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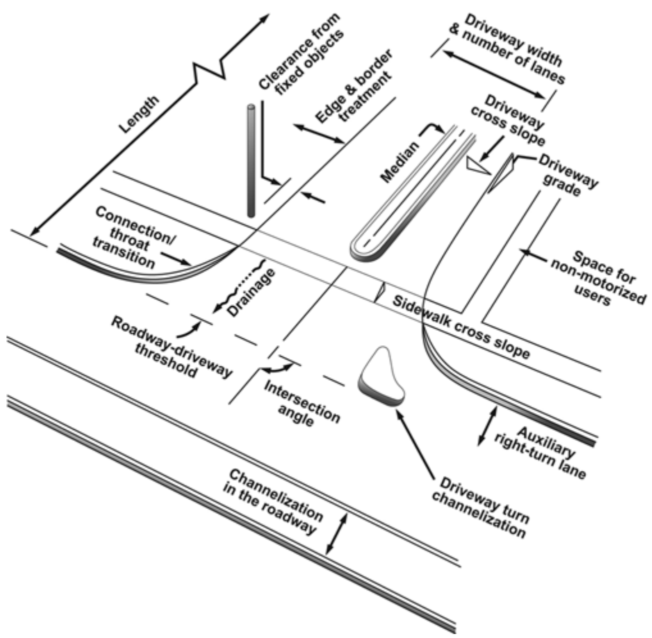
PROGRAM

REPORT 659

Guide for the Geometric Design of Driveways



TRANSPORTATION RESEARCH BOARD
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Guide for the Geometric Design of Driveways

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TRANSPORTATION RESEARCH BOARD

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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Dr. James L. Gattis, Professor of Civil Engineering at UA, was the Principal Investigator. Jerome S. Gluck of AECOM was the Co-Principal Investigator. Janet M. Barlow (Accessible Design for the Blind), Ronald W. Eck (West Virginia University), William F. Hecker (Hecker Design, LLC), and Herbert S. Levinson were special consultants for the project.

FOREWORD

By David A. Reynaud
Staff Officer
Transportation Research Board

This report presents guidelines that will be of use to state departments of transportation, local governments, and consultants for the geometric design of driveways. It contains driveway-related terms and definitions, basic geometric controls, a summary of access spacing principles, and detailed discussions of various geometric design elements. Material related to and supporting the contents of this publication, including an extensive review of literature, can be found in *NCHRP Web-Only Document 151: Geometric Design of Driveways.* (This supporting document is available on the TRB website (www.trb.org), search for "NCHRP Web-Only Document 151".)

The design of driveways has benefited from little comprehensive research and no national design guidance since the American Association of State Highway Officials (AASHO) publication, *An Informational Guide for Preparing Private Driveway Regulations for Major Highways,* was published in 1959. Since then, roadway design, function, and volumes have changed as have vehicle design and many other aspects of the roadway environment.

Driveways, especially busy commercial drives, can have a significant impact on the adjacent roadway. Good driveway design should facilitate smooth vehicle egress and ingress to and from the roadway and should also provide for pedestrians and bicyclists. Driveway design needs to consider the roadway functional class and driveway usage to better accommodate varying roadway environments, community needs, and existing conditions. There is currently little guidance on this issue.

The *Draft Guidelines for Accessible Public Rights-of-Way,* disseminated by the U.S. Access Board for public comment in 2001, provides specific guidelines for such elements as minimum width, cross slope, grade, and edge conditions at the intersection of sidewalks and driveways to comply with the Americans with Disabilities Act. These guidelines are based on pedestrian needs and do not comprehensively address safe and efficient vehicle movements at driveways. Recommendations are needed to accommodate accessibility concerns as well as safe and efficient vehicle use of the driveway.

This research addressed the design of driveways in the form that roadway designers use—the area where the driveway intersects the public road. The objective of this research was to develop recommendations for the geometric design of driveways that consider standard engineering practice and accessibility needs and provide for safe and efficient travel by motorists, pedestrians, and bicyclists on the affected roadway. The importance of these issues is reflected in studies that show that up to 19 percent of reported urban traffic collisions involve driveway traffic. This design guide was prepared by James Gattis of the University of Arkansas and other consultants as a by-product of the research for NCHRP Project 15-35, "Geometric Design of Driveways." This research included a literature review, a survey of street and highway departments, and field studies leading to an improved understanding of the state of the practice. This guide presents changes to that state of practice based on the evolving requirements for driveways.

CONTENTS

CHAPTER 1

Introduction

Purpose and Scope of the Guide

This document contains guidelines for the geometric design of driveways. The guidelines are an outgrowth of a literature review and synthesis, a survey of state DOTS, and field studies that were a part of NCHRP Project 15-35, "Geometric Design of Driveways." This publication complements documents such as the AASHTO *Policy on the Geometric Design of Streets and Highways* (*1-1*) and the *Access Management Manual* (*1-2*). This guide is intended for use in both the public and private sectors.

The following driveway design objectives guided the authors during the preparation of this guide:

- Provide a safe environment for various users: bicyclists, motorists, and pedestrians (including pedestrians with disabilities and transit passengers).
- Provide geometry that accommodates the characteristics and limitations of the various users, and avoid geometric conditions that create traffic operations problems.
- Provide driveways that allow traffic to flow smoothly.
- Avoid driveway locations that create traffic operations problems.
- Provide driveways that are conspicuous and clearly delineated for the various users.

Although it may be impossible to perfectly achieve these objectives, some designs come much closer than others in achieving these objectives. Every driveway connection creates an intersection, which creates conflicts with bicyclists, pedestrians, and other motor vehicles. An objective of good design is to seek a balance that minimizes the actual conflicts and accommodates the demands for travel and access.

Driveways can be defined as private roads that provide access between public ways and activities or buildings on abutting land (*1-3*). However, when roadway designers use the term "driveway," they are often referring to just a part of a driveway—the area where the driveway intersects the public highway or street. With few exceptions, the contents of this guide reflect the roadway designer definition of driveway and do not address the design of a driveway well within a private site, except as such design affects the driveway intersection with the public roadway. Many of these recommendations were prepared to address access connections that are designed to look more like the typical driveway rather than those looking like public roadways.

Need for This Guide

Driveways are integral to the roadway-based transportation system. They are found along most roadways throughout urban, suburban, and rural areas. They range from single-lane connections serving single-family residences to multilane, divided-access connections to major activity centers.

Exhibit 1-1. The consequences of driveway design decisions.

(a)

(b)

Driveways vary in size and design according to the activities they serve and the associated traffic volumes, development densities, proximity to intersections, and exposure to bicyclists and pedestrians. The design and appearance of driveways have evolved over the years as technologies and land development patterns have changed.

Both anecdotal experience and structured research studies show that certain driveway design practices create problems for bicyclists, motorists, and pedestrians. Studies have found that anywhere from 11 to 19% of all reported urban traffic collisions involve a driveway (*1-4*). The location and design of a driveway affect both traffic flow and safety on both the driveway and on the adjacent public roadway.

There has been less study of driveways than of many other types of roadway facilities. Among the few publications that have addressed driveway design are the following:

- The American Association of State Highway Officials' (AASHO) guidelines published in 1959 (*1-5*),
- The Institute of Transportation Engineers (ITE) guidelines published in 1987 (*1-6*),
- Technical assistance from the U.S. Access Board published in 1999 (*1-7*), and
- The TRB *Access Management Manual* (*1-2*).

The growing emphasis on multi-modal transportation and the requirements of the Americans with Disabilities Act (ADA) also call for a re-examination of driveway design practices. During preparation of this document, it became apparent that structured studies and documented information on which to base recommendations is often limited. It is hoped that future research will help improve the knowledge base.

Exhibit 1-1 illustrates some of the operational and safety problems that can arise when driveway designs are inadequate.

Organization and Structure of the Guide

This guide consists of the following chapters:

- Chapter 2 lists terms and definitions.
- Chapter 3 discusses some of the basic geometric design controls. These controls include basic characteristics of users and vehicles, as well as site-specific controls, such as setting and land use, types of users, vehicle types, volumes, and speeds. These considerations affect the design practices recommended in the following chapters.
- Chapter 4 briefly mentions access spacing principles and guidelines and references other publications for more information.

- Chapter 5 sets forth various geometric design elements. These include plan and cross sections, driveway length, vertical alignment, and related elements.

Material related to and supporting the contents of this publication, including an extensive review of literature, can be found in *NCHRP Web-Only Document 151: Geometric Design of Driveways.*

References

1-1. AASHTO. *A Policy on Geometric Design of Highways and Streets.* Washington, DC (2004) 896 pp.
1-2. TRB Committee on Access Management. *Access Management Manual.* Transportation Research Board, National Research Council, Washington, DC (2003) 373 pp.
1-3. Webster's Collegiate Dictionary. G&C Merriam Company, Springfield, MA (1981).
1-4. Rawlings, J., and Gattis, J. L. "Detailed Study of Driveway Collision Patterns in an Urban Area." *Compendium of Papers,* 87th Annual Meeting, Transportation Research Board, National Research Council, Washington, DC (2008).
1-5. AASHO. *An Informational Guide for Preparing Private Driveway Regulations for Major Highways.* Washington, DC (October 10, 1959, copyright 1960) 31 pp.
1-6. ITE. *Guidelines for Driveway Location and Design.* Washington, DC (1987) 23 pp.
1-7. U.S. Access Board. *Accessible Public Rights of Way: Design Guide.* U.S. Architectural and Transportation Barriers Compliance Board, Washington, DC (1999).

CHAPTER 2

Terms and Definitions

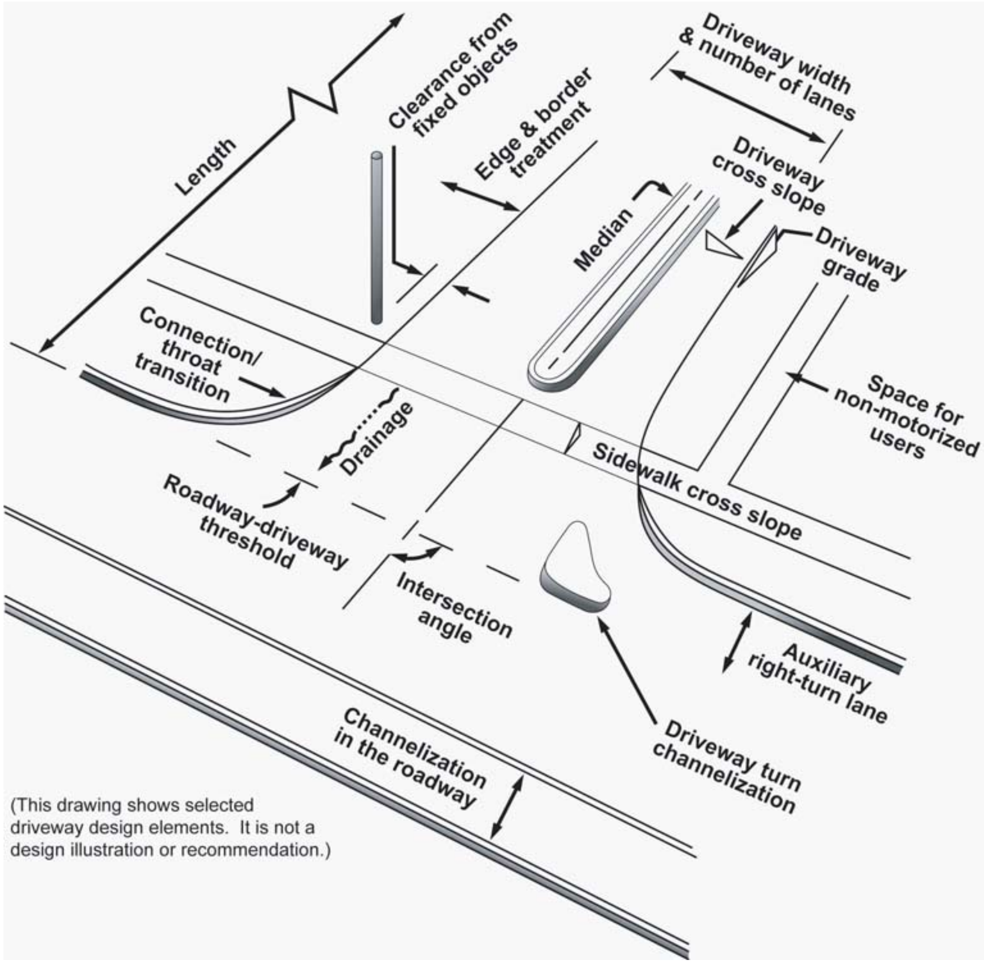
This chapter presents terms and definitions used in this report. Exhibit 2-1 illustrates the location of some of the named driveway design elements.

AASHO – American Association of State Highway Officials
AASHTO – American Association of State Highway and Transportation Officials
ADA – Americans with Disabilities Act of 1990
Blended transition – A connection with a grade of 5% or less between the level of the pedestrian walkway and the level of the crosswalk (*2-1*).
Breakover angle – The algebraic difference between two successive grades.
CBD – Central business district: the established "downtown" core or center of a city that traditionally included government, office, and retail activities.
Commercial driveway – Driveways that serve uses such as offices, retail, or services.
Connection – The junction of the subject roadway with a source of traffic from the side (e.g., a driveway, roadway, or ramp).
Contrast – A marked difference between dark and light. With regard to ADA contrast for detectable warnings, the ADA Standards state the following in the advisory appendix section.

> A4.29.2 Detectable Warnings on Walking Surfaces. The material used to provide contrast should contrast by at least 70%. Contrast in percent is determined by:
>
> $$\text{contrast} = [(B1 - B2)/B1] \times 100$$
>
> where B1 = light reflectance value (LRV) of the lighter area and
> B2 = light reflectance value (LRV) of the darker area.
>
> Note that in any application both white and black are never absolute; thus, B1 never equals 100 and B2 is always greater than 0.

Cross slope – The slope (or grade) perpendicular to the direction of travel. On a sidewalk or blended transition, it is measured perpendicular to the curb line or roadway edge. On a curb ramp, it is measured perpendicular to the longitudinal or running grade.
Driveway triangular island ("pork chop") – Roadway or driveway channelization in the form of a somewhat-triangular island.
Dust pan –A driveway entry or exit shape with the plan view designed with a flared or tapered edge. With this design, the curb height along the roadway edge transitions from full height to no curb height. Thus, the design incorporates a taper in both the plan and in the front elevation views.
Front overhang – The distance from the center of the front-most wheel to the front end of the vehicle.
Functional area of intersection – The area that includes not only the physical area where roadways cross each other, but also the areas upstream and downstream of the physical intersection, where driver reaction, deceleration, queuing, and acceleration occur that are related to the operation of the intersection.
Ground clearance – The distance from the bottom of a vehicle body to the ground.

Exhibit 2-1. Some driveway design elements.



Hang-up – When the underside of a vehicle comes into contact with the roadway surface, at grade breaks in the vertical profile, such that the vehicle is immobilized or stuck on the vertical geometry. Also referred to as lodged or high-centered.

Interface – The broader area where a driveway joins the roadway, including the curved or flared turning areas.

ITE – Institute of Transportation Engineers

MUTCD – *Manual on Uniform Traffic Control Devices.* The federal MUTCD is incorporated by reference in 23 Code of Federal Regulations (CFR), Part 655, Subpart F. It is recognized as the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel in accordance with 23 U.S.C. 109(d) and 402(a).

NCHRP – National Cooperative Highway Research Program

Non-restrictive median – A median designed to be easily crossed by a motor vehicle, such as a two-way left-turn lane (TWLTL).

Offset – The meaning of this term depends on the context. In the context of a driveway connection transition, it can refer to the situation where due to the presence of on-street parking, a bicycle lane, a shoulder, or similar space generally parallel to and outside of the traveled way, the physical end of a driveway is some distance away from the edge of the traveled way. The effect of this is that part of the turning movement of those vehicles entering or exiting the driveway takes place in that area between the edge of the traveled way and the physical end of the driveway.

PAR – Pedestrian Access Route

Pedestrian Access Route – A continuous and unobstructed walkway within a pedestrian circulation path that provides accessibility.

Ped – Pedestrian. From the 2003 MUTCD, Section 1A13.55: "a person afoot, in a wheelchair, on skates, or on a skateboard" (*2-2*).

Pork chop (driveway triangular island) – Roadway or driveway channelization in the form of a somewhat-triangular island.

P-vehicle – The passenger car design vehicle as defined by AASHTO. Also includes minivans, pick-up trucks, sport utility vehicles (SUVs), and standard size vans.

Rear overhang – The distance from the centerline of the rearmost axle to the rear end of the vehicle.

Restrictive median – A median, such as a raised or depressed median, designed not to be crossed by a motor vehicle except at selected locations.

RV – Recreational vehicle (e.g., a motor home).

Spillback – When a situation exists such that the traffic conditions at the subject driveway influence or affect the operation of vehicles in the outside through lane at or in advance of the driveway upstream of the subject driveway.

TCD – Traffic control devices, including signs, pavement markings, and traffic signals

Threshold – The edge, dividing line, or boundary where the driveway meets the public roadway. In many cases, this is a line along the curb edge.

Throat length – The distance from the outer edge of the traveled way of the intersecting roadway to the first point along the driveway at which there are conflicting vehicular traffic movements. Also referred to as the driveway connection depth, driveway reservoir length, driveway stacking distance, driveway storage length.

Traveled way – The portion of the roadway for movement of vehicles, exclusive of shoulders (*2-3*).

TRB – Transportation Research Board

Wheelbase – The distance between the centers of two axles or wheels. Sometimes shown as the length from the front axle to the rear axle.

References

2-1. "R105.5 Defined Terms" in *Revised Draft Guidelines for Accessible Public Rights-of-Way*. http://www.access-board.gov/prowac/draft.htm#105 (as of Nov. 23, 2005).

2-2. FHWA. *Manual on Uniform Traffic Control Devices.* Washington, DC (2003) 760 pp.

2-3. AASHTO. *A Policy on Geometric Design of Highways and Streets*. Washington, DC (2004) p. 305.

CHAPTER 3

Design Controls

As with other types of roadway geometric features, the test of how well or how poorly a driveway connection is designed is determined by how well or how poorly the connection operates after it is opened. To anticipate the consequences of a design choice before a facility is actually constructed and opened for use, the designer needs to identify the setting and understand the performance characteristics and limitations of the users—bicyclists, drivers, pedestrians, and motor vehicles.

Although there will always be exceptions, the following material describes generally prevalent situations in the United States. These considerations are incorporated into the more detailed design guidelines presented in Chapters 4 and 5.

The Driveway Setting

The design of a driveway is affected by its setting and land use. The environment can be urban, suburban, or rural. The various characteristics of a driveway serving a tract with commercial land use are quite different from a driveway serving a single-family residence. Combinations of these characteristics and other factors affect the final design choices.

The differences between urban, suburban, and rural settings can be characterized by development density, the spacing of parallel and intersecting streets, levels of bicycle and pedestrian traffic, and the availability of public transit service. In contrast to rural areas, built-up urban areas typically have lower speeds, more frequent intersections, many more pedestrians, and often bus service. In urban settings, especially in central business districts (CBDs), driveway geometry can be more constrained than in suburban and in rural areas. Exhibit 3-1 lists the relative importance of travel modes, based on the location and development density of the activities to be served. The relative importance can help the designer determine how to address the sometimes conflicting needs of different modes.

Although all types of property tracts need access to and from public roadways, the nature of that need varies according to the type of land use (e.g., agricultural, commercial, and residential). The type of land use is typically associated with factors such as the volume of traffic and the types of vehicles in and out of the driveway. Exhibit 3-2 lists common types of driveways, illustrative applications, and some considerations affecting the design. The organization reflects combinations of factors that designers commonly encounter. “Standard” driveways are grouped by intensity of use—very high, higher, medium, and lower. “Special situation” driveways include those that create special needs (e.g., a driveway in a city center or serving a farm or ranch, a field, or an industry).

Exhibit 3-2 does not list all of the possible combinations of land use and surrounding environment; a list of all combinations would be extremely complex and unwieldy. The designer

Exhibit 3-1. Driveway settings and the importance of various modes.

Area Type	Descriptive Attributes	Relative Importance of Mode (as determined by the actual choices the public is observed to make)			
		Auto	Bicycle	Ped	Transit
Urban Core (CBD and other major urban centers)	Connected buildings Sidewalk paved from curb edge to the face of buildings Shorter blocks Higher pedestrian volumes In some locales, higher volumes of transit vehicles and riders Motor vehicle traffic is often congested and moving relatively slowly	Medium	Medium	High	High to Medium
General Urban	May include special districts (e.g., outlying business districts that are not in an urban core) Bicycles and pedestrians are present In some locales, public transit vehicles and riders are present	High	Medium	Medium	Medium
Suburban	Motor vehicles are predominate mode A few bicycles and pedestrians are present In some locales, occasional public transit is present	High	Low	Low	Low
Exurban	Motor vehicles are predominate mode Bicycles, pedestrians, and/or transit are infrequent	High	Low	Low	Low
Rural (farm or ranch)	Motor vehicles are predominate mode Higher speeds need longer access spacing	High	Very low	Very low	Very low

NOTES: "Ped" = Pedestrian
"Relative Importance" is affected by region. For instance, public transit is more prevalent in some regions than in others.

must exercise good judgment that reflects an understanding of traffic characteristics when categorizing a particular driveway and applying design standards. For instance, the small radius and steep grades that some agencies allow for residential driveways will probably be unsuitable for a single-family residential driveway connecting to a busy thoroughfare. Land use type alone is not a sufficient criterion for design; the designer must consider other factors, including the site environment.

User Mix Considerations

Bicyclists, motorized-vehicles (e.g., automobiles, buses), pedestrians, pedestrians with disabilities (e.g., persons using mobility aids such as wheelchairs, or pedestrians with visual impairments) all occupy and use transportation facilities in the United States. In the area where the roadway, the sidewalk, and the driveway intersect, there are three distinct user groups with different and sometimes conflicting needs (see Exhibit 3-3). Although members of each group typically want to make their trips as expeditiously as possible, the roadway user is usually moving at a greater speed and therefore is often focused on the roadway some distance ahead. The sidewalk users (e.g., pedestrians, pedestrians with mobility disabilities) are moving at a much slower pace, and are unprotected and vulnerable to vehicles. The area may be used by those waiting for a bus or taxi. The driveway user typically has a speed and a path that can create conflicts with the other two user groups.

Exhibit 3-2. Driveway categories.

Category	Description of Common Applications*	Considerations Affecting Design
STANDARD DRIVEWAYS		
Very high intensity	Urban activity center, with almost constant driveway use during hours of operation. Typified by a driveway serving a post-1950 major shopping center or office complex. These driveways often look like public roadways. Not uncommon for these driveways to be signalized.	Very high site volume. These sites are often on streets with relatively high speeds and volumes. For these driveways, refer to street design guides.
Higher intensity	Medium-size office or retail, such as community shopping center, with frequent driveway use during hours of operation. Also includes land uses with extreme peaking patterns, such as public schools, worship assemblies, and employee parking lots.	These sites are often on streets with relatively high speeds and volumes. Expect more than one exiting vehicle at a time.
Medium intensity	Smaller office or retail, such as convenience stores, with occasional driveway use during hours of operation. Also includes some apartment complexes.	These sites may be on streets with relatively high speeds and volumes. Seldom more than one exiting vehicle at a time.
Lower intensity	Typical applications include single-family or duplex residential, or other types with low use. May not apply to rural residential.	If on a lower-speed, lower-volume roadway, conflicts with other vehicles are relatively less frequent. The driveway is used by only one vehicle at a time.
SPECIAL SITUATION DRIVEWAYS		
Central business district	Building faces are close to the street. May have on-street parking or bus stops, a continuous sidewalk from the curb to faces of buildings, and higher pedestrian usage than in most other environments. Many situations will serve P-vehicles and some single-unit trucks.	Vehicles entering a driveway may encounter a higher frequency of conflict with other users, such as pedestrians. Through motorists expect more frequent traffic interruptions.
Farm or ranch	May be a mixture of residential and industrial characteristics, used by a mix of design vehicles, such as P-vehicle, single-unit truck, and agricultural equipment.	May be on a highway with a posted speed of 50 mph or more. Pedestrian use is extremely rare. The driveway is used by only one vehicle at a time.
Field (Very low intensity)	Serves a field or other similar land area that is seldom trafficked. Higher-clearance P-vehicles or heavy vehicles are expected.	Many days may elapse between uses. Pedestrian use is extremely rare. The driveway is used by only one vehicle at a time.
Industrial	Driveways frequently used by buses, tractors with semi-trailers, and other vehicles longer and wider than the design P-vehicle.	The extra axles and longer wheelbase will lead to much greater offtracking of vehicles entering the driveway.
Other	Identify the specific vehicles that will use the facility. Example – bus terminal Example – emergency vehicles	Bus terminal – Consider the width, and swept path of turning buses and circulation patterns. Emergency vehicles – Need to exit heading out, not backing. May need on-site turn around.

