transportation Officials

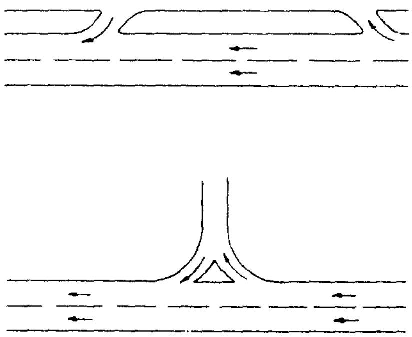


Figure 4. *One-way angle driveways, left turns prohibited.*

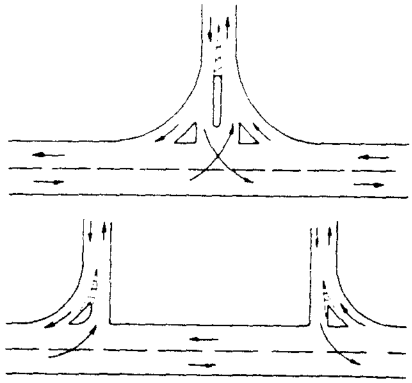


Figure 5. *Ninety-degree highway design allowing good entry and exit speeds; not for use in high pedestrian activity areas.*

examples of both types. Their use is *not* recommended for two-way driveways on two-way streets since both entering and exiting drivers might presume that the driveways were one-way. Since an angled driveway permits both entering and leaving vehicles to move at greater speeds, this presumption might create an unusually hazardous condition.

Alternative designs for 90-degree driveways are shown in Figure 5. These allow relatively high entering and exiting speeds. The use of a prominent "keep right" sign in the center median of the driveway is strongly recommended with the fully channelized driveway shown at the top of Figure 5. This should minimize the possibility of motorist confusion when entering by a left turn.

A special twin-drive arrangement suitable to serve a development with a high traffic generation rate is shown in the lower part of Figure 5. The possibility of left turn movements conflicting with each other has been precluded.

Angled driveways are not recommended for single-throat driveways with movements to and from both directions of traffic. Acute-angle turns must be made more slowly and thus cause greater interference with through traffic. If physical obstructions make use of an angled driveway unavoidable, the angle should be as near 90 degrees as possible.

Due to the relationship between driveway angle and operating speeds, angles of 70 degrees or greater are recommended in areas of high pedestrian activity along major traffic routes. For secondary routes, angles as flat as 60 degrees should not be hazardous, even where pedestrians are numerous. For all other conditions on major and secondary routes in both urban and rural areas, a minimum angle of 45 degrees is suggested, with one-way operation angles are recommended for the principal categories of land use and roadway speeds:

1. Single-family residential—rural and other high-speed roadways: Where through traffic normally travels faster than 50 mph, it is desirable that vehicles entering and leaving driveways make their turns at speeds in excess of 15 mph except on very low volume roads.

2. Commercial (including multipleunit residential developments of more than five units): Similar relationships of highway speeds and entering/exiting driveway maneuvers are pertinent to driveways serving commercial and multipleunit residential complexes. A one-way driveway should not be less than 45 degrees unless an on-site deceleration lane can be provided. A two-way driveway should not be less than 70 degrees except on a low-speed, low-volume street.

3. Industrial: Driveways that must accommodate large volumes of truck traffic should be designed for their particular situation. Turning templates should be used to test movements to and from both directions of travel. Large trucks usually do not enter and leave driveways at high speeds so driveways at flat angles will seldom be hazardous. Facilitating the movement of trucks on and off traveled ways without impeding through traffic can best be accomplished by using angled driveways. For these reasons, flat angles and one-way drives should be encouraged. No minimum angle should be specified for entrances to one-way truck driveways, but exits should be at an angle of not less than 30 degrees to assure that drivers will have a good view when merging with through traffic.

Spacing

The spacing of driveways should be related to adjacent driveways and nearby street intersections. The spacing and number of driveways serving a single piece of property is also a consideration.

Spacing criteria seek to achieve several objectives. One is to leave a useable island between driveways for utility poles and traffic control devices. Since this aspect of spacing relates to a section of tangent curb, it is appropriate to measure the distance between the points of tangency rather than across driveway throats. Where curb returns are adequate, a single item such as a pole, a fire hydrant or a sign usually can be placed safely at the junction point where one driveway radius ends and the next begins. In areas of high pedestrian activity, however, it may be desirable to leave a larger island which also can serve as a refuge for pedestrians. Where curb parking is allowed, care should be taken to avoid setting up substandard length parking stalls between driveways. A tangent curb 10 to 15 feet long, measured between ends of curb returns, will constitute an inviting but inadequate parking space. Special "no parking" signs would be needed to prevent parking in such places.

Driveways should be at least 5 to 20 feet from the point of tangency of curb radii at street intersections, especially at major cross streets. Parking usually

