HUDSON OAKS

TRAFFIC ENGINEERING DESIGN STANDARDS AND POLICY GUIDELINES

PUBLIC WORKS DEPARTMENT
City of Hudson Oaks, Texas

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FOREWARD

The Traffic and Transportation Engineering design data and policies contained in this manual provide recommended standards and criteria for issues frequently encountered in land development. These standards and criteria are intended to ensure consistent Traffic and Transportation design practices in new development or the redevelopment of land in the City limits and its extra-territorial jurisdiction. Much of the material contained herein has been drawn from City ordinances, regulations, and policies. Other data has been gathered from nationally recognized engineering texts and publications of the Institute of Transportation Engineers (ITE), the American Association of State Highway and Transportation Officials (AASHTO), the Traffic Institute of Northwestern University, Evanston, Illinois, and from the Thoroughfare Plan for North Central Texas developed by the North Central Texas Council of Governments.

Any variance from the policies, standards, and criteria contained herein will be at the discretion of the official, department, or agency responsible for their implementation.

SECTION 1

FUNCTIONAL CLASSIFICATION AND STREET PATTERN DESIGN

1-1. INTRODUCTION.

1-2. This section contains information concerning the functional classification of urban streets and recommended standards and practices for designing local street patterns. It includes concepts and practices which, when properly applied, greatly enhance the ability of the street system to accommodate traffic demand in an efficient and effective manner. In so doing, these criteria can have a direct and positive effect on traffic mobility and operation.

1-3. LAND USE RELATIONSHIPS.

1-4. The basic interrelationships between land uses and transportation facilities are illustrated by the somewhat oversimplified cycle diagram shown in Figure 1-1. This continuous cycle starts with land use; activities on the site generate trips; these trips, connecting points of origin and destination, identify transportation needs; transportation facilities, in turn, provide additional access to land; with the provision of such access, land value is enhanced; increased land value completes the cycle by affecting the land use. Continued operation of the cycle leads to more intensive land uses on more expensive land with greater transportation demands, and can eventually culminate in a breakdown of the transportation facility.

1-5. As evidenced in this land use-transportation cycle, it is vital that the transportation facilities be protected from functional obsolescence in order that they continue to provide the level of service (or capacity) for which they were designed. Effective policies and standards for use in the planning, design, construction, and management of these transportation facilities can contribute significantly to this functional protection.

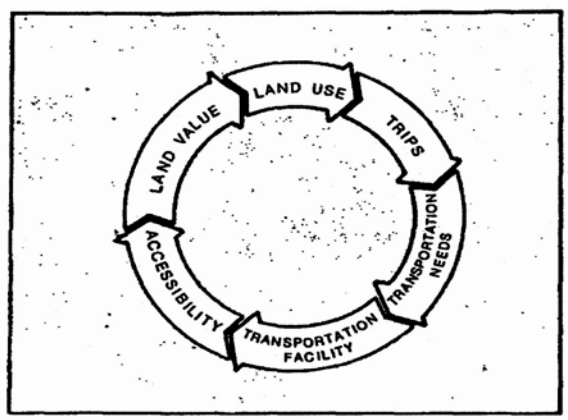


FIGURE 1-1. Interrelationship of Land Use and Transportation Facility

1-6. FUNCTIONAL CLASSIFICATION.

1-7. THE BASIS OF CLASSIFICATION.

1-8. The concept that a roadway system contains a hierarchy of streets, each with a different ratio of emphasis on traffic mobility and property access, is well accepted. This concept recognizes the fact that many advantages lie in the efficiency of homogeneous traffic flow provided by specialized design. Roadways of different types are intended to serve defined needs, with a specific balance between mobility and access to adjacent property. In other words, each category (or classification) of roadway serves a specific use or function.

1-9. Over considerable time, categories of roadways have evolved ranging from freeways, which place total emphasis on traffic mobility, to local streets whose primary function is to provide access to property. Thus, the classification of roadways according to their use or purpose they are intended to serve is called functional classification. Figure 1-2 shows the general relationship between land access and traffic mobility for the three classifications of urban streets, namely, arterial streets, collector streets, and local streets.

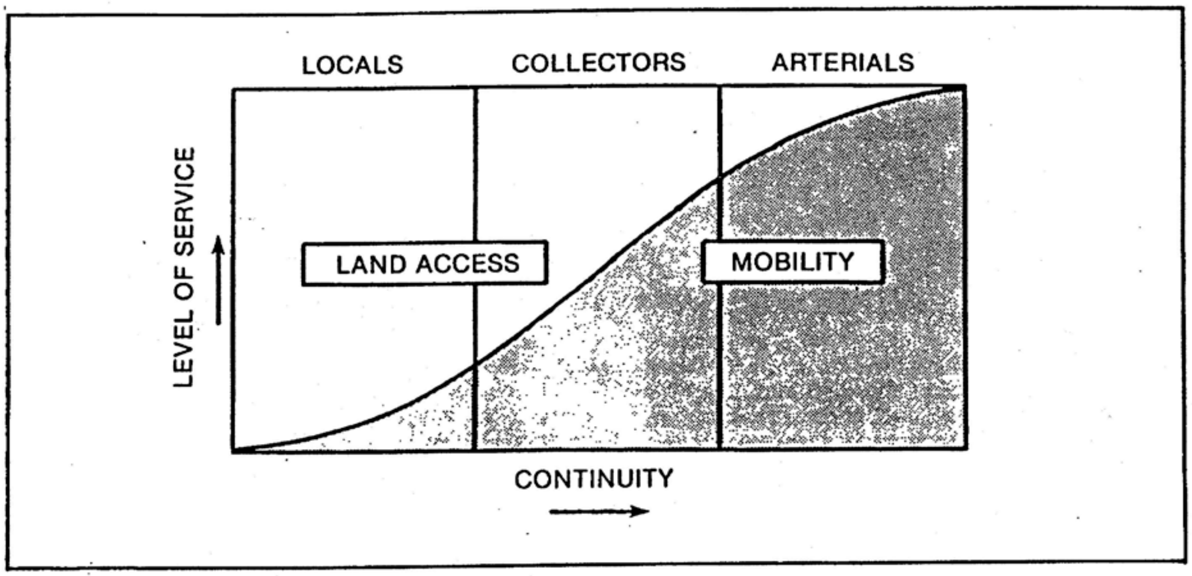


Figure 1-2. General Relationship of Land Access and Traffic Mobility.

1-10. GENERAL STREET CLASSIFICATIONS (TABLE 1-1)

1-11. ***Major Arterial Streets.***

1-12. The major arterial street system should serve the major centers of activity of a metropolitan area, the highest traffic volume corridors, and the longest trip desires. The major arterial system should carry a high proportion of the total urban area travel on a minimum of mileage. This system should be integrated, both internally and between major outlying areas.

1-13. The major arterial system should carry the major portion of trips entering and leaving the urban area, as well as the majority of through movements desiring to bypass the central city. In addition, significant intra-area travel, such as between central business district and outlying residential areas, between major inner city communities, or between major suburban centers should be served by this class of facility. Frequently the major arterial system will carry important intra-urban as well as intercity bus routes. Average traffic volumes on major arterial streets should not exceed 36,000 vehicles per day.

<table>
<tr><th colspan="2" rowspan="2">Criteria</th><th colspan="4">Functional Classification</th></tr>
<tr><th>Major Arterial</th><th>Minor Arterial</th><th>Collector</th><th>Local</th></tr>
<tr><td rowspan="2">Trips Served</td><td>Trip Length</td><td>Long</td><td>Moderate to Long</td><td>Under 1 Mile</td><td>Under ½ mile</td></tr>
<tr><td>Traffic Volume</td><td>High</td><td>Moderate to High</td><td>Moderate to Light</td><td>Light</td></tr>
<tr><td colspan="2">Service to Activity Center</td><td>Major Generators and Specialized Land Uses</td><td>Minor Generators and Individual Communities</td><td>Local Areas and Neighborhoods</td><td>Individual Sites</td></tr>
<tr><td rowspan="5">System Characteristics</td><td>System Continuity</td><td>Interconnects with Higher System-Intercommunity Continuity</td><td>Interconnects with Higher System-Intercommunity Continuity</td><td>Interconnects with Higher Systems-Neighborhood Continuity</td><td>Connects Individual Sites</td></tr>
<tr><td rowspan="2">Facility Spacing</td><td>1 to 5 miles</td><td>½ to 2 miles</td><td>1/8 to ½ mile</td><td>N/A</td></tr>
<tr><td colspan="2">Should Not Penetrate Neighborhoods</td><td colspan="2">Penetrate Neighborhoods</td></tr>
<tr><td>Access Control</td><td>Partial</td><td>Partial</td><td>None</td><td>None</td></tr>
<tr><td>Transit Service</td><td>Normal</td><td>Normal</td><td>Some</td><td>Limited/None</td></tr>
</table>

Table 1-1. Characteristics of Street Functional Classification.

1-14. ***Minor Arterial Streets.***

1-15. The minor arterial street system should interconnect with and augment the major arterial system and provide service to trips of moderate length at a somewhat lower level of travel mobility than major arterials. This system also distributes travel to geographic areas smaller than those identified with the higher system.

1-16. The minor arterial street system includes all arterials not classified as major and contains facilities that place more emphasis on land access than the higher system, and offer a lower level of traffic mobility. Such facilities may carry local bus routes and provide intercommunity continuity, but ideally should not penetrate identifiable neighborhoods. Average traffic volumes on minor arterial streets should not exceed 24,000 vehicles per day.

1-17. ***Collector Streets.***

1-18. The collector street system differs from the arterial systems in that facilities on the collector system may penetrate neighborhoods, distributing trips from the arterials through the area to the ultimate destination which may be on a local or collector street. Conversely, the collector street also collects traffic from local streets in the neighborhood and channels it into the arterial systems. In some cases, due to the design of the overall street system, a minor amount of through traffic may be carried on some collector streets.

1-19. The collector system provides for both land access service and local traffic movements within residential neighborhoods, commercial areas, and industrial areas. Such facilities contain the collector portion of some bus routes. Average traffic volumes on collector streets should not exceed 5,000 vehicles per day in residential areas, and 8,000 vehicles per day in commercial or industrial areas.

1-20. ***Local Streets.***

1-21. The local street system is made up of all facilities not on one of the higher systems. It serves primarily to provide direct access to abutting land and access to the higher order street systems. It offers the lowest level of mobility and usually contains no bus routes. Service to through traffic movement usually is deliberately discouraged.

1-22. HUDSON OAKS STREET CLASSIFICATIONS (TABLE 1-2).

Street Classification	Designation	R.O.W Width	Roadway Width F-F	No. of Lanes & Width	Parking Lanes	Median Width	Parkway/Sidewalks
Major Arterial	"AA"	120'	(2) 36'	6 - 12'	None	16'	16'/Yes
Major Arterial	"A"	100'	(2) 33'	6 -11'	None	14'	10'/Yes
Minor Arterial	"B"	90'	(2) 26'	4 - 13'	None	14'	12' / Yes
Minor Arterial	"B-5"	90'	62'	4-12' & 1-14'	None	14' center lane	14'/Yes
Major Collector	"C"	80'	(1) 48'	4 - 12'	None	0'	16' / Yes
Major Collector	"C-3"	80'	(1) 45'	3-15'	None	15' center lane	17.5'/Yes
Minor Collector	"D"	60'	40'	2-12' & 2-8'	2-8'	0'	10' / Yes
Local	B	50'	36'	2-10' & 2-8'	2-8'	0'	7' / Yes
Local	A	50'	30'	1-14' & 2-8'	2-8'	0'	10' / Yes
Rural	NA	60'	24' / 4' Shoulders	2-12'	None	0'	14' / No

Additional R.O.W. will be required at major intersections and may be required at high volume driveways to provide for left and right turn lanes in order to maintain traffic volume capacities through intersections. Also, additional utility and drainage easements may be required beyond the R.O.W.

TABLE 1-2. HUDSON OAKS STREET CLASSIFICATIONS

1-23. The City of Hudson Oaks street classifications for new development are identical to those discussed in the preceding paragraphs as they relate to major arterials, minor arterials, and collectors, except that the expressway arterial classification has been developed, which is a special form of the major arterial, and the local streets are subdivided into three categories: Local A, Local B, and Rural. Each type of local street has a different function, right-of-way width, and pavement width. The functions of each of these classifications are discussed in the following paragraphs.

1-24. ***Expressway Arterial Streets.***

1-25. An expressway arterial street is a special variety, or higher category, of major arterial street having grade separations at selected intersections with other arterial streets. At the grade separations, entrance/exit ramps and frontage roads provide traffic interchange with the cross streets. Design criteria is generally greater than those of major arterials and is established on a case-by-case basis. Average traffic volumes on expressway arterial streets should not exceed 45,000 vehicles per day.

1-26. Only a very few facilities of this type will be constructed, therefore utilization and location must be approved by the Director of Planning and Development and the Director of Community Development during the planning phase of the street system.

1-27. ***Local B* Streets.**

a. Local B streets carry traffic to and from collector streets, Local A streets, cul-de-sacs, and loop streets.

b. Local B streets serve low-density residential areas, and very limited public facilities.
c. Average traffic volumes on Local B streets should not exceed 2,500 vehicles per day.

1-28. ***Local A Streets.***

a. Local A streets carry traffic directly to and from collector streets or to and from Local B streets, and provide access to and from low-density/single family residences.
b. Local A streets are short in length and noncontinuous to discourage through traffic.
c. Average traffic volumes on Local A streets should not exceed 1,000 vehicles per day.

1-29. ***Rural Streets.***

a. Rural streets serve only developments that contain estate type lots. These streets are generally located in the extra territorial jurisdiction (ETJ) or in predominantly rural areas of the City. Restriction of construction of Rural streets is based on minimum lot size of the development served by the street.

1-30. ***STREET PATTERN DESIGN.***

1-31. The arrangement, character, extent, and location of streets shall generally conform to the Hudson Oaks Thoroughfare Plan and must be considered in their relation to existing and planned streets, to topo-graphical conditions, to drainage in and through the proposed and adjacent subdivisions, to public convenience and safety, and to their appropriate relation to the proposed uses of land to be served.

1-32. MANDATORY REQUIREMENTS.

1-33. The requirements listed below are mandatory in the planning, design, and construction of all new subdivision streets.

1-34. ***Block Length.***

a. Blocks should not be less than 400-feet nor more than 1600-feet in length.
b. In cases where physical barriers, property ownership, or industrial land use create conditions where it is appropriate that these standards be varied, the length may be increased or decreased to meet existing conditions, having due regard for connecting streets, circulation of traffic, and public safety.

1-35. ***Dead End Streets.***

a. Streets designated to be dead-end permanently shall be constructed with a paved cul-de-sac 80-feet in diameter.
b. Any dead-end street of a permanent or temporary nature, if longer than 200-feet, shall have a surfaced turning area 80-feet in diameter for a cul-de-sac. All temporary dead-end streets shall have provisions for future extension of the street and utilities and, if the temporary cul-de-sac is required, a reversionary right to the land abutting the turn-around for excess right-of-way shall be provided.
c. Where adjacent property contains an existing dead-end street over 200-feet in length, without a cul-de-sac, which abuts the proposed development, the City shall require the construction of a cul-de-sac as described above.

1-36. ***Cul-De-Sacs.***

1-37. A Street ending permanently in a cul-de-sac shall not be longer than 600-feet, and shall be provided with a turn-around having an outside roadway (pavement) diameter of at least 80-feet, and a street right-of-way diameter of at least 100-feet.

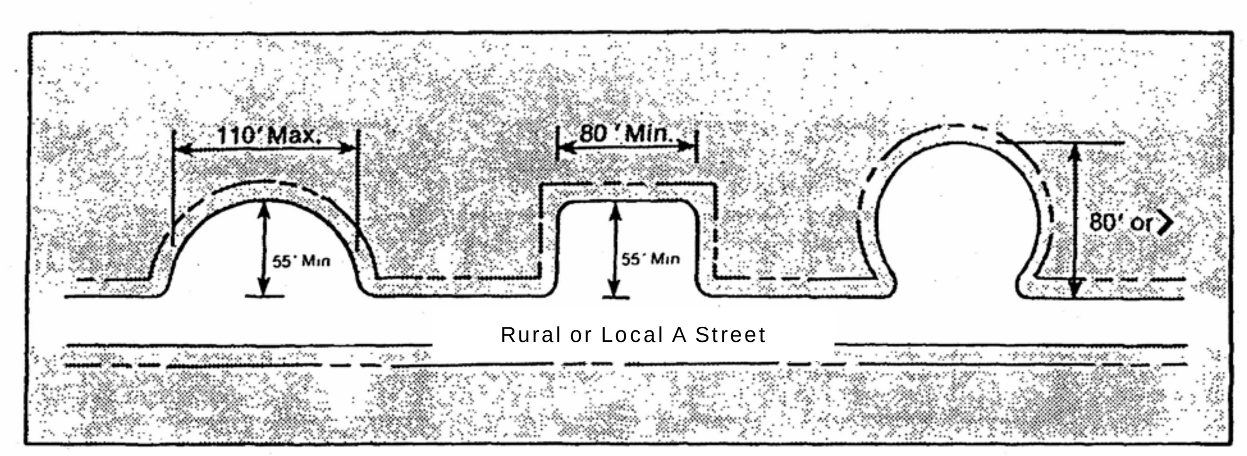


Figure 1-3. Examples of Partial Cul-de-sacs.

1-38. ***Partial Cul-De-Sacs.***

1-39. When partial cul-de-sacs (Figure 1-3) are utilized to provide additional frontage for irregular shaped lots dictated either by choice or by topography or other constraints, consideration must be given to their effect, or potential effect, on the safety of the motoring public. These facilities, by improper design and location, may encourage both head-in and parallel parking behind the curb line of the through street in a random fashion. Sufficient room must be provided within the partial cul-de-sac to allow complete vehicle maneuvering behind the curb line so that they may turn around and head out, rather than to back out, onto the through Street.

1-40. In order to accomplish these objectives and to provide optimum traffic safety for vehicles entering or exiting the partial cul-de-sac and those motorists traveling on the through street, the design criteria described below shall be observed. All partial cul-de-sacs:

a. Shall be used on Rural or Local A type streets only.

b. Shall have a minimum depth of not less than 55-feet, measured from the curb line of the intersected street to back curb line of the partial cul-de-sac. When the depth exceeds 80-feet, the facility shall be constructed as a conventional cul-de-sac.

c. Shall be not less than 80-feet, nor more than 110-feet in width.

d. Shall not be located on the crest of a hill where the street turns abruptly.

e. Shall be permitted only when the property is zoned and used for single family or two-family residential.

1-41. ***Emergency Access Easements And Fire Lane Easements.***

a. In general, emergency access and fire lane easements shall have a minimum width of 24-feet.

b. All emergency access and fire lane easements more than 100-feet in length shall either connect at each end with a public street, or be provided with a cul-de-sac having a minimum diameter of 80-feet with an additional distance of 10-feet on all sides clear of all permanent structures.

c. Development plans are reviewed by Fire Department personnel. A specific layout may generate additional requirements to ensure access by emergency vehicles.

1-42. ***Offset Intersections.***

a. Offset intersections shall be avoided whenever possible. Streets shall be designed to align with existing streets in adjoining subdivisions.

b. If an offset intersection is necessary, the centerline offsets shall be at least 150-feet (see Figure 1-4). Greater centerline offsets may be required in special cases to ensure traffic safety.