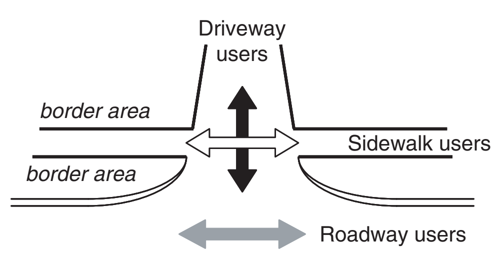
NOTE: P-vehicle is a passenger car design vehicle, which includes minivans and pickup trucks.
* These descriptions are intended to help the designer form a mental image of some of the more common examples of the category.

These interactions take place within or near the border, the area between the roadway edge and the right-of-way line. Objects in the border can affect the users. For instance, a poorly placed roadside bus shelter can be an impediment in the path of a pedestrian with a visual impairment and may make it more difficult for a motorist exiting the driveway to see oncoming traffic.

Driveway design practice should address many issues. Some broad considerations include the following:

- Convenient and safe vehicle egress and ingress;
- Sight distance and safety for sidewalk users;

Exhibit 3-3. Users in the driveway, roadway, sidewalk area.



- Accessibility for pedestrians with disabilities and incorporating requirements of the ADA Accessibility Guidelines);
- Interactions where bicycle lanes or paths are present; and
- Interactions where public transportation stops are in the vicinity of the driveway.

These considerations affect design details such as sidewalk alignment and cross slope across the driveway, driveway entry shape (curved or straight) and dimension, and driveway width.

Attributes of Bicyclists, Drivers, and Pedestrians

The capabilities and limitations of the people using the driveway, whether as bicyclists, drivers, or pedestrians, affect design choices. An appreciation of the concept of driver work load leads to the objective of trying to limit the number of (1) decisions a driver has to make and (2) potential conflicts with different streams of traffic. Acknowledging that rain, fog, and nighttime conditions can make physical objects more difficult to detect, a designer tries to create well-defined edges and increase the contrast between different surfaces, such as between the driveway opening and the border area. Refer to the AASHTO guides for the design of bicycle facilities (*3-1*), highways and streets (*3-2*), and pedestrian facilities (*3-3*) for a discussion of user characteristics. *Characteristics of Emerging Road and Trail Users and Their Safety* (*3-4*) provides data for a wide range of users, including bicyclists and pedestrians.

Driveways are crossed by pedestrians on sidewalks. Exhibit 3-4 shows a distribution of the walking speeds of pedestrians under 60 and over 60. In both age groups, most pedestrians walk at speeds between 3 and 6 ft/s.

A synthesis of default values (*3-5*) cited one study listing 15th percentile walking speeds for those less than 60 years old as 3.8 ft/s, and 3.5 ft/s for those over 60. Another study listed 15th percentile walking speeds for those less than 65 years old as 4.0 ft/s, and 3.1 ft/s for those over 65.

When estimating the time required for a pedestrian to cross the driveway, make an allowance for the pedestrian not starting from the exact edge of the driveway. A pedestrian may be standing 2 or more feet back from the driveway edge when the pedestrian begins to walk across the driveway.

Bicyclists also cross the paths of vehicles entering and leaving driveways. On shared use paths ("a bikeway physically separated from motorized vehicular traffic," the 1999 AASHTO bicycle guide (*3-1,* p.3) suggested a design speed of at least 20 mph on shared use paths, noting that grade and wind can affect the speeds of bicyclists. With a downgrade greater than 4%, a design speed of 30 mph or more was offered (*3-1,* p.36). Discussing urban street design criteria, the *Urban Street Geometric Design Handbook* by ITE (*3-6,* p.41) stated:

> Studies show that nearly all bicyclists travel within a range of 7 to 15 mph, with an average of 10 to 11 mph.

A study that examined characteristics of a wide range of users found that the 85th percentile speed for bicycles was 14 mph, and for recumbent bicycles was 18 mph (*3-4,* p.74).

Motor Vehicle Traffic Attributes

The designer should consider the attributes of the motor vehicles used by the drivers. Attributes that affect driveway design include vehicle width, vehicle length, vehicle height, vehicle turning radius, vehicle off tracking, and vehicle ground clearance dimensions.

Exhibit 3-4. Distribution of pedestrian walking speeds.

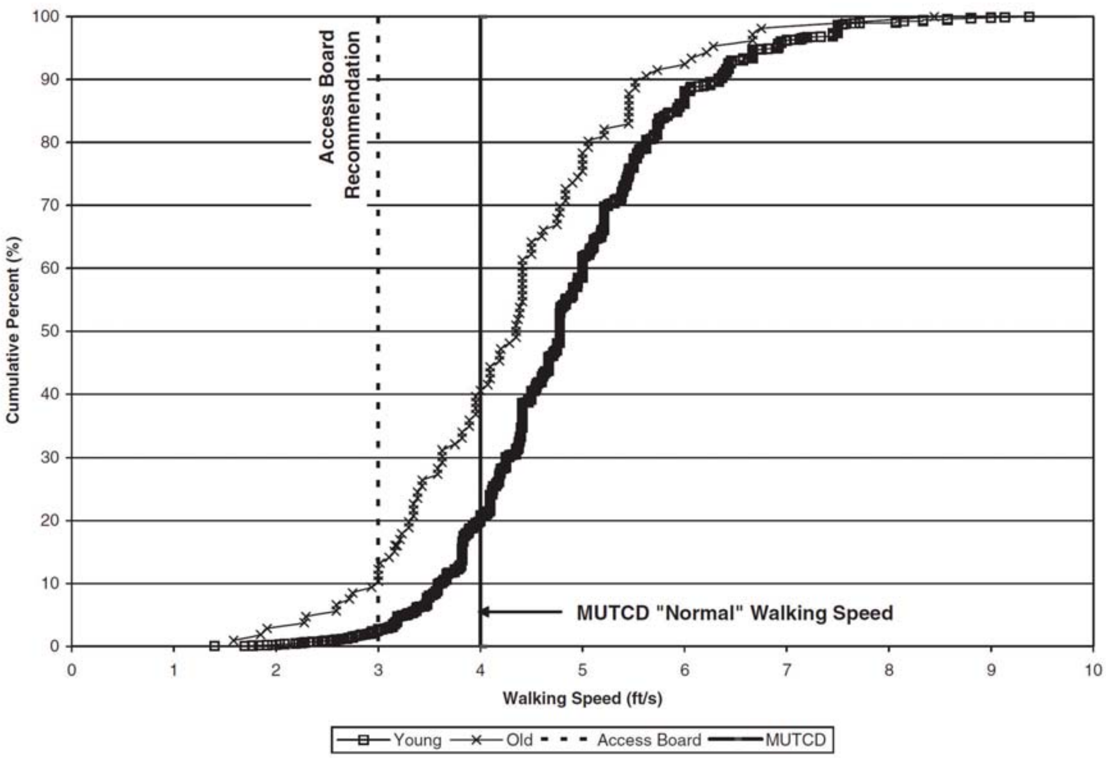


Figure 22. Older than 60 (Old) and 60 and younger than 60 (Young) walking speed distribution.

Source: Fitzpatrick et al., *Improving Pedestrian Safety at Unsignalized Crossings*, TCRP Report 112/NCHRP Report 562, p. 44, 2006

Design Vehicles

In its design policy, AASHTO indicates that key controls in roadway geometric design are the physical characteristics and the percentages of vehicles of various sizes using the roadways. According to AASHTO, it is appropriate to examine all vehicle types, establish general class groupings, and select vehicles of representative size within each class for design use: These selected vehicles, with representative weight, dimensions, and operating characteristics, used to establish highway design controls for accommodating vehicles of designated classes, are known as design vehicles (*3-2,* p.15).

AASHTO identifies general classes of design vehicles and dimensions for design vehicles within these general classes. The design policy advises that "the designer should consider the largest design vehicle likely to use the facility with considerable frequency or a design vehicle with special characteristics appropriate to a particular intersection in determining the design of such critical features as radii at intersections and radii of turning roadways." General guidance is given for selecting a design vehicle. With one exception (i.e., a passenger car may be selected when the main traffic generator is a parking lot), the guidelines deal with road and street intersections as opposed to driveway-roadway intersections.

Design Vehicle Dimensions

Widths and turning paths of design vehicles can be found in the latest edition of the AASHTO design policy. There is some indication that slow-turning vehicles may follow a path with a smaller radius than indicated in the turning dimensions and the turning templates provided in the current AASHTO Green Book (*3-2,* pp.16–43).

Underclearance or ground clearance is the distance from the bottom of the vehicle body to the ground (*3-7*). Ground clearance and wheelbase are critical dimensions at a crest situation. The ground clearance, in combination with either the front or rear overhang, is critical at sag situations. For example, rear-load garbage trucks may drag in the rear; therefore, rear overhang is the critical parameter. Car carrier trailers can drag in the rear or hang up between the wheels; therefore, either wheelbase or rear overhang may be critical. When the designer does not take these dimensions into account, the result can be vehicles dragging, scraping, and even becoming lodged on the vertical profile grade changes.

Although a designer can consult the AASHTO design policy for lengths, widths, overall heights, turning radii, and swept path templates for a menu of vehicle types, the policy does not include vehicle ground clearance or underclearance data. Exhibit 3-5 presents vehicle ground clearance dimensions. Note that dashes (—) in cells in the table indicate that hang-up problems are not expected on this part of the vehicle.

Exhibit 3-6 shows the findings from a recent study in which the underside dimensions of a select group of vehicles were measured. From this, the crest and sag angles at which underside dragging would occur were calculated. These values reflect the physical limits of the vehicles.

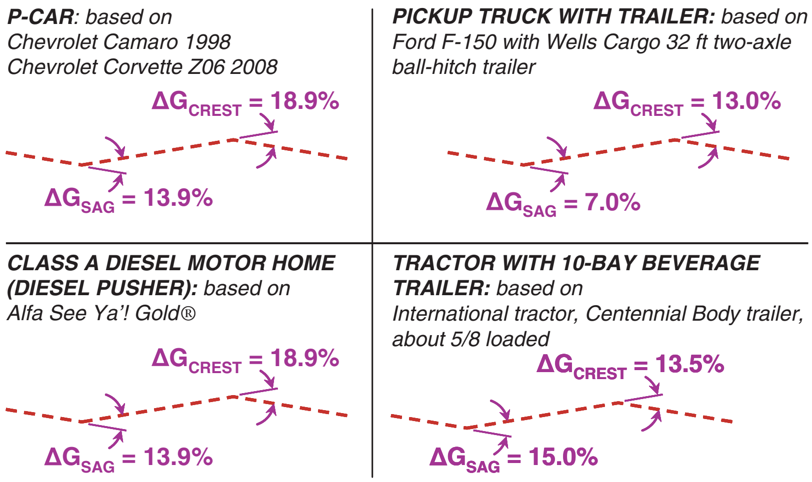
Exhibit 3-5. Vehicle ground clearance dimensions.

Design Vehicle	Rear Overhang (ft)	Wheelbase (ft)	Front Overhang (ft)	Ground Clearance for Rear Overhang (in)	Ground Clearance for Wheelbase (in)	Ground Clearance for Front Overhang (in)
Rear-Load Garbage Truck	10.5	20	--	14	12	--
Aerial Fire Truck	12	20	7	10	9	11
Pumper Fire Truck	10	22	8	10	7	8
Single-Unit Beverage Truck	10	24	--	8	6	--
Articulated Beverage Truck	--	30	--	--	10	--
Low-Boy Trailer <53 feet	--	38	--	--	5	--
Double-Drop Trailer	--	40	--	--	6	--
Car Carrier Trailer	14	40	--	6	4	--
Belly Dump Trailer	--	40	--	--	11	--
Mini-Bus	16	15	--	8	10	--
School Bus	13	23	--	11	7	--
Single-Unit Transit Bus	--	25	18	--	8	6
Motorcoach	10	27	7.6	8	7	10
Articulated Transit Bus	10	--	--	9	--	--
Passenger Vehicle and Trailer - Private Use	13	20*	--	5	5	--
Passenger Vehicle and Trailer - Commercial Use	13	24*	--	7	7	--
Recreational Vehicle (RV)	16	27	7.8	8	7	6

NOTES: * indicates distance from rear wheels to hitch
-- indicates hang-up problems not expected on this part of the vehicle
These dimensions reflect only the physical limits of vehicles. They do not account for the effects on vehicles in operation (e.g., dynamic load—vehicle bounce). The desirable maximum grade changes will be less than those reflected in these values.

Exhibit 3-6. Ground clearance geometry for specific models.

These calculations do not account for effects of static load (weight of passengers or cargo) or dynamic load (vehicle bounce). Maximum desirable grade change will be less than these values.



Pick-up with trailer and beverage truck calculations by R. Eck.
Passenger car and motor home calculations by J. Gattis.

Angles used for design, reflecting attributes of vehicles under actual operation conditions, should be less than these.

Selecting a Design Vehicle

The activities served and the location of a driveway will affect the types of vehicles using the driveway. Typical vehicles include passenger cars, service vehicles, and bicycles. Large trucks, with their wide offtracking, use many commercial driveways—although usually few in number, larger trucks must be able to negotiate curves and grades. They should be the design vehicle for driveways serving industrial areas.

Design vehicle selection involves two conflicting mandates: (1) select a vehicle with sufficiently large dimensions so that all users can negotiate the driveway in the future and (2) confine the dimensions so that the driveway is not overdesigned. Designers can easily believe that they lack information needed to select a design vehicle. Designers may not know how frequently certain larger vehicles will use a site; regardless, the word "considerable" in the phrase "use . . . with considerable frequency" is undefined. Designers are left to their judgment to assess to what extent it is acceptable for offtracking turning vehicles to encroach into other lanes. Not only is the frequency of vehicle use a consideration, but the volume and speeds on the main roadway are also factors.

Exhibit 3-7 lists suggested design vehicles for various types of driveways. Exhibit 3-8 shows an example from a state transportation agency.

Vehicles for Farm/Ranch and Field Entrance Design

Design vehicle information for farm vehicles is not generally available. The County Engineer for Delaware County, Iowa, Mark J. Nahra, P.E., observed that large equipment will be found using both the field entrances and driveways to farm residences. Also, P-vehicles use field entrances, so the designer should use both the standard driver eye height for a P-vehicle and the eye height for a heavy vehicle.

Despite their size, large combines and other pieces of farm equipment are very maneuverable. Large combines are usually less than 16 feet wide. Based on this, farm driveways and

Exhibit 3-7. Suggested design vehicles for common driveway types.

Category	Description of Common Applications	Design Vehicles
STANDARD DRIVEWAYS		
Very high intensity	Urban activity center, with almost constant driveway use during hours of operation.	Large truck, buses (May be P-vehicle if have separate truck entrances.)
Higher intensity	Medium-size office or retail (e.g., a community shopping center) with frequent driveway use during hours of operation.	Large truck, buses (May be P-vehicle if have separate truck entrances.)
Medium intensity	Smaller office or retail, some apartment complexes, with occasional driveway use during hours of operation.	P-vehicle, single-unit truck
Lower intensity	Single-family or duplex residential, other types with low use. May not apply to rural residential.	P-vehicle
SPECIAL SITUATION DRIVEWAYS		
Central business district	Parking lot or garage for automobiles only	P-vehicle
	Other than exclusive automobile facility	Single-unit truck
Farm or ranch	Mix of residential and industrial characteristics	Single-unit truck, farm equipment
Field	Seldom used, very low volume	Single-unit truck, farm equipment
Industrial	Driveways are often used by large vehicles	Large truck
Other	Bus terminal	Bus
	Fire or Ambulance station	Emergency vehicle

Notes: P-vehicle is the AASHTO passenger car design vehicle.
Large truck may be WB-50, WB-62, or WB-65.
These descriptions are intended to help the designer from a mental image of some of the more common examples of the category.

field entrances should be at least 16 feet wide, although 20 feet is recommended. A 30-foot top-width over the driveway culvert is recommended to allow large combines and tractor-semitrailer combinations to pull into farm driveways. A radius of at least 20 feet is recommended to allow service vehicles (e.g., propane or fuel oil trucks) (single-unit vehicles) to be able to turn safely into a rural residential driveway. A site review is recommended to assess ground clearance issues.

Exhibit 3-8. Example design vehicles for driveway types.

Design Vehicle by Land Use	
Land Use(s) Served by Access	**Design Vehicle**
Residential	Passenger Car/Pickup
Residential on Bus Route	Single Unit Truck
Office with Separate Truck Access	Passenger Car/Pickup
Office without Truck Access	Single Unit Truck
Commercial/Retail with Separate Truck Access	Passenger Car/Pickup
Commercial/Retail without Truck Access	WB-50 Truck
Industrial with Separate Truck Access	Passenger Car/Pickup
Industrial without Separate Truck Access	WB-50 Truck
Recreational without Water or Camping	Passenger Car/Pickup
Recreational with Water or Camping	Motor Home/Boat
Agricultural Field Access	Single Unit Truck
Municipal and County Roads	WB-50 Truck

- "with Separate Truck Access" indicates truck prohibition from primary access.
- "without Water" indicates no recreational watercraft.

Source: New Mexico DOT, *State Acc. Mgmt. Manual*, Ch. 8, Sec. 18, p. 86, Sept. 2001

Design Volumes

Estimating the expected driveway volume can help identify how many driveway lanes are needed. For more information, refer to publications that discuss methodology for site impact studies. The basic steps are as follows:

1. Establish the extent to which access is allowed, and estimate the number of driveways. Review the local access policy and spacing standards of the governing agency to establish whether the desired access will be allowed and, if so, to identify the number of driveways.
2. Identify the type and size of land use activity to be served.
3. Determine the daily and peak-hour vehicle trip rates. If the site currently exists and traffic volumes are expected to remain the same, then counts of existing traffic can be made. For proposed development, the designer may use ITE Trip Generation or locally developed trip generation rates. By definition, median rates are exceeded 50% of the time, so it may be desirable to calculate and use the 80th to 90th percentile trip rates rather than using median or average rates. If driveways are or will be in the CBD or outlying urban business districts, some person trips to or from activities may be made as pedestrians or via public transit. In these cases, some downward adjustment of published ITE vehicle trip rates may be warranted.
4. Estimate the daily and peak-hour trips ends for the activity. Multiply the trip generation rate by the appropriate independent variable to arrive at the total number of expected trip ends.
5. Estimate the driveway volumes. Based on the preceding steps, estimate how much site traffic will use each driveway.

Exhibit 3-9 lists examples of land uses and their expected number of driveway trips.

Design Speeds

Various factors, including the setting and the functional classification, will affect the design speed of a given roadway. After a roadway has been constructed and is in operation, actual speeds on the roadway can be observed. The speeds on the through roadway will normally govern geometric features such as sight distance and the length of acceleration or deceleration lanes.

A few studies have measured the speeds at which drivers turn into driveways or side streets. Studies of turning behavior have reported speeds of less than 15 mph for a radius of 30 ft or less. Different studies may measure speeds at different locations or over different lengths during a turn. Exhibit 3-10 shows findings from an older study.

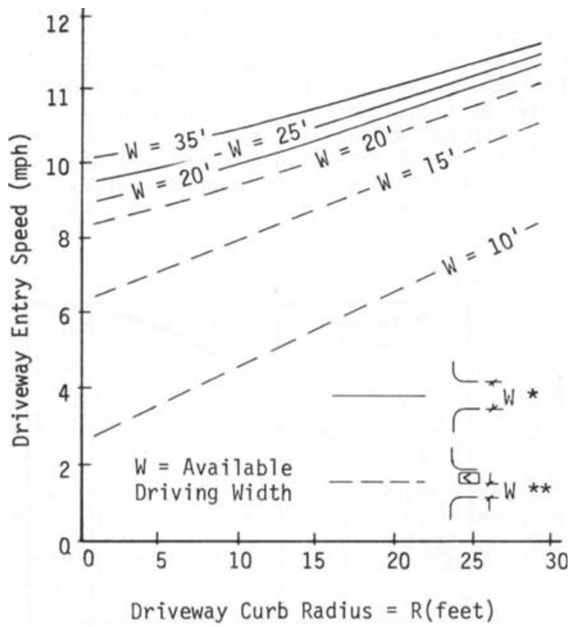
In 2007 and 2008, the speeds of over 1500 vehicles entering 12 driveways were measured near the roadway-driveway intersection and in the driveway throat (see Exhibit 3-11). All of the sites were lower-intensity commercial (e.g., retail and professional offices) developments in built-up suburban environments along multilane arterial roadways with either 40-mph or 45-mph posted speed limits. The right-turn entry radii ranged from 13 to 19.5 ft. Almost all of the vehicles in the study were passenger cars. Sidewalks were present at all sites, but pedestrian volumes were

Exhibit 3-9. Estimated number of trips from given sites.

Example Land Uses	Expected Number of Site Trips
150,000 sq. ft. shopping center Grocery/drugstore with 10-15 smaller stores (9,000 daily trips split w/2 driveways)	Over 4,000 trips/day or over 400 trips/hour
Small "strip" shopping center (20,000-75,000 sq. ft.) Gas station/convenience market	601-4,000 trips/day or 61-400 trips/hour
3 to 60 housing or apartment units Small office in converted home "Mom and pop" business	21-600 trips/day or 6-60 trips/hour
1 or 2 single-family homes	1-20 trips/day or 1-5 trips/hour

Source: *Driveway Handbook*, Florida Dept. of Transportation, March 2005

Exhibit 3-10. Driveway entry speed related to driveway radius and width.

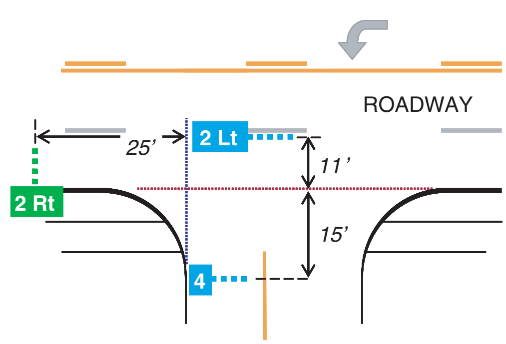


Source: FHWA, *Syn. of Safety Research*, Vol. 1, FHWA-TS-82-232, p. 4-8

Exhibit 3-11. Measured speeds of vehicles entering driveways.