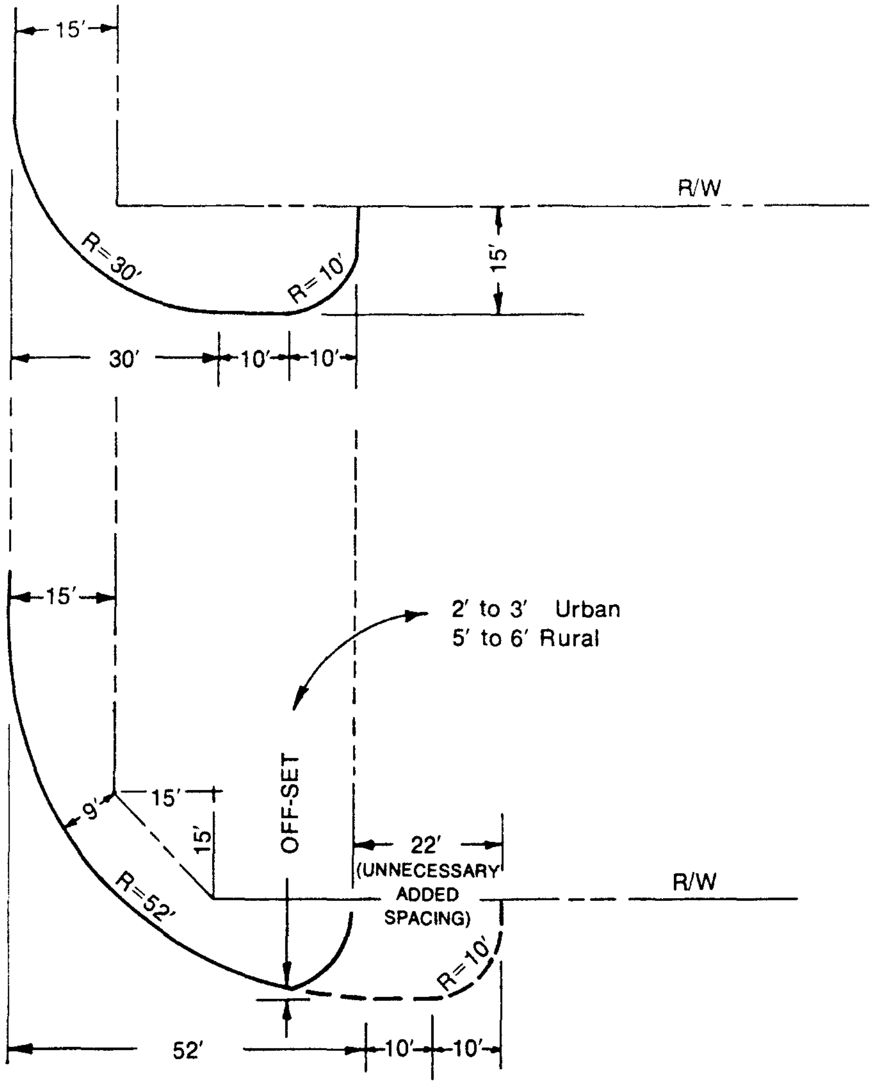


Figure 6. *Application of off-set corner radius allowance for driveway at intersection of two major routes with large radius.*

is not allowed in such sections as a matter of policy, and keeping a driveway away from an intersection, even by such small distances, reduces conflicts. When large corner radii are used at intersections, however, adhering to this criteria may place the driveway an unreasonable distance away from the intersection. Figure 6 shows a typical corner of the intersection of two major routes.

The American Association of State Highway Officials recommends 12 to 16 feet as a desirable border width: (Table E-2, page 16, 1957 Urban Policy). The same text recommends a 30-foot radius for the curb at this type of intersection. If 10 feet of tangent curb is left between the end of the intersection curb radius and the beginning of the driveway radius and a minimum radius of 10 feet is used for the driveway, then the edge of the throat is 50 feet back from the curbline of the intersecting major route. If the stop line is placed at the end of the intersection curb radius, the edge of the driveway is 20 feet back, which should be sufficient in most instances.

The lower part of Figure 6 shows the same intersection corner except that an added 15 x 15-foot leg corner triangle of right-of-way has been used to permit a curb return with a 52-foot radius. This results in the same distance from the narrowest point of right-of-way line to the face of curb as in the upper drawing. Application of the same guidelines for driveway placement, however, would move the driveway 22 feet farther away from the intersection. Since the stop line for the intersection would not usually be back this far, there appears to be little justification for changing the location of the driveway.

Many agencies have handled this problem by allowing the driveway radius to compound with the corner radius. These agencies have established a maximum offset dimension as shown in the lower part of Figure 6. Opinions differ as to what the allowable dimension should be, but two or three feet in urban areas and five or six feet in rural areas have been applied satisfactorily.

As a general rule, driveways should be far enough from an interior property line to permit the curb radius to fall entirely in front of the subject property. At some locations, particularly where frontages are narrow, it is impossible to design satisfactory driveways within this limitation. In this situation, it should be recognized that roadways are usually centered in the public right-of-way, and the area between the edge of roadway and the right-of-way line is public property. If this is the case, it should be permissible for a driveway curb radius to swing in front of an adjacent lot. The engineer should be given latitude to make variations from basic criteria and to permit construction of driveways close to property lines.

For agencies which strive to minimize the occasions where driveway curb radii extend in front of adjacent lots, the design guidelines recommend a zero spacing (the curb radius starting at the projection of the interior property line) *except* in the case of industrial driveways. The larger turning radii that must be accommodated at the latter makes a curb radius in front of adjacent property almost unavoidable.

Much of the concern over permitting a driveway near an interior lot line has to do with the possibility of a property line driveway being built on the adjacent property, thus creating an extremely wide driveway. While this sometimes occurs, unrealistic restraints to prevent it may result in inefficient driveway layouts. The permit engineer may suggest a common driveway for two abutting property owners in such cases.

There is ample precedent for zero spacing of radii from interior property lines: Michigan's Standard and Procedures for Driveways, 1960; Georgia's Rules and Regulations for the Control and Protection of State Highway Rights of Way, 1953; Arkansas' Regulations for Access Driveways to State Highways, 1962; and Virginia's Entrance Standards, 1958. Some states also permit "encroachment" of the driveway radius in front of adjacent property. Except in the few cases where highway right-of-way has not been acquired, and private ownership still extends to the edge of the road or even to the centerline of the highway, this "border area" between right-of-way line and roadway edge is available for public use. The portion of any driveway within this border area is intended for public use. Functionally, it may be appropriate to have a driveway curb radius in front of adjacent interior property, just as an intersection curb return may be in front of the corner property (Figure 6).

The second element of spacing concerns the number of driveways to be permitted to serve a single property. Research by three engineers has resulted in conflicting findings on this element. Head's study of more than 186 miles of urban highways found that the number of either commercial or residential driveways was a relatively *unimportant* factor in predicting accident rates.[28] He found that the number of commercial *units* was a much greater factor. This implies that there is little if any rationale in terms of traffic safety for restricting the number of driveways serving a given piece of property. Schoppert concluded that the frequency of driveways was a major factor per se,[36] but Petersen found that the number of establishments per mile was not an important variable.[32] While these studies are not entirely definitive, they suggest a flexible approach to the number of driveways permitted to serve a piece of land.

An additional factor concerns the spacing of high-volume driveways where deceleration or acceleration lanes are required. Examples would include driveways into community and regional shopping centers as well as those into major industrial, commercial and apartment complexes. At least several hundred feet between major driveways is desirable. Factors to be considered include the volumes of entering and leaving traffic and the resultant merging movements upstream and downstream.

In some cases, a long deceleration lane may result in low volume driveways (particularly into abutting properties upstream from the development) connecting into the deceleration lane. If the low volume driveways are of relatively little importance, no basic problems should result. Public agencies should not be prevented from requiring deceleration lanes extending in front of adjacent properties by the driveway needs of those properties. The same policy should apply to acceleration lanes.

Median Cuts

Conditions justifying breaks in medians are much too complex for detailed discussion in this Recommended Practice. General guidelines are suggested, however.

On a major urban street with frequent intersections and parallel streets or service roads, it is usually possible to prohibit left turns into driveways without causing undue hardships for motorists. Under such conditions, breaks in barrier medians may not be warranted. In fact, it may be desirable to extend barrier medians across intersecting local streets. Courts have generally upheld the rights of governmental agencies to block left turn access and/or egress by left turn prohibitions or physical barriers.