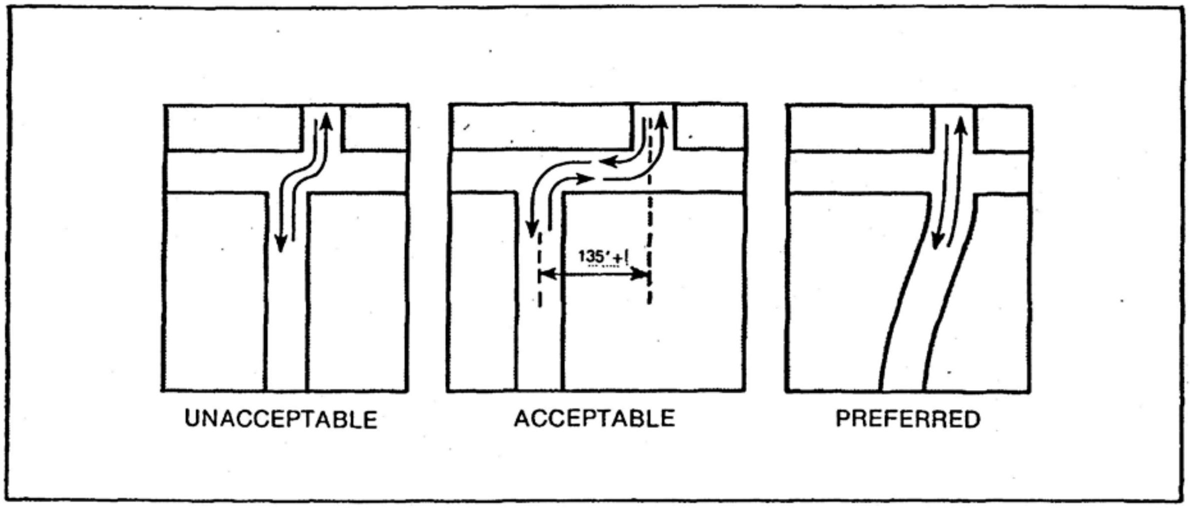


Figure 1-4. Offset Intersections.

c. For maximum traffic safety and ease of traffic operations, all streets should intersect at 90.degree angles.

d. No street intersecting a major or minor arterial street shall vary from a 90-degree angle of intersection by more than 5-degrees.

e. Intersections of two collector streets, or a collector and a Local B shall not vary from a 90-degree angle of intersection by more than 5-degrees.

f. Intersections of Local B and Local A streets, or two Local A streets shall not vary from a 90-degree angle of intersection by more than 10-degrees.

1-43. RECOMMENDED PRACTICES.

1-44. The principles presented below are strongly recommended in the planning and design of all subdivision streets. These principles concern the design of entire street systems rather than individual elements of the system, and therefore express concepts rather than specific standards. In applying these principles, however, specific standards for pavement widths, intersection design, and related design features must also be followed.

1-45. Basic considerations in the design of local street systems must recognize key elements of (a) safety, for both vehicular and pedestrian traffic, (b) efficiency of service, for all users, (c) livability or amenities, especially as affected by traffic in the circulation system, and (d) economy, of both construction and use of land, again as affected by or related to the traffic circulation system. Each of the following principles is an elaboration of one or more of these elements, and are not intended as absolute criteria, since instances may arise where certain principles conflict. Therefore, the principles should be used as guides for proper system layout as shown in schematic form in Figure 1-5. The design principles are shown incorporated into a site plan of a single-family housing development in Figure 1-6.

a. Local Street Systems should be designed to Minimize Through Traffic Movements. Through traffic on local and collector streets increases the average speed and volume, and thus the accident potential, thereby reducing residential amenities. This can be attributed sometimes to inadequate peripheral arterial street capacity, but often the fault lies with improper residential street design. Through traffic may be discouraged by creating discontinuities in the local street pattern, by offsetting local street intersections, and by channelizing or controlling median crossings along peripheral arterial routes.

b. Adequate Vehicular and Pedestrian Access Should be provided to All Parcels. The primary function of local streets is to provide access to abutting properties. Street widths, placement of sidewalks,

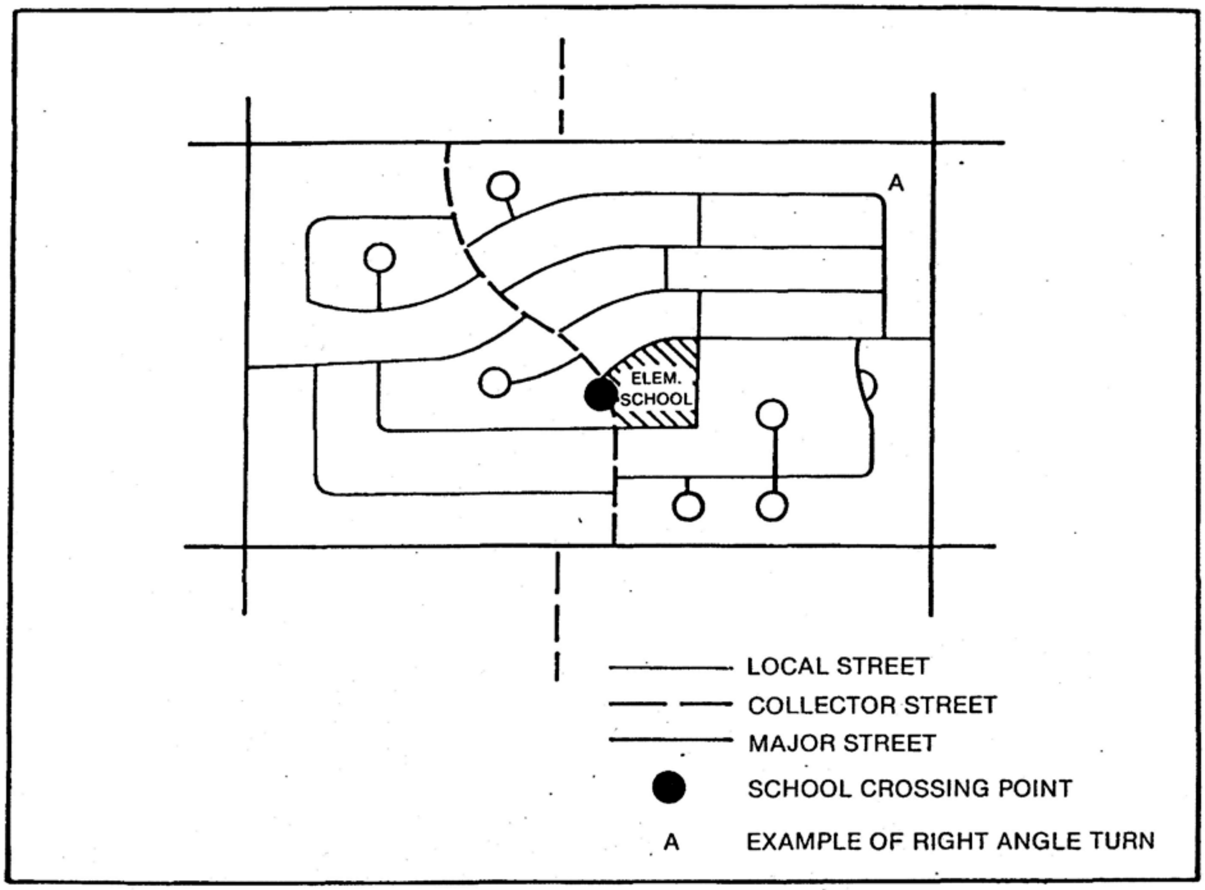


Figure 1-5. Schematic of Design Principles for Local Street Systems.

pattern of streets and number of intersections, are related to safety and efficiency of access to abutting lands.

c. There should be a Minimum Number of Intersections. Within the subdivision and especially along abutting arterial routes, intersections pose a major accident potential. The fewer intersections there are, consistent with other requirements, the fewer accidents there will be. From the standpoint of hazard, however, use of two T-type intersections with proper offset is preferable to using one cross-type.

d. Local Streets should be related to Topography from the Standpoint of Both Economics and Amenities. Local streets will be more attractive and economical if they are constructed to closely adhere to topography.

e. The Local Street System should be designed for a Relatively Uniform Low Volume of Traffic. To the extent possible, the design of the local and collector street system should recognize the need for residential amenities along all streets in the neighborhood. This suggests that the street system should be designed for uniformly low volumes on all streets after contiguous land development is complete. Where traffic volumes tend naturally to be higher, as along collectors, then variations in the land development pattern (i.e., permissible land uses, building setbacks, etc.) might be considered to compensate for the reduction in amenities.

f. Local Streets should be designed to Discourage Excessive Speeds. Residential streets should be designed to discourage fast movement (more than 25 to 30 mph), through the use of curvilinear alignments and discontinuities in the street system.

g. Street Patterns Should Minimize Out-of-the-Way Vehicular Travel. Ideally, every part of a residential area should be interconnected with every other part, and with peripheral developments, as directly as possible. Although strict application of this principle may conflict with other principles, excessive indirect travel is annoying to the individual area's livability. Moreover, the added vehicle-miles of travel within the neighborhood increase mid-block frictions, such as with parked cars, driveways and pedestrians, with resultant increased hazard.

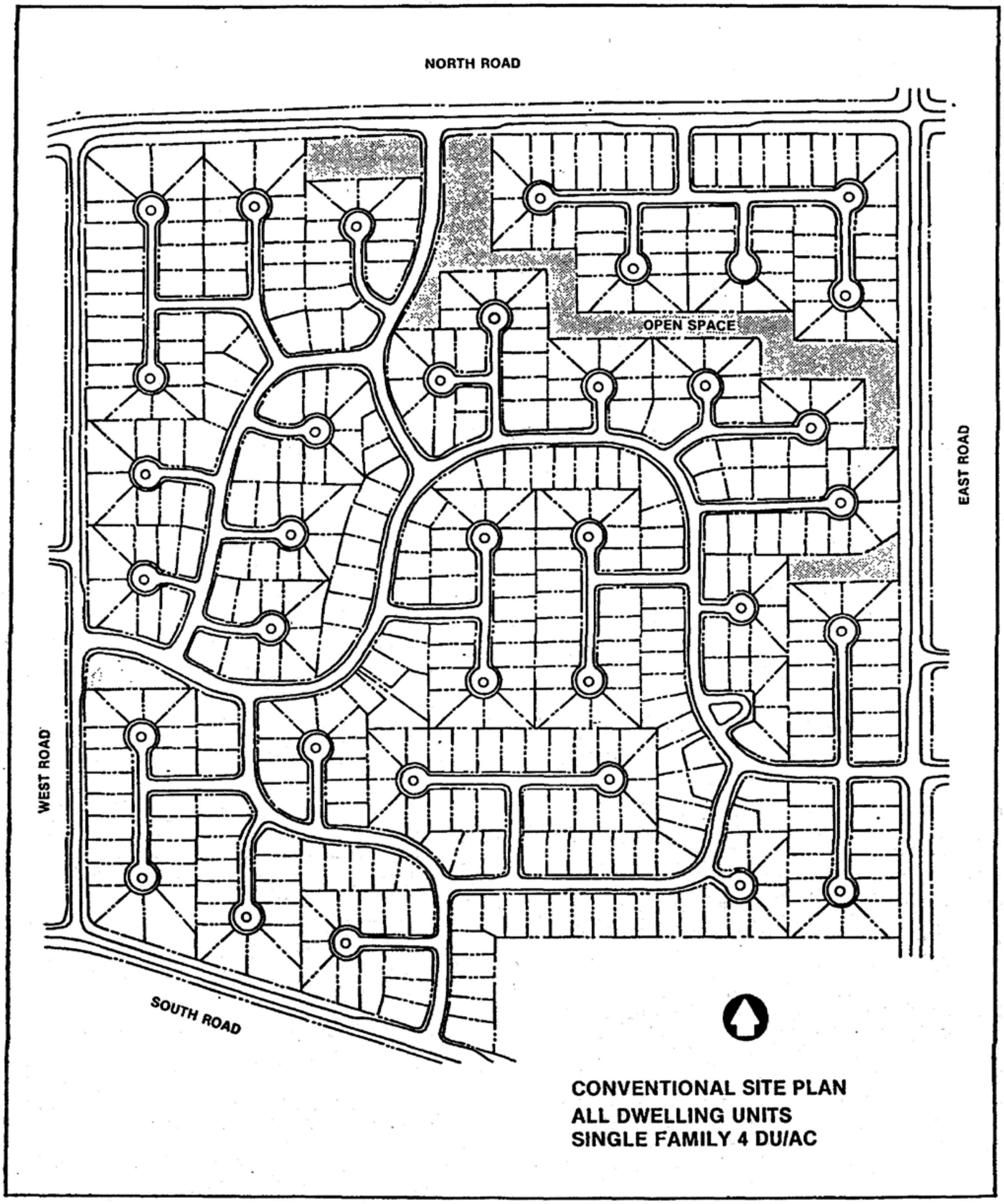


Figure 1-6. Design Principles for Local Street System Incorporated into Site Plan.

h. Pedestrian-Vehicular Conflict Points should be minimized. Pedestrian travel within the area (such as home to school) or from within the area to points outside should require a minimum of street crossings. Sometimes this may be achieved through proper design of street patterns, land use arrangements, school district boundaries and pedestrian routes. Typical methods include use of cul-de-sac and looped streets, special pedestrian routes or walkways, and the proper placement of high pedestrian traffic generators. In general, while vehicular flow must be outward-oriented to the peripheral arterials, pedestrian travel should be inward-oriented to avoid these heavier vehicular flows.

i. Local Street Systems should be Logical and Comprehensible. Systems of Street Names and House Numbers Should be Simple, Consistent, and Understandable. The pattern of local streets, their names and the house numbering system should be designed to satisfy the needs of visitors, delivery trucks, and emergency vehicles as well as local residents. A reasonable repetition in the street pattern, or conformance to topography can help in achieving an understandable street system. Streets which wander directionally or which turn back on themselves tend to be confusing, and should be avoided.

j. Local Circulation Systems and Land Development Patterns Should Not Detract from the Efficiency of Bordering Arterial Routes. This principle may involve control of driveways, intersection placement, and full or partial control of access. Ideally, land development should occur so that no parcels require direct access to arterial routes. Non-channelized intersections along arterial routes should be properly placed for efficient signalization.

k. Elements in the Local Circulation System Should Not Have to Rely on Extensive Traffic Regulations in Order to Function Efficiently and Safely. Consideration of the type and intensity of land use, off-street parking areas, zoning and subdivision requirements, off-street maneuver areas, and other accessory circulation elements concurrently with street design standards will minimize the need for traffic regulation and enforcement. Development controls should be sufficient to provide the circulation amenities necessary to keep the need for enforcement to a minimum.

l. Traffic Generators Within Residential Areas should be considered in the Local Circulation Pattern. Schools, shopping facilities, and churches may cause major traffic congestion on the local street system. To the extent necessary, they should serve as focal points for circulation, not only from within the area but from adjacent neighborhoods as well.

m. Planning And Construction of Residential Streets Should Clearly Indicate their Local Function. These streets should have an appearance commensurate with their function as local streets. They should not be over-designed or overbuilt. Appurtenances should be in keeping with the residential character.

n. If Necessary and Appropriate Provisions for Transit Service Within Residential Areas Should be established. The routing of transit vehicles through a residential area may involve special consideration of street thickness, street widths, pattern of streets, pedestrian circulation system, and pattern of land development. In areas served by a local surface transit company, contact should be made to ascertain whether the company wishes to consider bus routing within the proposed subdivision. The probability and desirability of such service may be expected to increase with development density per acre. In the event transit service is to be considered, the company should, of course, be given the option of plan review with respect to geometric design features. In hilly areas, special attention must also be given to grades. Generally, transit routing should involve use of only collector roadways. Adherence to design standards for collectors will usually result in compatibility with transit vehicle characteristics.

o. A Minimum Amount of Space should be devoted to Street Uses. It is desirable to minimize local street mileage to reduce construction and maintenance costs, as well as to permit the most economic land use.

p. The Arrangement of Local Streets Should Permit Economical and Practical Patterns, Shapes, and Sizes of Development Parcels. Streets as a function of land use must not unduly hinder the development of land. Distances between streets, angles of intersections, numbers of streets, and related elements all have a bearing on efficient development of an area.

SECTION 2

GEOMETRIC DESIGN

2-1. INTRODUCTION.

2-2. This section deals with that phase of street design concerning the visible configuration of the roadway rather than with the structural features of the pavement. It involves those elements and dimensions which have a direct bearing on driver behavior and traffic performance. The various design controls, criteria, and elements presented in this section shall be used to design each roadway facility in such a manner that it will accommodate the expected traffic volume, and will provide consistency and uniformity in traffic operations.

2-3. DESIGN CONTROLS AND CRITERIA.

2-4. DESIGN VEHICLES.

2-5. Design vehicles are selected motor vehicles, the weight, dimensions, and operating characteristics of which are used in street and highway design. In geometric design, the selected design vehicle should be one with dimensions and turning radius as large as almost all vehicles in its class expected to use the street.

Design Vehicle Type	Symbol	Dimensions in Ft.									
		Overall			Overhang		WB_1	WB_2	S	T	WB_3
		Height	Width	Length	Front	Rear					
Passenger car	P	4.25	7	19	3	5	11				
Single-unit truck	SU	13.5	8.5	30	4	6	20				
Single-unit bus	BUS	13.5	8.5	40	7	8	25				
Articulated bus	A-BUS	10.5	8.5	60	8.5	9.5	18		4[a]	20[a]	
Combination trucks											
Intermediate semitrailer	WB-40	13.5	8.5	50	4	6	13	27			
Large semitrailer	WB-50	13.5	8.5	55	3	2	20	30			
"Double Bottom" semitrailer-fulltrailer	WB-60	13.5	8.5	65	2	3	9.7	20	4[b]	5.4[b]	20.9
Recreation vehicles											
Motor home	MH		8	30	4	6	20				
Car and camper trailer	P T		8	49	3	10	11	5	18		
Car and boat trailer	P B		8	42	3	8	11	5	15		

a Combined dimension 24, split is estimated.
b Combined dimension 9.4, split is estimated.
WB_1, WB_2, WB_3, are effective vehicle wheelbases.
S is the distance from the rear effective axle to the hitch point.
T is the distance from the hitch point to the lead effective axle of the following unit.

Table 2-1. Design Vehicle Dimensions.

a. Design vehicle characteristics are used to develop sight distance, intersection design, and other geometric design data.

b. Several design vehicles are used in geometric design, one of which is selected having dimensions and characteristics equal to or greater than those of the largest vehicles expected to use the facility in appreciable numbers (see Table 2-1).

c. Public roadways should never be designed for less than a SU vehicle.

2-6. DESIGN SPEED.

2-7. Design speed is that speed chosen for design and correlation of the physical features of a roadway that influence vehicle operation. It is the maximum safe speed maintainable over a specified section of street/highway when conditions permit design features to govern.

a. Design speed has a direct effect on horizontal curvature, sight distance, and grades.

b. Selection is based on terrain, land use served, functional classification, anticipated volumes, and economic factors.

c. Generally, higher-level functional classifications warrant higher design speeds (see Table 2-2).

d. Design speed should always be higher than the posted speed limit, which is normally set at the 85th-percentile speed.

Street Classification	Design Speed (mph)
Major Arterial	
“AA” & “A”	45
Minor Arterial	
“B” Divided	45
“B5” Undivided	40
Collector	40
“C”	40
“C3” & “D”	35
Local B	30
Local A	30
Rural	30

Table 2-2. Design Speeds for Hudson Oaks Streets.

2-8. DESIGN VOLUME.

2-9. Design volume is the traffic volume determined for design representing the amount of traffic expected to use the facility during a given period.

a. Current average daily traffic (ADT), expressed in vehicles per day, is used in the design of City streets.

b. Design volume represents the traffic ‘load” that the street must accommodate, and determines to a large degree the type of facility, pavement width, and other geometric features required.

2-10. DESIGN DESIGNATION.

2-11. Design designation indicates the major controls for which a particular street is designed. The following tabulation is an example of a design designation for an arterial street.

Design Year	1995
Average Daily Traffic (current year)	10,200
Average Daily Traffic (design year)	18,300
Design Speed	45 mph
Design Level of Service	C
Percent Trucks	5

2-12. Other necessary information for geometric design includes:

a. Applicable design vehicle

b. Type, location, and nature of parking, if required

c. Vehicle turning movements

d. Pedestrian volumes and locations of crossings.

2-13. ROADWAY DRAINAGE.

2-14. The operational ability of roadways is directly affected by the design of associated drainage facilities. For instance, curb drainage inlets which result in roadway depressions in the portion of the traveling lane adjacent to the curb cause "dips" which reduce traffic capacity and create safety hazards. For these reasons, recessed inlets should be used to make the full lane width usable to moving traffic.

2-15. Since it is not economically feasible to design drainage structures to handle the maximum runoff an area is capable of yielding, certain tradeoffs must be made. These tradeoffs may be expressed in terms of design standards and can be stated in general as follows:

a. The design frequency storm must be accommodated. This frequency (recurrence interval or return period) is the average interval of time within which the given flood will be equaled or exceeded once, expressed in years. Thus, a 50-year storm is expected, based on statistical analysis of historical data, to recur within an approximate 50-year period of its last occurrence. It has a 2% chance occurring in any one year. Likewise, the recurrence chance for a 5-year storm is 20%, a 10-year storm is 10%, and a 25-year storm is 4%.

b. The roadway width required to remain open or clear of standing water, generally described in terms of "ponded width."