Land Use Type	Entry Lane Width (ft)	Entry Radius (ft)	Location Where Measured	Rt. Turn Entry 90th% Speed (mph)	Lt. Turn Entry 90th% Speed (mph)
Commercial	13 ft	13.0-19.5	2Rt	15.5 to 18.0	na
Commercial	13 ft	13.0-19.5	2Lt	na	10.0 to 13.0
Commercial	13 ft	13.0-19.5	4	7.0 to 10.4	7.8 to 13.9

LOCATION NOTES -- Speeds measured at:
2Rt-right turn, 25 ft before the near perpendicular edge of the driveway
2Lt-left turn, one lane width in advance of the driveway threshold (curb line)
4-in the driveway throat, 15 ft. past the driveway threshold (curb line)
NOTE: "na" = not applicable



very low. None of the measurements were taken at regional shopping centers or other similar large urban activity centers.

At a point 25 feet in advance of the near edge of the driveway, 90% of drivers about to turn right had decelerated to between 15.5 and 18.0 mph or less. Only 10% of drivers turning left had measured speeds of more than 10.0 to 13.0 mph when their vehicles were one lane away from the driveway end. At approximately the position at which the rear bumper had cleared the roadway, 90th percentile speeds ranged from 7.0 to 13.9 mph.

References

3-1. AASHTO. *Guide for the Development of Bicycle Facilities.* Washington, DC (1999) 78 pp.
3-2. AASHTO. *A Policy on Geometric Design of Highways and Streets.* Washington, DC (2004) 896 pp.
3-3. AASHTO. *Guide for the Planning, Design, and Operation of Pedestrian Facilities.* Washington, DC (July 2004) 127 pp.
3-4. Landis, B. W., Petritsch, T. A., and Huang, H. F. *Characteristics of Emerging Road and Trail Users and Their Safety.* FHWA-HRT-04-103 (October 2004) 117 pp.
3-5. Zegeer, J. D., et al. *NCHRP Report 599: Default Values for Highway Capacity and Level of Service Analyses.* Transportation Research Board, National Research Council, Washington, DC (2008) pp. 55–58.
3-6. Elizer, R. M. "Chapter. 2: Design Philosophy and Controls." *Urban Street Geometric Design Handbook,* ITE, Washington, DC (2008) p. 41.
3-7. French, L. J., Clawson, A., and Eck, R. W. "Development of Design Vehicles for the Hang-Up Problem." *Transportation Research Record 1847,* Transportation Research Board, National Research Council, Washington, DC (2003) pp. 11–19.

CHAPTER 4

Driveway Location and Spacing

For many decades, knowledgeable transportation professionals have recognized the need to manage access along roadways to preserve safety and mobility (see Exhibit 4-1 for an example). In practice, this includes regulating the number of, location of, spacing between, and geometric design of driveways.

Several access management guidelines have been developed to assist agencies in balancing the competing needs for mobility along the roadways and access to abutting land developments. One of the most complete sources of information is the *Access Management Manual* (*4-1*). Other salient guidelines are contained in

- *NCHRP Report 348: Access Management Guidelines for Activity Centers* (*4-2*),
- *NCHRP Report 420: Impacts of Access Management Techniques* (*4-3*),
- *Transportation and Land Development* (*4-4*), and
- *A Policy on Geometric Design of Highways and Streets,* the AASHTO Green Book (*4-5*).

Given that access management is addressed by other publications, this design guide will only briefly discuss the topic. For more information, refer to access management publications and websites.

General Guidelines

Although private property enjoys the right of access to the general system of public roadways, this is not an unlimited right. The right of access must be balanced with the needs of and potential harm to the general traveling public. To preserve mobility and provide safety for the traveling public, many transportation agencies have established regulations and programs to manage access to their roadway network. The regulations are more restrictive for major arterials, the roadways intended to accommodate higher volumes and speeds; however, some objectives and practices apply to most driveways.

Access management programs restrict the number of driveways allowed. These practices affect when and where direct driveway access will be allowed onto the roadway network, whether alternative access should be provided, and the need for shared access. If direct access is allowed, the guidance includes the extent of that access (i.e., right-in and right-out versus full movement) and circumstances in which multiple driveways are allowed. In addition, agencies may require that steps be taken to mitigate projected traffic operations and/or safety impacts. An example of mitigation would be providing an auxiliary lane to remove driveway turning traffic from the through traffic lanes on an arterial.

As noted in the AASHTO Green Book (*4-5,* p.729), driveways should not be located within the functional area of an intersection or in the influence area of an adjacent driveway. The functional area extends both upstream and downstream from the physical intersection area and includes the longitudinal limits of auxiliary lanes. As a result, the functional area encompasses the area where motorists are responding to the intersection, decelerating, and maneuvering into the appropriate lane to stop or complete a turn. The AASHTO Green Book also notes that a driveway influence area includes the following:

- Impact length (the distance back from a driveway that cars begin to be affected by driveway traffic),
- Perception-reaction distance, and
- Vehicle length.

Additional guidance related to computing driveway influence areas is available in *NCHRP Report 420: Impacts of Access Management Techniques* (*4-3,* pp.48–62).

Another general guideline that applies to driveway location is that sight distance must be sufficient. The AASHTO Green Book (*4-5,* pp.110–155 and 651–677) contains detailed guidance on the purpose and computation of sight distance. In addition, driveways must be located so that they are conspicuous and clearly delineated for the various users.

Exhibit 4-1. Experts have long recognized the deficient state of the practice.

> Lack of access control along arterial highways is the largest single factor resulting in functional obsolescence of highway facilities. Frequent driveways and curb cuts increase points of conflict and potential accident locations….
>
> Few cities in the United States and Canada exercise effective access control along arterial streets … restrictions on driveway location and spacing are frequently minimal and the criteria are loose.
>
> Marks, H. *Traffic Circulation Planning for Communities*, Gruen Associates, Los Angeles, CA (1974) p. 232.

One major objective is to avoid driveway queuing that backs up into a public roadway. This is accomplished through design of the throat length, internal circulation, and traffic control within a site. Queuing of traffic exiting a site does not affect the operation of the public roadway, but could affect site circulation and parking lot operations. This internal queuing is affected by the throat length, number of egress lanes, and traffic control at the public roadway intersection.

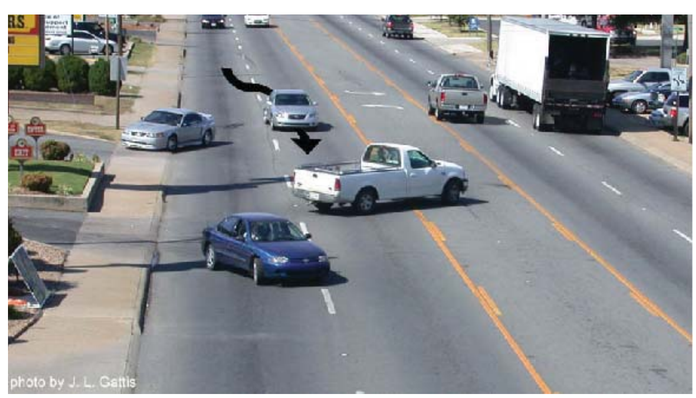
Exhibit 4-2 illustrates the confusion and potential for crashes when vehicles slow, change lanes, and try to enter or exit driveways that are too close to each other. Exhibit 4-3 clearly shows the increased potential for traffic conflicts when driveways are too close to the intersection of two public roadways. Exhibit 4-4 shows a vehicle conflict resulting from a driveway too close to the exit ramp off of a freeway.

General guidelines often applied by agencies deciding whether to allow or deny access follow:

- Along the main roadways, limit the number of access points. Encourage property access from secondary roads and streets or “backage” roads.
- One carefully located and well-designed driveway per site is often adequate.

Exhibit 4-2. Driveways too close to each other allow more conflicts to occur.

(a)



(b)

Exhibit 4-3. Driveways too close to roadway intersections allow more conflicts to occur.

Exhibit 4-4. Driveways too close to exit ramp terminals allow more conflicts to occur.

- Where two lower-volume sites are adjacent, access to both can be provided by a single shared driveway. When access from the major roadway is required, sharing access with adjacent tracts reduces the overall number of connections to the major roadway. Shared access arrangement should be implemented by an appropriate joint easement.
- For higher volume sites, additional access points may be needed. The assessment of this need must consider (1) whether or not good site planning principles have been applied and (2) the traffic safety and operational effects of the additional access.
- Along major roadways, the left-turn exit movement from driveways should be kept to a minimum. If a roadway is converted from undivided to divided, left-turn access may be closed in one or both directions. Where physically practical, direct left-turns can be replaced by right turns followed by u-turn movements.

When access is not available from parallel or cross streets, or across adjacent tracts, it may be necessary to provide property access from the major roadway. This access often should be limited to right turns only. However, in some situations, limiting access to only right turns will result in left-turning movements migrating to and overloading a nearby intersection—in such cases, it may be better to allow left-turn movements at the subject access point. An assessment may be needed as to which arrangement helps preserve the functionality of the roadway and the mobility of the traffic.

Driveway Location and Spacing

Experience has shown that certain driveway locations tend to be problematic, and that for better safety and mobility, the frequency of driveways should be minimized. This section discusses the following four types of driveway spacing:

- Spacing between unsignalized connections;
- Spacing of driveways from signalized intersections (corner clearance);
- Spacing for a signalized driveway; and
- Spacing of a driveway from an interchange ramp.

Spacing Between Unsignalized Connections

Spacing between unsignalized connections (whether between two driveways or a driveway and a roadway) should not interfere with safe and relatively unimpeded movement on the through roadway. Driveway spacing practices should provide reasonable access to abutting private property. General guidelines pertaining to unsignalized driveway spacing follow:

- The needed distance between successive connections (both driveways and side streets) increases with higher operating speeds, higher access classifications for the public roadway, and higher driveway volumes.
- A driveway should not be located within the functional area of an intersection or in the influence area of the upstream and downstream driveways.
- Left-turn lane storage requirements should be considered when determining the driveway influence area and can limit how closely driveways can be spaced.
- On roadways that are undivided or have TWLTLs, the alignment of driveways on opposite sides of the road needs to be considered. Driveways on opposite sides of a lower-volume roadway may be aligned across from each other. Alternatively, they should be spaced so that those drivers desiring to travel between the driveways on opposing sides of the roadway need to make a distinct right turn followed by a left turn (or a left followed by a right). A much longer separation is needed on a higher-speed, higher-volume roadway (*4-4*).
- On roadways with restrictive medians, the spacing between right-turn access points on opposite sides of the road can be treated separately.
- Ideally, driveway access for a major development involving left-turn egress movements should be located where effective coordination of traffic signals would be achievable if there is a need to signalize the driveway.
- Driveway connections to public roadways are subject to the same intersection control device analyses as are street intersections. If existing or future volumes warrant installing a traffic signal, and signalized spacing requirements cannot be met, left-turn access should be subject to closure in one or both directions.

Driveway spacing from roundabout considerations are similar to those of other types of intersections, but driveways may be closer to a roundabout because of shorter queuing. Driveways should not interfere with operation of the roundabout.

General guidelines for unsignalized access spacing are contained in the *Access Management Manual* (*4-1*) and *NCHRP Report 348* (*4-2*).

Spacing of Driveways from Signalized Intersections

The needed minimum separation distance (i.e., corner clearance) from a driveway to a signalized upstream or downstream location will depend on the function, operation, and design features of the roadway and the characteristics of the access connection. The basic principle of locating one connection outside of the functional area of another connection applies to driveways.

For a driveway upstream of or approaching a signalized location on a major road, the functional area includes the perception-reaction time, maneuver distance, and storage length of the traffic on that approach. The spacing should provide separation between the conflicting movements occurring at the signal and the conflicting movements occurring at the driveway. In addition, this spacing would enable the driveway to operate without being obstructed by the traffic backing up from the signal.

The spacing for a driveway downstream of the departure leg (i.e., far side) of a signalized location on a major road should be sufficient to minimize the adverse effects of the driveway operations on the intersection. According to *Transportation and Land Development* (*4-4,* p.6–28), the minimum downstream corner clearance should be no less than the stopping sight distance.

Along the far side of an intersection of a crossroad with an arterial, the corner clearance distance to the first driveway varies. If the arterial does not have a channelized right-turn lane for traffic turning onto the crossroad, one source recommends that the driveway be spaced a minimum of 120 feet from the intersection. If the arterial has a channelized right-turn lane for traffic turning onto the crossroad, the clearance distance should reflect the inside corner radius. The clearance should be 200 feet for a 50-foot radius, 230 feet for a 75-foot radius, and 275 feet for a 100-foot radius (*4-4,* p. 6–35). The stopping sight distance principle also applies to driveways connecting to crossroads, along the far side of the intersections of crossroads with major roads.

For crossroads, the near side corner clearance should extend beyond the normal queuing distance along the crossroad.

Spacing for a Signalized Driveway

Signal spacing is a function of travel speed and signal cycle length. The same criteria for signal spacing apply to both a signalized driveway and a signalized public roadway intersection. If a driveway is going to be signalized, then it should be located to "fit" into the traffic signal progression along an arterial roadway and not interfere with the progression of traffic from one signalized intersection to the next.

Desirable spacing is shown in Exhibit 4-5. When signalized driveways and intersections can be placed at these distances, there is no loss in green-band (through band) width. Small deviations (e.g., less than 10%) will have minimal negative effects on the progression. Further guidelines for green-band width are contained in *NCHRP Report 348* (*4-2,* p.56–58) and in the *Access Management Manual* (*4-1,* p.140–149).

Where the recommended spacing in the table exceeds ½ mile (2,640 feet), designers can limit the actual spacing to 2,640 feet.

Spacing of a Driveway from an Interchange Ramp

The needed driveway separation distance from an interchange area depends on the geometric design of and methods of traffic control at the freeway ramp joining the roadway. It is also affected by the speed, volume, and number of lanes on the through roadway, the ramp volume

Exhibit 4-5. Signalized intersection spacing for various progression speeds and cycle lengths.

	Speed (mph)						
Cycle length	25	30	35	40	45	50	55
60	1100	1320	1540	1760	1980	2200	2420
70	1280	1540	1800	2050	2310	2570	2820
80	1470	1760	2050	2350	2640	2640	2640
90	1630	1980	2310	2640	2640	2640	2640
120	2200	2640	2640	2640	2640	2640	2640

NOTES: Spacing distances are in feet.
Where the recommended spacing in the table exceeds ½ mile (2,640 ft), designers can limit the actual spacing to 2,640 ft.

and speed, the number of vehicles turning into the driveway, the type of traffic control at the driveway, and whether the subject driveway is on the same or opposite side of the road from the entry ramp.

Where the ramp entry is signalized, signal spacing criteria should govern where access connections are provided. A time-space analysis of the signals along the arterial, including any ramp signalization, can help in identifying the best locations for signalized access.

Unsignalized ramp entry junctions can be either stop- or yield-controlled, with a geometry that is either free flowing or one that forces the ramp vehicle to come to a stop before entering the roadway. If a driveway is too close to an upstream ramp that is entering an arterial, this can cause congestion with spillback onto the ramp and additional conflict on the through roadway segment. This concern can be heightened where there is insufficient distance for the following sequence to occur: vehicles exit the ramp, merge into the outside lane of a multilane arterial, weave across through travel lanes, and finally enter an inside or left-turn lane to turn into a driveway on the opposite side of the roadway from the ramp. Vehicles making this maneuver have to wait for gaps in the through traffic lanes before weaving to the left. At locations with higher volumes, higher speeds, or free-flow movements from the ramp to the roadway, a longer distance is required to safely make this maneuver. *NCHRP Report 420* is one source of spacing guidelines (*4-3*).

References

4-1. TRB Committee on Access Management. *Access Management Manual.* Transportation Research Board, National Research Council, Washington, DC (2003) 388 pp.
4-2. Koepke, F. J., and Levinson, H. R. *NCHRP Report 348: Access Management Guidelines for Activity Centers.* Transportation Research Board, National Research Council, Washington, DC (1992) 111 pp.
4-3. Gluck, J. S., Levinson, H. R., and Stover, V. G. *NCHRP Report 420: Impacts of Access Management Techniques.* Transportation Research Board, National Research Council, Washington, DC (1999) 157 pp.
4-4. Stover, V. G., and Koepke, F. J. *Transportation and Land Development,* 2nd edition. ITE (2002) 700 pp.
4-5. AASHTO. *A Policy on Geometric Design of Highways and Streets.* Washington, DC (2004) 896 pp.

CHAPTER 5

Geometric Design Elements

This chapter sets forth geometric design concepts and guidelines for various driveway design features and components. Exhibit 5-1 suggests that driveways created as afterthoughts are less likely to perform well. The design of a driveway should be integrated into and take place during the design of the overall site. Before the overall site design is finalized, it may need to be adjusted and readjusted so as to have an acceptable driveway design.

Exhibits 5-2 and 5-3 list geometric design elements that a designer may need to consider; not all elements will be present in every situation. This chapter groups some of these driveway geometric elements into the sections listed below and presents specific guidelines and suggested dimensions:

- Driveway throat transition geometry
- Driveway width and number of lanes
- Median in driveway
- Right turn channelization in the driveway
- Channelization in the street
- Cross slope
- Horizontal alignment
- Intersection angle
- Space for nonmotorized users
- Driveway edge and border treatments
- Clearance from fixed objects
- Length
- Driveway grade (sidewalk cross slope), change of grade, and vertical alignment
- Sidewalk cross slope (driveway grade)
- Roadway-driveway threshold treatment
- Drainage of surfaces occupied by user groups
- Auxiliary right-turn lanes

Presenting separate design guidelines for every conceivable combination of factors would make a publication unwieldy and overwhelm the user. For instance, when discussing the minimum connection transition radius needed for a residential driveway, not only is the width of the driveway important, but the needed radius is also affected by the width of the roadway and the absence or presence of on-street parking on one or both sides of that roadway. Therefore, the authors have presented recommendations suitable for more commonly encountered scenarios. Some of the guidelines may not apply to unusual situations.

Exhibit 5-1. Unacceptable driveway designs.

Exhibit 5-2. Driveway geometric design considerations that may be within the control of the designer.

Shared Elements, Surroundings

1	Illumination	
2	Conspicuity	(to visually detect an element at a distance)
3	Sight obstructions	

Driveway

4	Width	(maximum and minimum; sufficient for ped. refuge)
5	Lanes	(number, width)
6	Median in driveway:	(absence or presence)
7	width	
8	type	(raised, flush, depressed)
9	nose-end recessed from edge of through-road	
10	Cross slope, cross slope transition runoff	
11	Horizontal alignment, curvature	
12	Connection depth (throat length)	
13	Traffic controls or other potential impediments to inbound traffic (inc'l entry gate)	
14	Paving length	(applicable where have unpaved driveway)
15	Onsite turnaround capability	(where backing into roadway is undesirable)
16	Driveway edge	(edge drop off, barrier)
17	Space for nonmotorized users	(e.g., pedestrian movement parallel to driveway)
18	Driveway border treatments	(sideclearance, sideslope)
	Vertical profile	
19	grade	(maximum and minimum)
20	change of grade (grade breaks)	
21	vertical curve design criteria	
22	Vertical clearance	(from overhead structures, utility lines)
23	Drainage	(separate from intersection drainage)
24	Other special situations	(e.g., railroad crossing, trail, bridle path, etc.)

Sidewalk-Driveway Intersection

25	Sidewalk cross slope (i.e., driveway grade)	
26	Path definition	(e.g., visual, tactile cues)
27	Crossing length (i.e., driveway width)	
28	Angle of intersection with driveway: flat-angle (turn angle < 90°); right-angle (turn angle ≈ 90°); sharp-angle (turn angle > 90°)	
29	Bearing of sidewalk relative to street (i.e., sidewalk diverging from, parallel to, or converging with the street)	
30	Grade of sidewalk (i.e., driveway cross slope)	
31	Vertical profile of pedestrian route	(abrupt elevation change: max. 1/4")
32	Sidewalk-driveway interface treatment: i.e., detectable warnings for visually impaired (e.g., truncated dome)	(only at certain locations, inc'l. at signalized crossing; refer to guidelines)

(continued on next page)

Exhibit 5-2. (Continued).

	Roadway-Driveway Intersection	
33	Angle of intersection with street: flat-angle (turn angle < 90°); right-angle (turn angle ≈ 90°); sharp-angle (turn angle > 90°)	
34	Cross slope of street and shoulder, considered with driveway grade	
35	Curb threshold treatment	(rolled, vertical lip, counterslope, continuous)
36	Curb-termination treatment	(abrupt end, drop-down, returned)
37	Entry transition shape	(e.g., radius, flare/taper, straight)
38	Entry transition-shape dimensions	(radius, flare dimensions)
39	Channelization of right turn from street into driveway	
40	Channelization of right turn from driveway into street	
41	Channelization in the driveway (e.g., triangular island to prohibit in and out left-turns)	
42	Channelization in street - street median prohibits all left-turns in/out of driveway	
43	Channelization in street - street median prohibits one but not both left-turns	
44	Drainage: confining the gutter flow	
45	Drainage: inlet type and location	
46	Clearance from fixed objects, appurtenances	
47	Pavement surface deformity	(corrugation, potholes)

	Traffic Controls (for driveway vehicles)	
48	Driveway-roadway intersection control	(none, yield, stop, signal)
49	Turn restrictions	
50	One-way operation	(one-way, do not enter)
51	Markings	(pavement, delineators)
52	Other	

	Roadway in Vicinity of the Driveway	
53	Right-turn lane attributes:	(absence or presence)
54	lane width	
55	lane deceleration, storage length	
56	lane entry transition shape	
57	lane offset	
58	Left-turn lane attributes:	(absence or presence)
59	lane width	
60	lane deceleration, storage length	
61	lane entry transition shape	
62	lane offset	
63	Number of driveways per site	
64	Driveway spacing from upstream access connection	
65	Driveway spacing from downstream access connection	

Sight Distance and Conspicuity

Two considerations that are frequently part of the discussion of many design elements are sight distance and conspicuity.

There are many types of sight distance. The basics of stopping sight distance and intersection sight distance are explained in the AASHTO Green Book (*5-1,* pp. 109–114 and 650–676), and an understanding of these basics is a mandatory prerequisite for anyone designing a roadway or driveway connection to a roadway. The designer should check that walls, wide utility poles, vegetation, or other objects do not block the lines of sight that a bicyclist, driver, or pedestrian needs to maneuver safely.

Conspicuity is the attribute of standing out so as to be noticed or observed. As applied to driveways, conspicuity means that users (whether bicyclists, motorists, or pedestrians) approaching the driveway can detect and recognize the presence of the driveway far enough in advance so as to make any needed adjustments in their travel trajectory or speed. Also, as the user either on the roadway or on the "private side" nears the driveway, the user can detect the precise edge or

Exhibit 5-3. Driveway considerations generally outside the control of the designer.