Studies have shown that the most prevalent type of driveway accident involves left turning vehicles.[19, 24] As many as half of all driveway accidents may involve left turns and a very high percentage of accidents reported as rear-end collisions are thought to involve cars attempting to turn left into driveways. The number of such accidents can be greatly reduced by a median area of sufficient width to accommodate a recessed left turn bay. Thus, at high-volume driveways, well designed breaks in the median may be preferable to the alternative of diverting relatively high turning volumes to downstream intersections. The added intersection turns, together with the attendant circuitous routing, may be more hazardous than the turns into driveways from a left turn bay that has been properly designed.

Other factors affecting median openings include:

1. Potential number of left turns into driveways.
2. Length of frontage along the street right-of-way line of the property proposed to be served.
3. Distance of proposed opening from adjacent intersections or other openings.
4. Length and width of the left turn storage lane as functions of the estimated maximum number of vehicles to be in the lane during peak hours.
5. Traffic control, including signalization, that will be necessary at the median cut. If a traffic signal at a median cut is within 1,500 feet of another traffic signal, the two usually should be coordinated.

Sight Distance

Before issuing a permit for egress from a parcel of land, the responsible agency should ensure that vehicles can exit from the proposed development with minimum hazard and disruption of traffic. The sight distances shown in Tables 3 to 6 are designed to enable exiting vehicles:

1. Upon turning left or right, to accelerate to the operating speed of the street without causing approaching vehicles to reduce speed by more than 10 miles per hour; and
2. Upon turning left, to clear the near half of the street without conflicting with vehicles approaching from the left.

The sight distance criteria shown in Tables 3 to 6 should be considered essential in designing commercial and industrial driveways and desirable in connection with residential driveways.

The sight distance requirements for passenger cars are based on a 3.5′ height of eye and 4.5′ height of object. The distances for semitrailers are based on a 6.0′ height of eye and 4.5′ height of object.

The operating speed on each approach is assumed to be, in order of

OPERATING SPEED	SAFE SIGHT DISTANCE—LEFT[b]	SAFE SIGHT DISTANCE—RIGHT[b]
20 MPH	150′	130′
30	350	260
40	530	440
50	740	700
60	950	1050

[a] Values are for urban conditions. On rural highways, distances should be increased by 10 percent to allow for longer driver reaction time.
[b] Measured from a vehicle ten feet back of the pavement edge.

Table 3. *Safe sight distance for passenger cars exiting from driveways onto two-lane roads.*[a]

OPERATING SPEED	SAFE SIGHT DISTANCE—LEFT[b]	SAFE SIGHT DISTANCE—RIGHT[c]
20 MPH	130′	130′
30	220	260
40	380	440
50	620	700
60	950	1050

[a] Values are for urban conditions. On rural highways, distances should be increased by 10 percent for slower driver reaction.
[b] Measured from a vehicle ten feet back of the pavement edge to a vehicle in the outside lane.
[c] Measured from a vehicle ten feet back of the pavement edge to a vehicle approaching in the median lane.

Table 4. *Safe sight distance for passenger cars exiting from driveways onto four- and six-lane roads.*[a]

OPERATING SPEED	SAFE SIGHT DISTANCE—LEFT[b]	SAFE SIGHT DISTANCE—RIGHT[b]
20 MPH	300′	200′
30	500	400
40	850	850
50	1600	1600
60	2500	2500

[a] Values are for urban conditions. On rural highways, distances should be increased by 10 percent to allow for slower driver reaction.
[b] Measured from a vehicle ten feet back of the pavement edge.

Table 5. *Safe sight distances for semi-trailers exiting from driveways onto two-lane roads.*[a]

desirability, a) the 85th percentile speed, b) the speed limit if based on an engineering study, or c) in the case of a new facility, 80 percent of the design speed. (Source: Table II-6, p. 97, ref. No. 43).

Vehicles slowing down and turning left to enter a *two-way* driveway will have adequate sight distance ahead of them if the distances shown in Tables 3 to 6 have been provided to allow safe exit from the drive itself. The sight distances shown in Table 7 are needed by vehicles turning left and entering a one-way driveway to allow them to clear oncoming through vehicles safely.

On low-volume four- and six-lane roadways, there is adequate space to maneuver into adjacent lanes. Therefore, when projected peak hour volumes on the heaviest approach are less than 400 vph and 600 vph respectively, the sight distances shown in Tables 4 and 6 may be replaced by the safe stopping sight distances shown in Table 8. On two-lane roads, however, the sight distance requirements shown in Tables 3 and 5 apply regardless of approach volumes.

One of the assumptions used in calculating the sight distances shown in Tables 3 through 6 was that through traffic would be amenable to a reduction in speed of 10 miles per hour. When the engineer believes that through traffic on the highway would accept a 20 mph reduction in speed, values in these tables should be reduced by one-third.

The sight distances shown in Tables 3 through 8 are for urban conditions. In order to convert these to rural conditions, where driver reaction times are longer, the sight distances should be increased by 10 percent.

The sight distances in Tables 3 through 6 apply when highway grades are zero to 3.0 percent (either up or down). When an upgrade is steeper than 3.0 percent, adjustments should be made to compensate for the longer time required to reach the speed of highway traffic. The time is less than shown when the highway is descending. Adjustment factors below apply to grades only in that portion of the road between the driveway and the downstream point at which a vehicle emerging from the driveway has been able to accelerate to within 10 miles per hour of the route speed.

When the highway, in the section to be used for acceleration after leaving the driveway, ascends at 3 to 4 percent, then sight distance in the direction of approaching ascending traffic should be increased by a factor of 1.4. When the driveway ascends at 5 to 6 percent, sight distance should be increased by a factor of 1.7.

When the road in the section to be used for acceleration after leaving the driveway descends at 3 to 4 percent, sight distance in the direction of approaching descending highway traffic should be reduced by a factor of 0.6. If the road descends at 5 to 6 percent, reduction factor should be 0.5.

When the criteria for sight distances to the right cannot be met, the need can be eliminated by prohibiting left turns by exiting vehicles.

Restriction of turning movements to right turns in and out of a driveway, together with provision of a right turn acceleration lane designed in accordance with AASHTO standards, eliminates the need for the sight distances shown in Tables 3 through 6.

OPERATING SPEED	SAFE SIGHT DISTANCE—LEFT[b]	SAFE SIGHT DISTANCE—RIGHT[c]
20 MPH	200′	200′
30	400	400
40	850	850
50	1600	1600
60	2500	2500

[a] Values are for urban conditions. On rural highways, distances should be increased 10 percent to allow for slower driver reaction.
[b] Measured from a vehicle ten feet back of the pavement edge to a vehicle in the outside lane.
[c] Measured from a vehicle ten feet back of the pavement edge to a vehicle approaching in the median lane.