2-16. Recommended minimum standards for each of these factors are shown in Table 2-3 by roadway classification. As indicated, a five-year design frequency is recommended for the roadway drainage elements of the storm sewer system. Limits are set on the spread of water, or ponded width, so that a certain portion of the roadway remains clear to serve traffic flow. Actual ponded width permitted is dependent on the roadway cross-section and functional classification as shown. The actual design of specific storm sewers and drainage facilities to meet the above standards should be done in coordination with the functional and physical design of other roadway elements.

Street Classification	Design Frequency (years)	Area Free of Storm Water
Major Arterial	**5**	**One lane in each direction**
Minor Arterial	**5**	**One lane in each direction**
Collector	**5**	**One lane (12' center lane)**
Local	**N/A**	
Rural	**N/A**	

Table 2-3. Minimum Drainage Design Standards.

2-17. DESIGN ELEMENTS.

2-18. The design elements contained in the following paragraphs are common to all types of streets, and are essential for their proper design and operation.

2-19. LANE WIDTHS.

2-20. Through lanes on all arterial and collector streets should be 12-feet wide. This width is considered to be the optimum width for capacity and proper operation. In new construction, total roadway widths *are* predicated upon use of 12-foot lanes by the street classification system previously presented. In reconstruction projects, however, stringent controls of right-of-way and existing development may make the use of 11-foot lanes necessary. Any width less than 11-feet must be approved by the appropriate City and/or State officials after consideration of all constraints of the specific situation.

2-21. Generally, parking lanes are incompatible with arterial traffic. Therefore, provisions for parking lanes have been made only on collector and local streets in the street classification system. In these cases, a parking lane width of 8-feet has been provided.

2-22. SIGHT DISTANCE.

2-23. The ability of the driver to see the road ahead and his awareness of the features and conditions of the road which lie before him are of utmost importance in the safe and efficient operation of any roadway. This ability to see is referred to as sight distance, which is simply the length of roadway ahead visible to the driver.

2-24. ***Stopping Sight Distance.***

2-25. Stopping sight distance is the length of roadway ahead visible to the driver, measured from a driver's eye height of 3.50 feet to an object height of six inches. It is composed of two parts: (1) brake reaction distance, which is the distance a vehicle travels from the time the driver sights an object to the time the brakes are applied, and (2) braking distance, which is the distance required for the vehicle to stop after the brakes are applied. Stopping sight distance should be adequate at every point along a roadway for drivers to come to a safe stop before reaching an object.

2-26. Stopping Sight Distance (SSD) in feet is determined from the formula:

$$SSD = 1.47PV + \frac{V^2}{30(f \pm G)}$$

where

V = speed from which stop is made, in miles per hour,
P = perception-reaction time, in seconds, (normally 2.5 seconds).
f = coefficient of friction (for wet pavement), and
G= percent of grade divided by 100 (added for upgrade or subtracted for downgrade).

2-27. The minimum and desirable stopping sight distances for various street classifications and design speeds are given in Table 2-4. Desirable stopping sight distances should be used for design if at all possible. Values less than the minimum should never be considered.

Street Classification	**Design Speed (mph)**	**Stopping Sight Distance (ft.)**	
		Minimum	**Desirable**
Major Arterial (divided)			
"AA"	45	360	400
"A"	45	360	400
Minor Arterial			
"B" (divided)	45	360	400
"B5" (undivided)	40	300	335
Collector			
"C"	40	300	350
"C3" & "D"	35	250	285
Local "A" & "B"	30	200	235
Rural	30	200	235

Table 2-4. Minimum and Desirable Stopping Sight Distances.

2-28. ***Intersection Sight Distance.***

2-29. For determination of intersection sight distance, refer to Section 3.

2-30. HORIZONTAL ALIGNMENT.

2-31. Horizontal alignment of roadways requires the use of circular curves to form smooth transitions from one straight roadway section to another. Criteria for determining the maximum allowable limits of such curves are based on the laws of mechanics and consider factors such as the practical limitations of superelevation and friction factors representative of pavement surfaces. The basic formula for determining horizontal alignment is:

$$e + f = \frac{v^2}{15R}$$

where e = rate of roadway superelevation, foot per foot,
f = side friction factor

v = vehicle speed, mph
R = radius of curve in feet

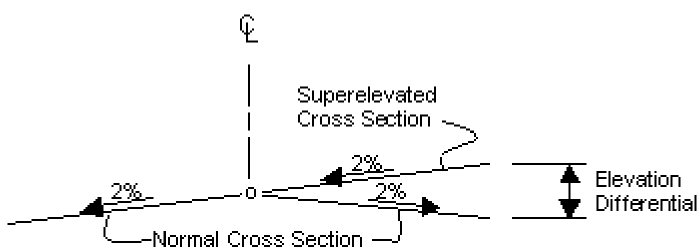
or, since horizontal curves are usually described by their radius,

$$R = \frac{v^2}{15(e+f)}$$

Street Classification	Street Width (ft)	Urban Street Speed Category	Design Speed (mph)	Side Friction Factor	Superelevated Cross Section (ft/ft)	Minimum Roadway Centerline Radius		Elevation Differential with 2% Superelevation (ft)
						Normal Cross Section (ft)	2% Superelevated section (ft)	
AA	2-36	High	45	.154	.020	1000	NA	NA
A	2-33	High	45	.154	.020	1000	NA	NA
B	2-26	High	45	.154	.020	1000	NA	NA
B5	62	High	40	.160	.020	760	700	1.24
C	48	High	40	.160	.020	760	700	0.96
C3	45	Low	35	.190	.020	480	410	0.90
D	40	Low	35			480		
Local B	36	Low	30			300		
Local A	30	Low	30			300		
Rural	24	Low	30			300		
SOURCE – AASHTO Recommendations from *A Policy on Geometric Design of Highways and Streets*, Copyright 1984. *Sufficient tangent distance on both ends of horizontal curves must be available in order to obtain appropriate transition sections.								

Table 2-5. Minimum Radii for Horizontal Curve Design.

2-32. Table 2-5 provides the minimum roadway centerline radii for horizontal curves on roadways with City of Hudson Oaks standard “roof top” cross section at 2% cross slope, and for horizontal curves on roadways with a 2% superelevation across the pavement section. With approval of the City Engineer, superelevation may be used in accordance with the values provided in Table 2-6.



Street Classification	Street Width (ft)	Design Speed (mph)	Superelevation (ft/ft)	Minimum Centerline Radius (ft)	Elevation Differential (ft)	Superelevation Transition Length (ft)
B5	62	40	0.020	700	1.24	200
C	48	40	0.020	700	0.96	200
C3	45	35	0.020	410	0.90	135

Table 2-6. Minimum Superelevation Transition Lengths

2-33. VERTICAL ALIGNMENT.

2-34. Vertical alignment consists of combinations of straight sections, referred to as tangents or grades, and curves, referred to as vertical curves. The selection of lengths of grade and vertical curve is based upon assumptions concerning driver, vehicle, and roadway characteristics. The significant terms used to describe profile points are shown in Figure 2-1.

2-35. ***Grades.***

2-36. Driving performance of vehicles with respect to grades varies greatly. Modern passenger vehicles are equipped with sufficient power to ascend grades up to 7 and 8 percent without appreciable reduction in speed. The effect of grades on trucks is much more pronounced than on speeds of passenger cars. On upgrades, the maximum speed that can be maintained by a commercial vehicle is dependent primarily on the length and steepness of grade and upon the ratio of the gross vehicle weight to the engine horsepower. Certain combinations of rate and length of grade cause trucks to decelerate to the point of constant critical or "crawl" speed, for some trucks as low as eight to 10 mph. Maximum grades have been set relative to design speeds in recognition of such characteristics. Table 2-9 includes a summary of allowable grades for streets in Hudson Oaks.

2-37. Minimum grades are based upon drainage considerations. On curbed streets, a minimum grade of 0.5 percent is accepted for design. Grades of roadside channels may vary from the roadway profile to provide adequate drainage.

2-38. ***Vertical Curves.***

2-39. The simple parabola is used for design of vertical curves by AASHTO and throughout North America. There is no significant difference between the circular curve and the parabola within the practical limit of moderate grades used in current design. The general properties of vertical curves are summarized in Figure 2-1 and 2-1A.

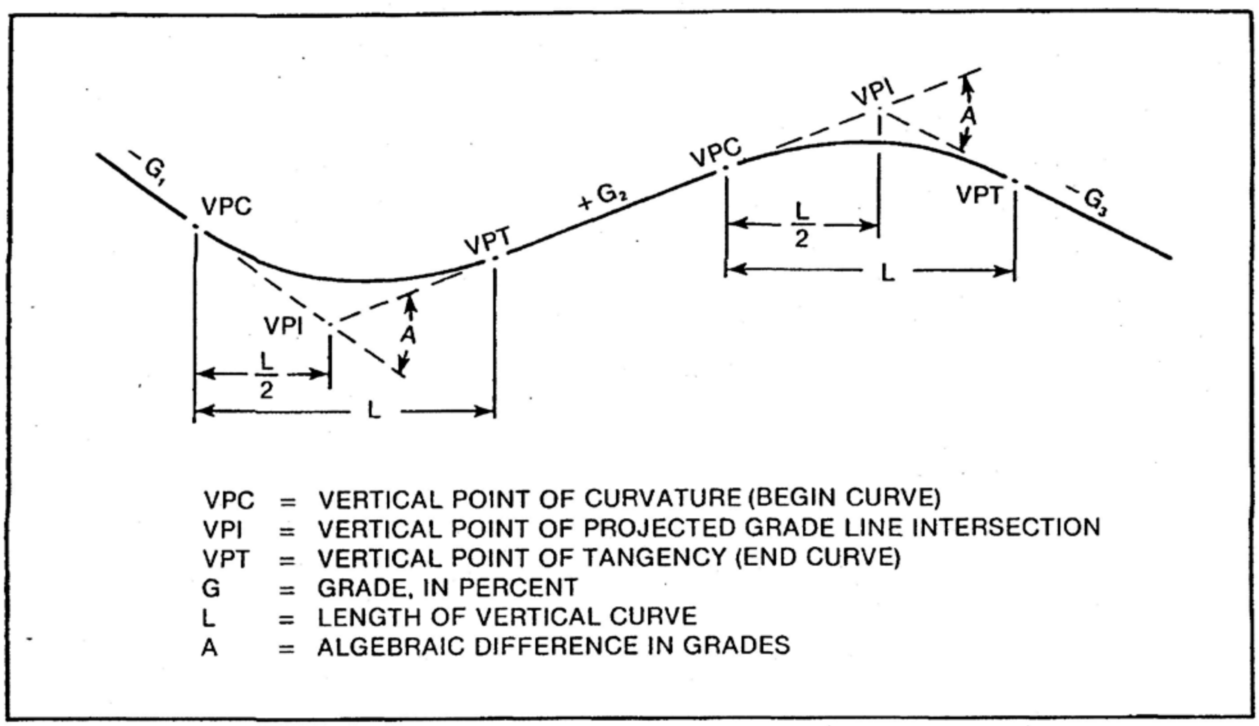


Figure 2-1. Vertical Curve Profile Components and Nomenclature.

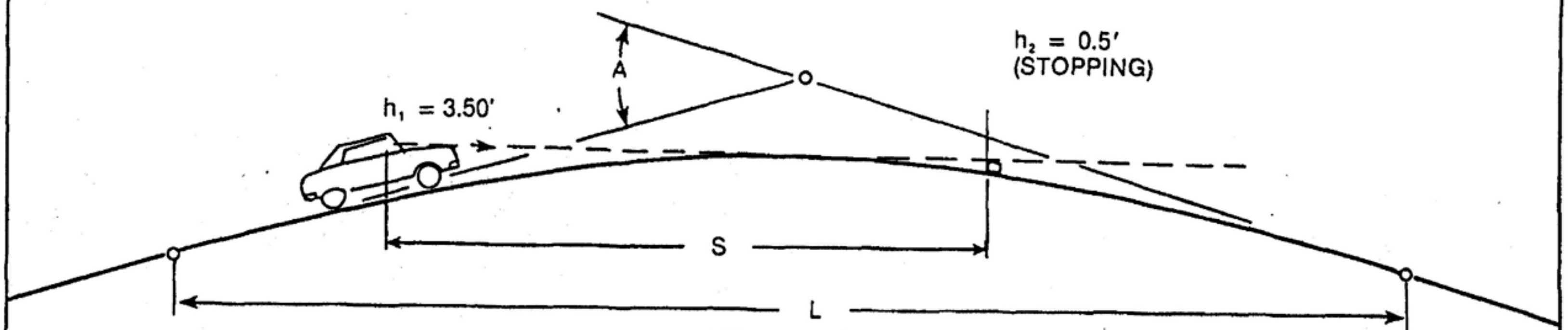
2-40. The length of curve for a given combination of grades, and thus the rate of curvature (K), is affected by considerations of (1) sight distance, (2) comfort, (3) drainage, and (4) appearance or aesthetic quality. The determining factor in both the minimum length of curve and K for a given design speed usually is the minimum sight distance, although vertical curves should be of liberal length where feasible.

2-41. The relationship between vertical curve properties and sight distance is illustrated for both crest and sag curves in Figure 2-2. The lengths of curves to satisfy the requirements of sight distances, expressed in terms of K values, for various design speeds are presented in Table 2-8. The vertical curve design criteria are thus conveniently identified by K values, since the property of the vertical curve adopted is such that the ratio L/A, termed K, is a constant amount for equal increments of horizontal distance. Expressing it another way, K is the horizontal distance in feet required to effect a 1 percent change in gradient. Thus, having the value of K established, the length of curve is found by multiplying K by the algebraic difference in grades (i.e. L = KA).

Design Speed, mph	**30**	**35**	**40**	**45**
K value for:				
Crest Vertical Curves	30	50	80	120
Sag Vertical Curves	40	50	70	90

Table 2-8. K Values for Vertical Curves Based on Stopping Sight Distances

2-42. Drainage requirements for vertical curves, particularly for sags (although crests likewise can have sufficiently flat portions), are difficult to achieve on high design speed streets. Both for sags and crests, a minimum grade of 0.35 percent within 50-feet of the level point on the curve, corresponding to a K value of 167, is considered maximum curvature for drainage.

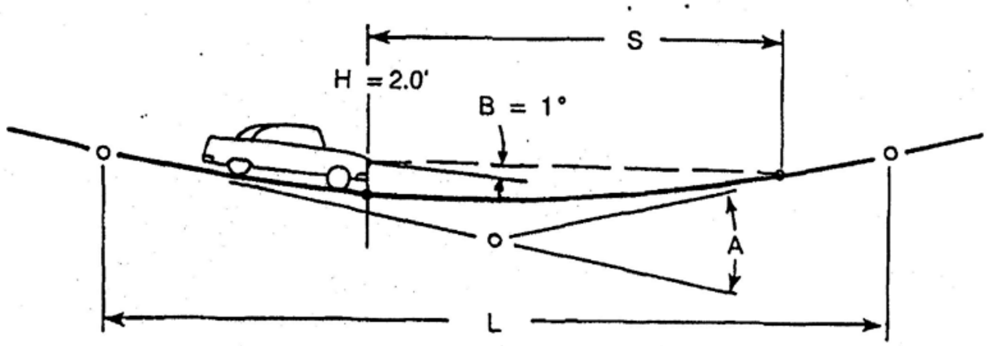


CREST : WHEN $S < L$ $\quad L = \dfrac{AS^2}{100\left(\sqrt{2h_1} + \sqrt{2h_2}\right)^2}$

But when h_1 is 3.50' and h_2 is 0.5' then

when $S < L$, $L = \dfrac{AS^2}{1{,}329}$ or $K = \dfrac{S^2}{1{,}329}$

(FORMULA DIFFERENT FOR WHEN $S > L$, BUT DOES NOT APPLY TO GEOMETRIC DESIGN CRITERIA)



L = LENGTH OF VERTICAL CURVE, FT.
A = ALGEBRAIC DIFFERENCE IN GRADES, %
S = SIGHT DISTANCE, FT.
K = VERTICAL CURVATURE, L/A
H = HEADLIGHT HEIGHT, FT.
B = UPWARD DIVERGENCE OF LIGHT BEAM, DEGREES
h_1 = DRIVER'S EYE HEIGHT
h_2 = OBJECT HEIGHT IN ROADWAY

SAG: WHEN $S < L$, $\quad L = \dfrac{AS^2}{200\,(H + S \tan B)}$

FOR PASSENGER CARS: $L = \dfrac{AS^2}{(400 + 3.5\,S)}$ or $K = \dfrac{S^2}{(400 + 3.5\,S)}$

Figure 2-2. Relationship of Vertical Curve Properties to Sight Distance.

2-43. **SUMMARY OF STREET DESIGN CRITERIA AND ELEMENTS.**

2-44. Table 2-9 provides a summary of all of the street design criteria and design elements for each of the various street classifications presented in Sections 1 and 2.

Criteria/Element	**Street Classification**									
	Major Arterial		Minor Arterial		Major Collector		Minor Collector	Local B	Local A	Rural
	"AA"	"A"	"B"	"B5"	"C"	"C3"	"D"			
R.O.W. (ft)	120'	100'	90'	90'	80'	80'	60'	50'	50'	60'
Roadway width (ft)	(2) 36'	(2) 33'	(2) 26'	1-62'	(1) 48'	(1) 45'	(1) 40'	(1) 36'	(1) 30'	(1) 24'
# lanes & width (ft)	6-12'	6-11'	4-13'	4-12' & 1-14'	4-12'	3-15'	2-12' & 2-8'	2-10' & 2-8'	1-14' & 2-8'	2-12' & 2-4' shoulders
Parking Lanes	-	-	-	-	-	-	2-8'	2-8'	2-8'	-
Median Width	16'	14'	14'	-	-	-	-	-	-	-
Tn. Ln. Width (ft)	-	-	-	14'	-	15'	-	-	-	-
Parkway width	15.5'	9.5'	11.5'	13.5'	15.5'	17'	9.5'	6.5'	9.5'	14'
Sidewalk	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Design Speed	45	45	45	40	40	35	35	30	30	30
Grade										
Max. %	6	6	6	6	8	8	8	10	10	10
Min. %	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Design Frequency (yrs)	5	5	5	5	5	5	5	-	-	-
For Lane Free of Storm Water	1 Each Way	1 Each Way	1 Each Way	1-14' Ctr. Ln	1-12' Ctr. Ln	1-12' Ctr. Ln	1-12' Ctr. Ln	-	-	-
Stopping Sight Distance										
Desirable (ft)	400'	400'	400'	335'	350'	285'	285'	235'	235'	235'
Minimum (ft)	360'	360'	360'	300'	300'	250'	250'	200'	200'	200'
Horizontal Curves										
Min. Centerline Radius										
W/Normal X sec	1000'	1000'	1000'	760'	760'	480'	480'	300'	300'	300'
W/2% superelevation	-	-	-	700'	700''	410'	-	-	-	-

Table 2-9. Summary of Street Design Criteria and Elements

PAVEMENT STANDARDS SUMMARY	
STREET CLASSIFICATION	**STANDARD PAVEMENT SECTION**
MAJOR ARTERIAL	• 8” Reinforced Concrete
MINOR ARTERIAL	• 8 “ Reinforced Concrete
MAJOR COLLECTOR (commercial)	• 8” Reinforced Concrete • 2” HMAC Type “D”-6” HMAC Type “B”
MINOR COLLECTOR (residential)	• 2” HMAC Type “D” – 11” base Course • 2” HMAC Type “D” – 6” HMAC Type “B” • 8” Reinforced concrete
LOCAL B	• 2” HMAC Type “D” – 8” base Course • 2” HMAC Type “D” – 4” HMAC Type “B” • 5” Reinforced concrete
LOCAL A	• 2” HMAC Type “D” – 8” base Course • 2” HMAC Type “D” – 4” HMAC Type “B” • 5” Reinforced concrete
RURAL	• 2” HMAC Type “D” – 8” Base Course
NOTES: ALL STREETS EXCEPT RURAL STREETS SHALL HAVE A 24” CURB & GUTTER SECTION. See construction standards. ALL CONCRETE SHALL BE CLASS “C” (MINIMUM 3600 P.S.I.). See construction standards.	
Table 2-10.	

- 6” soil stabilization is required where:

a) P.I. ≥15, Hydrated lime applied at 6% by weight (27#/S.Y. Min.)
b) P.I. ≤ 10, Portland Cement applied at 5% by weight (26#/S.Y. Min.)

Quantity of lime or cement may vary, or a combination of both, as recommended by a geotechnical report based on subgrade soil investigation.

SECTION 3
INTERSECTION DESIGN

3-1. INTRODUCTION.