	Shared Elements, Surroundings	
1	Land use	
2	User and vehicle mix and composition	
3	Temporal variation: season, day of week, time of day	
4	Weather and weather effects	
	Sidewalk-Driveway Intersection	
5	Sidewalk placement	(adjacent to or offset from the curb or edge)
	Roadway-Driveway Intersection	
6	Elevation difference between roadway surface and abutting property	
	Roadway in Vicinity of the Driveway	
7	Width of roadway	
8	Lanes	(number, width)
9	Lane type	(travel, HOV, bicycle, turn, parking)
10	Cross slope	(travel lanes, shoulders)
11	Horizontal alignment of roadway	
12	Vertical profile of roadway	
13	Sight distance restrictions	
	User Characteristics - Bicyclist	
14	Bicyclist perception-reaction process, time	
15	Speed	
16	Braking capability	
17	Sight distance need	
	User Characteristics - Pedestrian	
18	Pedestrian perception-reaction process, time	
19	Speed	
20	Sight distance need	
	Special needs groups	
21	General - children, elderly	
22	Those with disabilities (e.g., mobility, visual)	
23	Legal mandates - those related to disabilities	
	User Characteristics - Vehicle, Driver	
24	Driver perception-reaction process, time	
25	Speed	
26	Deceleration characteristics (typical)	
27	Braking capability (limiting)	
28	Sight distance need	
29	Vehicle width	
30	Vehicle length	
31	Vehicle turning radius	
32	Vehicle front overhang, wheelbase, rear overhang, and ground clearance dimensions	

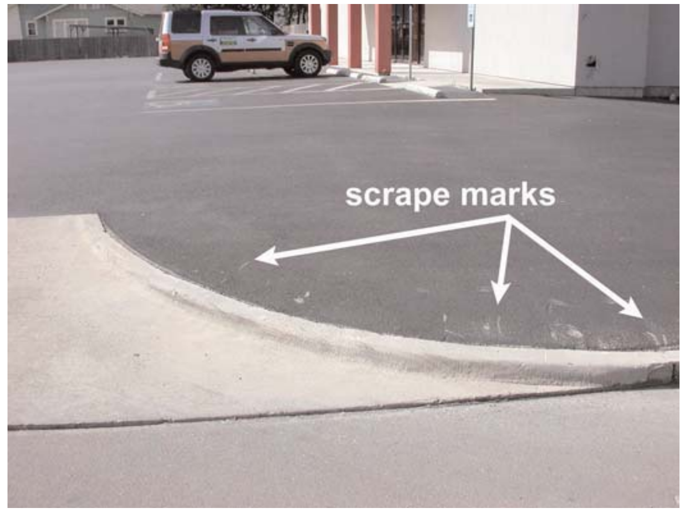
other elements that will affect the user's position and path when crossing, entering, or exiting the driveway. Means to improve conspicuity include the following:

- Clearly defining the edges of shapes, so as to differentiate between shapes (e.g., the edge between a sidewalk and a driveway);
- Providing contrast between light and dark surfaces;
- Placing a business sign near the driveway, to reinforce its location; and
- Installing artificial illumination.

Exhibits 5-4 and 5-5 show undesirable design practices. Exhibit 5-4 shows how a planter and a utility pole near the intersection of a driveway with a roadway restrict the sight distance. Visual

Exhibit 5-4. Placement of planter and utility pole limit the sight distance for a driveway exit.

Exhibit 5-5. Poorly defined edge leads to scrapes.



obstructions may also make it difficult for motorists on the roadway approaching the driveway connection to have an adequate preview of the driveway or vehicles in the driveway.

In Exhibit 5-5, the driver's view from the street side provides clear definition of the edge. However, for the driver in the parking lot, the curb edge drop off is hidden, so, unable to detect the dropoff, some vehicles drive over the curb. Practices similar to that shown in this exhibit, which create a continuous expanse of pavement and no distinction between the actual driveway and the curb dropoff, should be avoided.

A similar problem can occur when a driveway that slopes downward from the roadway edge is located on the high side of a superelevated roadway. Drivers in the roadway attempting to enter the driveway may have difficulty determining where the driveway edges are. A designer may consider adjusting the driveway profile so that it rises slightly before descending, or adding delineators or soft landscaping to help drivers identify the driveway edges.

Exhibit 5-6 offers guidance for sight distance and conspicuity elements.

Exhibit 5-6. Visibility design concerns.

Concern or Issue	Design Response	Specific Procedure and/or Information
Bicyclists, motorists in vehicles, and pedestrians need to see each other far enough in advance to avoid collisions.	At driveway intersections with public roadways, have unobstructed lines-of-sight that provide adequate stopping sight distance. Along high-type public roads, adequate intersection sight distance also should be provided. However, this may not always be practical in built-up areas. Do not place anything in the border that blocks needed sight lines.	Refer to the latest edition of the AASHTO Green Book for the procedure to calculate the needed stopping sight distance or intersection sight distance.
To have time to react, drivers need to detect the driveway well in advance and be able to visually define its shape before entering or exiting.	Have driveway edge color contrast with the color of the abutting surface. Have driveway pavement color contrast with the color of the roadway. Consider illumination during darkness. For non-residential, place a monument sign very close to the driveway intersection with the roadway.	Curbed driveways provide a clearer delineation of the driveway entry shape than "dust pan" designs do.

Driveways serving parking garages sometimes have restricted sight distance, especially where the vehicles exiting the garage cross the sidewalk abutting the edge of the garage structure. For guidance, refer to the AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities* (*5-2*). Future studies could provide a better understanding of this.

Bicyclists

The driveway designer should recognize and accommodate interactions involving bicyclists, motor vehicles, and pedestrians. In this context, the main area of interaction involving bicyclists is where they cross driveways. This may occur either when a bicyclist is riding in the public roadway, crossing a driveway intersection, or on a bike path or other separate facility that crosses a driveway.

Although bicyclists often are not allowed to ride on sidewalks, there are exceptions. In some communities, younger children are allowed to ride on the sidewalk, except in the downtown area (*5-3*). In some suburban and exurban areas, shared-use sidepaths are a common feature along arterial roadways.

In general, bicyclists are more likely to be a consideration at driveways in urban and suburban areas than they are in rural areas. Exhibit 5-7 lists some pertinent design principles.

Pedestrians and Pedestrians with Disabilities

In many environments, especially in built-up areas, pedestrians will be either crossing the driveway or walking parallel to the driveway. Therefore, pedestrian needs must be considered when designing a driveway. In some environments, pedestrian volumes will be practically nil, and in these situations pedestrian considerations may have less effect on design choices.

Where either existing sidewalks cross or future sidewalks will cross driveways, the driveway designer must consider the horizontal alignment, the vertical alignment, and the cross slope of the pedestrian path. In the crossing area, the sidewalk design must conform to ADA requirements. Some sidewalk locations and some sidewalk and driveway designs more easily conform to ADA requirements than do others. Exhibit 5-8 lists some pedestrian design considerations.

Exhibit 5-7. Driveway design considerations related to bicyclists.

Concern or Issue	Design Response	Specific Procedure and/or Information
Bicyclists, motorists in vehicles, and pedestrians need to see each other far enough in advance to avoid collisions.	Provide horizontal and vertical alignment that provides an adequate advance view of the driveway intersection. Do not place anything in the border that blocks needed sight lines.	Refer to the latest edition of the AASHTO Green Book for the procedure to calculate the needed stopping sight distance or intersection sight distance.
Abrupt change in cross slope causes bicyclists to lose balance.	Where a bicycle path or other similar route crosses a driveway, do not have an abrupt change where the bike path cross slope meets the driveway grade.	
Abrupt change in surface elevation causes bicyclists to lose control.	Where a bicyclist could turn into or turn out of a driveway, do not have an abrupt change in surface elevation that creates a bump for the bicyclist.	
Relatively thin bicycle tires are vulnerable to openings in the surface.	Do not have any grate openings that a bicycle tire could drop into.	

Exhibit 5-8. Driveway design considerations related to pedestrians.

Concern or Issue	Design Response	Specific Procedure and/or Information
Bicyclists, motorists in vehicles, and pedestrians need to see each other far enough in advance to avoid collisions.	Provide horizontal and vertical alignment that provides an adequate advance view of the driveway intersection. Do not place anything in the border that blocks needed sight lines.	Refer to the latest edition of the AASHTO Green Book for the procedure to calculate the needed stopping sight distance or intersection sight distance. Also check sight for people of lower height, such as children or wheelchair users.
An excessive sidewalk cross slope (or driveway grade) adversely affects the crossing by pedestrians with vision impairments and those in wheelchairs.	ADA requirements specify a pedestrian travel path (called a Pedestrian Access Route or "PAR" in the Draft Public Rights-of-Way Accessibility Guidelines) with a cross slope that does not exceed 2%.	The PAR requirement applies not only to the crossing of the driveway, but also to the sidewalk connections. The combination of 2% maximum cross slope and the different sidewalk location options affect the vertical alignment of the driveway in different ways.
Is there a suitable pedestrian route across the driveway?	The sidewalk alignment across the driveway should be straight and not have "steps" or other abrupt changes in vertical elevation.	

Exhibit 5-9 shows methods of aligning sidewalks at driveway crossings, so that the sidewalk does not exceed the ADA 2% cross slope requirement. (Some of these designs could just as easily have a radius return instead of a flared return.)

- With the setback or recessed sidewalk location, the driveway rises to the sidewalk elevation over the distance of the sidewalk setback from the curb.
- With the ramp or dipped sidewalk, the elevation of the sidewalk drops near the driveway crossing. The slope of the ramp on each side of the driveway is not to exceed 8%.
- With a sidewalk of sufficient width, a dustpan taper can be constructed adjacent to the curb, and still leave an adequate pedestrian route along the back edge of the sidewalk.
- The offset sidewalk is an adaptation of the wide sidewalk, with the sidewalk widened in the vicinity of the driveway to provide enough width for a dustpan and a pedestrian crossing.

The accompanying photo shows such an offset or jog in the sidewalk alignment, created so the pedestrian path will not have an abrupt change in elevation. If the normal sidewalk position had been recessed or set back from the curb, with a grass strip between the sidewalk and the curb, then the pedestrian path could continue straight across the driveway, without the jog. Exhibit 5-10 shows an unacceptable treatment.

Exhibit 5-11 shows a driveway with very limited sight distance intersecting a sidewalk and a street.

A pedestrian crossing a driveway may be affected by factors such as the width of the driveway to be crossed, the volume and the speed of vehicles using the driveway, the design of the sidewalk crossing the driveway, the presence or absence of a pedestrian refuge island, or the presence and location of a transit stop or other destination near the driveway.

A wider driveway increases a pedestrian's time of exposure to conflicts with driveway vehicles. The width of the driveway crossing may be more of an issue for a child or older pedestrian who walks slowly than for a wheelchair user.

A wider driveway may be more likely to seriously disorient a pedestrian with impaired vision. If pedestrians with impaired vision veer or are misaligned when they cross a driveway, unless

Exhibit 5-9. Sidewalk-driveway treatments.

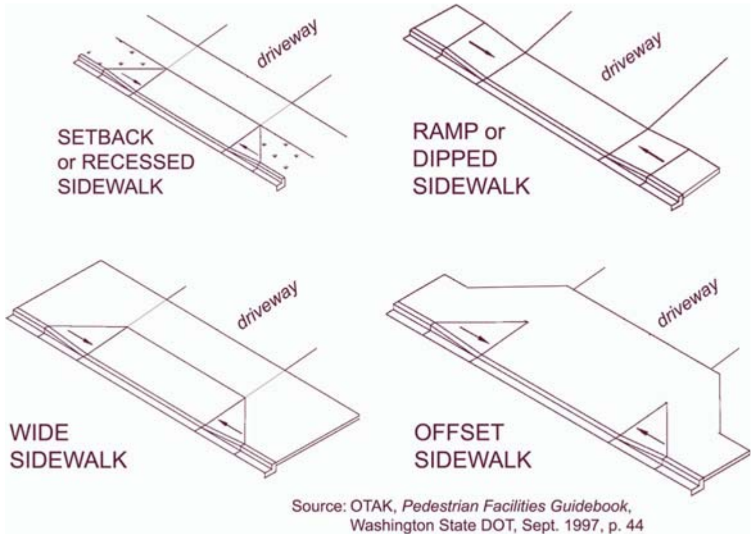


Exhibit 5-10. Unacceptable vertical curb where sidewalk crosses driveway.

Exhibit 5-11. Driveway with very limited sight distance.

another cue such as parallel traffic, a slope, or a guide strip is present, their veer can be expected to be relatively constant during that crossing (*5-4*). As a result, if someone crossing a driveway initially has a 10-degree bearing error, they will likely continue in that direction. The wider the driveway, the greater the chances are that pedestrians are farther from the sidewalk when they reach the far side of the driveway. On a 20-foot crossing, a pedestrian with a slight veer might be just outside the sidewalk area, and be able to easily locate the sidewalk by reaching out with a cane. On a 30- or 40-foot crossing with the same veer angle, a pedestrian may no longer be able to easily locate the sidewalk on the far side of the driveway area. A cut-through median, a textured pedestrian crossing, or a delineating guide strip across the driveway width might mitigate this situation on a wide driveway. Guidance strips are sometimes installed in the sidewalk to help guide pedestrians with impaired vision across wide driveways. However, there is little current research on the ability of pedestrians with impaired vision to use these guidance strips effectively (*5-5*).

Drivers may be more likely to yield to pedestrians if there is a wide landscape strip between the curbline and the sidewalk or an auxiliary deceleration lane, so the vehicle turning into the driveway can stop outside of the main travel lane of the roadway.

For pedestrians with impaired vision, it can be helpful if the driveway design discourages vehicle encroachment onto the sidewalk area. Also, identifying the appropriate time to cross the driveway can be a problem at a busy driveway—this problem may not be amenable to a geometric remedy, except one that discourages high vehicular speeds.

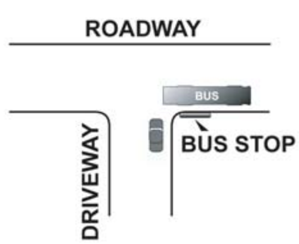
Public Transit Facilities

The driveway designer should consider the location of transit routes and stops in the vicinity of the driveway. The following problems can arise when driveways and transit stops are too close to each other:

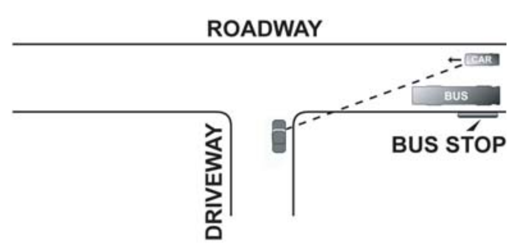
- A stopped transit vehicle blocks the driveway.
- Transit patrons block the driveway.
- Standing transit patrons are uncomfortably close to driveway traffic.
- Standing transit patrons block drivers' lines-of-sight.

Exhibit 5-12 illustrates that a bus stop should be located to avoid blocking a driveway and set back a sufficient distance from the driveway to help ensure adequate sight distance. In many cases, a transit stop on the far side of the driveway connection with the roadway is preferable to one on the near side, because far-side bus stops do not interfere with vehicles turning right into driveways and do not block the line of sight to the left of motorists exiting the driveway. When possible, bus stops or driveways may need to be relocated to reduce conflicts with each other. Exhibit 5-13 provides guidance on the location and design of bus stops near driveways. Details on bus stop location and design can be found in *TCRP Report 19: Guidelines for the Location and Design of Bus Stops* (*5-6*).

Exhibit 5-12. Bus stop locations near driveways.



AVOID - Bus at stop blocks driveway



GOOD - Bus at stop does not block sight line

Exhibit 5-13. Driveway design considerations related to nearby bus stops.

Concern or Issue	Design Response	Specific Procedure and/or Information
Do not block drivers' lines-of-sight	Provide adequate stopping sight distance or intersection sight distance. Provide separation from driveway edge to bus stop. Do not place bus shelters in a location that blocks needed sight lines.	Refer to the latest edition of the AASHTO Green Book for the procedure to calculate the needed stopping sight distance or intersection sight distance.
Space so that the bus does not physically block the driveway	Provide distance from driveway edge to bus stop	Length of city transit bus: typical bus, about 40 ft. articulated bus, about 60 ft Additional length along roadway needed for maneuvering: where buses do not change lanes: 20 ft where a lane change is required: 50 ft
Patrons loading or unloading from transit vehicle do not occupy the driveway	Provide a pedestrian standing area separate from and removed from the driveway Connect the bus loading area to the sidewalk	Pedestrian connection at least 5 feet wide, where possible

Driveway Plan and Cross-Section Elements

The following sections discuss driveway plan and cross-section elements, such as the type of entry/exit geometry, the amount of flare or radius, the driveway width, and driveway channelization.

Driveway Width, Number of Lanes, and Connection Transition

This section discusses and presents recommendations for three plan view elements:

1. The normal width of the driveway throat, which does not include the normally found widening or transition with a radius or a flare near the driveway intersection with the roadway;
2. The number of driveway lanes needed; and
3. The shape and dimensions of the shape at the connection (throat entry/exit) transition.

The driveway width and the driveway connection transition are separate elements, but the design of each can affect the design of the other, so the discussion of these elements has been combined.

Objectives for designing the driveway entry and exit geometry include the following:

1. Define the edge so it is visible for bicyclists, drivers, and pedestrians.
2. Minimize the width of the driveway that bicyclists and pedestrians will need to cross.
3. Design a shape that conforms to the path of the turning vehicle, which enables vehicles to enter a driveway without encroaching into other lanes.
4. Design to enable vehicles to enter the driveway without significantly impeding the upstream flow of through traffic on the roadway.
5. Provide adequate driveway capacity, including providing separate right- and left-turning exit movements, when needed.
6. Design for easy construction.

Exhibit 5-14 raises questions that address the design of the connection transition, and Exhibit 5-15 shows the effects of inadequate geometry in this area. The geometry should not force normal right entry or exit movements to cross over the driveway curb or edge, drive on

Exhibit 5-14. Design issues for a vehicle turning right into or from a driveway.

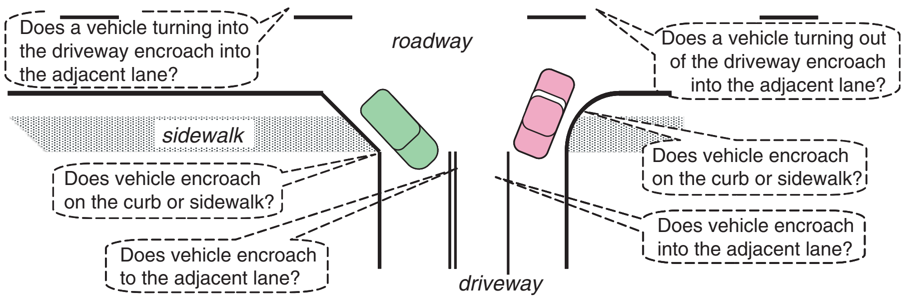


Exhibit 5-15. Effects of inadequate driveway radii.

(a)

(b)

(c)

the sidewalk, or swing wide so that the left side encroaches into adjacent lanes. But excessive width unnecessarily increases the distance across the driveway that bicyclists and pedestrians must cross.

Interrelated Factors Affecting the Design

Various factors act in concert as a vehicle turns into or out of a driveway and as the vehicle crosses a bicycle lane or sidewalk parallel to the roadway. The following interrelated elements come into play as a driver turns into or out of a driveway intersection (*5-7*):

1. Visibility and conspicuity of the features that shape the driveway (e.g., opening, edges, markings);
2. Vehicle turning radius;
3. Vehicle tracking width and offtracking characteristics;
4. Intersection-corner treatment and treatment dimensions (e.g., radius or taper dimensions);
5. Width of the lane from which the turn is made (includes offsets, edge flares);
6. Width of the lane into which the turn is made (includes offsets, edge flares);
7. Angle of the intersection;
8. Cross slope of the pavement surface in the turn;
9. Pavement surface condition (e.g., in extreme cases, a corrugated surface or pothole can impart vertical acceleration to a turning vehicle, decreasing the available side friction);
10. Turning speed;
11. Driver's tolerance of lateral acceleration; and
12. Driver's ability to perceive these elements.

The vertical profile also affects the driving experience.

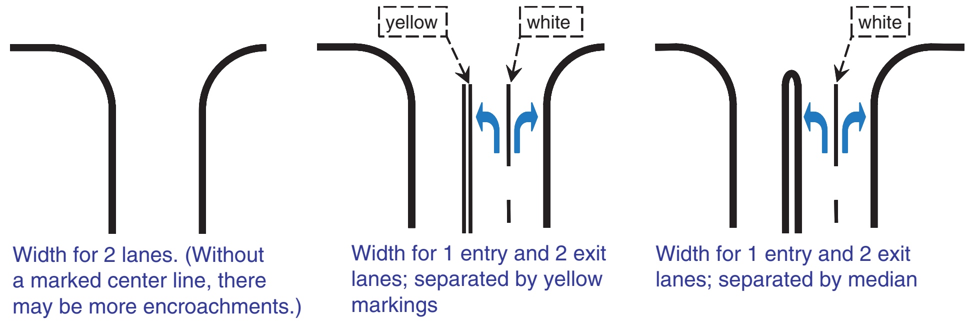
Before selecting the dimensions of the connection transition, the designer should identify design vehicles for the particular driveway. Chapter 3 includes a discussion of design vehicle considerations. Where heavy vehicles may run over area behind the curb and damage surfaces such as a sidewalk or a driveway median, the designer should consider a strengthened pavement surface for the affected area behind the curb.

Number of Lanes

A basic driveway design question is "how many driveway lanes should be provided?" Typically, driveways serving a single-family residence are one or two lanes wide, often reflecting the width of the garage. Driveways serving farms and fields are typically one lane wide, although the width of that lane is quite wide, reflecting the widths of farm machinery. In general, driveways serving commercial and industrial sites should have at least two lanes (one-way driveways are an obvious exception), operating with one lane in each direction.

With increasing driveway volume, adding a second exit lane becomes highly desirable in order to avoid excessively long queues and delay. Without two exit lanes, a motorist waiting for gaps in both traffic directions before turning left out of the driveway will unnecessarily block other motorists in the exit queue who could otherwise turn right when there are gaps in the traffic from the left. However, the number of lanes exiting from the development and turning in one direction must not exceed the number of available traffic lanes on the roadway in that direction. For example, for a driveway entering a two-lane two-way roadway, no more than one lane in each direction (a total of two exit lanes) should be allowed to exit the driveway. Generally, dual exit-lane driveways are desirable when the exit volume reaches the level that more than one vehicle will want to exit the driveway within the time interval it takes one left-exiting vehicle to wait for and accept an adequate gap in roadway traffic, or when the driveway intersection with the public road is signalized. Exhibit 5-16 shows some of the more common commercial driveway configurations, excluding those for very high volumes.

Exhibit 5-16. Common choices for a range of commercial driveway designs.



If the driveway forms the fourth leg of an intersection, additional lanes may be needed. In such cases, a configuration of three exit lanes (left turn, through, and right turn) and/or two entry lanes may be desirable. At what might be considered the high-volume end of the spectrum, sites such as major shopping centers and urban activity centers, even more lanes may be needed.

If there is a question of whether additional lanes are needed, an operational analysis of the intersection between the driveway and the roadway, perhaps using calculations from the *Highway Capacity Manual* (*5-8*), could be performed. Variables reflected in the operational analysis include the volume on the main roadway, the volume and directional distribution of the driveway traffic, the number of adequate size gaps in through street traffic, and the form of traffic control at the driveway/roadway intersection.

Driveway Width

The width of a driveway is its normal width, measured some distance back from its intersection with the roadway. It is not the width that includes widening near the intersecting roadway. The width of a driveway is a function of the number of driveway lanes, the widths of those lanes, and the presence and width of a median.

The width of a driveway should reflect the needs of both vehicular and pedestrian traffic. The competing goals of reducing vehicle delay by adding lanes and reducing pavement width to facilitate pedestrian crossings need to be recognized.

Exhibit 5-17 shows a wide-open, undefined driveway across what appears to be the full frontage of the tract. These designs are particularly unfriendly to bicyclists and pedestrians crossing the excessive driveway opening width. Because of the lack of lane definition, vehicles enter and leave such sites in random positions and are more likely to cross paths. Such a design should be avoided.

Exhibit 5-17. Undesirable wide-open driveway.

Exhibit 5-18. Range of reported driveway widths and radii.

	Normally, Use This in Most Situations (ft)			Commercial (ft)			Residential (ft)		
	Smallest reported	Average	Largest reported	Smallest reported	Average	Largest reported	Smallest reported	Average	Largest reported
Width for 2-way: normal maximum (ft.)	24	34	40	35	40	46	12	23	30
Width for 2-way: normal minimum (ft.)	12	24	35	12	22	30	8	12	15
Entry-shape plan-view dimensions									
for curved radius, maximum R (ft.) =	20	41	75	40	50	70	10	23	35
for curved radius, minimum R (ft.) =	3	16	25	15	21	30	3	11	15

NOTE: These values reflect survey responses from 1 local and 16 state transportation agencies.