Table 6. *Safe sight distances for semi-trailers exiting from driveways onto four- and six-lane roads.*[a]

OPERATING	SAFE SIGHT DISTANCE IN FEET[b]		
SPEED	2-LANE	4-LANE	6-LANE
20 MPH	150	160	170
30	230	250	270
40	370	390	420
50	520	550	580
60	700	740	780

[a] Values are for urban conditions. On rural highways, distances should be increased by 10 percent to allow for slower driver reaction.
[b] Measured from the point where a left-turning vehicle stops to a vehicle in the outside lane.

Table 7. *Safe sight distances for passenger cars entering driveways by left turns.*[a]

OPERATING	SAFE SIGHT DISTANCE IN FEET[b]		
SPEED	2-LANE	4-LANE	6-LANE
20 MPH	260	280	300
30	400	440	480
40	570	620	670
50	810	880	950
60	1000	1100	1200

[a] Values are for urban conditions. On rural highways, distances should be increased by 10 percent to allow for slower driver reaction.
[b] Measured from the point where a left-turning vehicle stops to a vehicle in the outside lane.

Table 8. *Safe sight distances for semi-trailers entering driveways by left turns.*[a]

Direct access to a parcel should be denied when the sight distances shown cannot be attained and when restrictions on turning movements to and from a proposed development would not be practical. When a responsible agency denies access, it may be faced with the following alternatives:

1. Paying compensation to adjacent property owners to acquire access to the subject parcel through easements.
2. Constructing a frontage road serving the subject property and connecting with a highway point where safe access can be provided.
3. Compensating the denied owner for loss of access.

In order to minimize the costs associated with such alternatives, access sight distance elements should be made a part of local standards. Zoning controls can be used to restrict certain types of developments on parcels where it would be impossible to provide proper sight distances for the types of vehicles generated by such developments.

Driveway Grades

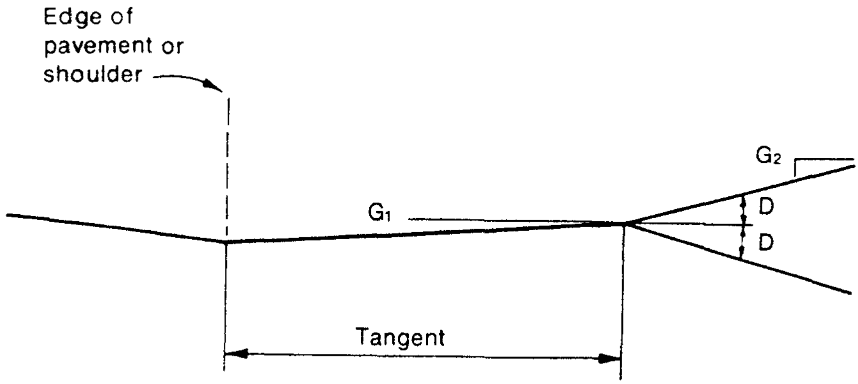
Vehicles entering and leaving driveways which have abrupt changes in grade must travel at extremely low speeds. For those entering, the possibility of rear-end collisions on the public street is greatly increased. Exiting vehicles must wait for larger gaps in traffic, and thus hazards may become greater. The driveway profile is also an important design element with respect to comfort of vehicle occupants and as it affects potential damage to the undersides of vehicles.

Underside clearances of automobiles have not changed appreciably since 1955. During that time, several agencies have developed satisfactory driveway design standards. Most of the criteria produce similar results although they consist of combinations of tangent slopes and lengths and vertical curves.

Acceptable vertical profiles of driveways are generally governed by the operating characteristics of vehicles. Maximum grades are established by the physical dimensions of vehicles (principally wheelbase) and braking capabilities, primarily of trucks. Designs must then be further refined as to a) curb and shoulder cross-section within the right-of-way, and b) whether a sag or a crest curve is required to complete the driveway beyond the right-of-way.

Figure 7 shows desirable and suggested maximum grade changes for three classes of driveways. For the values shown, no vertical curve connecting the tangents is necessary. The value of G_1 is limited by shoulder slope or by the presence of a sidewalk within the right-of-way.

For grade changes more abrupt than those shown in Figure 7, vertical curves at least 10 feet long should be used to connect tangents. A template is helpful in checking clearances for more critical conditions. A design vehicle drawn to a scale of 1″ = 20′ -0″ is useful in checking grade limitations. Adjustable templates combining grades and a design vehicle are helpful in explaining clearance limitations to persons concerned with driveway design. Dimensions and break-over angles of new vehicles are published annually by the Automobile Manufacturers Association.[40]



	Suggested Maximum Grade Change (D)	
	Desirable	Maximum
High Volume Driveway	0 %	± 3 %
Low Volume Driveway on Major or Collector Streets	± 3 %	± 6 %
Low Volume Driveway on Local Streets	± 6 %	Controlled by Vehicle Clearance

Figure 7. *Suggested driveway profile.*

Maximum grades (G_2) generally should be limited to 15 percent for residential driveways and to 5.0 to 8.0 percent for commercial and industrial driveways. If possible, driveways that must be steeper than these recommended limits should have longer tangent sections (at G_1 grade) than those discussed below.

Within the right-of-way limits, the driveway grade should be limited to 6.0 percent when possible. Preferably, the maximum difference between the downward cross slope of the traveled way (usually 2.0 percent or less) and the upward slope of the driveway to the sidewalk should not exceed 8.0 percent. If possible, it is desirable for the driveway crossing of the sidewalk to be made with little or no change in the sidewalk grade or cross-section. If the provision of adequate curb return radii precludes meeting this objective, the sidewalk should be warped into the driveway grade. Alternatively, for special circumstances as previously discussed in this Recommended Practice, step-down curbs may be used for the driveway. When possible, it is desirable that the driveway slope upward from the gutter line on a straight slope (no vertical curve) at least 10 feet long for residential driveways and 40 feet long for commercial and industrial driveways. This relatively flat area permits vehicles to turn off a roadway without immediately climbing or descending, and exiting vehicles have a waiting area at approximately roadway level.

Mountable curbs are used along local streets in many areas, and often the curb is not modified when a driveway is installed. Such a design has the obvious advantage of costing the developer less to construct. However, they result in considerable "bounce" for occupants in vehicles riding over the curb. Due to this discomfort and the accident hazard when such driveways are entered at relatively high speeds, it is recommended that such driveways have the curb lowered to approximately the elevation of the gutter.