3-2. The successful operation of urban streets depends largely upon the design of at-grade intersections. Normally, all through and turning movements must be accommodated through these intersections where many of the most critical problems of traffic operation, capacity, and safety frequently occur. This section provides information concerning those elements and criteria of design which must be considered in the design of efficient at-grade urban intersections.

3-3. BASIC INTERSECTION FORMS.

3-4. There are four basic forms of at-grade intersections: three-leg (T or Y), four-leg, multi-leg, and rotary. Each of these basic forms can be further classified as unchannelized, flared, or channelized as shown in Figure 3-1. The selection of intersection type and configuration should consider:

a. Total approach traffic, design hourly volumes, and turning volumes.
b. Composition of traffic (percent of passenger cars, buses, trucks, etc.)
c. Operating speed of vehicles on the streets.
d. Adjacent land use.

3-5. DESIGN OBJECTIVES.

3-6. There are several main objectives to be accomplished in the design of intersections. These objectives concern safety, efficiency, and driver convenience.

a. One of the most important objectives is to reduce the severity of potential conflicts while facilitating the ease and comfort of drivers in making the necessary maneuvers.

1. Four types of vehicular maneuvers take place in intersection areas and involve potential conflicts. The four maneuvers are diverging, merging, weaving, and direct crossing, and are shown in Figure 3-2.

2. The relative severity of the potential conflict in each maneuver increases in the same order.

b. The design should fit the natural transitional paths and operating characteristics of drivers and vehicles. Smooth transitions should be provided for changes in direction.

c. Grades should be as nearly level as possible.

d. Sight distances should be sufficient to enable drivers to prepare for and avoid potential conflicts.

e. On arterial and collector streets, intersections should be evenly spaced to the greatest extent possible. Such an arrangement enhances the synchronization of signals, increases driver comfort, improves traffic operation, and reduces fuel consumption.

3-7. DESIGN PRINCIPLES:

3-8. Individual maneuvering areas are the smallest unit of intersection design. They may be combined in many different ways to produce various geometric designs for any intersection. To a considerable degree their arrangement, extent, and whether certain features can be provided, even where otherwise desirable, is governed by traffic demands, topography, land use, and economic considerations. Intersection design should always consider the following fundamental principles:

a. Reduce number of conflict points. The number of conflict points among vehicular movements increases significantly as the number of intersection legs increases. For example, an intersection with four two-way legs has 32 total conflict points, but an intersection with six two-way legs has 172 conflict points. Intersections with more than four two-way legs should be avoided wherever possible.

b. Coordinate design and traffic control. Maneuvers at intersections accomplished at low relative speeds require a minimum of traffic control devices. Maneuvers accomplished at high relative speeds are unsafe unless traffic controls such as stop signs or traffic signals are provided. Designs should physically divert or block the path of vehicles making dangerous movements. Intersection design should be accomplished simultaneously with the development of traffic control plans.

c. Use the optimum crossing method. Vehicle crossing maneuvers can be accomplished in four ways: (1) uncontrolled crossing at-grade, (2) traffic sign or signal-controlled crossing at-grade, (3) weaving, and (4) grade separation. In general, both operational efficiency and construction cost increase in this

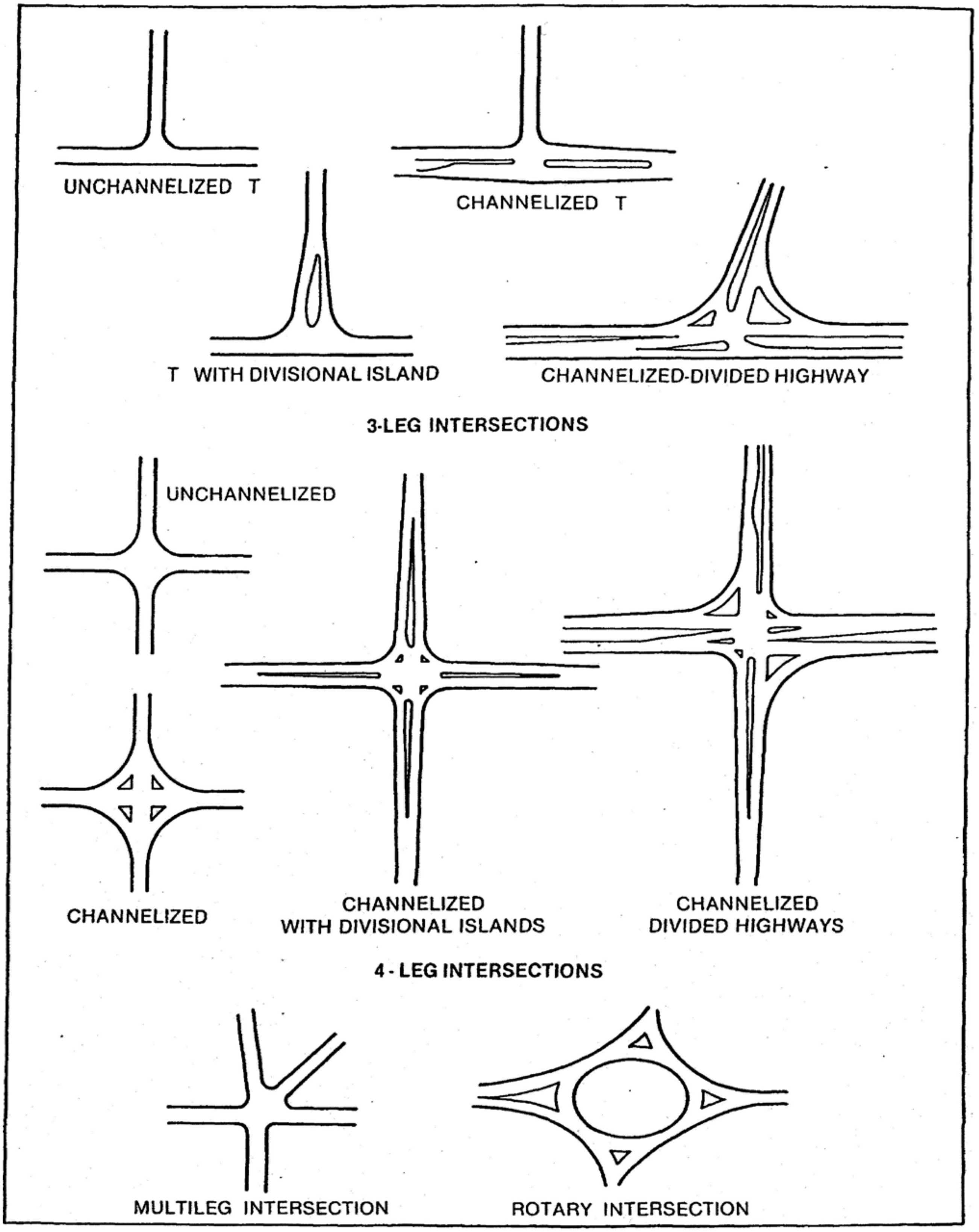


Figure 3-1. Basic Forms of At-Grade Intersections.

order. The type used should be consistent with the numbers and types of vehicles using the intersection.

d. Provide an alternative turning path. The method of providing turns can be changed. Separate roadways can be provided both for right- and left-turning vehicles, thereby reducing conflicts in the intersection area. For example, a direct connection can be provided to accommodate right turns at an intersection.

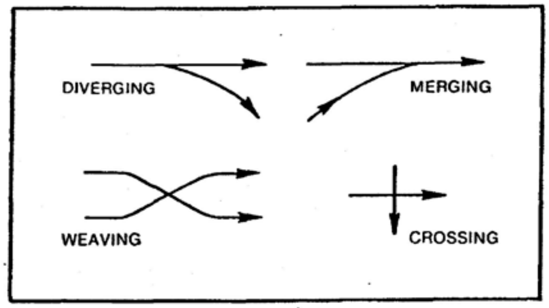


Figure 3-2. Intersection Vehicular Maneuvers Involving Conflict.

e. Avoid multiple and compound merging and diverging maneuvers. Multiple merging or diverging requires complex driver decisions and creates additional conflicts.

f. Separate conflict points. Intersection hazards and delays are increased when intersection maneuver areas are too close together or when they overlap. These conflicts may be separated to provide drivers with sufficient time (and distance) between successive maneuvers for them to cope with the traffic situation.

g. Favor the heaviest and fastest flows. The heaviest and fastest flows should be given preference in intersection design to minimize hazard and delay.

h. Reduce area of conflict. Excessive intersection area causes driver confusion and inefficient operations. Large areas are inherent in skewed and multiple-approach intersections. When intersections have excessive areas of conflict, channelization should be employed.

i. Segregate nonhomogenous flows. Separate lanes should be provided at intersections when there are appreciable volumes of traffic traveling at different speeds. For example, separate turning lanes should be provided for turning vehicles.

j. Consider the needs of pedestrians and bicyclists. For example, when there are pedestrians crossing wide streets, refuge islands should be provided so that more than five lanes do not have to be crossed at a time.

3-9. INTERSECTION DESIGN ELEMENTS.

3-10. Geometric design elements have a strong influence on the safety and efficiency of operation of at-grade intersections, and cannot be neglected. The requirements for turning movements, cross sectional features, turning lanes, intersecting profiles, sight distance, and driveways are presented in the following paragraphs.

3-11. TURNING MOVEMENTS.

3-12. The horizontal design of a roadway in the area of an intersection is the same as for the approaching roadways, except for the provision of turning movements and sometimes widening through the intersection to accommodate through traffic. The layout to accommodate the turning movements and the necessary through lanes determines the design of an intersection.

3-13. *Turning Speeds.*

a. Left turns necessitate direct crossings of opposing vehicle paths and are usually made at speeds of 10-mph or less for reasons of safety and economy.

b. Right turns are also usually made at minimum speeds. However, right turns do not involve potential conflicts of such severity as left turns, and are more suited to individual treatment because they take place at the outside of the intersection area. Therefore, right turns may be designed for higher than minimum speeds in some special urban situations where adequate right-of-way is available for wider turns.

3-14. ***Turning Paths.***

a. The intersection should be able to accommodate right turns by the selected design vehicles without having to back up to complete the maneuver.

b. The shapes and dimensions of turning paths vary for different turning speeds, different angles of turn, and for different types and sizes of vehicles.

c. Selection of the appropriate design vehicle depends upon the types of vehicles expected in the intersection area. However, allowance should be made for occasional semitrailer combinations in most intersection designs even where very few of these vehicles are expected to travel. Even on facilities designed primarily for passenger vehicles, the SU design vehicle is recommended as the basis for selection of minimum intersection dimensions.

d. The WB-40 and WB-50 design vehicles should be used where trucks approximating these sizes will turn repeatedly and for important turning movements on all major public streets.

e. Curb Returns at intersections shall have a minimum radius as follows:

Arterial/Arterial	35 feet*
Arterial/Collector	30 feet*
Arterial/All others	30 feet
Collector/Collector	30 feet
Collector/All others	20 feet
All others	20 feet

* 80-foot radius is desirable for free right turn lanes.

The minimum radius for the travel surface on a residential cul-de-sac shall be 40 feet (40.5 feet to back of curb) with a right-of-way radius of 50 feet.

3-15. ***Simple Curves.***

3-16. Simple circular curves with suitable tapers may be used for right turns which are to be made at higher than minimum speeds. Table 3-1 provides design data where tapers and simple curves are used; compound curves may also be used.

Angle of Turn (deg)	Design Vehicle	Simple Curve Radius (ft)	Simple Curve Radius with Taper		
			Radius (ft)	Offset (ft)	Taper
75	P	30	25	2.0	10:1
	SU	55	45	2.0	10:1
	WB-40	—	60	3.0	15:1
	WB-50	—	65	3.0	15:1
	WB-60	—	90	3.0	15:1
90	P	30	20	2.5	10:1
	SU	50	40	2.0	10:1
	WB-40	—	45	4.0	10:1
	WB-50	—	60	4.0	15:1
	WB-60	—	75	4.0	15:1
105	P	—	20	2.5	8:1
	SU	—	35	3.0	10:1
	WB-40	—	40	4.0	10:1
	WB-50	—	55	4.0	15:1
	WB-60	—	65	5.0	15:1
120	P	—	20	2.0	10:1
	SU	—	30	3.0	10:1
	WB-40	—	35	5.0	8:1
	WB-50	—	45	4.0	15:1
	WB-60	—	50	6.0	15:1
135	P	—	20	1.5	15:1
	SU	—	30	4.0	8:1
	WB-40	—	30	8.0	6:1
	WB-50	—	40	6.0	10:1
	WB-60	—	45	7.0	10:1
150	P	—	18	2.0	10:1
	SU	—	30	4.0	8:1
	WB-40	—	30	6.0	8:1
	WB-50	—	35	7.0	6:1
	WB-60	—	40	7.0	8:1
180	P	—	15	0.5	20:1
	SU	—	30	1.5	10:1
	WB-40	—	20	9.5	5:1
	WB-50	—	25	9.5	5:1
	WB-60	—	25	14.5	5:1

Table 3-1. Minimum Edge of Pavement Designs for Turns at Intersections.

3-17. **CROSS SECTIONAL FEATURES.**

3-18. ***Lanes.***

a. The number of lanes is determined by the width and functional classification of the street. Refer to Section 1 for the number and width of lanes for each type street.
b. In intersection reconstruction projects, 11 to 13-feet widths are required for all through and turning lanes, with 12-feet being the optimum width.
c. Parking lanes are 8-feet wide.
d. The use of through or turning lanes less than 11-feet wide must be approved by the City Engineer.

3-19. ***Curbs.***

a. Barrier curbs are used on most City streets, medians, traffic channelization islands, and pedestrian refuge islands.
b. Barrier curbs are normally 6-inches high with an 18-inch gutter. (24” curb & gutter section.)

c. Barrier curbs used for traffic channelization or pedestrian refuge islands, or otherwise introduced intermittently along the edge of the roadway, must be set back 2-feet from the normal edge of pavement.

3-20. ***Medians.***

a. Median widths range from 16 feet to 14 feet on arterial streets down to a minimum of 4 feet for traffic separation for left turn lanes, and the placement of traffic signal standards and/or street signs.

b. Barrier curbs are used in the construction of medians.

c. For curbed medians 5-feet wide, the end (nose) is usually semi-circular. For wider widths, the ends are normally shaped to a bullet nose pattern to better conform with the path of turning vehicles.

d. Considering the range of radii for minimum turns, the following control radii can be used for minimum practical design of bullet nose median ends.

1. R = 40' accommodates P vehicles and occasional SU vehicles with some swinging wide (Figure 3-3). These radii should be used where the cross street is either a Local A or a Local B Street.
2. R = 50' accommodates SU and occasional WB-40 vehicles with some swinging wide (Figure 3-4). These radii should be used where the cross street is a Collector.
3. R = 75' accommodates WB-40 and WB50 vehicles with only minor swinging wide at end of turn. These radii should be used where the cross street is either a Major or Minor Arterial.

e. For information concerning median opening width, spacing, and associated left-turn channelization, refer to Section 5.

3-21. TURNING LANES.

3-22. The primary purpose of turning lanes at intersections is to provide storage space so that right and left turning vehicles can stand clear of traffic in the through lanes. Another purpose is to provide space for turning vehicles to decelerate from the normal speed of traffic to a stopped position in advance of the intersection or to a safe speed for the turn in case a stop is unnecessary. When placed on the left of traffic to accommodate left turning vehicles, they are referred to as left-turn lanes, left-turn slots, or left-turn bays, and those on the right are referred to as right-turn lanes. On divided arterial streets, left-turn lanes within the median are sometimes referred to as median lanes. At signalized intersections, right-turn lanes also serve as a bypass lane so that right turning vehicles can maneuver around a standing queue for a right turn on red or free right turn under yield conditions without adding to the congestion at the intersection.

3-23. ***General Features.***

a. The width of turning lanes should be a minimum of 11-feet; a width of 12-feet is preferred.

b. The length of turning lanes consists of three components: storage length, taper, and deceleration length.

c. Desirably, the total length of the turning lane should be the sum of the length of the three components. It is common practice, however, to accept a moderate amount of deceleration within the through lanes and to consider the taper as part of the deceleration length.

d. Where intersections occur as frequently as four per mile, it is customary to forego most of the deceleration length and to provide only the storage length plus taper.

3-24. ***Storage Length.***

a. The storage length provided in turning lanes should be sufficiently long to store the maximum number of vehicles likely to accumulate during a critical period.

b. The storage length should be long enough so that the entrance to the storage lane is not blocked by vehicles stopped in the through lanes waiting for a signal change.

c. The storage length should also be long enough to avoid the possibility of vehicles in the storage lane backing up into the through lanes.

d. If turning volumes are known or can be accurately estimated, the required storage length can be calculated from the expression:

$L = 25N$

Where L = Length of storage lane, in feet and N = Number of vehicles expected in the queue during the peak 30-minute traffic period, using a Poisson Distribution, a 90% confidence level, and a 90-second arrival period.

e. If turning volumes are unknown, or insufficient data is available to accurately determine turning volumes, then the storage lengths described below under "Supplementary Design Requirements for Turning Lanes" should be provided as a minimum.

3-25. ***Taper.***

a. The taper should be long enough to avoid a dead spot of unused pavement where full width is attained.

b. For collector streets, the taper shown in Figure 3-6 should be used.

c. For undivided arterial streets, the taper shown in Figure 3-7 should be used.

3-26. ***Deceleration Length.***

a. The deceleration length required is the length needed for a comfortable stop from a speed that is typical of the average running speed on the street.

b. Deceleration lengths needed to bring a vehicle to a stop are given in Table 3-2. These lengths include the length of taper.

c. On some arterial streets, it may not be feasible to provide the full length for storage. In such cases, at least part of the deceleration must be accomplished in the through lane before entering the taper.

d. Deceleration lengths shown in Table 3-2 are applicable to both left and right turning lanes. However, average vehicle speeds are usually lower in the right through lane than in the left lane.

Average Running Speed (mph)	Deceleration Length Including Taper (feet)
20	160
30	250
40	370
45	435

Table 3-2. Desirable Deceleration Lengths.

3-27. SUPPLEMENTARY DESIGN REQUIREMENTS FOR TURNING LANES.

3-28. Additional right-of-way will often be required at intersections where additional lane width or channelization is needed to provide vehicle storage for efficient traffic operations. Ideally, the traffic capacity through an intersection should be equal to the traffic capacity of all streets entering the intersection. Since each approach of an intersection must share time with conflicting movements, the intersection will become a traffic "bottleneck" unless additional capacity is provided for the streets approaching the intersection. Maximum intersection capacity, then, can only be attained by providing additional separate lanes for right and left turning movements.

3-29. In order to provide the most efficient intersection design, roadway widening for additional lanes or channelization will be required at intersections as discussed in the following paragraphs.

3-30. Collector *Streets.*

3-31. Collector streets should be widened to a minimum of 44 feet at least 180 feet in advance of their intersection with another collector street or with any arterial street. This widening will provide for two lanes of storage on the collector street approaching the intersection. The additional lane thus provided may be used for either a left-turn or right-turn lane. The widening should occur to the right side of the collector street approaching the intersection. Since vehicles will be required to negotiate the offsetting maneuver, the transitional curb section should be designed with horizontal curve radii adequate for the design speed of the roadway. Figure 3-6 shows the roadway widening design approach recommended for use on collector streets.

3-32. *Arterial Streets.*

3-33. Left Turn Channelization.

a. All arterial streets should have left turn channelization on their approaches to collector streets and to other arterial streets. Left turn lanes should be 12-feet wide with a minimum storage length of 150-feet at intersections with collector or minor arterial streets, and 200-feet at intersections with major arterial streets.
b. All median openings on divided arterial streets shall have a left turn lane for both approaches to the median opening. The storage length thus provided shall be at least 100-feet in length. Figure 3-8 shows the design requirements for left turn lanes constructed within the median area of divided arterial streets.
c. Left turn lanes on divided arterial streets can be accommodated by constructing the turning lane within the median area. However, left turn lanes on undivided arterial streets require a transition of the through lanes in order to create additional space for the left turn slot. This requires additional right-of-Way throughout the storage length and transition area. In order to minimize the transition offset for the through lanes of undivided arterial streets, the roadway should be widened equally on both sides of the normal roadway width. This will create a transition offset of only six feet for the through lanes. Since vehicles in the through lanes are required to make the offsetting maneuver, the horizontal radii of the outside curbs will be dictated by the design speed of the roadway. Figure 3-7 shows the design approach recommended for use on undivided arterial streets.