Exhibit 5-18 presents ranges of driveway widths and radii given in response to a survey of transportation agencies.

Connection Transition Shape

For a driveway to intersect a public roadway, a break in the curb line or the edge of the roadway is required. This section discusses aspects of the transition that occur past the break, within the first few feet of the driveway. This transition may be designed with a perpendicular edge, rectangular apron, flare or taper, or curved radius. Exhibit 5-19 shows basic types of driveway connection transition geometries.

The driveway connection transition, where turning vehicles enter and exit the driveway, is usually a critical design area, given that it is the location of potential interaction of entry and exit movements (*5-9*). One of the key aspects of good driveway design is accommodating the entry and exit movements so that they do not encroach on one another or vehicles in other lanes (*5-9*). In some situations, this requires that the driveway radius be almost as large as the turning radius of the selected design vehicle.

Except on low-volume, low-speed roadways, the curb radius or flare dimensions should be designed so that normal right-turn entry movements do not have to slow down to a near stop in the through travel lanes on the roadway. The dimensions should also allow drivers to turn into or from a driveway without encroaching into conflicting lanes of traffic.

Where the roadway is curbed, the entry shape also acts in concert with the curb termination treatment at a driveway entry. Curbs may be terminated abruptly, by means of a drop-down curb, or by a return curb. Exhibit 5-20 shows curb termination treatments. (When the drop-down curb design accompanies a flare/taper transition edge shape, this is sometimes called a “dust pan.”)

Exhibit 5-21 compares the connection transition shape alternatives. The perpendicular edge is the easiest to construct, but the least conspicuous to both motorists and pedestrians and does not conform to or help define the path of a turning vehicle. The rectangular apron is better than

Exhibit 5-19. Types of driveway connection transition geometry.

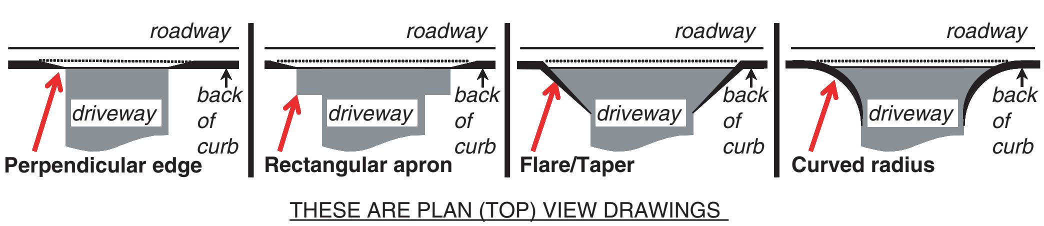
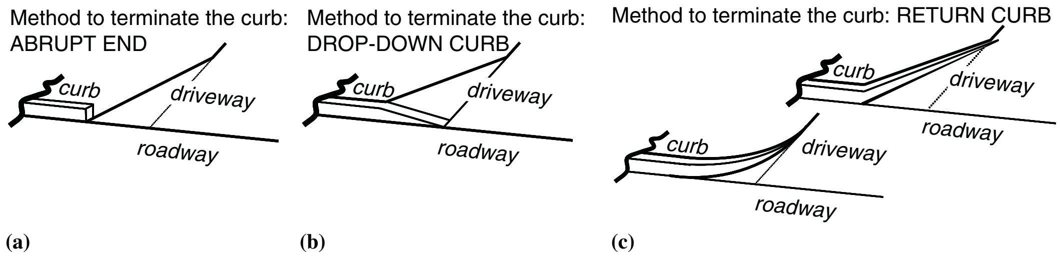


Exhibit 5-20. Methods to terminate the curb.



the perpendicular edge in terms of functionality, but slightly more difficult to construct. The use of both types should be limited to single-family or duplex residential units. The flared taper is easier to build than the curved radius, but is less effective in terms of conspicuity and conforming to the path of a turning vehicle. Therefore, the use of the flared taper generally should be limited to low intensity or medium intensity uses.

It has been stated that "Flared driveways are preferred because they are distinct from intersection delineations . . . " (*5-1,* p.398); in other words, because they do not look like roadway intersections, motorists can distinguish between driveways and side streets. While this may be a benefit in a few situations, in many situations there is no benefit to be had from this distinction, and even if there were, other aspects of driveway design will provide a visual difference for motorists to rely on.

As for curb termination treatments, an abrupt end is more likely to snag a vehicle tire, and therefore is undesirable. A returned curb has a vertical face, which provides entry-edge definition for an approaching motorist.

A discussion of design treatments for sidewalks crossing the driveway in this area is in Pedestrians and Pedestrians with Disabilities.

Exhibit 5-22 presents a table from the 2005 Florida *Driveway Handbook* (*5-9,* p.31), which was derived from much older sources. The numerical values illustrate the inverse relationship between entry radius and the width of the entry lane: as the size of the radius increases, less entry lane width is needed. Based on recent experience, these dimensions may be generous for many drivers of passenger cars.

Connection Transition Design Suggestions

The preceding discussion of driveway transition shapes leads to the suggestions in Exhibit 5-23.

Driveway Width Design Suggestions

When establishing driveway widths and driveway opening treatment dimensions (e.g., size of radius or flare), it is not uncommon to encounter opposing viewpoints; there may be conflicting objectives between the various driveway users, such as pedestrians and motorists, with some

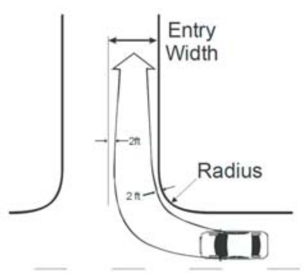
Exhibit 5-21. Comparison of connection transition shape alternatives.

Design Objectives	Perpendicular Edge	Rectangular Apron	Flare/Taper	Curved Radius
Conforms to path of turning vehicle	worst (1)	poor (2)	better (3)	best (4)
Definition of edge for motorists	poor (2)	worst (1)	better (3)	best (4)
Definition of edge for pedestrians	best (4)	worst (1)	poor (2)	better (3)
Ease of construction	best (4)	better (3)	better (2)	worst (1)
Overall score				**best (12)**

NOTE: Cannot compare scores directly, because the importance or weight of each objective is not equal.

Exhibit 5-22. Inverse relationship between entry radius and entry lane width.

Exhibit 15



Radius or Flare (ft.)	Single Lane Width for Entry for Passenger Vehicles (ft.)
Typical flared driveway	22 ft (Pavement striping should be used if entry is this wide)
10 ft Radius	19 ft
15 ft Radius	17 ft
20 ft Radius	14 ft
25 ft Radius	14 ft
Over 25 ft Radius	12-14 ft

Source: adapted from Access Management for Streets and Highways, Flora and Keith, FHWA, 1982 p 63

Source: FDOT *Driveway Handbook*, p. 31, March 2005

Exhibit 5-23. Driveway transition shape design guidelines.

Category	Description of Common Applications*	Suggested Driveway Transition Shape Design (assuming curbed roadways in urban area, uncurbed in rural area)
STANDARD DRIVEWAYS		
Very high intensity	Urban activity center, with almost constant driveway use during hours of operation. Typified by a driveway serving a post-1950 major shopping center or office complex. Not uncommon for such driveways to be signalized.	Design as a street intersection. Provide separate right- and left-turn lanes on approaches to public roadways.
Higher intensity	Medium-size office or retail, such as community shopping center, with frequent driveway use during hours of operation. Also includes land uses with extreme peaking patterns, such as public schools, worship assemblies, and employee parking lots.	Use curb radius design. Consider separate right- and left-turn lanes on approaches to public roads.
Medium intensity	Smaller office or retail, such as convenience stores, with occasional driveway use during hours of operation. Also includes some apartment complexes.	Curb radius design is preferred.
Lower intensity	Typical applications include single-family or duplex residential, other types with low use. May not apply to rural residential.	Use either the curb radius or the flare/taper design.
SPECIAL SITUATION DRIVEWAYS		
Central business district	Building faces are close to the street. May have on-street parking or bus stops, a continuous sidewalk from the curb to faces of buildings, and higher pedestrian usage than in most other environments. Many situations will serve P-cars and some single-unit trucks.	Design will vary depending on location, land use, and traffic volumes.
Farm or ranch	May be a mixture of residential and industrial characteristics, used by a mix of design vehicles, such as P-car, single-unit truck, and agricultural equipment.	Design uncurbed radius or taper to accommodate farm/ranch vehicles.
Field	Serves a field or other similar rural land area that is seldom trafficked. Higher-clearance P-vehicles or heavy vehicles are expected.	Design uncurbed radius or taper to accommodate farm/ranch vehicles.
Industrial	Driveways frequently used by buses, tractor with semi-trailers, and other vehicles longer and wider than the design passenger car.	Design for trucks. The driveway may need a special design to accommodate the extra axles and longer wheelbase that will lead to much greater offtracking of vehicles entering the driveway.

* These descriptions are intended to help the designer form a mental image of some of the more common examples of the category.

calling for smaller dimensions to make crossing the driveway easier for pedestrians, and others wanting larger dimensions to facilitate motor vehicle ingress and egress.

An operational analysis of the intersection between the driveway and the roadway provides a basis for decisions regarding the number of driveway lanes. The connection transition and the driveway width dimensions should complement each other to produce good driveway operations. The driveway width and the curb radius can perform in concert, so to some degree one can increase as the other decreases. In other words, a wide driveway can be used together with a small radius or flare to achieve similar operations to a narrower driveway with a larger radius or flare. When only one vehicle is expected to be using the driveway at any given time, such as a residential driveway serving a two-car garage, the smaller radii are suitable with the greater widths.

Exhibit 5-24 offers guidelines for driveway width and radius. These dimensions do not consider the presence of an offset between the outer edge of the traveled way and the end of the

Exhibit 5-24. Driveway width and curb radius guidelines.

Category	Description of Common Applications (Note: These descriptions are intended to help the designer form a mental image of some of the more common examples of the category.)	Driveway Width	Driveway Curb Radius (in ft)		
			Higher speed road	Moderate speed road	Lower speed road
STANDARD DRIVEWAYS					
Very high intensity	Urban activity center, with almost constant driveway use during hours of operation.	Many justify two lanes in, two to three lanes out. Refer to street design guides.	30–50	25–40	NA
Higher intensity	Medium-size office or retail (e.g., community shopping center) with frequent driveway use during hours of operation.	One entry lane, 12–13 ft wide Two exit lanes, 11–13 ft wide.	25–40	20–35	NA
Medium intensity	Smaller office or retail, with occasional driveway use during hours of operation. Seldom more than one exiting vehicle at any time.	Two lanes, 24–26 ft total width	20–35	15–30	NA
Lower intensity	Single-family or duplex residential, other types with low use, on lower speed/volume roadways. May not apply to rural residential.	May be related to the width of the garage, or driveway parking. Single lane: 9–12 ft Double: 16–20 ft	15–25	10–15	5–10
SPECIAL SITUATION DRIVEWAYS					
Central business district	Building faces are close to the street.	Varies greatly, depending on use	NA	20–25	10–15
Farm or ranch; Field	A mix of design vehicles; some may be very low volume.	Min. 16 ft, desirable 20 ft. Affected by widths of field machinery.	30–40	20–30	NA
Industrial	Driveways are often used by large vehicles.	Minimum 26 ft	50–75	40–60	40–60

NOTES: These widths do not include space for a median or a parallel bike lane or sidewalk.
Additional width may be needed if the driveway has a curved horizontal alignment.
For a flare/taper design, use the radius as the dimension of the triangular legs.
For industrial or other driveways frequented by heavy vehicles, consider either a simple curve with a taper or a 3-centered curve design.
For connection angles greatly different than 90 degrees, check the radius design with turning templates.
For connection corners at which a turn is prohibited, a very small radius is appropriate. Also see the section, Driveway Horizontal Alignment and Angle.
Driveways crossing an open ditch should have a minimum 2 ft shoulder on each side.
(source: Statewide Urban Design and Specifications, Iowa State U., Ames, IA (October 21, 2008) p. 4.
If the roadway has a usable shoulder, a somewhat smaller radius may perform acceptably.

Exhibit 5-25. One-way driveway widths from selected states.

Agency	Source	Category	Width for one-way
Florida	Driveway Handbook	Urban	12 ft. minimum
Missouri	940.16 (5/13/09)	Driveway	20–30 ft
New Jersey	C-11 (6/20/07)	Driveway	20–23 ft
New York	608-03 (1/8/09)	Minor Commercial	12–24 ft; 16 ft normal
Utah	12.1.1601.10	Driveway	12–32 ft

driveway, i.e., the driveway threshold. There are arguments for and against adjusting the radius when an offset is present. Some agencies reduce the required radius when an offset is present, expecting turning vehicles to follow an effective radius that utilizes the space between the outer edge of the traveled way and the threshold. Arguments against this practice include an assumption that some drivers may not follow the imaginary effective radius, but instead try to follow the visible physical connection transition edges. Also, it is possible that, in future, the roadway cross section width may be reallocated and the offset eliminated, resulting in an undersized connection transition.

One-Way Driveway Widths

Only a small fraction of driveways operate in a one-way mode. Information on which to base guidance for the design of one-way driveways is limited and, as Exhibit 5-25 shows, current agencies' standards differ considerably. Structured studies of one-way driveway design elements would be helpful.

Throat Transition Design for Larger Vehicles

The offtracking of even-turning single-unit trucks can result in tires running over the curb or the sidewalk behind the curb. But if the designer accommodates turning trucks with a simple radius design, this accommodation may create a very wide entry opening. To better accommodate the wheel paths of turning trucks without paving such a wide area, refer to the AASHTO Green Book's (*5-1,* p. 583–621) discussion of designing simple curves with a taper and designing three-centered compound curves. Exhibit 5-26 dissects the geometry of a three-centered curve at a 90-deg. intersection.

Throat Width for Curved Driveways

If the driveway horizontal alignment is curved instead of straight, then additional driveway width may be required to account for the effects of vehicle offtracking. Refer to the AASHTO Green Book (*5-1,* p. 202–223) for procedures to determine how much additional width is needed.

Throat Transition Widening

Some driveways are constructed with a wider section close to the intersecting roadway, then the width tapers to a narrower section some distance back from the intersecting roadway. Two of the reasons for doing this are to widen the driveway

1. To provide additional lanes at the intersection with the public roadway; and
2. To accommodate the offtracking and swept paths of turning vehicles entering and exiting driveways at the entry/exit area.

In either case, the designer will need to design a transition from the wider cross-section width to the narrower cross-section width. Exhibit 5-27 shows a schematic of this concept.

A 6:1 taper would be adequate for an assumed design speed of 19 mph. Tapers of 8:1 to 12:1 should be more than adequate for the typical driveway, excluding those that look and operate like public roadways.

Exhibit 5-26. Geometry of a symmetrical 3-centered curve.

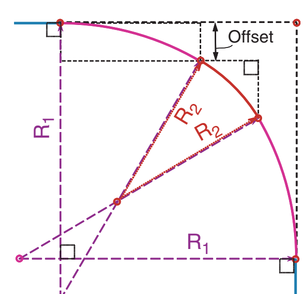


Exhibit 5-27. Taper to effect throat transition widening.

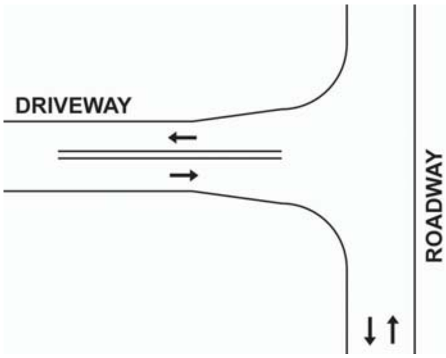


Exhibit 5-28. Example taper design.

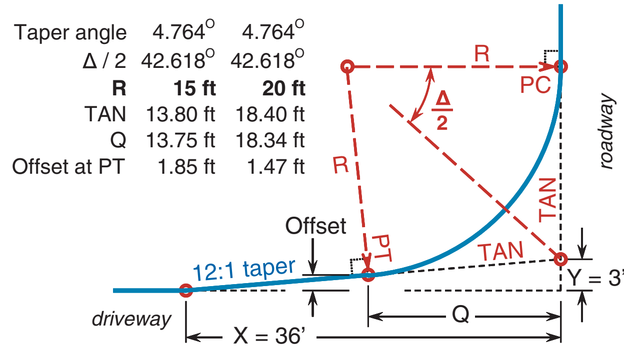


Exhibit 5-28 shows an example 12:1 taper design. For a driveway having 12-ft-wide lanes, the 15-ft radius provides a motorist with a 13.9 ft (12.0 + 1.9) opening at the point of tangency (PT), and the 20-ft radius produces a 13.5 ft (12.0 + 1.5) opening at the PT.

Channelization

Various types of channelization are sometimes incorporated into driveway designs. These include medians in the driveway, islands in the driveway, and channelization in the roadway at the intersection with the driveway. The general design objectives for channelization are to

- Separate conflicting movements (including opposing directions of travel)
- Control the angle of conflict
- Reduce excessive pavement area
- Regulate traffic and indicate proper use of driveway/intersection
- Provide pedestrian refuges/protection
- Provide for protection and storage of turning and crossing vehicles

Where channelization is desired but there is not sufficient space to accommodate the width of a median or island, some agencies have installed channelizing devices such as tubular markers. These are discussed later in the section, Traffic Controls.

Channelization in the Roadway

Medians are sometimes labeled as being either non-restrictive or restrictive. A non-restrictive median is a median or painted centerline that does not provide a physical barrier between center traffic turning lanes or traffic lanes traveling in opposite directions; examples include continuous center turn lanes and undivided highways. Restrictive medians physically separate vehicles traveling in opposite directions and restricts the movement of traffic across the median; (e.g., a concrete barrier or guard rail, a raised curb island, or a grassed or swaled median). Either type can be designed to provide some degree of separation between opposing traffic flows and provide space for left-turning vehicles out of the through lane.

Restrictive medians offer several safety benefits. Restrictive medians in the roadway provide refuge for pedestrians crossing the roadway. Some median openings allow all traffic movements to be made. Other openings restrict left-turn and other movements across the median. Prohibiting movements translates into fewer conflicts, greater safety, and more uniform travel speeds along the arterial. However, these benefits may be somewhat offset by the increased turning volumes where there are full-movement median openings. Restrictive medians are often used because, as

Exhibit 5-29. Driveway crash types related to maneuver and orientation.

Maneuver	Turn	Collision	Percent of Total Driveway Crashes
Entering	Left	Rear-end	26
Leaving	Left	Right-angle	24
Entering	Left	Head-on angle	15
Entering	Right	Rear-end	12
Leaving	Right	Right-angle	7
Leaving	Right	All other	8
Leaving	Left	All other	3
Entering	Right	All other	3
Entering	Left	All other	2
			100

Source: Box, *Public Safety Sys.*, 1969

indicated in Exhibit 5-29, more than two thirds of driveway crashes are related to left-turn entry or exit movements (*5-10*).

Exhibit 5-30 shows how restrictive medians may be used to eliminate some or all of the left-turn movements in and out of driveways. They may be channelized to allow for left-turns from the roadway, while prohibiting left-turns out. Alternatively, they may be channelized to allow for left-turns from the driveway, while prohibiting left-turns in.

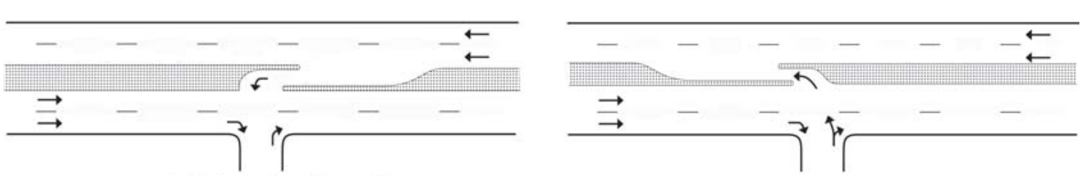
The following items are aspects of good median approach-island design (*5-11*):

- The approach nose should be offset from the approach lanes to minimize accidental impacts.
- The shape of the island should be based on the turning path of the design vehicle and the island function.
- The length of the island should be related to approach speed and reflect available width, taper design, and local constraints.
- The width of the island should adequately serve its intended functions (e.g., access control, pedestrian refuge, separation of conflicts, and shielding left-turn lanes).
- Median islands should begin on tangent alignment and on upgrades or well past crest vertical curves. It may be appropriate to extend a median island to avoid its introduction on a horizontal curve or within an area of limited sight distance.

Designs that prohibit some left-turn movements are often accompanied by an analysis of traffic patterns that identifies alternate means of accomplishing a left turn, such as downstream U-turns or other indirect means.

U-turns are used as an alternative to direct left turns to reduce conflicts and improve safety along arterial roadways. They make it possible to eliminate left-turn movements into and out of driveways. They also make it possible to eliminate the need for certain traffic signals (or reduce the number

Exhibit 5-30. Using restrictive medians to eliminate some left-turn movements.



a. Left-turn in allowed

b. Left-turn out allowed

Source: *Transportation and Land Development,* Second Edition.

of signal phases) that would not fit into a progression pattern (*5-12*). The median openings where U-turns would be made need to be designed to accommodate the additional turning movements.

Requests for a median opening or opposition to closing a median opening may be based on an assumption that a direct left-turn egress maneuver is preferable to a right turn followed by a U-turn. However, observations show that drivers often make a right turn followed by a U-turn where the median opening design permits a direct left turn from a driveway (*5-13*). The additional travel distance of turning right and then making a U-turn is offset by travel time savings by not having to wait for a gap in both directions that is needed for direct, left-turn egress.

Medians in the Driveway

The benefits of restrictive medians in a roadway can also accrue when medians are installed in driveways. Medians in a driveway may be appropriate where one or more of the following conditions exists:

- The driveway has two or more entrance lanes.
- The driveway has two or more exit lanes.
- There is a large pavement area that may confuse drivers.
- The driveway operates as right-in/right-out, and this may be unclear to some drivers.
- The driveway serves a high volume of traffic.
- The driveway is or will be signalized.

A median in a driveway that separates the ingress and egress movements is appropriate for very high-intensity driveways, where the median may provide refuge for pedestrians, separate the opposing traffic flows, and channelize the traffic movements. Exhibit 5-31 provides guidance for when a median in a driveway may be beneficial.

The presence of a median will make the overall length of the pedestrian crossing wider. However, this may be more than offset by the pedestrian refuge effect the median creates in the middle of the driveway.

Where a driveway median is needed, there are minimum dimensions that apply to avoid having a median that is too short and narrow. There is also a possibility that if the median island is too wide, drivers may mistake one driveway with a median for two separate driveways (*5-9*, p. 46).

Exhibit 5-31. Driveway median use recommendations.

Driveway Category	Description of Common Applications (Note: These descriptions are intended to help the designer form a mental image of some of the more common examples of the category.)	Applicability of Median in Driveway
STANDARD DRIVEWAYS		
Very high intensity	Urban activity center, with almost constant driveway use during hours of operation.	Applicable
Higher intensity	Medium-size office or retail, such as community shopping center, with frequent driveway use during hours of operation.	May be applicable
Medium intensity	Smaller office or retail, some apartment complexes.	Usually not applicable, but may be applicable for some wider driveways
Lower intensity	Single-family or duplex residential, other types with low use. May not apply to rural residential.	Not applicable
SPECIAL SITUATION DRIVEWAYS		
Central business district	Building faces are close to the street.	Usually not applicable, but may be applicable for some wider driveways
Farm or ranch; Field	A mix of design vehicles; some may be very low volume.	Usually not applicable
Industrial	Driveways are often used by large vehicles.	Often not applicable, but may be applicable for some wider driveways

Exhibit 5-32. Driveway median design guidelines.