The same physical limitations apply to roadways with shoulders except that the driveway grade across the shoulder should be that of the shoulder. The grade between the outer edge of the shoulder and the property line should be appropriate for the type of drainage provided. If the roadway is in a cut, a driveway sloped to the low point of the ditch line would often result in a breakover angle that would be too sharp for satisfactory driveway speed, especially on uncurbed high-speed rural highways. As an alternative, a flat driveway with a culvert under it is recommended.

If the roadway is in a hilly area, the driveway may require sufficient rise above shoulder level to prevent excessive run-off onto adjacent property.

Paving

Unless a driveway is paved and well maintained, pot holes and other surface imperfections are likely to develop. This may cause vehicles using the driveway to come almost to a stop before entering or leaving the traffic stream, causing excessive interference with through traffic. Furthermore, if the pavement is allowed to become badly deteriorated, circulation paths in any adjoining parking area may be adversely affected. Other undesirable characteristics of nonpermanent driveway surfacing include the difficulty of maintaining the desired surface profile, higher maintenance expenses, reduced skid resistance, tracking of loose material onto sidewalks, streets and highways, possible damage to the pavement if pot holes develop at the edge of the pavement, and problems of snow removal in northern climates.

Permanent types of paving include surfacing with portland cement concrete or asphaltic concrete and bituminous surface treatment. Gravel and other materials without a permanent surface are not considered satisfactory. Portland cement concrete has been identified as better than asphaltic concrete or bituminous surface treatment where fuel may be spilled, such as around pump islands of service stations, and where heavy wheel loads have to be sustained for long periods, such as at truck loading docks.

Driveways should be well maintained to ensure that the original profile is retained, that operational speeds are not reduced by rough surfaces, and that no damage to or deterioration of the public roadway pavement is caused by the condition of a driveway. The quality of maintenance also should be adequate to ensure that drivers will not deviate from logical circulation patterns to avoid driveways in poor condition.

In general, permanent pavement should extend at least to the end of the driveway curb radii, to the side-walk, or to any other portion of the driveway within the public right-of-way. In the case of commercial and industrial driveways, permanent pavement is desirable for at least 50 feet from the edge of the highway pavement.

If a driveway connects with an unpaved street or road, stabilized material of at least as high a standard as the roadway should be required to the right-of-way line. It is desirable to carry such stabilized material well back into private property—at least 50 feet from the edge of the public roadway.

When separate turn lanes and/or tapers are built along a paved street or road to serve a driveway, the permanent paving should be of the same type as that used on the public roadway or of contrasting surface material. The pavement should be designed to have at least the same structural strength as the public road. Separate turn lanes and tapers along unpaved streets and roads generally are not recommended. If they are installed, stabilized material of at least the same standard as the roadway should be specified.

Recommended Guidelines

Basic Driveways

Basic widths, curb spacing, radii and angles of driveways suggested for various land uses in urban and rural areas are given in Table 9. Methods of measurement and portions of previous text are footnoted below the table, and are illustrated in Figure 8.

In some driveway permit regulations, the term "curb cut" is used. The word "driveway" is preferred, since curb cut has little relation to the practical function of a driveway, and may be confusing when applied to roadways without curbs. If used, curb cut should be clearly defined as representing the effective driveway width together with the curb radii on both sides. Control dimensions should be adjusted accordingly. Thus, a 30-foot driveway with a 15-foot radius on each side becomes a 60-foot curb cut.

It should be stressed that these design values are *guidelines*. The dimensions should be adjusted by the driveway permit engineer as required to handle expected traffic conditions.

Major Driveway Design Factors

Special care should be taken in designing driveways serving very high generation uses such as community and regional shopping centers, large industrial plants, major office building complexes, and high density apartment developments. Specific elements have been discussed in this Recommended Practice under sections on Volumes, Successive Entrances, Angles, Spacing, Median Cuts, Sight Distances, and Paving. Shaw found that left-turn bays could be justified on the basis of reductions in accidents and delays at typical major intersections having medians, and that the cost could be amortized by the savings in as short a period as five years.[41]

	Dimension Reference (See Fig. 8)	Urban			Rural		
		Residential	Commercial	Industrial	Residential	Commercial	Industrial
Width[1]	W						
Minimum		10	15	20	10	15	20
Maximum		30	35	40	30	40	40
Right turn radius[2]	R						
Minimum		5	10	15	10	15	25
Maximum		15	20	25	25	50	50
Minimum spacing[3]							
From property line	P	0	0	–R	0	0	–R
From street corner	C	5	10	10	10	15	20
Between driveways	S	0	0	0	0	0	0
Angle[4]	A	45%	45%	45%	45%	45%	45%

[1]The minimum width of commercial driveways is intended to apply to one-way operation. In high pedestrian activity areas such as in a central business district or in the same block with auditorium, school or library, the maximum basic width should be 30 feet. The width shown applies to rural routes and most city streets including neighborhood business, residential, and industrial streets. The width is intended to be measured along the right-of-way line, in most instances, at the inner limit of a curbed radius or between the line of the radius and the near edge of a curbed island at least 50 feet square in area. For exceptions see Figure 6.

[2]On the side of a driveway exposed to entry or exit by right turning vehicles. In high pedestrian activity areas, the radii should be half the values shown. The maximum radii for major generator driveways such as shown in Figures 4 and 5 should be much higher than the values shown.

[3]Measured along the curb or edge of pavement from the roadway end of the curb radius, except for conditions noted in Figure 6. In high pedestrian activity areas, the minimum spacing between driveways should be five feet.

[4]Minimum acute angle measured from edge of pavement, and generally based on one-way operation. For two-way driveways, and in high pedestrian activity areas, the minimum angle should be 70 degrees.

Table 9. *Recommended basic driveway dimension guidelines.*

Presumably, similar findings would apply to major driveways with heavy volumes of left-turning vehicles. In fact, it is common practice at high generation developments to require medians of adequate width to accommodate left-turn bays.

An interesting treatment of a left-turn access problem in Alexandria, Virginia is shown in Figure 9. An overpass was constructed in the median of Duke Street, an otherwise at-grade, four-lane major route.