3-34. Right Turn Channelization.

a. All major arterial streets shall have separate right turn lanes on their approach to other arterial streets unless specifically waived by the City Engineer. Minor arterial streets may be required to have separate right turn lanes on their approach to other arterial streets. Such requirements will be made at the time of platting. The City of Hudson Oaks has adopted two types of right turn lane configurations:

   Controlled right turn lane — A right turn lane where vehicles must conform to the traffic control devices regulating the main intersection.
   Free right turn lane—A right turn lane separated from the main intersection by a right turn island that permits low speed turning movements operating under “yield” control.
b. Normally, the controlled right turn lane is used for design involving undivided arterial streets, and the free right turn lane is used for design involving divided arterial streets. Since the right turning movements are reduced speed minor movements, the transitions need not be dictated by the design speed of the arterial street. The transitions should, however, be designed to provide for vehicular lane changes at speeds of 30 to 35 miles per hour.
c. Figure 3-9 shows the controlled right turn lane design approach recommended for use on undivided arterial streets. Figure 3-10 shows the free right turn lane and other variable design parameters recommended for use on divided arterial streets.

3-35. ***Special Design Considerations.***

3-36. There are many factors which may influence requirements for additional turning lanes or channelization that are not discussed above. T-intersections, skewed intersections, or intersections with unusual geometric or geographical conditions may require unique applications of roadway widening or channelization techniques, or, perhaps, none at all. These situations should be brought to the attention of the City Engineer as early as possible in the design phase of the roadway project so that acceptable variations can be agreed upon. This will likely prevent most difficulties in obtaining plan approval during the final review process.

3-37. INTERSECTING PROFILES.

3-38. The intersecting and combining of grade lines that must take place in an intersection area can pose some unusual problems in profile design.

a. It is desirable generally to avoid substantial grade changes and combinations of grade lines that could make vehicle control difficult.
b. The gradients of intersecting roadways should be held as near level as practicable for those pavement surfaces where vehicles must stop and wait as in left turn storage lanes.
c. Grades in excess of three-percent should be avoided. A practical maximum grade of two-percent is desirable.
d. Drainage design should avoid the use of valley gutters or swales across the major roadway within

the area of an intersection.

e. Figure 3-11 shows one example of profile adjustment technique which may be employed successfully in profile design. In this case the profile and cross section of the minor road is adjusted to fit the main road. The pavement of the minor road is warped by rotating the crowned section to a tilted plane that has the same slope as the main road profile. The result is a smooth and continuous pavement along the main road and three breaks in grade for vehicles crossing the intersection on the minor road. This treatment would be acceptable where traffic on the minor road can be expected to stop or slow to a minimum speed before entering the intersection.

3-39. INTERSECTION SIGHT DISTANCE.

3-40. There are potential vehicle conflicts at every intersection. The possibility of these conflicts actually occurring can be greatly reduced through proper channelization and appropriate traffic controls, but the avoidance of accidents and the efficiency of traffic operation must still depend to a large extent upon the judgment, capabilities, and responses of the individual driver. The intersection design must provide sufficient sight distances for the driver to perceive potential conflicts and to carry out the actions needed to negotiate the intersection in safety.

3-41. ***Approaches.***

3-42. On the approaches to an intersection, the required sight distances depend upon the approach speeds and the particular action that the drivers may be required to take before reaching the point of potential conflict. In general, each driver has three possible actions: to accelerate, slow down, or stop.

3-43. ***Departures.***

3-44. After a vehicle has stopped at an intersection the driver must have sufficient sight distance to make a safe departure through the intersection area. The intersection design should provide adequate sight distances for each of the vehicle maneuvers permitted upon departure from the stopped position.

3-45. ***Design Criteria for Sight Distance.***

3-46. Table 3-3 gives a simplified and acceptable method of determining required sight distance along a street for a stopped vehicle to cross the street as shown in Figure 3-12. The width of the median is not considered in the table and may be ignored if it is 20-feet wide or less. However if the median is greater than 20-feet wide, the required sight distance may be based on a two-stop crossing considering the width of each one-way pavement at a time. This method is taken from the 1973 AASHTO red book, "A Policy on Design of Urban Highways and Arterial Streets". The method of determining intersection sight distance contained in the 1984 AASHTO green book, "A Policy on Geometric Design of Highways and Streets" is also fully acceptable and may be used if desired.

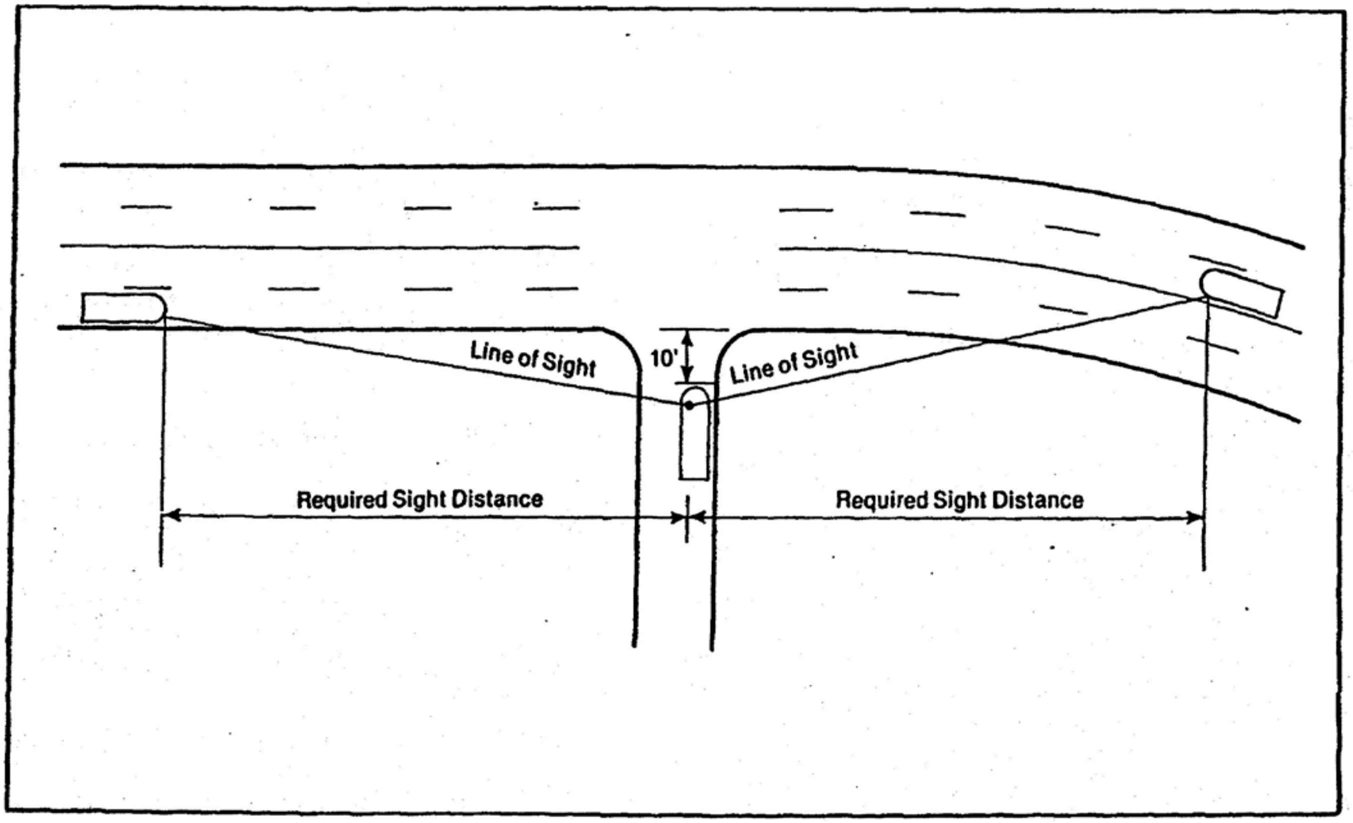


Figure 3-12. Sight Distance Required Along Street for a Vehicle Stopped on Cross Street.

Design Vehicle Crossing Street	Sight Distance in feet per 10-mph of street design speed, for street width of:		
	2-Lanes	4-Lanes	6-Lanes
P	100	120	130
SU	130	150	170
WB-50	170	200	210

Table 3-3. Required Sight Distance Along Streets for a Vehicle Stopped on the Cross Street.

3-47. Minimum sight triangles, in the form of a Visibility, Access and Maintenance (V.A.M.) Easement, are required on all corner lots.

a. A 25' x 25' V.A.M. easement, measured at the property line, is required on corner lots at the intersection of two public streets.
b. A 15'x 15' V.A.M. easement, measured at the property line, is required at the intersection of a dedicated alley and a public street.
c. A 10' x 10' V.A.M. easement, measured at the property line, is required on each side of the driveway or turnout at its intersection with a dedicated alley.
d. No structure, object, or plant of any type within the V.A.M. easements described above may obstruct vision from a height of 24 inches to a height of 11 feet above the top of the curb. However, on commercially zoned lots, a single pole for mounting a sign may be placed within the easement area provided the pole does not exceed 12-inches in diameter, and provided every portion of the sign has a minimum height clearance of 11 feet between the bottom of

the sign and the ground.

3-48. CHANNELIZATION.

3-49. Potential conflicts between vehicles and between vehicles and pedestrians may be reduced through channelization of traffic movements. The traffic channels may be designed to separate and direct traffic movements into specific and clearly defined vehicle paths.

3-50. ***Islands.***

3-51. The edges of traffic channels are formed and delineated by traffic islands. Islands may be formed by curbs or other raised devices or may simply be marked out in paint on the pavement surface. In some cases barrier curbs are required to protect pedestrians. Within an intersection area, medians and outer separations are also considered as islands.

3-52. Islands can be grouped into three functional classes and most islands serve two or all of these functions:

a. Directional islands to control and direct traffic movement and to guide the motorist into the proper channel.
b. Divisional islands to separate opposing traffic flows, to alert the driver to the crossroad ahead and to regulate traffic through the intersection. These islands are often introduced on undivided highways at intersections and are particularly advantageous in controlling left turns at skewed intersections and to prevent wrong way turns into right turning traffic lanes.
c. Refuge islands at or near crosswalks to aid or protect pedestrians crossing the roadway. Such an island may be required for pedestrians in intersections where complex signal phasings are used. Refuge islands may also serve as areas for installation of traffic control devices.

3-53. ***Functions of Channelization.***

3-54. Channelization is used for one or more of the following purposes:

a. To separate conflicts caused by the over-lapping of maneuver areas. This separation makes it possible to present the driver with only one important decision at a time.
b. To control the angle of conflict and reduce relative speeds in merging, diverging, weaving and crossing maneuvers. The potential severity of conflict may be decreased substantially by reducing the angle between the vehicle paths.
c. To reduce excessive pavement areas caused by skewed and flared intersection arrangements. Large areas of open pavement may confuse drivers and cause erratic and improper maneuvers.
d. To control speed by bending or funneling movements to support stop sign controls or reduce speed differentials prior to merging, weaving or crossing maneuvers.
e. To protect pedestrians by providing a safe refuge between traffic streams.
f. To protect and store turning and crossing vehicles by enabling them to slow or stop out of the path of other traffic flows. This is sometimes referred to as “shadowing’:
g. To block prohibited movements by making it impossible or inconvenient to perform illegal, improper, or unsafe maneuvers.
h. To segregate traffic movements with different requirements in terms of speed, direction, and stop or right-of-way control.
i. To locate and protect traffic control devices such as signs and signals where the most desirable location for these devices is within the intersection area.

3-55. ***Principles of Channelization Design.***

3-56. Channelization design does not lend itself to standardization. Traffic volumes, pedestrian patterns, and physical conditions vary, requiring individual treatment of each intersection. AASHTO policy presents guides for various elements of the design, but the combination of elements within a specific design is an engineering art.

3-57. Good channelization design should adhere to the following principles:

a. The proper traffic channels should seem natural and convenient to drivers and pedestrians.

b. There should be no choice of vehicle paths leading to the same destination.
c. The number of islands should be held to a practical minimum to avoid confusion.
d. Islands should be large enough to be effective. Islands that are too small are ineffective as a method of guidance and often present problems in maintenance. The area of an island should be at least 75 square feet. Accordingly, triangular islands should not be less than about 8 feet and preferably 12 feet on a side, after the rounding of corners. Elongated or divisional islands should be at least 4 feet wide and 12 to 20 feet long.
e. Channelization should be visible. It should not be introduced where sight distance is limited. When an island must be located near a high point in the roadway profile or near the beginning of a horizontal curve, the approach end of the island should be extended so that it will be clearly visible to approaching drivers.
f. The major traffic flows should be favored. In "bending" the roadways, those having the heaviest traffic volumes or the fastest speeds should be "bent" the least.
g. Conflicts should be separated so that drivers and pedestrians may deal with only one conflict and make only one decision at a time.
h. Islands should be designed for the assumed design speed of the road. The approach end treatment and delineation should be carefully designed to be consistent with the speed characteristics of the roadway design.

3-58. ***Delineation of Islands.***

3-59. Delineation of islands is critical to good channelization design and can be divided into three types:

a. Raised islands outlined by curbs. This type can be applied universally and is the most effective. Standard curb and gutter sections should be used and be set back two feet from the normal edge of pavement.
b. Islands delineated by pavement markings, buttons, or raised (jiggle) bars placed on the pavement. This type is used in areas where speeds are low and space is limited.
c. Non-paved areas formed by pavement edges, possibly supplemented by delineators on posts or other type guide posts or appropriate landscaping. This type necessarily applies to larger islands and are logical mostly at outlying, semi-rural, intersections where there is sufficient space.

3-60. DRIVEWAYS.

3-61. Although driveways are essential to providing vehicular access to property, they can adversely affect the safety and operation of the adjacent roadway. Providing service for both through traffic and access to property are basically incompatible operational functions of a roadway.

3-62. The degree of incompatibility depends on several factors. Included in these factors are the classification or type of roadway, type of land use, number and proximity of driveways along the roadway, and the respective traffic volumes on both the roadway and the driveway. The detrimental effect of residential driveways on through traffic will be minimal, but heavily used commercial driveways often operate as a critical intersection in the street system.

3-63. ***Driveway Classifications.***

3-64. Driveways are classified by their operational characteristics (one-way or two-way) and by the type of land use being served. All driveways are classified as either residential or commercial.

a. Residential Driveways provide access to residential property containing single-family or two-family (duplex) dwelling units. Permits for the construction of residential driveways must be obtained from the Community Development Department.
b. Commercial Driveways provide access to all other facilities including offices, wholesale and retail businesses, institutional buildings, shopping centers, multi-family housing, industrial parks or facilities, warehouses, and truck terminals. Requests for commercial driveways must be approved by the City Engineer or his designated representative either (1) when securing a building permit for a new development, or (2) when a property owner desires to change an existing driveway or construct a new one. After approval of the driveway request by the City Engineer, the applicant must obtain a driveway construction permit from the Community Development Department.

3-65. For driveway design criteria and standards, refer to Section 6.

SECTION 4

SPECIAL DESIGN CASES

4-1. INTRODUCTION.

4-2. This section is provided as a convenient location for current and future special design cases which do not “fit” into other sections of this manual. Criteria are provided for several unrelated special design cases which are often encountered as individual or independent design problems in land development.

4-3. STACKING SPACE.

4-4. Minimum vehicle storage, or stacking space, is required for various commercial uses. Table 4-1 lists the minimum vehicle storage areas that must be provided for each type of land use. Each storage space must be located on private property behind the right-of-way line and be:

a. A minimum of 8 feet by 22 feet in size.
b. Separated from normal parking circulation aisles.
c. Designed to accommodate the appropriate design vehicle.

4-5. **ENTRANCES INTO SECURE AREAS.**

4-6. Entrances into secure areas utilizing either card key-operated parking gates or a security guard stationed in a guard-house must provide adequate turnaround space for vehicles denied access into the area. Apartment complexes, industrial facilities, etc. are examples of land uses which are sometimes designed and constructed to be secure areas. Figure 4-1 shows in general the type of turn-around area required. Each turn-around area must:

a. Be located entirely on private property behind the right-of-way line and in advance of the gate.
b. Provide for a minimum of three vehicles, of the type that will normally use the facility, to be stored between the parking gate or guard-house and the right-of-way line.
c. Be designed to accommodate the appropriate design vehicle.

Table 4-1.

TYPE OF FACILITY	VEHICLE STORAGE REQUIREMENTS
Financial Institutions	5 – spaces per window*
Drive-Through Restaurant	6 – spaces per menu/order board* 2 – spaces per order/pick-up window
Retail Operations and Kiosks	3 – spaces per window
Full-Service Car Wash	4 – spaces per wash bay***
Automated Car Wash	3 – spaces per wash bay**
Self-Service Car Wash	2 – spaces per wash bay**
Automobile Quick-Lube Facilities	3 – spaces per service bay

* One escape lane, of at least eight (8) feet in width, shall be provided (see zoning regulations)
** One stacking space shall be provided at the exit end of the wash bay.
*** Adequate vehicle stacking and storage space must be provided to keep finished vehicles out of circulation aisles, access easements, fire lanes, streets, etc.

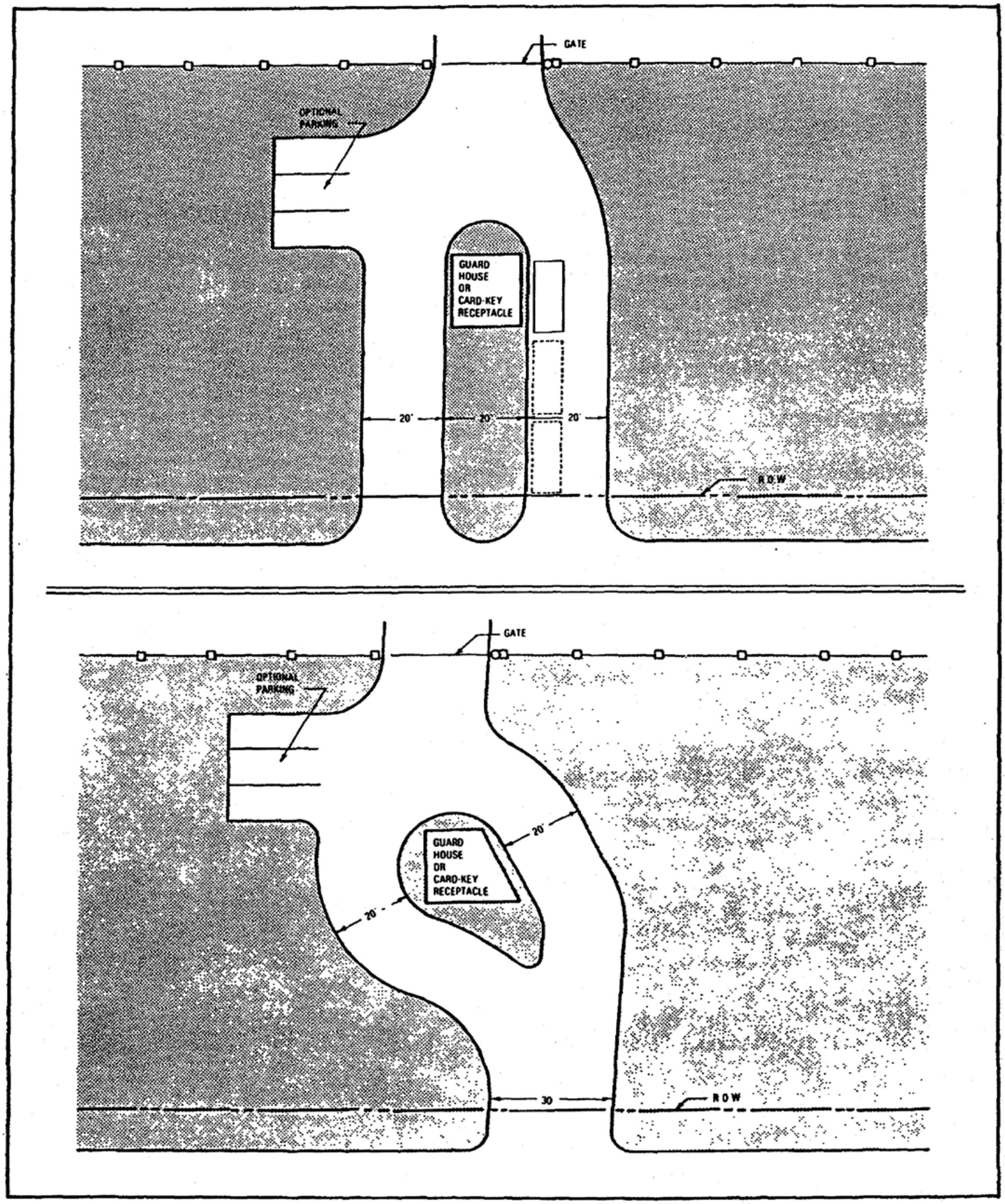


Figure 4-1. Typical Entrances into Secure Areas.