Aspect	Suggested Design	Rationale
Length	Minimum 40 ft, preferable 50 ft or more	Need adequate length for conspicuity, effectiveness.
Width	Absolute minimum: 4 ft Minimum to provide pedestrian refuge: 6 ft Width for visibility of landscaping: 8 to 10 ft Maximum for a driveway divisional island (width of the part that is unavailable for travel, i.e., not including turn lane widths): 12 to 16 ft.	Absolute minimum based on the Green Book. Maximum based on potential for drivers to mistake one driveway with a median for two separate driveways.
End treatment	The 2004 AASHTO Green Book states that for a median island less than 10 ft wide, a semicircular end shape is adequate. For median island widths of 10 ft or more, a bullet nose end shape is suggested. From observations, a bullet nose shape may be desirable for widths of less than 10 ft.	To fit the wheel path of a turning vehicle, per the 2004 Green Book (p.697).

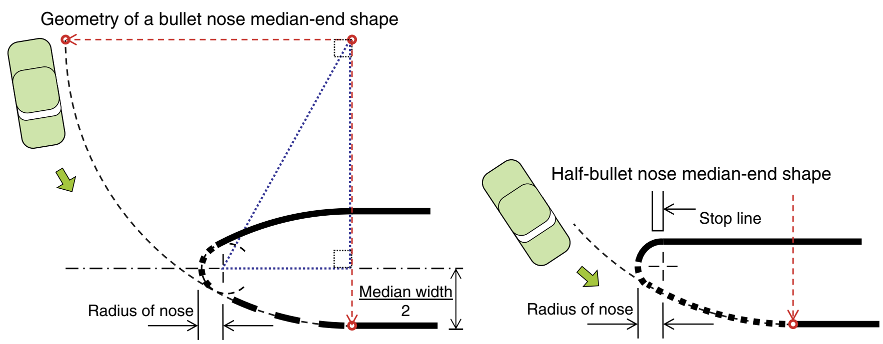


Exhibit 5-32 lists suggested minimum dimensions and presents two versions of bullet nose end geometry. The half bullet nose provides a larger radius to accommodate the path and offtracking of a vehicle nearing the end of its left turn. If the stop line and stopped position for vehicles leaving the site is close to the median nose end, then a lesser radius may be adequate for that movement. Examine the turning paths of left-turning vehicles to ascertain what shape will suffice.

Islands in the Driveway

Driveway triangular islands (pork chops) can be constructed in the driveway entry throat at driveway intersections with both divided and undivided roadways to

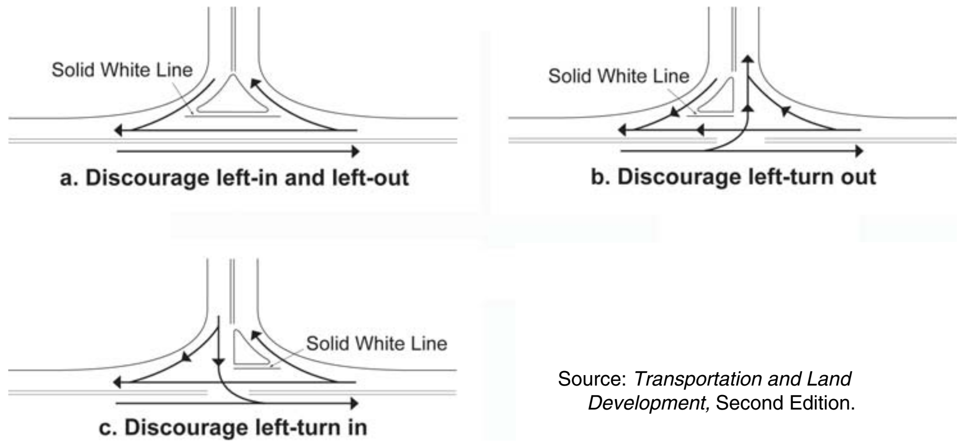
- Channelize right turns,
- Discourage or prohibit one or both left turns, or
- Provide refuge for pedestrians.

Exhibit 5-33 illustrates three different scenarios for using islands to discourage left turns.

A triangular island and an angled driveway can have some design objectives and features in common. The objectives of either design can include facilitating right turns and discouraging left turns. With both, the design can attempt to align vehicles at a skewed angle rather than perpendicular to the public roadway.

Exhibit 5-34 shows two schematics for islands to channelize right turns exiting a driveway (*5-13*). In the (a) schematic, a flatter entry-angle combined with a larger radius may increase the speed at which right-turning vehicles leave the driveway. The flatter entry-angle requires the driver's head to turn a greater number of degrees to the left to monitor oncoming traffic from the left. If the design evokes a subconscious association with a freeway entry ramp, it could theoretically give the driver a false sense of a free entry into the through roadway. This arrangement has been criticized for being

Exhibit 5-33. Using islands to discourage left-turn movements.



Source: *Transportation and Land Development,* Second Edition.

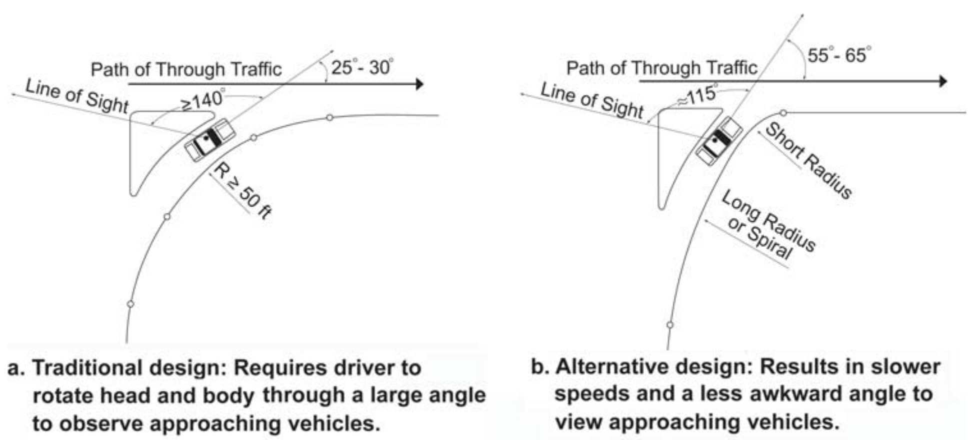
unfriendly to pedestrians because of the relatively high speed of the right turn and the need for drivers to scan a wide angle for pedestrians. The practice of placing the pedestrian crosswalk in the middle of the curve, however, affords drivers an improved view of pedestrian crossings.

The second schematic (b) shows an alternative design that has several advantages. Motorists turning right from a driveway can more easily see approaching through traffic. This design is more pedestrian friendly because drivers have a better view of the sidewalk and the speeds are relatively slow.

The island area should be sufficiently large to command attention. Refer to the AASHTO Green Book (*5-1*) to find the recommended minimum area and dimensions on a side. At locations where there is a likelihood of traffic, especially large trucks, overrunning the island, there may be a need for a mountable curb and structural pavement within the island.

Along roadways lacking a restrictive median, observations of traffic movements at triangular islands indicate it is not uncommon for drivers to make unusual maneuvers to circumvent the island and make prohibited movements. It is challenging to identify a shape, size, radius, and other features that will effectively discourage drivers from circumventing the island. Florida DOT does not use driveway triangular islands on undivided roadways (*5-9*). Lakewood, Colorado, uses a 40- by 18-ft island (360 sq ft) where all left turns are prohibited and a 20- by 18-ft (180 sq ft) island where only the left turns leaving the driveway are prohibited. A design recommended for South

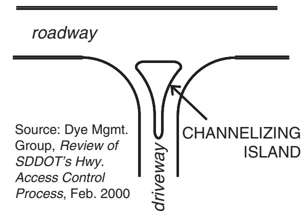
Exhibit 5-34. Comparing two right-turn island designs.



Source: *Transportation and Land Development,* Second Edition.

Dakota incorporated a long stem on the driveway-end of the triangular island to discourage wrong-way movements (see Exhibit 5-35). To better achieve the objective, triangular island installations have been accompanied by the installation of a barrier median or by vertical pylons (traffic posts) along the middle of the public roadway.

Exhibit 5-35. Design proposed to discourage circumventing triangular island.



Inappropriate Channelization

Although channelization can be beneficial, it can also be ineffective or inappropriate in some situations. One does not have to look far to find examples (e.g., Exhibit 5-36) of questionable

Exhibit 5-36. Channelization with dubious benefits.

(a)

(b)

(c)

island designs. The islands in the photos seem too small. It appears that the island in the upper photo is aligned in a way that forces right-turning vehicles off of the pavement into the dirt. One can guess at the intent for islands in photos (b) and (c), but one wonders if they have any positive effects on traffic, or if they are just obstacles and nuisances.

Visual and Tactile Cues

Providing visual and tactile cues that distinguish the sidewalk and define it separately from other driveway areas can assist pedestrians having visual impairments to cross the driveway efficiently and safely. Texture, visual contrast, and slope differences are desirable.

Exhibit 5-37 shows a sidewalk crossing a driveway. The driveway has a distinct slope toward the street. The slope between the street edge and the sidewalk edge is much greater than the slope across the sidewalk. The difference between the slopes may help pedestrians with vision impairments distinguish between the two areas and avoid accidentally veering into the street area as they cross the driveway. There is also a color difference between the sidewalk and the driveway throat area and a slight texture difference between the sidewalk and asphalt which can be detected by some pedestrians using a long cane.

Except for signalized driveways or a few other cases, the use of detectable warning surfaces, such as truncated domes, is discouraged because overuse of detectable warnings surfaces may make it more difficult for pedestrians with vision impairments to recognize streets and to maintain their orientation (see Exhibit 5-38 for further discussion). Exhibit 5-39 shows a typical driveway construction plan for a detectable warning surface on a sidewalk at the edge of a signalized driveway.

Driveway Cross Slope

Where the driveway intersects the roadway, one side of a driveway will be higher than the other side, unless the roadway that the driveway intersects is perfectly level. Proceeding from the traveled edge toward the private property, the designer can alter the relative difference in elevation between the two outer edges of the driveway by having different edge profile grades. Throughout

Exhibit 5-37. Sidewalk with visual, tactile, and geometric cues crossing a driveway.

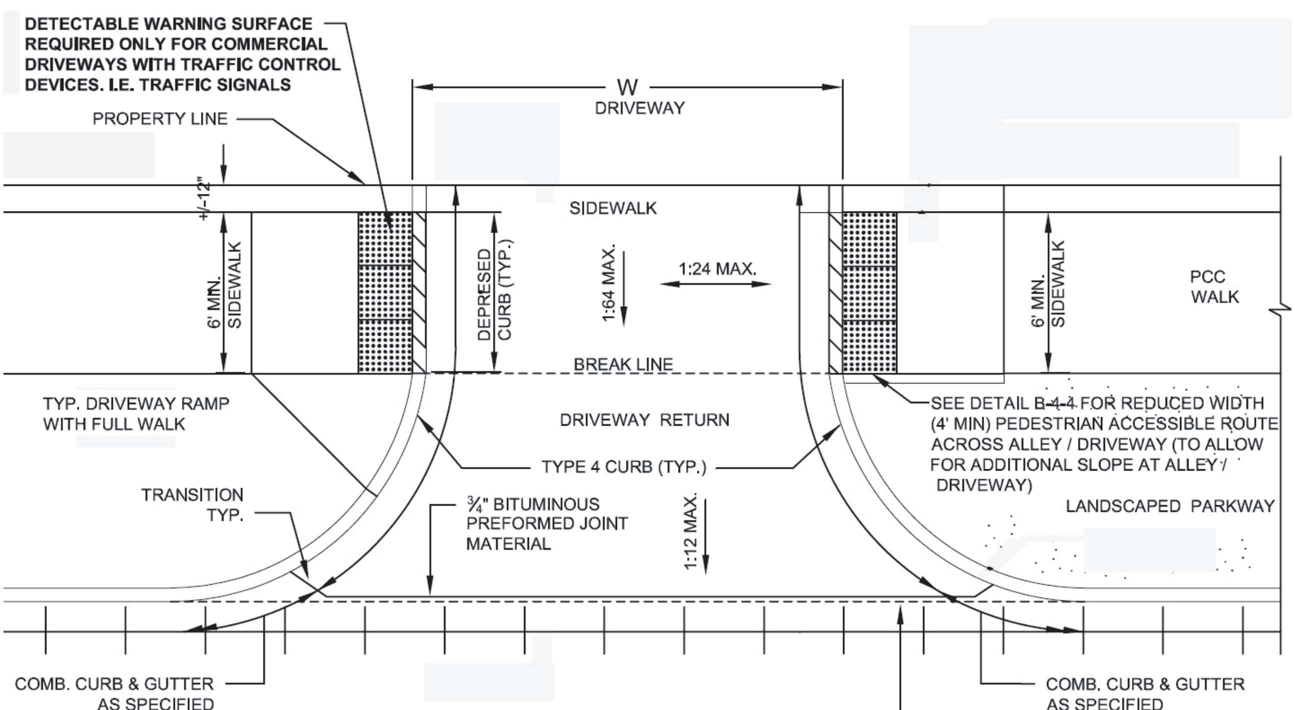
Exhibit 5-38. When to use detectable warning surfaces.

> Advisory R221 Detectable Warning Surfaces. Detectable warning surfaces are required where curb ramps, blended transitions, or landings provide a flush pedestrian connection to the street. Sidewalk crossings of residential driveways should not generally be provided with detectable warnings, since the pedestrian right-of-way continues across most driveway aprons and overuse of detectable warning surfaces should be avoided in the interests of message clarity. However, where commercial driveways are provided with traffic control devices or otherwise are permitted to operate like public streets, detectable warnings should be provided at the junction between the pedestrian route and the street.
>
> Source: Revised Draft Guidelines for Accessible Public Rights-of-Way, November 23, 2005 [http://www.access-board.gov/prowac/draft.htm#221]

the length of the driveway, one edge may be higher than the other, or the center line may be higher than the edges, creating driveway cross slope. Where the driveway and sidewalk intersect, the driveway cross slope is the same as the sidewalk grade.

In the absence of information specifically developed for driveways, these guidelines have incorporated cross slope recommendations from AASHTO. A minimum cross slope of 2% is recommended to provide surface runoff drainage. Where feasible, a maximum cross slope of 8% is recommended in areas where snow or ice can occur.

Exhibit 5-39. Example of a detectable warning surface at edge of signalized driveway.



Source: City of Chicago, Driveway Construction Sheet B-2-4, rev. 11/15/07

Driveway Horizontal Alignment and Angle

The alignment of a driveway near the connection with the public roadway affects traffic operations and safety on both the driveway and the roadway. This section addresses driveway horizontal alignment and the angle of intersection with the roadway.

When there are driveways on opposite sides of the roadway from each other, the designer should check the alignment of through lanes, turning lanes, and medians on both the intersecting roadway and the driveway for potential operational and safety problems. The through lanes should not be offset, but aligned. The review should include a check for whether the lane and median locations would create an offset that would obstruct sight distance (e.g., the sight distance between a vehicle turning left and an opposing through vehicle).

Angle of Intersection

Just as it is undesirable for two roadways to intersect at highly skewed angles, it is undesirable for most driveways to intersect the roadway at a large skew. When a skew angle forces drivers to deal with a turning angle that is much less than or greater than 90 degrees, drivers will have greater difficulty turning their heads to scan the through roadway for an adequate gap, and more distance and time is required to complete an acute angle turning movement. If the crossing is perpendicular to the driveway, it will also be more difficult for bicyclists and pedestrians about to cross a driveway to look over their shoulders to spot vehicles turning from the main roadway.

Research studies have concluded that the intersection angle should not be skewed from 90 degrees by more than 15 to 20 degrees (*5-14* through *5-16*). One-way driveways are an exception to this, and they have operated successfully with skew angle intersections with the roadway.

Exhibit 5-40 lists minimum allowable angles reported in a survey of transportation agencies. For two-way driveways, the average value allowed no more than about 20-deg. deviation from 90 degrees.

Where the one-way driveway is intended to operate in a right-turn entry-only or a right-turn exit-only manner, there are tradeoffs. One theory is that a flatter angle (e.g., 45 degrees) makes it less likely that drivers will violate the right-turn-only intention or use the driveway in the wrong direction. On the other hand, the flat exit requires that drivers entering the roadway turn their heads much more than 90 degrees to see oncoming traffic from the left. Also, the greater the skew angle, the greater the crossing distance parallel to the roadway for bicyclists and pedestrians.

A review of state standards indicates that few allow an angle less than 60 degrees at one-way driveways. Given strictly as an example, the following passage and drawing from the Ohio DOT manual regulate the angle at which a driveway intersects the roadway:

> 803.21 Drive Intersection Angle
> New drives should intersect the highway at an angle between 70° and 90°. However, in some cases, it may be necessary to retain existing drive angles that vary from these desirable angles.

Exhibit 5-40. Range of reported allowable driveway intersection angles.

	Normally, Use This in Most Situations			Commercial			Residential		
	Smallest reported	Average	Largest reported	Smallest reported	Average	Largest reported	Smallest reported	Average	Largest reported
For 2-way drive, minimum angle with the roadway allowed (90^{o} is right-angle)	60	68	90	60	69	75	60	70	90
For 1-way drive, minimum angle with the roadway allowed (90^{o} is right-angle)	45	64	90	45	68	90	45	66	90

NOTE: These values reflect survey responses from 1 local and 16 state transportation agencies.

Exhibit 5-41. Example of a skew-angle driveway.

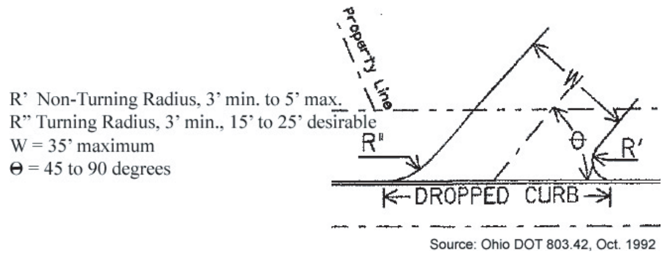


Exhibit 5-41 shows a guideline for angled, one-way driveways, from Ohio DOT design details. Exhibit 5-42 lists suggested minimum allowable intersection angles for driveways.

Driveway Horizontal Alignment

Past or back from the driveway connection transition area (the intersection with the roadway), the horizontal alignment (i.e., plan view) of a driveway should be straight, not curved. One reason for this is so the driver of a motor vehicle entering or leaving the driveway does not have the added task of steering in a compound or reverse or multiple curves, which diverts more attention from the task of monitoring crossing bicyclists, pedestrians, and vehicles. Another reason is that a straight alignment makes it easier for drivers to position and align their vehicles as they approach the intersection and make turning maneuvers and not sideswipe other vehicles. A third reason is to avoid creating situations where the vehicle exiting the site is unintentionally positioned at a skew angle to the roadway. Exhibit 5-43 recommends minimum lengths of straight approaches in advance of the actual physical intersection of a driveway with a roadway.

Space for Bicyclists and Pedestrians

Motor vehicles are not the only form of traffic traveling perpendicular to the roadway to and from a traffic generator set back from the roadway. Bicyclists and pedestrians also make these movements at many locations and, in the absence of a separate facility, they may bike or walk in the driveway.

Exhibit 5-44 shows a pedestrian on a gray, overcast day with light rain, forced to walk in the driveway because of the lack of a sidewalk. At this particular location, the lack of a sidewalk contributes to occasional conflicts between vehicles and pedestrians.

Exhibit 5-42. Suggested driveway intersection angles with roadway.

Driveway Category	Description of Common Applications*	Minimum Allowable Driveway Intersection Angle in Degrees
STANDARD DRIVEWAYS		
Very high intensity, Higher intensity, Medium intensity		70
Lower intensity	Very infrequent use, such as single-family or duplex residential, on urban lower volume, lower speed roadways	60
SPECIAL SITUATION DRIVEWAYS		
CBD, Farm or ranch, Field, Industrial		70
One-way, for either right-turn entry-only or right-turn exit-only	Flat, acute angle may discourage wrong-way use	45 to 60

* These descriptions are intended to help the designer form a mental image of some of the more common examples of the category.

Exhibit 5-43. Suggested minimum lengths of straight driveway alignment.

Driveway Category	Description of Common Applications*	Minimum Length of Straight Alignment on the Driveway Approach Adjacent to the Connection Transition with a Public Roadway
STANDARD DRIVEWAYS		
Very high intensity	Urban activity center with almost constant driveway use during hours of operation.	75 ft (based on length of 3 P-car) Local requirements for tangent at a signalized intersection may apply.
Higher intensity	Medium-size office or retail (e.g., community shopping center) with frequent driveway use during hours of operation.	50 ft (based on length of 2 P-car)
Medium intensity	Smaller office or retail, some apartment complexes, with occasional driveway use during hours of operation.	25 ft (based on length of 1 P-car)
Lower intensity	Single-family or duplex residential, other types with very low use. May not apply to rural residential.	25 ft (based on length of 1 P-car)
SPECIAL SITUATION DRIVEWAYS		
CBD, Farm or ranch, Field, Industrial	A mix of design vehicles.	Length equal to the design vehicle length, plus 5 ft

NOTE: The recommended lengths are based on orienting a likely number of vehicles to be present up to and through the driveway-roadway intersection. Further study to develop these values is needed.
* These descriptions are intended to help the designer form a mental image of some of the more common examples of the category.

Exhibit 5-45 suggests situations where a separate facility parallel to the driveway may be needed and where it may be acceptable for the bicyclist or pedestrian to share the driveway with motor vehicles.

Driveway Edge and Border Treatments

A driveway edge should be clearly defined and visible to all users, so users can ascertain the lateral limits of motor vehicle operation. From observations such as in Exhibit 5-46, a vertical wall at the edge of a driveway causes drivers to shift their vehicles toward the center line. It is suggested that no vertical face (e.g., a retaining wall) be within 2 feet of the edge of the intended way for vehicle use. A wider offset must be provided if there will be a sidewalk parallel to the driveway.

Exhibit 5-44. Lack of a sidewalk forces the pedestrian into the driveway.

For driveways with flat edges (i.e., no curb) in a fill, drivers will find it harder to determine where the edge is in rain, fog, or darkness. The designer should not place a sudden drop off at such an edge. A relatively flat shoulder with a minimum width of 2 ft (after any rounding) is suggested before the side slopes downward. Some property owners install reflectors or other similar devices at the edge to help deal with this problem.

As shown in Exhibit 5-47a, the toe of a slope should not extend to the base of a driveway or sidewalk edge, because runoff and erosion can lead to a mud-covered driveway or sidewalk surface. Exhibit 5-47b shows the toe of the slope recessed from the pavement edge, a method which yields better results.

Edge Clearance from Fixed Objects

Fixed objects such as utility poles, fire hydrants, and drainage inlets should be set back from the edge of the driveway and from the edge of the roadway. Reasons for this include allowing

Exhibit 5-45. Suggestions for separate facilities for bicyclists and pedestrians.

Driveway Category	Description of Common Applications*	Need for a Facility Parallel to Driveway for Bicyclists or Pedestrians
STANDARD DRIVEWAYS		
Very high intensity	Urban activity center with almost constant driveway use during hours of operation.	Bicycle – the need for separate lane or path depends on bicycle use in the area Pedestrian – often need sidewalk
Higher intensity	Medium-size office or retail (e.g., community shopping center) with frequent driveway use during hours of operation.	Bicycle – shared use may be adequate Pedestrian – may need sidewalk
Medium intensity	Smaller office or retail and some apartment complexes with occasional driveway use during hours of operation.	Bicycle – shared use usually adequate Pedestrian – may need sidewalk
Lower intensity	Single-family or duplex residential, other types with low use. May not apply to rural residential.	Shared use is adequate
SPECIAL SITUATION DRIVEWAYS		
CBD	Building faces are close to the street.	Seldom applicable, because buildings are close to the street
Farm or ranch, Field	Seldom used, very low volume.	Shared use is adequate
Industrial	Driveways are often used by large vehicles. May have separate driveways for employees and/or customers.	Depends on the specific site plan and transportation modes used by the employees.