An unsignalized major driveway at grade may be considered to be similar to an unsignalized intersection as studied by Harmelink.[42] He found left-turn storage lanes to be justified for extremely low volumes. As shown in Figure 10, a left turn volume of 50 vehicles per hour from a four-lane highway facing an opposing volume of 300 vehicles per hour, for example, would justify a

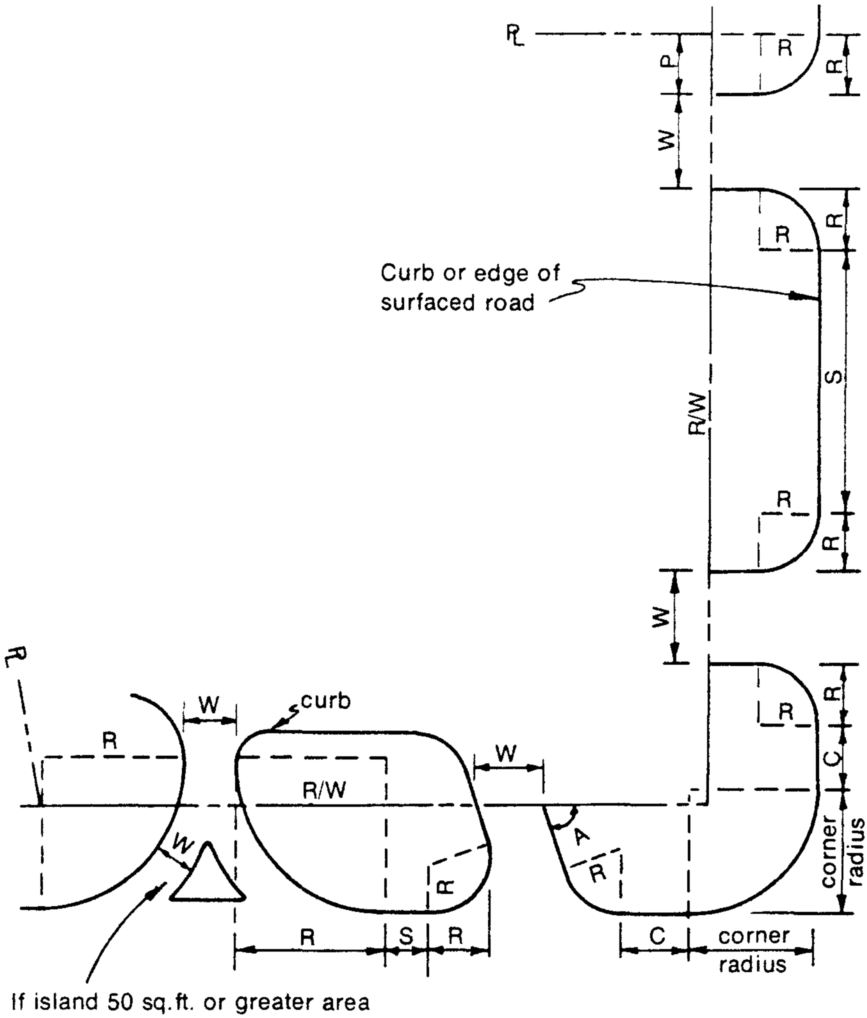


Figure 8. *Driveway dimensions measurements (see Table 9).*

left-turn bay 50 feet in length. If the opposing volume was 1,100 vehicles per hour, a bay length of 100 feet would be needed. Harmelink also analyzed needs for left-turn bays on two-lane highways as a function of speed and percentage of left turns as related to approaching and opposing volumes. His data is given in Figures 2 through 19 of his report.[42] While too extensive to be incorporated in these guidelines, Harmelink's findings may be considered for inclusion in the operating practices or design guidelines of local agencies.

When left-turn bays are to be provided at major driveways, a minimum spacing is automatically established for successive driveways that are to

Figure 9. *Left-turn lane overpass to Landmark Regional Shopping Center in Alexandria, Virginia.*

have left turn entry or exit. The basic factors are the distance required for the median taper (customarily with at least a 10:1 ratio) and the length of the storage bay. If a driveway on a major route is opposite a local street, a left-turn bay for the local street also should be incorporated in the median. This will further increase the required distance between major driveways.

The distance of a major driveway, with left-turn channelization from a nearby major intersection which also has left-turn bays, will vary depending on whether the driveway is on the approach or departure side of the intersection with repect to the left-turn lane. This may be illustrated by two examples. Assume a north/south route and a requirement for a northbound left-turn bay to a major driveway. Assume that a bay 100 feet long is needed. If the major intersection is north of the driveway and requires a left-turn bay 200 feet long with a 120-foot taper, the closest permissible location for a driveway would be 320 feet from the intersection. If the major driveway were on the north side of the intersection, the required distance would be equal to the length of the left-turn storage bay for southbound traffic at the intersection (again assume 200 feet), the taper of 120 feet, and the 100-foot left-turn bay for the major driveway. These dimensions add up to a minimum distance from the intersection of 420 feet for a driveway.

These examples show the absurdity of attempting to specify the distances, consistent with all actual traffic needs, that driveways should be from intersections. It is important that driveways be designed for the particular traffic characteristics anticipated and that upstream and downstream factors affecting a driveway location should be considered in each instance.

As discussed under Successive Entrances, the entry movement to a series of driveways serving interconnected or common parking areas tends to be heavily concentrated at the first driveway in the series. Thus, deceleration lanes for right turns may be needed only at the first one or two driveways serving a given approach to a major facility. Conversely, acceleration lanes (if used they should be designed according to AASHTO standards) may be needed at all the driveways. The value in a deceleration lane and the length of lane required is a function of the right-turning volume into the driveway, the volume in the curb lane, and the speed of entry allowable by the driveway's geometric design. Driveways with relatively high-speed entries, such as the one shown in Figure 5, may require no deceleration lane.

Traffic signal control of high volume driveways is commonly accepted in most jurisdictions. The control is needed primarily to facilitate outbound left-turn movements, and heavy volumes of through traffic can be accommodated simultaneously. If the outbound left-turn movement is low, the two-way flow on the major route must be stopped by the signal for only a short period. However, efficient signal operation under such conditions requires *separate sensing* of the driveway's right- and left-turn traffic lanes. Unless these lanes are separated and are of sufficient width, this may not be feasible. If separate sensing is not used, excessive green time will be required to the detriment of through-traffic flow on the major route.

As noted under Median Cuts, driveway traffic signals within 1,500 feet of another signalized intersection shall be coordinated. As a general rule, this requires interconnection.

Because of the complexities and costs (both public and private) of providing access to major traffic generators, competent traffic studies should precede issuance of access permits. The intimate relationship between driveway locations and interior traffic circulation make it highly desirable that site plans also be prepared on the basis of traffic analyses. In this Recommended Practice, the value of this procedure is emphasized in Design Considerations 22 and 23, which call for consideration of driveway access elements in both site layout and zoning.

Reservoir Space

In designing driveways, attention should be given those situations where on-site geometrics affect safe and efficient movement of traffic on public rights-of-way. This problem is most evident with the drive-in service developments which generate high volumes and require drivers to remain in their vehicles while being served or until service begins. Examples of this type of development are drive-in banks, automatic car washes, drive-in theaters and attendant-park lots and garages. In such cases, the design should provide adequate off-street reservoir space for waiting vehicles. Extreme care must be taken to minimize the probability that a queue of waiting vehicles will extend into the roadway.