SECTION 5

LEFT-TURN CHANNELIZATION AND MEDIAN OPENINGS

5-1. GENERAL

5-2. This section provides criteria for the design and construction of left-turn channelization and median openings in divided principal and minor arterial streets. Design, construction, and cost related information is presented for these facilities in both new development and existing streets.

5-3. **LEFT-TURN CHANNELIZATION.**

5-4. STORAGE LENGTH.

a. All left-turn channelization, constructed in either existing medians or in new construction, shall be full width (11-feet or 12-feet) and shall have a storage length as calculated from the following expression:

$$L = 25N$$

Where L = Length of storage lane, in feet

and N = Number of vehicles expected in the queue during the peak 30-minute traffic period, using a Poisson Distribution, a 90% confidence level, and a 90-second arrival period.

b. If information necessary to calculate the storage length is unavailable, a minimum storage length of 200 feet shall be used for the approach to a major arterial street, 150 feet shall be used for the approach to a minor arterial or collector street, and 100 feet shall be used for approaches to all other streets, unless the City Engineer requires additional storage length. In unusual circumstances, and upon approval by the City Engineer, storage lengths of a minimum of 60 feet may be approved, provided that a traffic hazard is not created.

5-5. EXISTING MEDIANS.

a. Left-turn channelization proposed to be added to existing medians must be approved by the City Engineer and be full width (11 feet or 12 feet).

b. Widths of 10 feet may be utilized in cases where the overall median width will not accommodate the full width design.

5-6. NEW CONSTRUCTION.

a. In the construction of new arterial streets, left-turn channelization shall be provided at all median openings, unless waived by the City Engineer.

b. This waiver *may* be granted at T-intersections where there is little or no likelihood that the street will be extended through, or at other special, low volume locations where a traffic hazard would not be created.

5-7. **MEDIAN OPENINGS**.

5-8. DESIGN CONSIDERATIONS.

a. Median openings spaced from 500 feet to 1,200 feet apart are encouraged. However, median openings closer or further apart may be approved if the applicable conditions described in the paragraphs below are fulfilled and do not otherwise create a safety hazard.

b. Design standards for medians, tapers, bullet-noses, etc., may be obtained from the Community Development Department.

5-9. EXISTING MEDIANS.

a. Median openings and associated left-turn slots proposed to be cut in existing medians, for any reason, must be approved by the City Engineer in accordance with the spacing provisions described under “New Construction” below.

b. Widening, relocating, or other alterations proposed to change or modify an existing median opening, for any reason, must be approved by the City Engineer.

5-10. NEW CONSTRUCTION.

a. Generally, the distance between median openings shall be determined by the amount of left-turn storage provided on each end of the median, the widths of the intersecting streets, the 10-foot setback from the intersecting curb-line to the nose of the median, and the radii of the taper of the left-turn channelization transition (Figure 5-1). Where unusual conditions so warrant, the City Engineer may specify additional design criteria as required.

b. On divided arterial streets (‘AA’, ‘A’ and ‘B’) the minimum centerline distance (nose to nose of median) between median openings shall be as given in Table 5-1.

c. The width of the median opening shall be the width of the intersecting street plus 20 feet (10-feet back of each curb-line), but in no case shall be less than 50 feet wide.

d. Median openings will normally be permitted at intersections with dedicated public streets, if considered necessary by the City Engineer, and if appropriate left-turn channelization can be constructed. However, median openings will not normally be permitted at intersections with short cul-de-sacs, modified cul-de-sacs, or minor streets less than 200-feet long.

e. Median openings will be permitted where a cul-de-sac serves a large number of residential lots, or where a street less than 200-feet long provides access to a large residential area or access to several businesses, provided appropriate left-turn channelization can be constructed.

f. Median openings may be permitted at intersections with private streets, if appropriate left-turn channelization can be constructed.

g. Median openings may be permitted to serve emergency access easements and private driveways of major traffic generators, provided appropriate left-turn channelization can be constructed, and provided the area served by the median opening contains two or more businesses, thirty or more parking places, or seven or more dwelling units.

If Streets Intersecting the Divided Arterial are:	**Minimum Centerline Distance between Median Openings (nose-to-nose) is:**	
	Minimum (ft)	Desirable (ft)
Major Arterial and Minor Arterial	474	494
Major Arterial and Collector	474	494
Major Arterial and Local B or Commercial Driveway	424	444
Major Arterial and Local A	424	444
Major Arterial and Rural	424	444
Minor Arterial and Minor Arterial	424	444
Minor Arterial and Collector	424	444
Minor Arterial and Local B or Commercial Driveway	374	394
Minor Arterial and Local A	374	394
Minor Arterial and Rural	374	394
Collector and Collector	424	444
Collector and Local B	374	394
Collector and Local A	374	394
Collector and Rural	372	394
Local B and Local B	324	344
Local B and Local A	324	344
Local B and Rural	324	344
Local A and Local A	324	344
Local A and Rural	324	344
Rural and Rural	324	344

TABLE 5-1. Minimum Distance Between Median Openings

5-11. COST PARTICIPATION.

5-12. LEFT-TURN CHANNELIZATION.

a. In existing medians, the cost of constructing left-turn channelization, for any reason, shall be paid by the party requesting the channelization.

b. In new development, the cost of constructing left-turn channelization for access to dedicated public streets shall be paid by the developer.

c. In new development, the cost of constructing left-turn channelization for access to private streets, emergency access easements, and private driveways shall be paid by the developer.

d. During reconstruction of existing streets, the cost of constructing left-turn channelization for dedicated public streets, and where necessary to allow the previously provided degree of access to private property, shall be paid by the City.

5-13. MEDIAN OPENINGS

a. In existing medians, the cost of constructing a new median opening, for any reason, shall be paid by the party requesting the opening.

b. In existing medians, the cost of widening, relocating, or otherwise changing or altering an existing opening, for any reason, shall be paid by the party requesting the alteration.

c. In new development, the cost of constructing median openings to provide access to dedicated public streets, where considered necessary by the City Engineer, shall be paid by the developer.

d. In new development, the cost of constructing median openings to provide access to private streets, emergency access easements, and private driveways, shall be paid by the developer.

e. During reconstruction of existing streets, the cost of constructing median openings for dedicated public streets, and where necessary to allow the previously provided degree of access to private property, shall be paid by the City.

SECTION 6

ACCESS CONTROL AND OFF-STREET PARKING

6-1. GENERAL.

6-2. The purpose of this section is to provide guidelines for access control to commercial, industrial, and multi-family housing property, and for the design and construction of commercial driveways and off-street parking areas. Design standards and criteria are provided for access control, commercial driveways and all types of off-street parking, along with paving standards for parking areas, and requirements for the number of parking spaces required for various land uses.

6-3. The information presented in this section is in full compliance with the off-street parking requirements of the Zoning Ordinance although no attempt is made herein to duplicate that document verbatim.

6-4. **ACCESS CONTROL**.

6-5. HIGHWAYS.

6-6. Access to U.S. Highways, State Highways, and freeway frontage roads within the Hudson Oaks City limits requires a permit from the Texas Department of Transportation. It is the intent of both the City and the State to minimize access points to highways. Direct access to highways will be strongly discouraged if the property has reasonable access to the City street system.

6-7. CITY STREETS.

6-8. The type, number and location of access points on City streets shall be approved by the City Engineer. The number of access points, particularly on arterial streets, shall be held to a minimum. The limitation of access to public streets, especially arterial streets, is based on the premise that greater accessibility will result in deterioration in the quality of traffic flow on the through street. Any hindrance to vehicular flow along a roadway detrimentally affects the efficiency and safety of the roadway. Although road users have rights of access to abutting property, they also have the right of minimum interference to travel on the roadway. When conflicts between the two cannot be resolved, preference will be given to the roadway.

6-9. The location of access points for commercial driveways shall be at the sole discretion of the City Engineer after proper consideration of anticipated driveway volumes and their affect on traffic safety. Property owners and developers are encouraged to meet with the City Engineer, or his designated representative, as soon as practical during the site planning and development process to determine the number, type, and location of access points for their site.

6-10. ACCESS DESIGN.

6-11. DESIGN STANDARDS AND CRITERIA.

6-12. The following paragraphs contain data and information pertaining to the number, type, location, and spacing of access points. In addition, criteria are provided for the various design elements of driveway design.

6-13. *Number of* Access *Points.*

a. One access point per property ownership shall be permitted, unless a site plan or traffic study approved by the City Engineer shows that additional access points are required to adequately handle driveway volumes and will not be detrimental to traffic flow on the public street.
b. Only one driveway per median opening will be permitted on each side of a divided street.
c. The need for more than one driveway to serve a site will be determined by the site trip generation functional uses, internal traffic circulation, and the effects of the driveways on traffic flow along the adjacent public street.

6-14. *Driveway Types.*

6-15. Three basic types of driveways are used in Hudson Oaks; the standard driveway approach, the high volume type driveway, and the intersection type driveway. The type used is based on the land use being served, the anticipated driveway traffic volume, and the vehicle types which will use the driveway.

a. Standard Driveway Approach. This is the familiar dust pan shaped driveway used almost universally for both residential and commercial driveways.
b. High Volume Type Driveway. This type of driveway is similar to the standard driveway approach, except that the sidewalk section through the driveway throat is lowered a few inches and the curb radii are significantly larger in order to provide smoother, easier, and faster accessibility. The lowered sidewalk section is ramped-up on each side of the driveway throat to match the grade of the adjoining sidewalk section. This type of driveway is required for especially heavy driveway traffic volumes into shopping centers, large apartment complexes, business parks, etc., from arterial streets.
c. Intersection Type Driveway. This type of driveway resembles a regular street intersection with rounded curb returns and ingress/egress pavement of varying widths. Usage of this type of driveway is reserved for specialized land uses such as regional shopping centers, industrial parks, and major trucking terminals. Special approval must be obtained from the City Engineer before this type driveway can be utilized.
d. When high volume or intersection type driveways are approved for use, adequate on-site vehicle reservoir capacity must be provided in the form of a protected driving aisle a minimum of 75 feet long, for both inbound and outbound vehicles to facilitate the safe and efficient movement of vehicles between the street and the development. The driving aisle must be protected from adjacent parking spaces, crossing aisles, or other internal traffic circulation interference.

6-16. Driveway Location.

6-17.The location of driveways is based on a number of factors, including the locations of individual property lines and available street frontage, requirements of internal site design, number of vehicles to be accommodated, and other concerns.

a. Driveways located in proximity to a major intersection have an especially adverse influence due to left turn maneuvers, both in and out of the driveway, which interfere with intersection movements.
b. As a general rule, the farther from an intersection a driveway can be located, the less it will affect the through traffic and the less delay it will cause the vehicles using the driveway.
c. The location of other driveways on the opposite side of the street shall be considered when locat-

ing a proposed driveway. If possible, driveways on both sides of the street shall be aligned in order to minimize adverse effects on through traffic and to optimize efficiencies of the driveways.

6-18. Driveway Spacing.

6-19. Unless sufficient spacing is provided between driveways as shown in Figure 6-3, vehicles may travel on a course requiring an evasive maneuver to avoid a collision. It is, therefore, necessary to coordinate the location of driveways for properties on opposite sides of the street so that they do not interfere with each other.

a. Driveways directly opposite each other are generally beneficial because they share a single access location.
b. If this is not possible, it is necessary to space the driveways so that adequate left turn storage capacity is provided in advance of each driveway in order to avoid the overlap of left turn lanes.
c. Where land uses are compatible, provisions for internal circulation to adjoining properties are often beneficial to property owners as well as advantageous to traffic on the adjacent street.
d. The number of driveways providing access to individual developments must be held to a minimum, so that complications arising from too many points of access do not become a problem.

6-20. *Driveway Design Elements.*

6-21. Driveway design will depend on land use, the volume and character of through traffic and traffic using the driveway, and the speed of traffic on the through roadway. Dependent upon these factors, the critical design elements include radii of curb returns, driveway throat width and angle between the driveway centerline and the edge of the roadway.

a. The curb return radii relates to the type of driveway and the classification of the street as given in Figures 6.4 and 6.4 (A).
b. The throat width varies in accordance with driveway traffic volume, whether it operates as one-way or two-way, and with the type of design vehicle.
c. The driveway angle can depend on whether the street is one-way or two-way and if left turns are permitted.
d. Figure 6.4 and 6.4 (A) also provide required dimensions for each of the driveway design elements.
e. Tapered or channelized deceleration lanes for vehicles turning right into high volume or intersection type driveways may be required on major and minor arterial streets. Figure 6-5 shows examples of the types of special treatment recommended.
f. The use of one-way driveways, supported by an appropriate internal circulation system, is encouraged so that entrances and exits can be separate driveways. This will promote smoother traffic flow into and out of the driveways and reduce traffic congestion in the through lanes on the street.
g. The use of joint (shared) driveways is encouraged so that adjacent property owners may have access to a median opening. Since only one driveway per median opening will be permitted on each side of a divided street, the adjacent property owners must agree on the size, type, and exact location of the joint driveway which they can share equally. In such cases, a letter of agreement signed by both property owners shall be submitted to the City Engineer as part of the Site Plan approval process.
h. In some cases, where necessary for the safe and efficient movement of traffic, the City Engineer may require that special design techniques be employed to restrict or limit turning movements into or out of a driveway before the driveway can be approved. Such restrictions do not affect the number and location of access points as specified elsewhere. Figure 6-6 gives

recommended minimum design criteria for limited movement driveways. Deceleration lanes may also be required to be incorporated into the design.

6-22. RESTRICTIVE PROVISIONS.

6-23. Access to public streets will not be approved where the conditions described below restrict or compromise the safety and efficiency of the access.

a. Backing Maneuvers. Access points shall not be approved for parking or loading areas that require backing maneuvers in a public street right-of-way except for single family or duplex residential uses on local streets.
b. Sight Distance Requirements. The minimum sight distance shall be provided at all access points as shown in Figure 6-7.
c. Intersections. Access drives within the area of intersection of public streets will not be permitted.
d. Provision of Access. If a property has frontage on more than one street, access will be permitted only on those street frontages where standards can be met. If a property cannot be served by any access point meeting these standards, the City Engineer shall designate access point(s) based on traffic safety, operational needs and conformance to as much of the requirements of these guidelines as possible.

6-24. PARKING LOT DESIGN**.**

6-25. GENERAL

6-26. The tendency when designing parking areas is to provide the maximum number of driveways and to crowd as many parking spaces as possible into the allotted area by reducing standards, such as narrowing the parking spaces and/or narrowing the aisles. The best design, however, must give full consideration to all design factors that affect the street through traffic and provide the most efficient access to and from the street, including internal movement, maneuvering of cars, convenience of patrons, security of vehicles, and safety.

6-27. The requirements given in the following paragraphs have been developed to provide for the successful accomplishment of these concerns. All driveways and off-street parking facilities shall be designed and constructed in accordance with these requirements.

6-28. DESIGN CRITERIA AND STANDARDS.

6-29. The average automobile is 18 feet long and 6 feet 9 inches wide. Adding to these dimensions an allowance for opening doors, the relative skill of drivers, the turning radius of the average automobile and a margin for safety, the criteria and standards described below, and shown in Figures 6-8 through 6-21, have been established. Parking areas built to these specifications will allow 80% of all cars to park with relative ease in one maneuver.

a. All vehicle parking spaces and maneuvering areas must be located on private property entirely off the public street right-of-way. Parking spaces shall be a minimum of 9 feet wide by 18 feet long, except for parallel parking spaces which shall be 8 feet wide by 22 feet long.
b. Parking lots shall be designed so that the parking spaces are arranged 90, 60, 45, or 30 degrees to the aisle (Figure 6-12). The greatest economy of space is obtained by placing the parking spaces at a 90 degree angle to the aisle. Acute angle (less than 90 degrees) parking provides fewer parking spaces for a given length of aisle than does 90 degree parking, but the parking maneuver is easier and smoother for drivers. Another advantage of acute angle parking is that the aisles can be narrower which permits lots too narrow for 90 degree parking to be used.
c. Large lots shall be designed for one-way counter-clockwise movement, where feasible, to provide smooth traffic flow and reduce traffic congestion. Where such lots are located on an arterial street, and high volume or intersection type driveways are utilized, the driving aisles leading to the driveways shall have a minimum depth of 75 feet from the street right-of-way line to the first point of cross traffic or other traffic interference.
d. Barrier curbs or reinforced concrete wheel stops (Figure 6-11) are required where parking adjoins or heads into an adjacent property, sidewalk, public parkway, or street right-of-way.
e. The first parking space in acute-angle parking lots shall be placed the minimum distance *from* the property line or sidewalk as shown in Figures 6-15 through 6-20. This is a safety measure

to provide adequate space for vehicles to back out without encroaching on the sidewalk, and thereby protects pedestrians on the sidewalk.

6-30. LOADING DOCKS.

a. All buildings, except one-family, two-family, three-family, or four-family dwellings, are required to have adequate permanent off-street facilities to provide for the loading and unloading of merchandise and goods within or adjacent to the building in such a manner as not to obstruct the freedom of vehicular or pedestrian movement on the public rights-of-way.
b. The minimum distance permitted from the loading dock to the right-of-way line will be 60 feet. Such proposed facilities are required to be submitted on a plat and approved by the City Engineer and the Building Official. The 60-foot minimum distance may be reduced by the approval of the City Engineer and the Building Official only under unusual circumstances. All required loading space is in addition to the vehicular parking required for such use.

6-31. PAVING STANDARDS.

6-32. Off-street parking areas must meet the requirements of the Zoning Ordinance, and be constructed in accordance with the provisions of this section.

a. Driveway and parking areas must be graded to drain and be paved with an all-weather, dust free, smooth surface adequate to support the anticipated loads and type of traffic that will use the facility.
b. Lots surfaced with gravel, oiled surfaces, or roofing material are not acceptable.
c. A properly designed gravel or crushed stone base with a minimum of 1 ½" Hot Mix Asphaltic Concrete (HMAC) surface will meet the requirements. The following publications may be used as a guide for the design of pavements:

"Building Quality Parking Areas" and "Concrete Industrial Driveways" both published by the Portland Cement Association, 5420 Old Orchard Road, Skokie, Illinois 60077-4321.
"Concrete Parking Lots — A Guide to Specification and Construction" *Construction Specifier.*
"Full Depth Asphalt Pavements for Parking Lots, Service Stations and Driveways" New edition, and "Asphalt Pavement Thickness Design" both published by The Asphalt Institute, Asphalt Institute Building, College Park, Maryland 20740.

6-33. NUMBER OF OFF-STREET PARKING SPACES REQUIRED.

6-34. The Zoning Ordinance specifies the minimum number of parking spaces required for development of various types of land use. It should be noted that these requirements, however, are minimum legal requirements and are not necessarily based on trip generation rates. The Zoning Ordinance requirements are presented below only for reference, and are not intended to preclude the need for an engineering investigation and the use of trip generation rates (provided in the Appendix) to determine parking space needs.

6-35. Vehicle maneuvering space is required to be completely off the right-of-way of a public street. All parking requirements applying to a stated unit of measurement are understood to include a parking space for each unit or fraction thereof.

6-36. Parking areas which would require the use of public right-of-way for maneuvering are not acceptable for the furnishing of required off-street parking spaces other than for single-family dwellings. Parking parallel to the curb on a public street cannot be substituted for off-street parking requirements.