* These descriptions are intended to help the designer form a mental image of some of the more common examples of the category.

Exhibit 5-46. Effects of a vertical wall too close to the driveway.

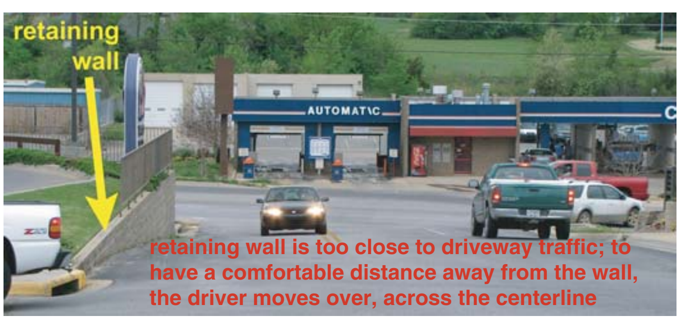
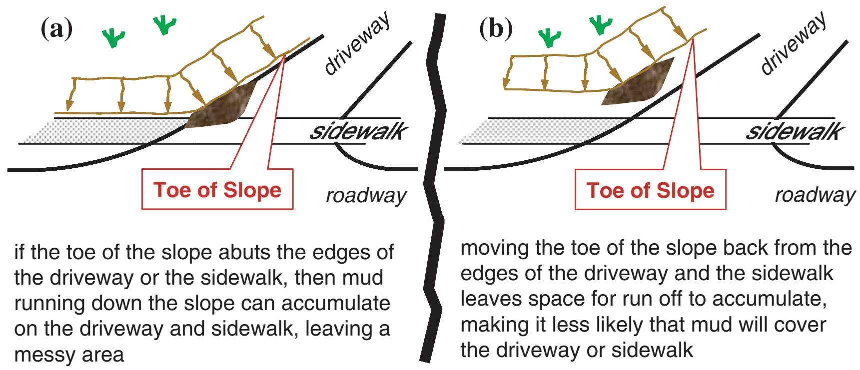


Exhibit 5-47. Locating the toe of a slope near a driveway.



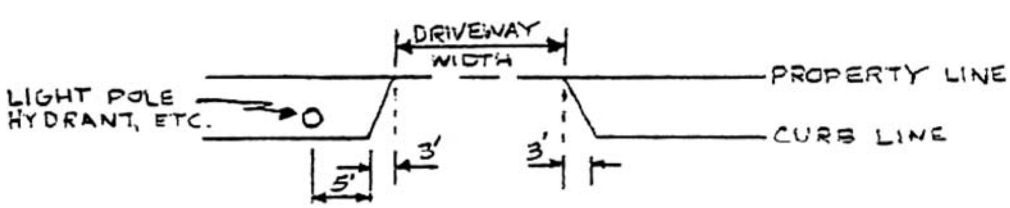
clearance for vehicle side mirrors and to account for the wheel and body paths of offtracking turning vehicles. Exhibit 5-48 shows drainage inlets flanking a driveway, with both inlets showing what appears to be damage from turning vehicles.

Example design criteria such as Exhibit 5-49 suggest a clearance from vertically projecting fixed objects (e.g., poles and fire hydrants) to the edge of the driveway of 5 feet or more. Objects such as curb inlets should clear the paths of vehicles turning into and out of the driveway. Clear zone design practices affect the lateral placement of objects with respect to the edge of the traveled way of a street or highway. The minimal urban clear zone may be inadequate in the immediate vicinity of the roadway-driveway intersection, and a larger dimension may better accommodate turning vehicle offtracking.

The adequacy of any given driveway design can be checked with the turning templates of the design vehicle. The designer should also check to ensure that roadside objects do not become obstacles for other users (e.g., bicyclists and pedestrians).

Exhibit 5-48. Drainage inlets too close to the edges of the driveway.

Exhibit 5-49. Driveway edge clearance from fixed objects.



Source: City of Chicago, IL Dept. of Public Works, Jan. 1984

Driveway Length

The following sections address the design of the following elements related to driveway length:

1. Minimum length of driveway to a barrier (e.g., garage door or gate)
2. Minimum length of driveway paving
3. Minimum length of the driveway throat or connection depth
4. Accommodating the need to reverse vehicle direction (i.e., turn around) within the private site.

Drawings showing different facets of driveway length were provided at the beginning of Chapter 2 as well as on the following pages.

Driveways can be divided into two groups. One group operates in the manner typical of single-family suburban driveways, at which vehicles enter the driveway and then come to a stop and park. The other group operates in a manner typical of commercial driveways—entering vehicles continue to move and proceed for some distance along the driveway, often into a parking lot. Some of the following controls are more likely to apply to the first category, while other controls are more likely to apply to the second category.

Minimum Length of Driveway

For this section, the length of a driveway is the distance from where the driveway on one end connects to the traveled way, to the other end where the driveway encounters some sort of barrier or terminates. This may be an intersecting circulation road within a site, the end of the pavement, a gate, a garage door, or other barrier that when in place, discourages or prevents a motor vehicle from proceeding. Even under the simplest of situations, many driveways will require a certain minimum length in order to avoid creating problems for one or more user groups.

Driveway Minimum Length Considerations

Problems can result when vehicles entering a driveway cannot proceed far enough into the driveway and parts of the vehicle then block the traveled way, bicycle lanes or paths, or sidewalks. Exhibit 5-50 shows vehicles parked in the driveways of townhouses constructed in the early 2000s. The rears of these vehicles partially block the sidewalk and lumber in the bed of the pickup truck in the foreground extends over the tailgate into the pedestrian path. This situation would be especially dangerous for a pedestrian with visual impairment using the sidewalk.

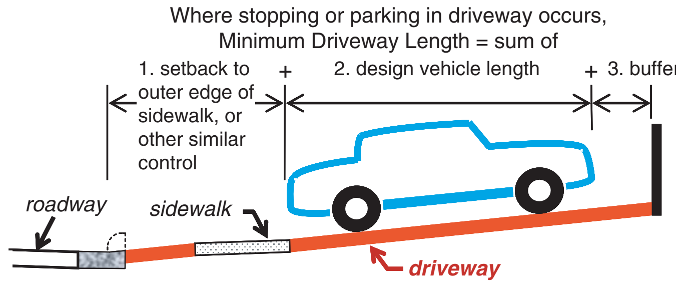
Unless a driveway is so short as to discourage its use for stopping or parking, the minimum length between controlling features on each end of the driveway is the sum of the following three components (see Exhibit 5-51):

1. Setback from the end toward the roadway to clear the outer edge of the traveled way, a bicycle lane or path, or a sidewalk
2. Length of the longest vehicle that typically would park there
3. Clearance buffer from a gate, garage door, or other similar end-barrier

The buffer allows a person to walk between the end of the vehicle and the end-barrier. The buffer should also accommodate many drivers' tendencies to shy away from a barrier, rather than pulling close to it. It is hoped that the driver of a vehicle with a load that slightly hangs over the rear will use the buffer to pull forward until the load clears the sidewalk.

Exhibit 5-50. Insufficient driveway length leads to vehicles blocking the sidewalk.

Exhibit 5-51. Minimum driveway length considerations.



Driveway Minimum Length Design Suggestions

Given that the minimum length of the driveway is the sum of three values, two of which can vary greatly, prescribing a single or even a few values is of little benefit. Instead, it is recommended that the designer follow this series of steps:

1. Determine the longest vehicle type likely to use the driveway.
2. Determine the length of that vehicle.
3. Estimate a front buffer dimension. In the case of a smaller design vehicle (e.g., a P-car), estimate 2 feet. For a larger design vehicle (e.g., a bus or large truck), select 3 feet. If the front buffer area involves a gate that swings outward, there also should be an allowance for the gate.
4. Estimate a value for the rear clearance. Where a sidewalk exists, this is the distance from the edge of the traveled way to the far edge of the sidewalk. If no sidewalk exists, allow a minimum of 2 feet.
5. Sum these values to determine the minimum driveway length.

Research would be helpful to better define these dimensions (e.g., the actual buffer taken by the drivers of various sizes of vehicles).

Minimum Length of Driveway Paving

If the driveway within the private property site is dirt or gravel, how far back from the edge of the traveled way to pave the driveway connection is an issue. A survey of transportation agencies found that practices varied among agencies, and no one practice predominated. Some agencies pave the driveway connection a fixed distance from the edge of the traveled way; others pave to the right-of-way line.

The objectives of paving the connection to a gravel or dirt driveway some distance back from the traveled way edge include (1) providing a more stable driveway surface "platform" from which to enter or exit the traveled way and (2) minimizing or eliminating the depositing of dirt, gravel, or mud onto the traveled way. Factors which can affect the extent to which debris from such a private driveway are deposited on the traveled way include

- The distance from the traveled way edge to the beginning of the gravel or dirt surface;
- The grade of the driveway;
- Surface drainage patterns, combined with the amount of precipitation; and
- The volumes and types of traffic using the driveway.

Given the lack of consensus among agencies and the factors that affect the extent to which debris from unpaved driveways is deposited on the traveled way, guidance on this matter is limited to advising designers to pave driveway connections some distance back from the edge of the traveled way. A designer may find guidance by observing the extent of the debris emanating from existing unpaved driveways in the vicinity of the driveway under consideration.

One specific suggestion is to pave a length at least as long as the length of the vehicles expected to use the driveway, plus a clearance from the edge of the traveled way or sidewalk. This will encourage vehicles that pull off the road to clear the roadway and sidewalk. Another suggestion is that local governments require on-site paving or other mitigation actions to prevent debris from washing onto the public roadway.

Minimum Length of Driveway Throat

The driveway throat length is the distance from the outer edge of the traveled way of the intersecting roadway to the first point along the driveway at which there are conflicting vehicular traffic movements. Similar or related terms include the driveway connection depth, reservoir length, stacking distance, and storage length. Exhibit 5-52 illustrates a driveway throat.

Sources differ as to what point actually defines the internal (i.e., within the private site) end of the throat. Examples of these variations include "end of the driveway inside the land development" (*5-17*), "the parking lot served by a driveway" (*5-18*), and "the furthest end of the driveway" (*5-19*). Given that an impetus for providing an adequate length for the driveway throat is related to allowing smooth traffic flow along the driveway between the street and on-site roadways or parking lots, the point at which conflicting traffic movements are encountered was selected to define the end of the driveway throat that lies within the site. So, implicit in the definition used herein is "non-conflicted" throat length.

Design Considerations

Providing an adequate driveway throat length or connection depth in which there are no conflicting movements can help create smoother traffic flows in and near the driveway throat and avoid conflicts to which drivers may not have adequate time to react (which in turn may lead to collisions). As Exhibit 5-52 shows, an inadequate throat length can produce traffic situations that adversely affect the flow of traffic on the public roadway. In this drawing, vehicles that have entered the driveway have formed a queue that blocks the sidewalk. Additional vehicles trying to enter the driveway will not be able to proceed; therefore, they will stop in and block the public roadway too.

Exhibit 5-53 portrays a different situation that can affect the length of the right or entry side of the throat. All parking spaces should be far enough from the roadway, bike path, and/or sidewalk, so that vehicles backing out of parking stalls do not encroach into the projection of the sidewalk or bike path across the driveway, or into the roadway. Even if a vehicle backing out of a parking space into the driveway throat does not encroach into one of these areas, the backing vehicle will

Exhibit 5-52. Driveway throat.

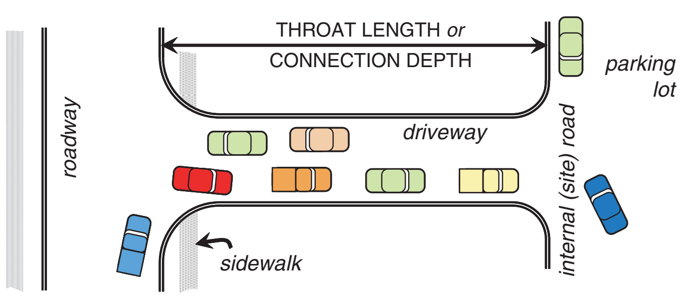


Exhibit 5-53. Driveway entry throat and parking stalls.

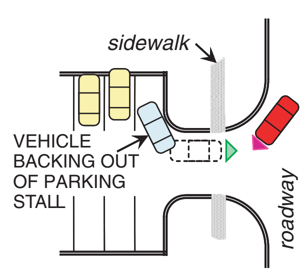


Exhibit 5-54. Undesirable speed control in driveway throat.

still block the driveway entry for the duration of the backing maneuver. In many situations, such a blockage would have undesirable effects on traffic, so in those cases, parking should not be allowed in the driveway throat area.

Exhibit 5-54 shows yet another type of conflict, a speed hump installed in a driveway entry. Observations of traffic at this driveway revealed that as vehicles turned into the driveway, drivers were surprised by the need to rapidly decelerate over a short distance. Such a rapid deceleration increases the driver's exposure to being struck on the side by through vehicles and in the rear by following vehicles. The process of slowing or stopping before turning into this driveway constitutes adequate traffic calming. When turning into a driveway while watching for conflicting bicyclists, pedestrians, and other vehicles, motorists should not be confronted with additional driving tasks until they have had time and distance to reorient themselves.

The following factors affect the distance needed to provide an adequate driveway throat length:

- The positions of bike paths and sidewalks.
- The queuing or stacking space needed for exiting vehicles. If the exit is signalized, then sufficient queuing length is needed to supply the green phase with vehicles proceeding at the saturation flow rate, accounting for lost time due to weaving on the driveway approach during the green phase.
- In cases of a multilane exit, the length needed for exiting vehicles to make weaving maneuvers as they change lanes in the driveway.
- The distance needed to provide motorists entering the driveway with time to reorient themselves and detect conflicting traffic movements from crossroads, parking spaces, bicycle routes, or pedestrian paths they encounter.
- The queuing or stacking space needed for entering vehicles.
- For a multilane entry, the length for entering vehicles to make weaving maneuvers as they change lanes in the driveway.
- For a one-way driveway, enough length to place Wrong Way/Do Not Enter signs so that the intent is obvious to motorists.

Other considerations for the length of the throat found in the literature review include the

- Functional category of the intersecting roadway,
- Type of driveway intersection traffic control (stop sign or signal) and traffic signal timing,
- Type and intensity of land use activities served, and
- Number of parking spaces (within the site) per exit lane.

Given that one of the underlying factors to consider is the driveway volume, both entering and exiting vehicles during the peak time period, it may be necessary to estimate likely driveway usage before designing the length of the driveway throat.

Design Suggestions

The throat length must be long enough to avoid internal site conflicts associated with crossing or weaving movements. It also must be adequate to avoid spillback onto the public road or internal circulation system. There are different controls:

1. Designing sufficient length to react to conflicts,
2. Designing sufficient length to accommodate traffic queues, and
3. Designing sufficient length to accommodate weaving.

Different sources have developed different approaches for establishing minimum throat lengths. The following narrative presents the approaches from various sources.

Koepke and Levinson Throat Length. When more detailed, site-specific information is available, one could apply the recommendations by Koepke and Levinson *in NCHRP Report 348* (*5-20*). For signalized driveways, suggested on-site throat lengths (per lane) were based on the equation $N = 2qr$, where

N = number of cars to store,
q = vehicles per hour per lane, and
r = effective red time per cycle.

Alternative guidelines were cited based on the number of parking spaces per exit lane for multi-family, residential, retail, office, and industrial uses. The following suggested guidelines were based on both sets of criteria:

- 50 feet for minor driveways that serve 50 to 100 apartments, less than 50,000 square feet of retail, or a quality restaurant;
- 150 feet, with at least two exit lanes, for shopping centers of up to 700,000 square feet, and office complexes up to 500,000 square feet; and
- 200 feet or more, with at least two exit lanes, for larger commercial complexes.

Stover and Keopke Throat Length. In *Transportation and Land Development,* Stover and Koepke (*5-13,* p. 7–28) state that the exit condition controls the throat length for high-volume traffic generators, while the entry condition controls the throat length for low-volume traffic generators. The exit side of a driveway should be designed to enable traffic to efficiently leave a site. The throat length and cross section are interrelated: the wider the cross section, the longer the exit throat length needed to accommodate the associated weaving maneuvers. Exhibit 5-55 presents the minimum throat length for stop-controlled and for signalized-access drives, based on the number of egress or exit lanes.

Exhibit 5-55. Minimum throat length based on the type of control and number of lanes.

Type of Control	Number of Exit Lanes Present 1 Exit Lane	2 Exit Lanes	3 Exit Lanes	4 Exit Lanes
STOP sign	30 to 50 ft	50 ft (2 cars)	--	--
Signal	--	75 ft	200 ft	300 ft

NOTE: -- indicates no value given

Sources: *Transportation and Land Development*, 2nd ed. (2002), p. 7-28 (*5-13*) and *Access Management Manual* (2003), p. 184-185 (*5-21*)

The throat length for a one-way exit driveway needs to be sufficient to allow for DO NOT ENTER or WRONG WAY signs to be installed to be effective in warning drivers turning from the roadway. This is related to liability, not queue length.

The throat length based on the entrance side of a driveway needs to minimize the potential for the conflicts on the access drive from adversely affecting the intersecting roadway. Drivers entering the site should clear the roadway intersection before encountering decision points and potential conflicts along the driveway. *Transportation and Land Development* indicates the minimum throat lengths for unsignalized access drives based on two driveway configurations – 1 entering/1 exiting lane and 1 entering/2 exiting lanes. For the 1 entering/1 exiting lane configuration, the minimum throat length is 75 feet to the first parking spaces on site or 30 feet to the first intersection on site. For the 1 entering/2 exiting lane configuration, the minimum throat length is 75 feet to the first parking spaces on site or 50 feet to the first intersection on site. For high-volume traffic generators, it is the exit condition that governs the needed throat length.

Roseville Throat Length. The Roseville, California, design standards (*5-22*) present a detailed procedure for estimating the needed length of the driveway throat. Agencies may apply the throat length criteria from other sources to help establish a similar type of procedure.

The Roseville procedure is part of the traffic impact study process that applies to proposed projects estimated to generate more than 50 PM peak-hour trip ends. The traffic study includes an evaluation of the Minimum Required Throat Depth (MRTD) needed on-site for each access point for a proposed development. The MRTD requirement does not apply to single-family residential or duplex uses. The MRTD is measured from the back of the sidewalk to the first drive aisle or parking stall. The purpose of the MRTD is to allow enough stacking distance for egressing vehicles so that the first drive aisle or parking stall is not blocked. This minimizes the possibility of incoming vehicles queuing out into the traveled way of the main street thereby creating a safety concern.

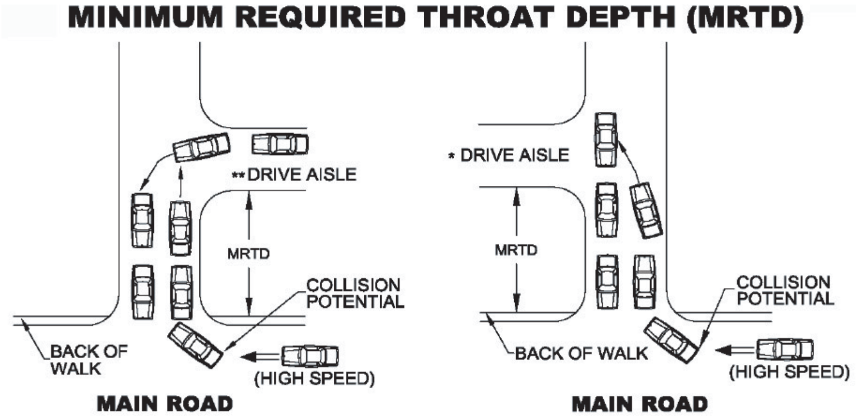
The MRTD is measured in car length increments of 25 feet and rounded up to the nearest multiple of 25 feet. The City does not allow a MRTD of less than 25 feet for any project. Throat depths greater than the calculated MRTD are encouraged. On-site parking is not permitted within the MRTD area.

The MRTD is a function of the length of the queue of vehicles waiting to exit the driveway. The length of this queue is a function of two variables: the number of vehicles desiring to egress during a given time period versus the number of vehicles that can enter the traffic stream of the main road during that same time period. If the calculated MRTD is physically or unreasonably too long for the proposed development, then the traffic study can suggest ways to reduce the MRTD by either decreasing the egress demand volume, or by increasing the movement capacity.

There are cases when an MRTD of 25 feet is acceptable, for example, when the first drive aisle is "one-way only" as shown in Exhibit 5-56. Another scenario where a MRTD of 25 feet is acceptable is when a raised center median is constructed in the driveway throat from the back of the sidewalk to the calculated MRTD distance. In this case, the nearest drive aisle can be two-way, but turning movements into and out of the drive aisle are restricted by the raised median.

Because of the different operations at signalized and unsignalized driveways, two different methodologies apply. At unsignalized project driveways, the MRTD is based on a series of regression equations that the City uses to estimate maximum queue lengths at minor stop-controlled intersections. These equations apply the methodology presented in "Estimation of Maximum Queue Lengths at Unsignalized Intersections" from the November 2001 *ITE Journal.* Exhibits 5-57 and 5-58 present the methodologies used for calculating the MRTD for various unsignalized driveway conditions. Major street volumes are based on projected future traffic volumes from the latest version of the citywide traffic model. Alternative methodologies for cal-

Exhibit 5-56. Roseville explanatory drawing.



* NOTE: IF THE DRIVE AISLE IS "ONE-WAY ONLY" TOWARDS THE DRIVEWAY THROAT, THEN A MRTD OF 25' IS ACCEPTABLE.

** NOTE: IF THE DRIVE AISLE IS "ONE-WAY ONLY" AWAY FROM THE DRIVEWAY THROAT, THEN A MRTD OF 25' IS ACCEPTABLE.

Source: City of Roseville, CA, Design Stds., Section 4, p. 9, March 2007

culating unsignalized MRTD lengths may be considered, but need to first be approved by the Public Works Department prior to incorporation into traffic studies.

At signalized project driveways, MRTD lengths are a function of egressing traffic volumes, lane geometrics, and traffic signal timing. Typically, signalized access locations will have more than one approach lane for egressing vehicles; therefore, the MRTD is determined from the lane with the longest queue. The MRTD is based on the Operational Analysis methodology contained in

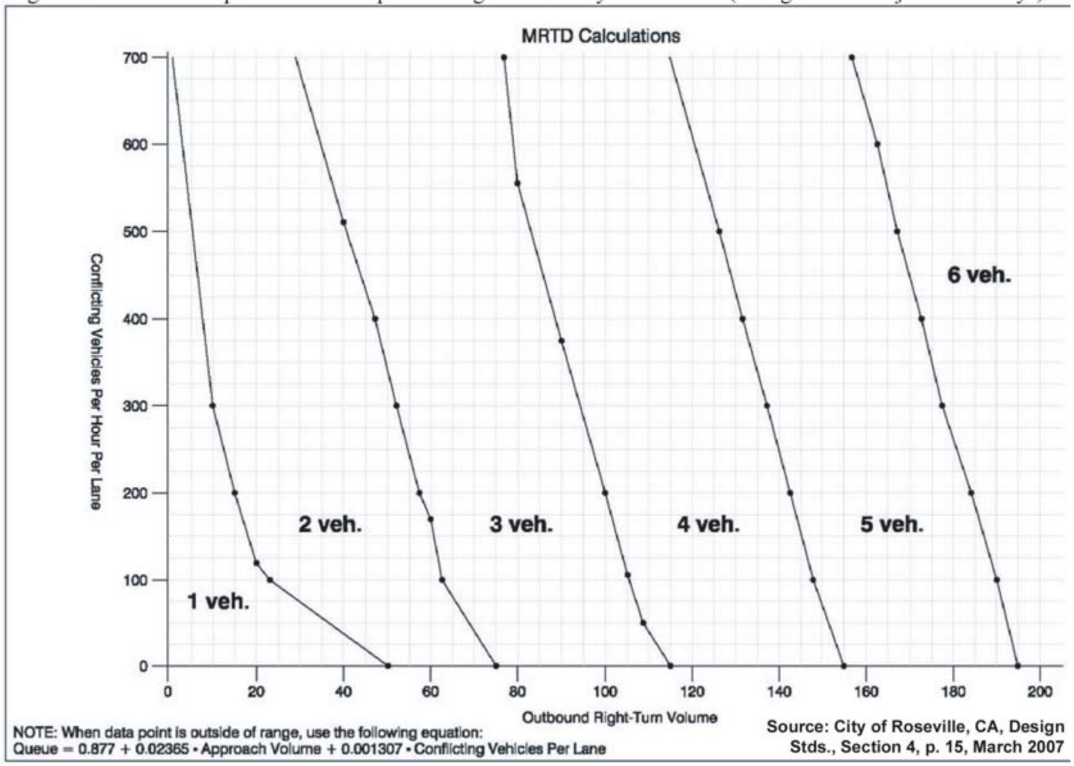
Exhibit 5-57. Minimum required throat depth regression equations.