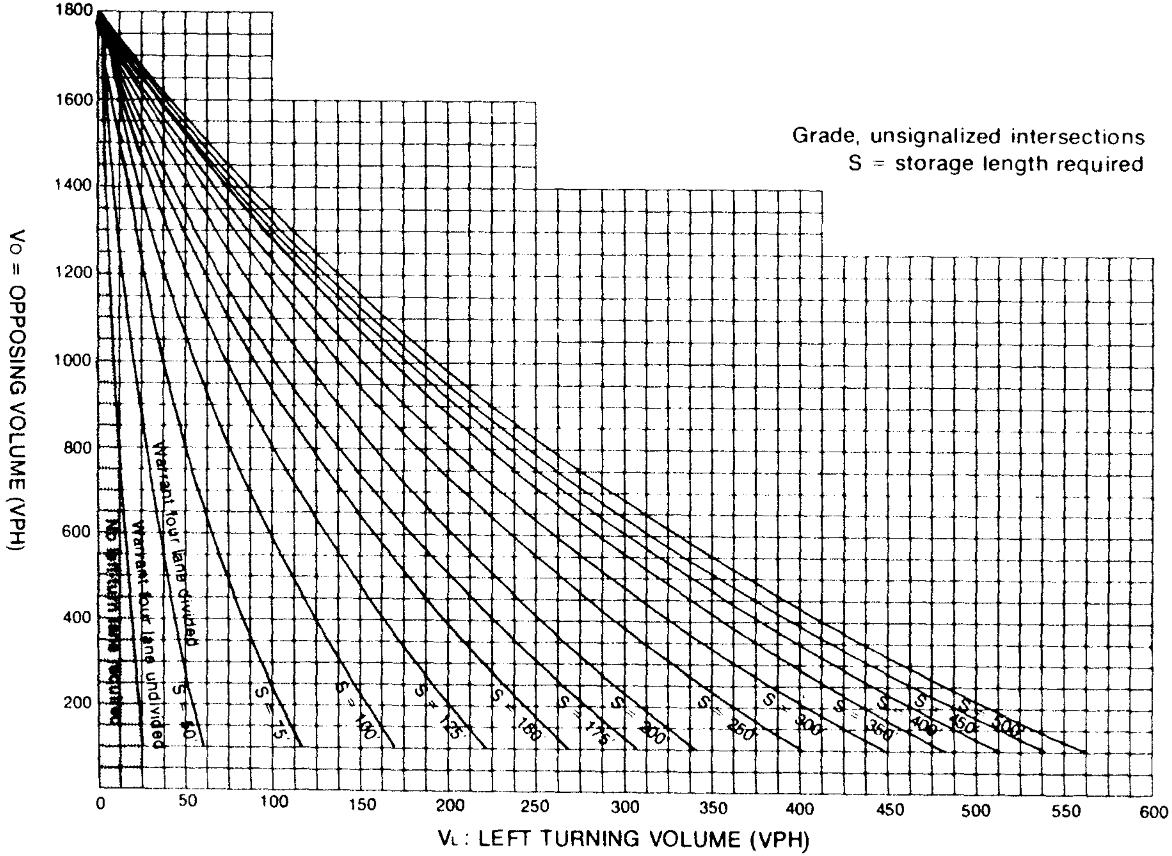


Figure 10. *Warrants for left-turn storage lanes on four-lane, at-grade, unsignalized highways. The section on graph lying between "undivided" and "divided" (V_L=25 to 55 vph for a V_O level of 200 vph) relates to a warrant for a one-space length as provided by an ordinary opening in a median about 20 feet wide.* Source: *Reference 42, Figure 1.*

In designing these site improvements, peaking within the design hourly volume is critical. Therefore, in addition to using the conventional critical *hourly* volume to measure the peak demand, the 5-minute, 15-minute or 30-minute demand may also warrant consideration.

Another important element in reservoir space design is the estimated accommodation or service time for vehicles using the facility. In connection with a proposed improvement, the service times can be measured at existing facilities with similar functions and similar geometrics. Knowing the short-term demand volume and service time, the needed reservoir area will be a function of that demand volume, the number of service facilities, and the service time per facility.

When determining design information it is important that facilities with similar geometrics be studied. Total service time includes not only the time for a vehicle to obtain service once within the service area, but also the time for the vehicle to maneuver into the service area after the driver has been directed to enter. This latter period is a function of the geometrics of the facility, particularly the width of the lanes, travel pattern, and the radius of the final approach turn. Wide lanes and flat approaches shorten the entering time. Good design calls for 11- to 12-foot approach lanes which are as straight as possible. For tight turns, a 30-foot outside radius is the practical minimum. When a turn exceeds 60 degrees, lanes within the turning area should be 13 feet wide. Following those criteria reduces total service time which in turn reduces storage requirements. The lanes adjacent to drive-in bank windows and ticket dispensing machines, of course, must be narrowed to 8.5 or 9.0 feet.

Care should always be taken to maximize reservoir areas no matter what the estimates indicate. One practical method is to place a service facility so that exiting vehicles have no more distance than needed to maneuver to the most convenient driveway. This maximizes the amount of storage space. Long exit lanes contribute nothing to the operation of a drive-in facility unless vehicles may have to wait before they can enter the street. Under such circumstances, sufficient space is needed between the curb lane and the service facility to preclude back-ups blocking the operation. Usually two or three spaces beyond each window will suffice.

If the potential reservoir area on the site would not be adequate, alternative uses of the land should be considered.

Based on the queuing calculations contained in the Woods and Messer study of drive-in banks, it was found that such facilities could serve an average of 40 vph per window.[45] Unpublished studies by Paul C. Box & Associates empirically determined that such facilities could handle 36 to 44 vph per window. Woods and Messer also found that lengths of queues were predictable as long as demand was less than 35 vph per window. Based on these observations and calculations, the following guidelines should be used in determining reservoir space:

1. Estimate demand for the site in question from counts of similar facilities in the same area.

2. Calculate the number of windows required, based on a rate of 30 vehicles per hour per window.

When cars can be served at a rate of 40 vph or more, and the average demand in the peak hour does not exceed 35 vph per window, a waiting area for approximately 20 vehicles will not overflow more than 5 percent of the time. If the margin between service rate and demand is estimated to be narrower, it becomes difficult to predict the amount of reservoir space required. It will certainly need to be more than 20.