6-37. For all of the facilities listed below hereafter erected, reconstructed, or enlarged so as to require additional parking spaces, except in the central business district (CBD), permanent provision must be made for the number of off-street parking spaces for passenger vehicles as described below:

a. Auditoriums, Theaters, and Places of Public Assembly – one (1) parking space for each three (3) seats or bench seating spaces (see current zoning regulations).
b. Boarding and Lodging Houses - one (1) parking space for each sleeping room, plus one (1) space for each host resident or employee during maximum (i.e., peak) shift.
c. Bowling Alleys – six (6) parking spaces fore each lane in the alley.

d. Churches – one (1) parking space for each three (3) seats in the main auditorium/sanctuary (see current zoning regulations).
e. Colleges and Universities – one (1) parking space for each two (2) teachers and member of the technical and administrative staff, plus one (1) space for each four (4) additional persons employed on the premises, plus one (1) space for each three (3) students residing on the campus, plus one (1) space for each five (5) day-students not residing on campus.
f. Commercial buildings – one (1) parking space per two hundred fifty (250) square feet of floor area.
g. Day Nurseries and Kindergarten – one (1) space per ten (10) pupils (based upon maximum occupancy and/or licensing capacity), plus one (1) space per teacher, plus one (1) space for each bus or van stored on the property (and sized to accommodate the vehicle).
h. Doctor's Clinics – one (1) parking space per two hundred (200) square feet of floor area. Facilities over 20,000 square feet shall use the parking standards set forth for hospitals.
i. Dormitories, Fraternity, and Sorority Houses – one (1) parking space for each two (2) occupants, or members in residence.
j. Dwellings, Single – two (2) enclosed parking spaces behind the front building line on the same lot as the main structure, plus two (2) additional parking spaces on a paved driveway having a minimum length of twenty-five (25') as measured from the street right-of-way line. All vehicular parking shall be on an improved, dust free surface. Other – (See current zoning regulations).
k. Dwellings, Multiple, and Apartment Hotels –
    a. One and one-half (1.5) parking spaces for each efficiency or one-bedroom unit.
    b. Two (2) spaces for each two-bedroom unit.
    c. Two and one-half (2.5) spaces for each three-bedroom unit.
    d. Three (3) spaces for each four- or more-bedroom unit.
    e. The average number of parking spaces for the total development shall be no less than two (2) spaces per dwelling unit, at least one (1) of which shall be enclosed (i.e., garage) for each dwelling unit.
    f. No parking space may be located closer than six feet (6') from any building, nor closer than two feet (2') from any side or rear lot line.
    g. All parking areas adjacent to public streets shall be screened from view. Screening may be in the form of live plant materials, berms, low masonry walls that match the exterior finish of the main buildings, or any combination of the above.
    h. See current zoning regulations for additional requirements.

l. Elementary and Junior High Schools, Public, Private and Parochial – one (1) parking space for each twelve (12) students (design capacity).

m. Hospitals, General – one (1) space for each two (2) beds or examination room, whichever is applicable; plus one (1) space fore very two (2) employees during periods of full occupancy.
n. Hospitals, Long Term; Nursing and Care Homes for the aged – one (1) parking space per six (6) beds; plus one (1) space for each three hundred (300) square feet of floor area devoted to offices, cafeterias, exercise/therapeutic rooms, and other similar ancillary uses; plus one (1) space for every two (2) employees at full occupancy.
o. Hotels – one (1) parking space per room for the first two hundred (250) rooms and 0.75 space per room for each room over two hundred fifty (250), plus one (1) space per five (5) restaurant/lounge area seats (based upon maximum occupancy), plus one (1) space per one hundred twenty-five (125) square feet of meeting/conference areas.
    a. One and one-tenth (1.1) spaces per room which contain kitchenette facilities, plus parking for restaurant and meeting areas per ratio stated in this paragraph.
    b. Two (2) spaces per guest room provided with full kitchen facilities plus parking for restaurant and meeting areas per the ratio stated in this paragraph.
    c. One (1) space fore every two (2) employees during peak (i.e., busiest) time periods when the hotel/motel is fully occupied.
p. Industrial Buildings (Not Warehouses) – See current zoning regulations.
q. Office and Professional Buildings – one (1) parking space for each three-hundred (300) square feet of floor area, except as otherwise specified herein.

r. Philanthropic or Eleemosynary institutions – ten (10) parking spaces plus one (1) space for each employee.
s. Private Clubs and Cocktail Lounges – one (1) parking space fore each one (1) hundred square feet of gross floor area (including indoor/outdoor play areas and patio dining areas), or one (1) space for every three (3) seats under maximum seating arrangement (i.e. occupancy), whichever is greater; required parking spaces are in addition to any stacking spaces that may be needed/provided for drivethrough or drive-in facilities (see current zoning regulations).
t. Restaurants, Cafeterias, and Drive-Ins – one (1) parking space for each one hundred (100) square feet of gross floor area (including indoor/outdoor play areas and patio dining areas), or one (1) space for every three (3) seats under maximum seating arrangement (i.e., occupancy), whichever is greater; required parking spaces are in addition to any stacking spaces that may be needed/provided for drive-through or drive-in facilities (see current zoning regulations).
u. Senior High Schools, Public, Parochial, and Private – one (1) parking space for each three students, faculty and staff (design capacity).
v. Temporary Tents or Outdoor Assemblies – one (1) space for each five (5) participants or spectators, calculated on the maximum capacity of the tent, stands, arena, enclosure, or area for participants and spectators.
w. Warehouse Buildings – one (1) parking space for five thousand (5000) square feet of gross floor area.

APPENDIX

LEVEL OF SERVICE

DEFINITION.

Level of service (LOS) is a qualitative measure describing operational conditions within a traffic stream, ranging from A (the best) to F (the worst). It is generally described in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety.

ARTERIAL LEVEL OF SERVICE.

The arterial level of service is based on the average travel speed for the segment, section, or entire arterial under consideration. The average travel speed is computed from the running time on the arterial segment(s) and the intersection approach delay using procedures presented in the 1985 Highway Capacity Manual.

The arterial levels of service are defined precisely in Table A-I, however, some broad descriptions of the various levels are useful.

Range of Free Flow Speeds (mph)	45 to 35	35 to 30	35 to 25
Typical Free Flow Speed (mph)	40 mph	33 mph	27 mph
Level of Service	**Average Travel Speed (mph)**		
A	≥35	≥30	≥25
B	≥28	≥24	≥19
C	≥22	≥18	≥13
D	≥17	≥14	≥ 9
E	≥13	≥10	≥ 7
F	<13	<10	< 7

Table A-1. Level of Service Criteria for Arterial Streets.

Arterial level of service is defined in terms of average travel speed of all through-vehicles on the arterial. It is strongly influenced by the number of signals per mile and the average intersection delay. On a given facility~ such factors as inappropriate signal timing, poor progression, and increasing traffic flow can substantially degrade the arterial LOS. Arterials with high signal densities are even more susceptible to these factors. Arterial LOS D will probably be observed even before substantial intersection problems, but both such problems and even poorer arterial LOS values are not far behind arterial LOS D.

The following general statements may be made regarding arterial level of service.

Level of service *A* describes primarily free flow-operations at average travel speeds usually about 90-percent of the free flow speed for the arterial class. Vehicles are completely unimpeded in their ability to maneuver within the traffic stream. Stopped delay at signalized intersections is minimal.

Level of service B represents reasonably unimpeded operations at average travel speeds usually about 70-percent of the free flow speed for the arterial class. The ability to maneuver within the traffic stream is only slightly restricted and stopped delays are not bothersome. Drivers are not generally subjected to appreciable tension.

Level of service C represents stable operations. However, ability to maneuver and change lanes in midblock locations may be more restricted than in LOS B, and longer queues and/or adverse signal coordination may contribute to lower average travel speeds of about 50-percent of the average free flow speed for the arterial class. Motorists will experience an appreciable tension while driving.

Level of service D borders on a range on which small increases in flow may cause substantial increases in approach delay and, hence, decreases in arterial speed. This may be due to adverse signal progression, inappropriate signal timing, high volumes, or some combination of these. Average travel speeds are about 40-percent of free flow speed.

Level of service E is characterized by significant approach delays and average travel speeds of one-third the free flow speed or lower. Such operations are caused by some combination or adverse progression, high signal density, extensive queuing at critical intersections, and inappropriate signal timing.

Level of service F characterizes arterial flow at extremely low speeds below one-third to one-quarter of the free flow speed. Intersection congestion is likely at critical signalized locations, with high approach delays resulting. Adverse progression is frequently a contributor to this condition.

LEVEL OF SERVICE FOR SIGNALIZED INTERSECTIONS.

Level of service for signalized intersections is defined in terms of delay. Delay is a measure of driver discomfort, frustration, fuel consumption, and lost travel time. Specifically, level of service criteria are stated in terms of the average stopped delay per vehicle for a 15-minute analysis period. The criteria are given in Table A-2.

Level of Service	Stopped Delay Per Vehicle (sec)
A	≤5.0
B	5.1 to 15.0
C	15.1 to 25.0
D	25.1 to 40.0
E	40.1 to 60.0
F	>60.0

Table A-2. Level of Service Criteria for Signalized Intersections.

Delay may be measured in the field, or may be estimated using procedures presented in the 1985 Highway Capacity Manual. Delay is a complex measure, and is dependent on a number of variables, including the quality of progression, the cycle length, the green ratio, and the v/c ratio for the lane group or approach in question.

Level of service A describes operations with very low delay, i.e., less than 5.0-seconds per vehicle. This occurs when progression is extremely favorable, and most vehicles arrive during the green phase. Most vehicles do not stop at all. Short cycle lengths may also contribute to low delay.

Level of service B describes operations with delay in the range of 51 to 15.0-seconds per vehicle. This generally occurs with good progression and/or short cycle lengths. More vehicles stop than for LOS A, causing higher levels of average delay.

Level of service C describes operations with delay in the range of 15.1 to 25.0-seconds per vehicle. These higher delays may result from fair progression and/or longer cycle lengths. Individual cycle failures may begin to appear in this level. The number of vehicles stopping is significant at this level, although many still pass through the intersection without stopping.

Level of service D describes operations with delay in the range of 25.1 to 40.0-seconds per vehicle. At level D, the influence of congestion becomes more noticeable. Longer delays may result from some combination of unfavorable progression, long cycle lengths, or high v/c ratios. Many vehicles stop, and the proportion of vehicles not stopping declines. Individual cycle failures are noticeable.

Level of service E describes operations with delay in the range of 40.1 to 60.0-seconds per vehicle. This is considered to be the limit of acceptable delay. These high delay values generally indicate poor progression, long cycle lengths, and high v/c ratios. Individual cycle failures are frequent occurrences.

Level of service F describes operations with delay in excess of 60.0-seconds per vehicle. This is considered to be unacceptable to most drivers. This condition often occurs with oversaturation, i.e., when arrival flow rates exceed the capacity of the intersection. It may also occur at high v/c ratios below 1.00 with many individual cycle failures. Poor progression and long cycle lengths may also be major contributing causes to such delay levels.

TRIP GENERATION RATES — INSTITUTE OF TRANSPORTATION ENGINEERS — 1982

LAND USE / BUILDING TYPE	UNITS	AVERAGE WEEKDAY VEHICLE TRIP ENDS	AM PEAK HOUR TRIP ENDS		PM PEAK HOUR TRIP ENDS		GENERATOR PEAK HOUR TRIPS				SATURDAY TRIP ENDS	SUNDAY TRIP ENDS
			ENTER	EXIT	ENTER	EXIT	AM ENTER	AM EXIT	PM ENTER	PM EXIT		
PORT AND TERMINAL												
Waterport	Ship Berth	171.5	—	—	—	—	—	—	—	—	—	—
Waterport	Acre	11.9	—	—	—	—	—	—	—	—	—	—
Commercial Airport	Employee	16.82	0.97	0.66	1.41	1.50	0.53	0.57	0.49	0.53	13.71	15.91
Commercial Airport	Ave. Flights/Day	11.83	0.16	0.11	0.24	0.25	0.37	0.40	1.93	2.08	23.59	26.14
Commercial Airport	Commercial Flights/Day	77.86	2.86	1.95	4.16	4.42	2.47	2.73	2.68	2.90	71.09	86.14
Gen. Aviation Airport	Employee	6.51	12.86	12.86	—	—	0.24	0.07	0.15	0.25	2.52	2.51
Gen. Aviation Airport	Ave. Flights/Day	3.06	0.18	0.18	—	—	0.47	0.14	0.22	0.36	3.03	2.38
Truck Terminals	Employee	6.99	0.27	0.39	0.26	0.29	0.27	0.39	0.29	0.33	1.47	0.92
Truck Terminals	1,000 Gross Square Feet	9.86	0.36	0.54	0.35	0.47	0.36	0.54	0.35	0.47	1.89	1.02
Truck Terminals	Acre	81.90	3.10	4.60	3.00	3.40	3.10	4.60	3.40	3.90	17.30	10.80
INDUSTRIAL/AGRICULTURAL												
Industrial	Employee	3.00	—	—	—	—	—	—	—	—	—	—
Industrial	1,000 Gross Square Feet	5.43	—	—	—	—	—	—	—	—	—	—
Industrial	Acre	59.90	—	—	—	—	—	—	—	—	—	—
Gen. Light Industrial	Employee	3.20	0.71	0.13	0.27	0.53	—	—	0.27	0.51	0.82	—
Gen. Light Industrial	1,000 Gross Square Feet	5.46	0.85	0.15	0.32	0.63	—	—	0.32	0.69	3.09	—
Gen. Light Industrial	Acre	52.40	18.20	3.30	6.90	13.60	—	—	6.90	13.30	25.20	—
Gen. Heavy Industrial	Employee	2.05	—	—	—	—	—	—	—	—	—	—
Gen. Heavy Industrial	1,000 Gross Square Feet	1.50	—	—	—	—	—	—	—	—	—	—
Gen. Heavy Industrial	Acre	15.6	—	—	—	—	—	—	—	—	—	—
Industrial Park	Employee	3.59	.35	.21	.10	.27	.29	.06	.14	.31	1.28	.31
Industrial Park	1,000 Gross Square Feet	7.00	.54	.16	.19	.59	.59	.10	.28	.47	2.73	.66
Industrial Park	Acre	62.8	10.1	3.2	3.0	9.4	8.1	2.0	4.1	8.5	41.1	10.0
Manufacturing	Employee	2.01	—	—	0.22	0.16	3.1	.08	.17	.32	.87	.36
Manufacturing	1,000 Gross Square Feet	3.86	—	—	.52	.39	0.79	0.40	0.52	0.59	1.49	.62
Manufacturing	Acre	38.9	—	—	—	—	—	—	—	—	—	—

TRIP GENERATION RATES — INSTITUTE OF TRANSPORTATION ENGINEERS — 1982

LAND USE / BUILDING TYPE	UNITS	AVERAGE WEEKDAY VEHICLE TRIP ENDS	AM PEAK HOUR TRIP ENDS		PM PEAK HOUR TRIP ENDS		GENERATOR PEAK HOUR TRIPS				SATURDAY TRIP ENDS	SUNDAY TRIP ENDS
			ENTER	EXIT	ENTER	EXIT	AM ENTER	AM EXIT	PM ENTER	PM EXIT		
INDUSTRIAL/AGRICULTURAL con't.												
Warehousing	Employee	3.89	—	—	—	—	—	—	—	—	—	—
Warehousing	1,000 Gross Square Feet	4.88	—	—	—	—	—	—	—	—	—	—
Warehousing	Acre	56.1	—	—	—	—	—	—	—	—	—	—
Mini-warehouse	1,000 Gross Square Feet of Building Area	2.8	—	—	—	—	—	—	—	—	2.5	1.7
Mini-warehouse	Storage Unit or Vault	0.28	—	—	—	—	—	—	—	—	.25	.18
Mini-warehouse	Acre	48.6	—	—	—	—	—	—	—	—	43.0	30.0
Utilities	Employee	—	.68	.07	.09	.66	—	—	—	—	—	—
RESIDENTIAL												
Single Family Detached Housing	Person	2.52	0.07	0.15	0.19	0.10	0.07	0.15	0.20	0.10	2.72	2.37
Single Family Detached Housing	Vehicle	6.50	0.20	0.40	0.40	0.20	0.20	0.30	0.50	0.20	7.10	6.20
Single Family Detached Housing	Dwelling Unit	10.00	0.21	0.55	0.63	0.37	0.21	0.55	0.63	0.37	10.10	8.70
Single Family Detached Housing	Acre	26.2	0.70	1.60	1.90	1.10	0.70	1.6	2.10	1.10	30.90	25.80
Apartment	Person	2.80	0.08	0.20	0.23	0.14	0.08	0.20	0.23	0.14	3.10	2.80
Apartment	Vehicle	5.10	0.10	0.20	0.20	0.10	0.10	0.20	0.20	0.10	3.10	2.80
Apartment	Dwelling Unit	6.10	0.10	0.40	0.40	0.20	0.10	0.40	0.40	0.20	6.3	5.6
Low Rise Apartment	Dwelling Unit	6.6	0.10	0.40	0.40	0.20	0.10	0.40	0.40	0.20	7.2	6.1
High Rise Apartment	Dwelling Unit	4.0	0.10	0.20	0.02	0.02	—	—	—	—	—	—
Residential Condominiums	Unit	5.2	0.07	0.37	0.37	0.18	0.07	0.37	0.37	0.18	5.29	4.6
Residential Condominiums	Person	1.93	0.04	0.14	0.13	0.06	—	—	—	—	—	—
Residential Condominiums	Vehicle	03.3	—	—	—	—	—	—	—	—	3.3	2.9
Mobile Home	Person	2.4	0.06	0.15	0.13	0.09	0.06	0.15	0.13	0.10	2.4	2.1
Mobile Home	Vehicle	3.39	0.05	0.22	0.22	0.13	0.07	0.22	0.23	0.14	3.43	2.94
Mobile Home	Unit (Occupied)	4.8	0.13	0.38	0.29	0.18	0.16	0.38	0.29	0.22	4.7	4.2
Mobile Home	Acre	39.1	—	—	—	—	—	—	—	—	—	—
Retirement Community	Dwelling Unit	3.30	—	—	—	—	—	—	—	—	2.60	2.50
Planned Unit Development	Dwelling Unit	7.8	0.10	0.50	1.50	0.30	0.10	0.50	0.50	0.30	8.00	7.00
Planned Unit Development	Acre	46.8	—	—	—	—	—	—	—	—	—	—
LODGING												
Hotel	Employee	11.30	0.36	0.24	0.20	0.19	—	—	0.39	0.13	10.40	9.60
Hotel	Room	10.50	0.58	0.29	0.36	0.37	—	—	—	—	8.10	8.80
Motel	Employee	12.81	—	—	—	—	—	—	—	—	11.20	9.76
Motel	Occupied Room	10.14	—	—	—	—	—	—	—	—	8.86	7.73

TRIP GENERATION RATES — INSTITUTE OF TRANSPORTATION ENGINEERS — 1982

LAND USE/BUILDING TYPE	UNITS	AVERAGE WEEKDAY VEHICLE TRIP ENDS	AM PEAK HOUR TRIP ENDS		PM PEAK HOUR TRIP ENDS		GENERATOR PEAK HOUR TRIPS				SATURDAY TRIP ENDS	SUNDAY TRIP ENDS
			ENTER	EXIT	ENTER	EXIT	AM ENTER	AM EXIT	PM ENTER	PM EXIT		
LODGING con't.												
Resort Hotel	Employee	10.30	—	—	—	—	—	—	—	—	13.60	10.20
Resort Hotel	Occupied Room	10.20	—	—	—	—	—	—	—	—	13.40	10.10
RECREATIONAL												
Recreational	Employee	22.80	—	—	—	—	—	—	—	—	162.20	—
Recreational	Parking Space	3.10	0.20	—	—	—	0.20	0.30	—	—	—	6.60
Recreational	Acres	3.6	—	—	—	—	—	—	—	—	—	2.5
Recreation Home	Dwelling Unit	3.16	.11	.05	.11	.16	.12	.12	.11	.16	3.07	2.93
Recreation Home	Acre	1.3	—	—	—	—	—	—	—	—	—	—
Park	Employee	96.20	—	—	—	—	—	—	—	—	—	193.20
Park	Parking Space	7.80	—	—	—	—	—	—	—	—	—	—
City Park	Employee	51.00	—	—	—	—	—	—	—	—	40.0	40.0
City Park	Acre	6.00	—	—	—	—	—	—	—	—	—	—
County Park	Employee	26.50	—	—	—	—	—	—	—	—	—	27.00
County Park	Parking Space	2.20	—	—	—	—	—	—	—	—	—	2.00
County Park	Acre	5.10	—	—	—	—	—	—	—	—	—	5.80
State Park	Employee	29.1	—	—	—	—	—	—	—	—	27.3	34.1
State Park	Camp Site	7	—	—	.40	.50	—	—	—	—	11	14
State Park	Parking Space	2.0	—	—	—	—	—	—	—	—	2.6	2.1
State Park	Acre	0.60	—	—	—	—	—	—	—	—	—	0.60
Marina	Employee	51.5	—	—	—	—	—	—	—	—	303.5	26.40
Marina	Boat Berth	3.0	—	—	—	—	—	—	—	—	3.2	7.90
Marina	Acre	20.90	—	—	—	—	—	—	—	—	24.90	34.50
Golf Course	Employee	20.6	—	—	—	—	—	—	—	—	25.3	23.2
Golf Course	Parking Space	5.3	—	—	.11	.20	—	—	—	—	4.3	4.0
Golf Course	Acre	6.9	.20	.05	.05	.20	—	—	—	—	5.8	5.9
Racquet Clubs	Court	44.3	—	—	—	—	—	—	—	—	30.70	27.40
Racquet Clubs	1,000 Gross Square Feet Building Area	11.7	—	—	—	—	—	—	—	—	—	—
Racquet Clubs	Member	0.59	—	—	—	—	—	—	—	—	0.83	0.84
Racquet Clubs	Employee	40.7	—	—	—	—	—	—	—	—	36.80	37.30
INSTITUTIONAL												
Military Base	Employee	1.80	—	—	—	—	—	—	—	—	—	—
Military Base	Vehicle	0.90	—	—	—	—	—	—	—	—	—	—

TRIP GENERATION RATES — INSTITUTE OF TRANSPORTATION ENGINEERS — 1982

LAND USE / BUILDING TYPE	UNITS	AVERAGE WEEKDAY VEHICLE TRIP ENDS	AM PEAK HOUR TRIP ENDS		PM PEAK HOUR TRIP ENDS		GENERATOR PEAK HOUR TRIPS				SATURDAY TRIP ENDS	SUNDAY TRIP ENDS
			ENTER	EXIT	ENTER	EXIT	AM ENTER	AM EXIT	PM ENTER	PM EXIT		
INSTITUTIONAL con't												
Elementary Schools	Employee	13.10	—	—	—	—	2.03	0.91	0.70	1.30	—	—
Elementary Schools	Student	1.02	—	—	—	—	0.11	0.05	0.04	0.07	—	—
High School	Student	1.39	—	—	—	—	0.19	0.07	0.07	0.13	0.77	0.23
High School	Employee	455.00	—	—	—	—	—	—	—	—	—	—
Junior/Community College	Student	1.55	0.15	0.02	0.04	0.08	0.16	0.03	0.05	0.11	—	—
University	Student	2.41	—	—	—	—	—	—	—	—	—	—
Library	Employee	51.00	—	—	—	—	1.40	1.40	3.80	3.40	41.00	36.50
Library	1,000 Gross Square Feet	41.80	—	—	—	—	1.10	1.10	3.00	2.70	33.60	3.40
MEDICAL												
Hospital	Employee	4.90	.17	.06	.17	.16	.23	.08	.27	.36	4.42	3.33
Hospital	Bed	11.4	.73	.28	.46	.81	.94	.40	.65	.94	9.3	7.15
Hospital	1,000 Square Feet	16.7	—	—	—	—	—	—	—	—	12.9	9.8
Nursing Home	Bed	2.6	—	—	.05	.16	—	—	.20	.23	2.1	2.4
Nursing Home	Employee	4.0	—	—	—	—	.13	.06	—	—	3.40	3.7
Clinic	Employee	5.9	.30	.15	.46	.65	.45	.45	.65	.65	3.4	6.0
Clinic	1,000 Gross Square Feet of Building Area	23.8	—	—	—	—	—	—	—	2.48	13.5	24.0
OFFICE												
General Office Building	Employee	3.59	0.35	0.06	0.08	0.24	0.35	0.06	0.08	0.24	0.81	—
General Office Building	1,000 Gross Square Feet	12.30	1.86	0.35	0.27	1.36	1.86	0.35	0.27	1.36	3.34	—
General Office Building	Acre	240.10	—	—	—	—	—	—	—	—	—	—
General Office, under 100,000 G.S.F.	1,000 Gross Square Feet of Building Area	17.7	1.45	.25	.19	1.14	2.23	.45	.36	1.88	2.4	1.2
General Office, under 100,000 G.S.F.	Employee	3.7	.36	0.7	.04	.27	—	—	—	—	—	—
General Office, under 100,000 G.S.F.	Acre	137	—	—	—	—	—	—	—	—	—	—
General Office, 100,000 to 199,999 G.S.F.	1,000 Gross Square Feet Building Area	14.3	1.87	.22	.44	1.76	1.87	.22	.44	1.76	3.5	2.4
General Office, 100,000 to 199,999 G.S.F.	Employee	3.8	.35	.05	.09	.23	—	—	—	—	—	—
General Office, 100,000 to 199,999 G.S.F.	Acre	166	—	—	—	—	—	—	—	—	—	—
General Office, over 200,000 G.S.F.	Employee	2.9	—	—	—	—	—	—	—	—	—	—

TRIP GENERATION RATES — INSTITUTE OF TRANSPORTATION ENGINEERS — 1982

LAND USE/BUILDING TYPE	UNITS	AVERAGE WEEKDAY VEHICLE TRIP ENDS	AM PEAK HOUR TRIP ENDS		PM PEAK HOUR TRIP ENDS		GENERATOR PEAK HOUR TRIPS				SATURDAY TRIP ENDS	SUNDAY TRIP ENDS
			ENTER	EXIT	ENTER	EXIT	AM ENTER	AM EXIT	PM ENTER	PM EXIT		
OFFICE con't												
General Office, over 200,000 G.S.F.	1,000 Gross Square Feet of Building Area	10.9	1.78	.18	.23	1.70	1.81	.34	.23	1.70	—	—
Medical Office Building	1,000 Square Feet	54.6	.64	.21	.89	3.05	2.68	4.51	3.47	5.17	34.7	3.8
Government Office Building	Employee	12.00	0.85	0.17	—	—	0.85	0.17	1.42	0.49	—	—
Government Office Building	1,000 Gross Square Feet	68.93	4.92	0.96	—	—	4.92	0.96	8.20	2.83	—	—
State Motor Vehicles Department	Employee	44.5	—	—	—	—	—	—	—	—	2.4	1.7
State Motor Vehicles Department	1,000 Gross Square Feet of Building Area	166.1	—	—	—	—	—	—	—	—	—	—
Post Office	1,000 Gross Square Feet of Building Area	139.7	—	—	—	—	—	—	—	—	80.3	44.4
Post Office	Employee	25.1	—	—	—	—	—	—	—	—	14.4	8.00
Civic Center	Employee	6.09	0.49	0.06	0.22	0.48	—	—	—	—	—	—
Civic Center	1,000 Gross Square Feet	25.00	2.00	0.25	0.89	1.96	—	—	—	—	—	—
Office Park	Employee	3.33	—	—	—	—	—	—	—	—	—	—
Office Park	1,000 Gross Square Feet	20.65	1.98	0.26	0.33	1.84	1.98	0.26	0.33	1.84	—	—
Office Park	Acre	276.60	—	—	—	—	—	—	—	—	—	—
Research Center	Employee	2.4	—	—	—	—	—	—	—	—	—	—
Research Center	1,000 Gross Square Feet	5.3	2.5	0.2	0.1	0.9	—	—	—	—	1.8	—
Research Center	Acre	57.2	—	—	—	—	—	—	—	—	—	—
RETAIL												
Specialty Retail Center	1,000 Gross Square Feet of Leasable Area	40.7	—	—	—	—	1.99	—	2.25	—	42.0	20.4
Discount Store	1,000 Gross Square Feet	70.1	—	—	1.40	1.90	—	—	2.60	2.40	72.7	42.9
Hardware Paint Store	1,000 Gross Square Feet	51.30	—	—	—	—	—	—	—	—	—	68.70
Hardware Paint Store	Employee	53.20	—	—	—	—	—	—	—	—	85.60	71.20
Hardware Paint Store	Acre	546.00	—	—	—	—	—	—	—	—	878.00	731.00

TRIP GENERATION RATES—INSTITUTE OF TRANSPORTATION ENGINEERS—1982

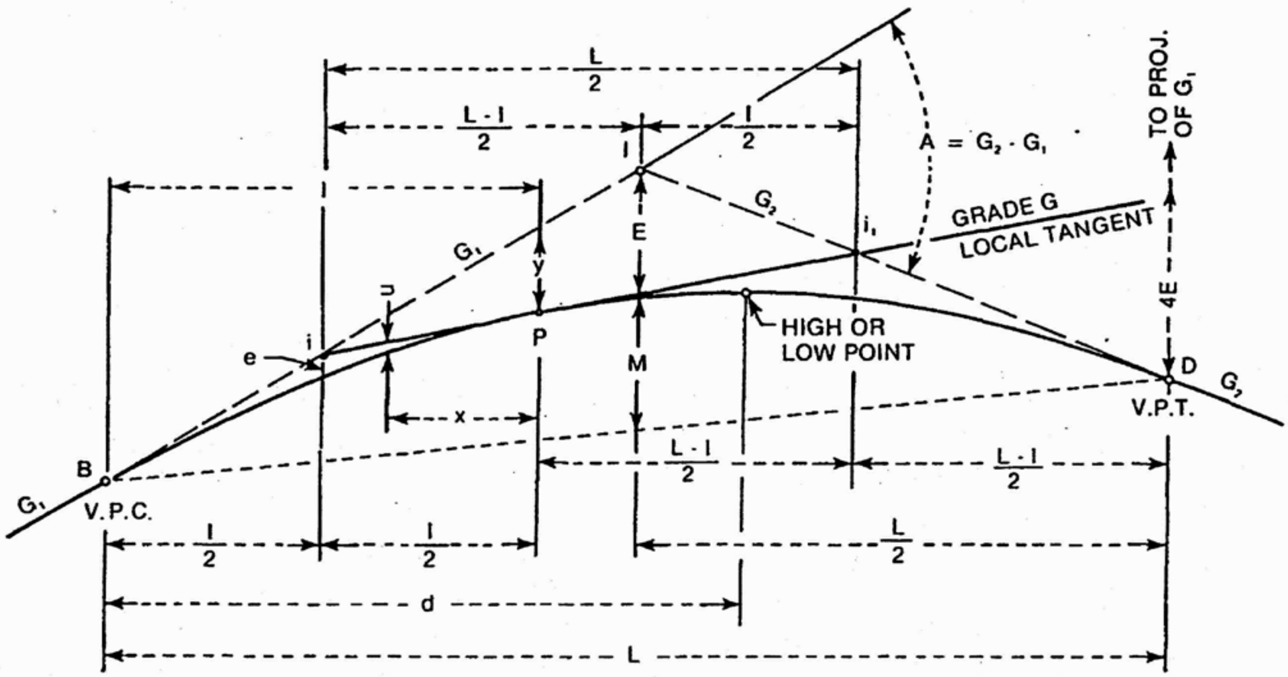
LAND USE/BUILDING TYPE	UNITS	AVERAGE WEEKDAY VEHICLE TRIP ENDS	AM PEAK HOUR TRIP ENDS		PM PEAK HOUR TRIP ENDS		GENERATOR PEAK HOUR TRIPS				SATURDAY TRIP ENDS	SUNDAY TRIP ENDS
			ENTER	EXIT	ENTER	EXIT	AM ENTER	AM EXIT	PM ENTER	PM EXIT		
RETAIL con't												
Wholesale	Employee	8.21	—	—	—	—	—	—	—	—	1.94	2.80
Wholesale	1,000 Square Feet of Building Space	6.73	—	—	—	—	—	—	—	—	1.59	2.29
Wholesale	Acre	128	—	—	—	—	—	—	—	—	—	—
Furniture Store	1,000 Gross Square Feet of Building Area	0.70	—	—	—	—	—	—	—	—	0.78	0.80
SERVICES												
Bank—Walk-In	1,000 Gross Square Feet	169.00	—	—	5.9	5.9	—	—	7.0	7.0	14.80	—
Bank—Walk-In	Employee	44.50	—	—	2.5	2.5	—	—	2.9	2.9	3.90	—
Drive-In Bank	1,000 Gross Square Feet	192.00	3.0	0.3	6.5	12.3	15.30	15.30	18.3	12.8	8.30	—
Drive-In Bank	Employee	47.40	—	—	2.30	4.40	5.40	5.40	6.50	4.50	1.90	—
Savings and Loan—Walk-In	1,000 Gross Square Feet	61.00	—	—	—	—	—	—	—	—	109.00	—
Savings and Loan—Walk-In	Employee	30.50	—	—	—	—	—	—	—	—	54.20	—
Savings and Loan—Drive-In	1,000 Gross Square Feet	74.00	—	—	—	—	—	—	—	—	28.00	—
Savings and Loan—Drive-In	Employee	49.00	—	—	—	—	—	—	—	—	18.00	—
Savings and Loan—Drive-In	Window	445.00	—	—	—	—	—	—	—	—	165.00	—
Insurance	1,000 Gross Square Feet	11.50	—	—	—	—	—	—	—	—	2.10	—
Insurance	Employee	2.45	—	—	—	—	—	—	—	—	0.46	—
Insurance	Acre	91.80	—	—	—	—	—	—	—	—	25.60	—

TRIP GENERATION RATES—INSTITUTE OF TRANSPORTATION ENGINEERS—1982

LAND USE/BUILDING TYPE	UNITS	AVERAGE WEEKDAY VEHICLE TRIP ENDS	AM PEAK HOUR TRIP ENDS		PM PEAK HOUR TRIP ENDS		GENERATOR PEAK HOUR TRIPS				SATURDAY TRIP ENDS	SUNDAY TRIP ENDS
			ENTER	EXIT	ENTER	EXIT	AM ENTER	AM EXIT	PM ENTER	PM EXIT		
RETAIL con't												
Shopping Center—0 to 49,999 Gross Square Feet	1,000 Gross Square Feet	117.9	0.91	0.80	5.77	5.81	2.07	2.03	6.84	7.03	—	—
Shopping Center—50,000 to 99,999 Gross Square Feet	1,000 Gross Square Feet	82.0	1.4	1.3	3.2	3.4	3.0	2.9	3.9	3.8	107.0	49.3
Shopping Center—100,000 to 199,999 Gross Square Feet	1,000 Gross Square Feet	66.7	0.9	0.8	2.9	3.1	2.6	2.5	3.6	3.5	112.4	50.2
Shopping Center—200,000 to 299,999 Gross Square Feet	1,000 Gross Square Feet	50.6	0.4	0.2	2.10	2.2	2.0	2.2	2.5	2.7	74.2	32.2
Shopping Center—300,000 to 399,999 Gross Square Feet	1,000 Gross Square Feet	41.9	1.6	0.7	3.1	3.3	3.0	3.0	3.7	3.6	69.6	32.2
Shopping Center—400,000 to 499,999 Gross Square Feet	1,000 Gross Square Feet	49.7	0.3	0.2	1.9	1.9	2.0	1.6	2.2	2.1	61.4	10.2
Shopping Center—500,000 to 999,999 Gross Square Feet	1,000 Gross Square Feet	37.2	0.38	0.23	1.59	1.65	1.40	1.35	1.68	1.81	45.3	19.5
Shopping Center—1,000,000 to 1,249,999 Gross Square Feet	1,000 Gross Square Feet	37.1	—	—	1.4	1.9	—	1.5	3.0	1.9	39.2	22.8
Shopping Center—Over 1,250,000 Gross Square Feet	1,000 Gross Square Feet	34.1	0.36	0.13	1.10	1.41	1.20	1.39	1.42	1.76	39.0	23.5
Quality Restaurant	Seat	2.34	0.03	0.02	0.09	0.05	—	—	0.16	0.15	2.60	—
Quality Restaurant	1,000 Square Feet GFA	74.9	0.85	0.46	2.74	1.69	6.48	1.14	7.71	2.80	99.2	71.6
High Turn-Over, Sit Down Restaurant	1,000 Square Feet	164.40	—	—	9.90	4.00	10.10	5.50	13.0	9.20	67.80	39.00
Drive-In Restaurant	1,000 Square Feet	553.00	49.70	40.20	17.00	14.60	—	—	44.40	41.90	—	—
New Car Sale	Employee	24.00	—	1.98	—	1.03	—	—	—	1.22	10.5	5.3
Service Station	Pump	133.00	1.00	0.75	1.88	1.75	2.75	2.75	3.25	2.75	—	—
Car Wash	Site	—	54	54	55	55	—	—	66	66	—	—
Highway Oasis	Site	—	34.00	43.00	27.00	55.50	44.00	48.5	40.00	64.50	—	—
15-16 Hour Open Convenience Market	1,000 Gross Square Feet	322.60	—	—	—	—	—	—	—	—	—	—
24-Hour Open Convenience Market	1,000 Gross Square Feet	625.2	—	—	—	—	—	—	—	—	—	—

TRIP GENERATION RATES — INSTITUTE OF TRANSPORTATION ENGINEERS — 1982

LAND USE / BUILDING TYPE	UNITS	AVERAGE WEEKDAY VEHICLE TRIP ENDS	AM PEAK HOUR TRIP ENDS		PM PEAK HOUR TRIP ENDS		GENERATOR PEAK HOUR TRIPS				SATURDAY TRIP ENDS	SUNDAY TRIP ENDS
			ENTER	EXIT	ENTER	EXIT	AM ENTER	AM EXIT	PM ENTER	PM EXIT		
RETAIL con't												
Wholesale	Employee	8.21	—	—	—	—	—	—	—	—	1.94	2.80
Wholesale	1,000 Square Feet of Building Space	6.73	—	—	—	—	—	—	—	—	1.59	2.29
Wholesale	Acre	128	—	—	—	—	—	—	—	—	—	—
Furniture Store	1,000 Gross Square Feet of Building Area	0.70	—	—	—	—	—	—	—	—	0.78	0.80
SERVICES												
Bank — Walk-In	1,000 Gross Square Feet	169.00	—	—	5.9	5.9	—	—	7.0	7.0	14.80	—
Bank — Walk-In	Employee	44.50	—	—	2.5	2.5	—	—	2.9	2.9	3.90	—
Drive-In Bank	1,000 Gross Square Feet	192.00	3.0	0.3	6.5	12.3	15.30	15.30	18.3	12.8	8.30	—
Drive-In Bank	Employee	47.40	—	—	2.30	4.40	5.40	5.40	6.50	4.50	1.90	—
Savings and Loan — Walk-In	1,000 Gross Square Feet	61.00	—	—	—	—	—	—	—	—	109.00	—
Savings and Loan — Walk-In	Employee	30.50	—	—	—	—	—	—	—	—	54.20	—
Savings and Loan — Drive-In	1,000 Gross Square Feet	74.00	—	—	—	—	—	—	—	—	28.00	—
Savings and Loan — Drive-In	Employee	49.00	—	—	—	—	—	—	—	—	18.00	—
Savings and Loan — Drive-In	Window	445.00	—	—	—	—	—	—	—	—	165.00	—
Insurance	1,000 Gross Square Feet	11.50	—	—	—	—	—	—	—	—	2.10	—
Insurance	Employee	2.45	—	—	—	—	—	—	—	—	0.46	—
Insurance	Acre	91.80	—	—	—	—	—	—	—	—	25.60	—



$A = G_2 - G_1$ ....(1)

$E = \frac{AL}{800}$ ....(2)

$E = M$ ....(3)

$K = \frac{L}{A}$ ....(4)

NOTE:

DISTANCES L, l, d, E, y, ETC. ARE IN FEET.

GRADES G_1, G_2, A AND G ARE IN PERCENT.

$y = \frac{l^2}{\left(\frac{L}{2}\right)^2}E = \frac{Al^2}{200L}$ ....(5)

$y = l^2C$...where $C = \frac{E}{\left(\frac{L}{2}\right)^2} = \frac{A}{200L}$ .....(6)

$g = G_1 - \frac{Al}{L} = G_1 - \frac{l}{K}$ ....(7)

$d = \frac{G_1L}{A} = G_1K$ ....(8)

THE FOLLOWING EQUATIONS SHOW THAT CURVES BP AND PD, FORMED BY INTRODUCTION OF LOCAL TANGENT AT P, ARE SIMILAR AND HAVE THE SAME PARABOLIC PROPERTIES AS THE ORIGINAL CURVE BD --

HORIZ. DISTANCES: $ii_1 = \frac{l}{2}$; $Bi = iP = Ii_1 = \frac{l}{2}$; $Di_1 = i_1P = I_1 = \frac{L - l}{2}$

ALSO, $u = \frac{x^2C}{(l/2)^2}$ $\frac{x^2E}{(l/2)^2}$

THUS, ONE LONG VERTICAL CURVE CAN BE BROKEN DOWN TO TWO OR MORE COMPOUND VERTICAL CURVES: OR CONVERSELY, TWO OR MORE VERTICAL CURVES HAVING THE SAME K VALUE CAN BE COMBINED INTO A SINGLE VERTICAL CURVE.

Figure A-1. Properties of Vertical Curves.