For all types of reservoirs, a length of 22 feet is suggested for each car space.[45]

Observations of queue lengths at automatic car washes of various types have resulted in recommendations of 30- to 50-space reservoirs.[46] The amount of space required varies inversely with the wash rate per hour and the number of bays or lines operated. Since car washes usually are built on restricted areas of land, most reservoirs do not have more than 10 to 20 spaces in each lane. The use of an attendant to direct motorists as they arrive is an important factor to be considered in design. □

References

1. Montgomery, J. M. "Traffic Generation and Parking Demand at a Medical Clinic"—1963.
2. Barton, Aschman & Associates, Inc., "Transportation Aspects of the Bunker Hill Urban Renewal Project"—1963.
3. Paul C. Box & Associates, file records, partially published and unpublished.
4. Maryland State Roads Commision, "Trip Generation Study"—1968.
5. Illinois Section, Institute of Traffic Engineers, "Trip Generation Study," *Traffic Engineering*—March 1970.
6. California Division of Highways, "First Progress Report on Trip Ends Generation Research Counts"—1965.
7. California Division of Highways, "Second Progress Report on Trip Ends Generation Research Counts"—1966.
8. California Division of Highways, "Third Progress Report on Trip Ends Generation Research Counts"—1967.
9. California Division of Highways, "Fourth Progress Report on Trip Ends Generation Research Counts"—1968.
10. California Division of Highways, "Fifth Progress Report on Trip Ends Generation Research Counts"—1969.
11. Western Section Institute of Traffic Engineers, "Trip Generation"—1967.
12. Alroth, W. A. "Parking and Traffic Characteristics of Suburban Industrial Developments," Highway Research Record No. 237—1968.
13. American Association of State Highway Officials, "An Informational Guide for Preparing Private Driveway Regulations for Major Highways," Washington, D. C.—1960.
14. Anaya, M., "Driveways and Approaches for Modern Automobiles," Presented at the 9th Annual California Street and Highway Conference, University of California, Berkeley, California, pp. 82—1957.
15. "A Policy and Standards for Entrances to State Highways," *Public Works*, p. 68—December 1966.
16. Preliminary Draft, "Driveways," for Automotive Safety Foundation (ref. 20), unpublished—August 1968.
17. Billion, C. E. and I. Scheinbart, "A Study of Ingress and Egress at Gasoline Service Stations on Rural State Highways Without Control of Access," *Proceedings*, Highway Research Board, p. 618—1956.
18. Box, P. C., "Access Control and Accident Reduction," *Municipal Signal Engineer*, p. 27—May-June 1965.
19. Box, P. C., "Driveway Accident and Volume Studies, Parts I, II, III," *Public Safety Systems*—May-June, July-August, and September-October 1969.
20. Box, P. C., "Driveways," Chapter 5, Traffic Control and Roadway

Elements—Their Relationship to Highway Safety/Revised, Highway Users Federation for Safety and Mobility—1970.

21. Box, P. C., "Driveway Accident Studies, Major Traffic Routes, Skokie, Illinois," (Unpublished)—1968.
22. Box, P. C., "Signal Control of High Volume Driveways," *Municipal Signal Engineer*, p. 21—November-December 1965.
23. Box, P. C., "The Curb Parking Effect," *Public Safety Systems*—January-February 1968.
24. Bruggeman, J. M., "Accident Investigation on Rural Expressways," Student Thesis, Civil Engineering Department, Northwestern University, Evanston, Illinois—1968.
25. "Driveway Accidents and Land Use," Alan M. Voorhees & Associates, Inc. (unpublished) 1970.
26. Horn, John W., et al., "The effect of Commercial Roadside Development on Traffic Operations," Project ERD-110-B, Engineering Research Department, North Carolina State College, Raleigh, North Carolina—1960.
27. "Information Relative to Effect of Service Station Access on Adjacent Streets and Highways," Western Oil and Gas Association Community Relations Department.
28. Head, J. A., "Predicting Traffic Accidents From Roadway Elements on Urban Extensions of State Highways," *Bulletin 208*, Highway Research Board, p. 45.
29. Koltnow, P. G., "Two-Way Left Turn Lanes are Proving Successful," *Traffic Engineering*, p. 40—October 1964.
30. "Model Ordinance Regulating Curb Cuts and Approaches to Service Stations," American Petroleum Institute Bulletin #1603—December 1959.
31. Parsons, N. C. and C. E. Billion, "Median Accident Study—Long Island, New York," *Bulletin 308*, Highway Research Board, p. 64.
32. Peterson, A. O. and H. L. Michael, "An Analysis of Traffic Accidents on a High Volume Highway," Purdue University—August 1966.
33. Ray, J. C., "Installation of a Two-Way Median Left Turn Lane," *Traffic Engineering*, p. 25—March 1961.
34. "Recommended Practice for Sub-Division Streets," *Traffic Engineering*, p. 15—January 1967.
35. "Regulations Governing Ingress and Egress at Gasoline Service Stations and Related Retail Establishments Fronting on all Non-limited Access Highways Under State Jurisdiction in Ohio," Ohio Department of Highways—Revised 1964.
36. Schoppert, D. W., "Predicting Traffic Accidents from Roadway Elements of Rural Two-Lane Highways with Gravel Shoulders," *Bulletin #158*, Highway Research Board, p. 4.
37. Stover, V. G., "Guidelines for Medial and Marginal Access Control of Major Roadways," National Cooperative Highway Research Program Report #93.
38. Tables of Existing State Driveway Standards and related material (pp. F-54 through F-73) National Cooperative Highway Research Program Project 3-13.
39. Varin, D. W., "Gasoline Service Station Location and Design," Information Report #140, American Society of Planning Officials—November 1960.
40. "Parking Dimension, 19—Model Cars," Engineering Notes, Automobile Manufacturers Association (published annually).
41. Shaw, Robert B., "Evaluation of Delays and Accidents at Intersections to Warrant Construction of a Median Lane," Joint Highway Research Project C-36-17EE, Purdue University—1966.

42. Harmelink, M. D., "Volume Warrants for Left-Turn Storage Lanes at Unsignalized Grade Intersections," Highway Research Record #211—1967.
43. "Policy on Geometric Design of Rural Highways," American Association of State Highway Officials—1965.
44. Netherton, Ross D., "Control of Highway Access," University of Wisconson Press, 430 Sterling Court, Madison 6, Wisconsin.
45. Woods, D. L. and C. J. Messer, "Design Criteria for Drive-in Banking Facilities," *Traffic Engineering*, p. 30—December 1970.
46. "Parking Principles," Highway Research Board Special Report #125—1971.
47. "Protection of Highway Utility," National Cooperative Highway Research Program Report #121—1971.
48. "Manual on Uniform Traffic Control Devices," U. S. Department of Transportation, FHWA—1961.