Movement	Condition	Equation
Major-street left turn	Approach volume ≤ 100 VPH/PHF	Max. Queue = −2.042 + 1.167 ln(AppVol) + 0.975*TS
	Approach volume > 100 VPH/PHF	Max. Queue = +4.252 − 1.23*Lanes + 0.07996*Speed + 1.412*TS − 374.028/AppVol + 0.00001144*AppVol *ConflVol
Minor-street left turn	Approach volume ≤ 60 VPH/PHF	Max. Queue = +0.958 + 0.00111*(AppVol)^2 + 0.000333*(ConflVol)
	Approach volume > 60 VPH/PHF	Max. Queue = +6.174 − 2.313*TS + 0.03307*Speed − 1201.644/ConflVol + 0.00006549 (AppVol)^2
Minor-street right turn	*See Exhibit 5-58*	
Minor-street shared left/through/right	All conditions	Max. Queue = −12.916 + 3.225ln(AppVol) +0.00569*(ConflVol for LTs & THs) − 0.000177*(ConflVol for RTs) − 2.109*(RT %) − 3.157*TS

Source: Fehr & Peers, Transportation Consultants
Based on the methodology presented in *Estimation of Maximum Queue Lengths at Unsignalized Intersections* (ITE Journal, November 2001).
Source: City of Roseville, CA, Design Stds., Section 4, p. 13, March 2007

Exhibit 5-58. MRTD for right-turn-only movements.

Fig. 4-2 Minimum Required Throat Depth For Right-Turn Only Movements (Unsignalized Project Driveways)



the latest version of the *Highway Capacity Manual* or other methodology as approved by the City's Public Works Department. Major street volumes are based on projected future traffic volumes from the latest version of the citywide traffic model. For existing traffic signals, it is recommended that the consultant discuss likely signal timing parameters with City staff. There may be some restrictions to signal timing parameters for existing signals because of progression and so forth.

The City also has provisions to help ensure that sufficient onsite storage is provided for drive-through service uses to ensure that vehicles will not queue into the public right-of-way.

The following definitions are for the terms used in the MRTD equations:

AppVol = hourly traffic volume divided by peak-hour factor (PHF) for subject movement

ConflVol = hourly traffic volume divided by PHF that conflicts with subject movement (refer to the *Highway Capacity Manual* to identify movements that conflict with subject approach)

TS = a dummy variable with a value of 1 if a traffic signal is located on the major street within one-quarter mile of the subject intersection and 0 otherwise

Lanes = number of through lanes occupied by conflicting traffic

Speed = posted speed limit on major street (in miles per hour)

RT% = Percentage of vehicles on shared left/through/right minor street approach that turn right

The following scenario employs several assumptions to illustrate another facet of principles related to adequate throat length—minimizing traffic conflicts of the entry side of the driveway throat. Assuming a level, 90-degree entry, it was hypothesized that as drivers turn right into a driveway, the eventual 90-degree reorientation of drivers' lines of sight is affected by factors such as the following:

1. Human factors. The span or width of drivers' fields of vision and the degree to which drivers can turn their heads.
2. Vehicle factors. Limitations imposed by the structure of the vehicle (e.g., the position and width of the front windshield posts).
3. Operational factors. Informal observations suggest that drivers maneuvering vehicles into a driveway are not free to devote attention to conflicts in the driveway throat length ahead until after the entering vehicle has cleared any conflicts at the entry. This includes conflicts with pedestrians and "sideswipe conflicts" between the left front corner of the entering vehicle and the left side of any vehicles exiting the driveway onto the public street.

Assume that drivers turning right into a driveway with a 25-ft radius at a speed of 15 mph or 22.0 ft/s give full attention to the driveway ahead after completing 60 degrees of the turn. At this point, drivers have sufficiently squared-up their lines of sight and can detect a conflict (e.g., a vehicle backing out of a parking stall or cross traffic within the site). The current AASHTO Green Book guidelines (*5-1,* pp. 110–114) allow 2.5 seconds for a driver to react to an unexpected situation ahead requiring the vehicle to stop; whether or not a conflict in the driveway ahead would constitute an unexpected situation is arguable. For this illustration, assume that the driver has a narrow focus on the driveway ahead and requires only 1.0 second of perception-reaction time and a deceleration rate of 11.2 ft/s^2. This leads to the following calculations:

25 ft radius $\times$ tan $(90° - 60°) = 14.4$ ft
25 ft tangent $-$ 14.4 ft $=$ 10.6 ft into driveway from edge of traveled way

Distance from driver to front bumper of vehicle: 6 ft

Distance into driveway + perception reaction distance + braking distance
10.6 ft $+ 6 + [22.0 * 1.0] + [0.5 \times 22.0^2 / 11.2] = 60$ ft of entry throat length

Therefore, the designer would require a minimum of 60 feet of driveway connection depth from the outer edge of the traveled way to the first crossroad or other conflicting movements within the site. If the first conflict encountered is with a vehicle backing out of a parking stall, then the position of the rear bumper of the vehicle that has just backed out of the stall will also need to be taken into account. Even with this non-conflicting connection depth, if a second vehicle is closely following the first and also turning right into the driveway, the driver of the second vehicle may not be able to react and stop or the second vehicle may come to a stop with its rear still in the through roadway.

Other Throat Lengths. For a comparison, Exhibit 5-59 presents minimum throat length criteria from two states, New Mexico and Florida. In both cases, the minimum requirement is 30 feet.

Exhibit 5-59. Throat length criteria from two states.

Access Connection Depths (feet)	
Land Use(s) Served by Access	**Connection Depth**
Regional Shopping Centers (malls)	250 feet
Community Shopping Center (supermarket, drug store, etc.)	80 feet
Small Strip Shopping Center	30 feet
Regional Office Complex	250 feet
Office Center	80 feet
Other Smaller Commercial Developments	30 feet

Source: New Mexico DOT, *State Acc. Mgmt. Manual* Ch. 8, Sec. 18, p. 91, Sept. 2001

(a)

Land Use	Driveway Length (In feet)
Any major entrance to a development with 4 or more total lanes in the driveway Typically malls, and "Super" retail centers	300 or greater, based on traffic study
Regional Shopping Centers (over 150,000 sq. ft.)	250
Community Shopping Center (100-150,000 sq. ft.) (Supermarket, drug store, etc.)	150
Small Strip Shopping Center	50
Smaller Commercial Developments (convenience store with gas pumps)	30

Source: Vergil Stover unpublished course notes
FDOT *Driveway Handbook*, p. 54, Mar. 2005

(b)

Providing Onsite Turnaround Capability

It is often undesirable or unsafe for vehicles to perform a backing maneuver from a driveway into a public roadway. Therefore, most sites should be designed so that once entering the site, a vehicle can be re-oriented and leave in a forward direction. This is highly desirable for all sites except for single-family and duplex residences along lower volume, lower speed streets.

The type and design of needed turnaround facilities depend on the size of and types of activities conducted on the site, the likely mix of vehicles, the building arrangements, and the circulation system for each site. Sometimes, turnaround needs can be accommodated by circulation on internal road systems or through parking areas. In other situations, a site needs a specific turnaround facility, such as a circle or other shape shown in Exhibit 5-60.

Internal Roadway Systems

Many developments, especially larger ones, have internal circulation systems that allow vehicles to enter the site and then, through a series of normal driving maneuvers, assume an orientation that allows the vehicle to head out of the site.

Circulation Through Parking Lots

Somewhat similar to an internal roadway system but on a smaller scale, other sites have a layout that allows vehicles to circulate through the parking lot and leave the site in a forward direction. This type of turnaround works well with cars and smaller trucks, but may not be adequate for large trucks, unless greater maneuvering spaces are provided.

One form of this is “Loop Routing,” shown in Exhibit 5-60 (a and b). Where two parallel driveways enter a site, it is sometimes practical to turn around via an inverted “U” movement. For traffic driving on the right side, a counter clockwise movement has less internal traffic conflict, and left turns around corners are easier for larger vehicles to negotiate than are right turns. Sometimes, a single driveway access point can be “split” via a loop road to provide the turnaround. This pattern is often seen at fast food restaurants, with the building located inside the loop.

Exhibit 5-60. Turnaround design schematics.

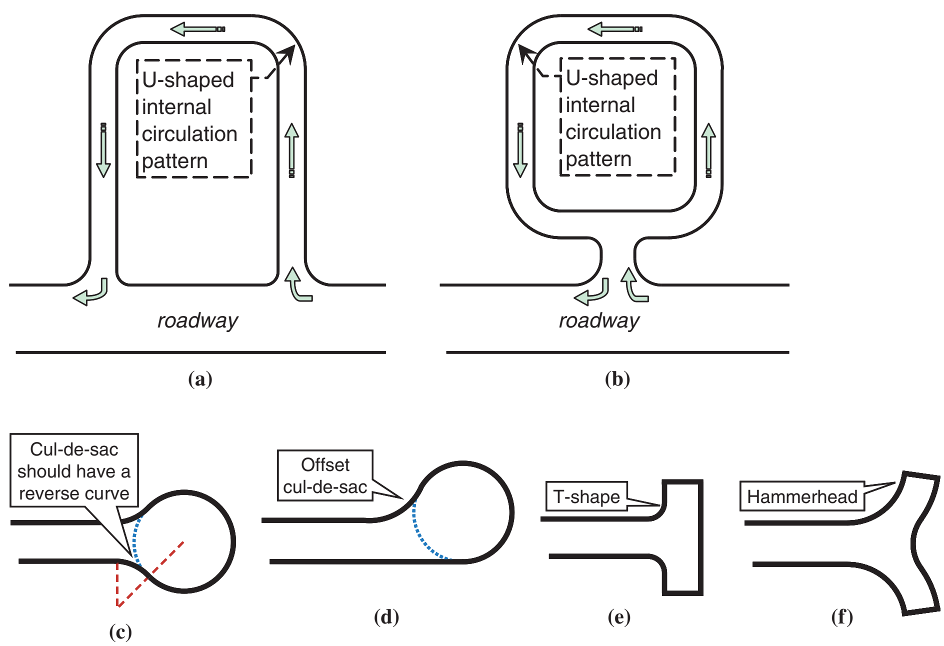


Exhibit 5-61. Minimum desirable circular turnaround dimensions.

Vehicles Accommodated	Radius to Face of Outer Curb (in feet)	Comments
Passenger cars only	30	
Passenger cars, school buses, delivery trucks, emergency vehicles	42	A 45-ft radius would allow a central landscaped island with an inside curb radius of 25 feet and a 20-ft-wide turning roadway. However, if a passenger vehicle is parked on the turning roadway, this geometry may not accommodate ambulance, fire truck, or solid waste vehicles.
Curb parking is permitted	50	Where a landing is provided at the base of the circle, a tangent section of 22 feet for each car should be provided.

Source: Kulash, *Residential Streets*, 3rd ed., Institute of Transportation Engineers, Washington, DC © 2001. Used by permission

Specific Turnaround Facilities

When a site does not include features such as an internal roadway system or parking lot circulation that allow a driver to re-orient a vehicle and proceed from the site in a forward direction onto the public roadway, then specific turnaround facilities may be needed.

One common form is the cul-de-sac or circular turnaround. A circular turnaround can be centered on the driveway or offset to one side. Circular turnarounds are generally preferable, although T-shaped and Y-shaped (hammerhead) turnarounds may be used. Exhibit 5-61 offers minimum desirable circular turnaround dimensions (*5-23*).

With the T- and Y-shapes, vehicles turn left into the special roadway at the end of the driveway, back across the drive, and then proceed forward to turn left into the driveway. For passenger cars, a 60- by 20-ft area is needed. Advantages of T- or Y-shaped turnarounds are that they have lower construction and maintenance costs and require less land than circular turnarounds. Because T- or Y-shaped turnarounds require all vehicles to make a back-up movement, their application is limited to very low-volume driveways.

Driveway Vertical Alignment Elements

This section provides guidelines for designing the vertical alignment (or profile), which consists of grades and vertical curves. Designers should establish a vertical alignment that allows vehicles to conveniently and expeditiously enter and exit the driveway. Designers should avoid profiles that allow the underside of a vehicle to drag or hang-up. When establishing the vertical alignment of the driveway, the designer must consider limitations on the sidewalk cross slope to accommodate pedestrians and pedestrians with disabilities. Also, designers should check the profile to make sure it is not creating drainage problems.

Vertical Clearance

For many driveways, vertical clearance is not an issue. But where there are overhead structures, utility lines, or vegetation, the designer should check that the vertical clearance is adequate for the design vehicles.

Sidewalk Cross Slope (Driveway Grade)

When this guide was prepared, the ADA design requirements for accessibility related to pedestrian facilities in the public right-of-way were still being developed. Although only draft accessibility guidelines and other technical assistance advisory documents from federal sources were available, the ADA does and will continue to apply to sidewalks, curb ramps, and pedestrian crossings at driveways that are newly constructed or altered since January 26, 1992. The scoping provisions of these draft guidelines define where and to what degree accessibility within the public right-of-way is required and state the following:

> R201.1 Scope. All newly designed and newly constructed facilities located in the public right-of-way shall comply with these requirements. All altered portions of existing facilities located in the public right-of-way shall comply with these requirements to the maximum extent feasible.

The ADA defines "facilities" very broadly and the US Department of Justice states in its ADA Title III regulations that this definition " . . . includes both indoor and outdoor areas where human-constructed improvements, structures, equipment, or property have been added to the natural environment" (see 56 Fed. Register page 35550). The pedestrian crossing at a driveway is a facility covered by the ADA and thus must be made accessible in new construction projects and must be made accessible to the maximum extent feasible in alteration projects. The draft ADA guidelines for public rights-of-way basically require that there be a continuous accessible pedestrian route (i.e., PAR) leading up to and crossing each driveway. This will typically include the following:

- The transition between the public sidewalk and the pedestrian crossing (marked or unmarked) at the driveway, which is usually achieved by means of an accessible curb ramp;
- The pedestrian cross walk pavement surface; and
- Any island improvements within the driveway that pedestrians must traverse.

The pedestrian crossing at newly constructed driveways must offer a minimum 48-in.-wide route with a cross slope no greater than 2 percent. Where the driveway is an alteration to existing improvements within the public right-of-way, the pedestrian crossing portion must offer a cross slope no steeper than 2 percent to the maximum extent feasible, given existing site-related constraints.

Site-related constraints that may prohibit strict compliance with the ADA maximum 2 percent cross slope specifications include severely limited right-of-way or sidewalk width in which to negotiate the vertical rise between the roadway elevation and the parking area, or steep existing grades on an adjoining, densely developed property that the driveway serves. Engineering judgment plays a key role during the design of driveway alteration projects where full accessibility is not being offered and that judgment may be challenged under ADA by experts analyzing every detail of the design and site factors that may or may not be found to justify any alleged access barriers created by the design.

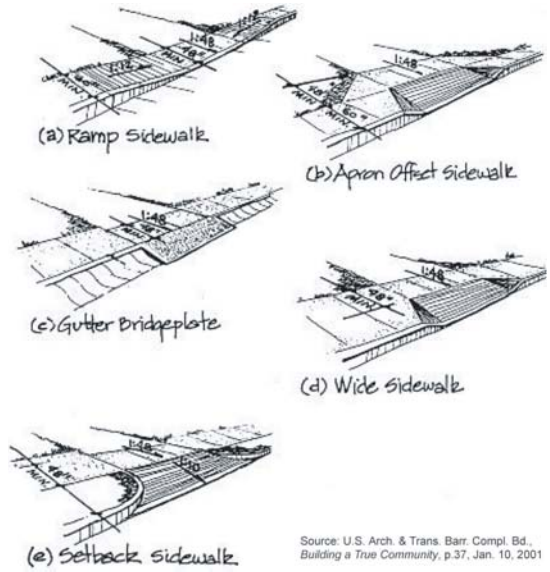
Exhibit 5-62 shows a driveway grade rising quickly from the gutter line, creating an excessive and unacceptable cross slope for the pedestrian path.

The five illustrations constituting Exhibit 5-63 (taken from the recommendations of the US Access Board's Public Rights-of-Way Accessibility Advisory Committee published in "Building a True Community") demonstrate driveway design options that comply with the accessibility specifications in the draft ADA guidelines.

- Option A, Ramp Sidewalk, shows the sidewalk simply ramping down at each side of the driveway with a maximum 2 percent or 1:48 cross slope along the pedestrian crossing.
- Option B, Apron Offset Sidewalk, shows a directional offset in the sidewalk to avoid the steep cross slope that would otherwise be created by crossing the driveway apron on the steeply sloping portion.

Exhibit 5-62. Example of driveway grade creating unacceptable sidewalk cross slope.

Exhibit 5-63. Examples of driveways that comply with accessibility specifications.



- Option C, Gutter Bridgeplate, shows the whole width of the sidewalk having a limited cross slope and employs a bridgeplate over the gutter at a rolled curb condition to limit the likelihood of vehicles bottoming out.
- Option D, Wide Sidewalk, uses the rear most 48 inches of the driveway apron to cross the drive without a cross slope steeper than 2 percent.
- Option E, Setback Sidewalk, shows how a more traditional returned curb style driveway apron can be installed between the gutter and the street side of the sidewalk which adjoins a landscaped green space.

At pedestrian crossings in driveways of more developed commercial sites where the driveway more closely resembles a street, the design and construction of the pedestrian crossing area between the curb ramps is subject to the same 2% maximum cross slope that other driveways are subject to. In Exhibit 5-64, the driveway leading into a regional shopping mall looks similar to a roadway intersection; the curb ramps and accessible pedestrian crossings should be constructed with a maximum 2% cross slope.

Exhibit 5-64. Driveway entrance at regional mall.

Driveway-sidewalk crossing transitions call for special attention. Of particular concern are the multi-dimensional tapers that arise from dust-pan and similar flared treatments. The 2004 AASHTO pedestrian design guide points out that "side flares and cross slopes at driveway aprons may cause a drive wheel, caster, or leg tip to lose contact with the surface" (*5-2*, p. 61–62). Therefore, such flares should not be used unless there is another suitable PAR, such as might be provided by a wide sidewalk.

Driveway Grade (Sidewalk Cross Slope), Change of Grade, and Vertical Alignment

Three types of control for the design of the driveway profile are physical, operational, and drainage:

- Physical controls call for a design that maintains enough clearance so the underside of a vehicle does not drag on the roadway or driveway surface. This control is necessary for all driveways, even one connecting to an alley. Because of the changes in vertical profile grade often found at driveway entrances, these locations are among the more vulnerable to hang ups when the undercarriage of the vehicle comes into contact with or drags the pavement surface.
- Operational controls dictate a vertical alignment for the driveway that allows a convenient and safe entry with minimal conflicts. To achieve this, the changes of gradient must not be too abrupt. This is especially important on driveways that intersect higher volume or higher speed roadways. Operational problems may arise from certain combinations of vertical profiles and vehicles. One problem is vehicle-occupant discomfort due to poor vertical alignment such as bumps, steep grades, and abrupt changes in grade. In extreme cases, there may be restricted sight distance, which affect safety adversely. In addition, excessive differences in speed between through vehicles and vehicles turning into or out of the driveway, because of the vertical profile, can also increase vehicles' exposure to crashes.
- Drainage, requires a profile that does not create undesirable drainage patterns. It may be unacceptable for surface runoff in the gutter to flow into the driveway opening and onto private property.

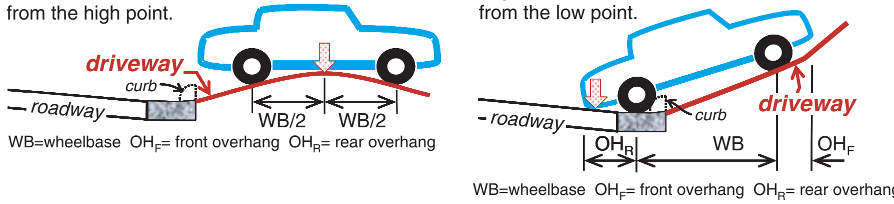
Physical Vehicle Ground Clearance Control

As Exhibit 5-65 shows, the underside of a vehicle entering or exiting a driveway can drag on either a crest or a sag alignment with an abrupt change of grade. Any excessive grade change between the cross slope of the roadway and the driveway grade, between the driveway grade and an intersecting sidewalk, or between successive driveway grades can cause a vehicle to drag (see Exhibit 5-66). Vehicles with low ground clearance and a long wheelbase or overhang can even become lodged (also referred to as "hung up" or "high-centered") on alignments with sharp grade changes. At best, hang-ups result in some vehicular delay and minor damage to the undercarriage of the vehicle and to the pavement surface. At worst, a crash can occur.

Exhibit 5-65. Geometry of ground clearance dragging.

CREST: Have problem if axle-to-axle underclearance is inadequate. For symmetrical crest, is critical when axles are a distance WB/2 from the high point.

SAG: Have problem if axle-to-bumper underclearance is inadequate. For symmetrical sag, is critical when one axle is at distance WB from the low point.



(a) (b)

Exhibit 5-66. Driveway with multiple scrapes from underside dragging.

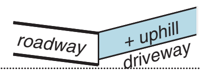
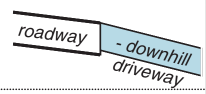
To design the vertical alignment elements, the designer needs to determine an appropriate design vehicle. As previously discussed, several types of long-wheelbase, low-ground-clearance vehicles can be expected to use some driveways, including articulated beverage trucks, car carriers, and passenger car-trailer combinations. The design vehicle for vertical alignment may be different from the design vehicle used to design the horizontal alignment (e.g., turning radii). The designer also needs to have a general understanding of the shape of the vertical profile to be negotiated by the design vehicle. This includes, for example, the roadway cross slope, the driveway grade line, and other controls (e.g., locations and elevations of intersecting sidewalks).

Using reasonable care in selecting a design vehicle and designing the vertical elements to accommodate that vehicle will not completely preclude hang-ups, dragging, or other operational problems from occurring. A vehicle longer and/or lower than the design vehicle may enter a driveway and encounter problems. To meet the needs of shippers, commercial vehicle manufacturers continue to introduce longer and/or lower vehicles and new vehicle configurations that will require periodic updating of the list of design vehicles. Similarly, as property changes hands or as redevelopment occurs, the nature of the land use served by the driveway may change over time. A different class of vehicle than originally intended may use the driveway. Although this is beyond the control of the designer, it offers an explanation of why hang-ups may happen at locations where they formerly did not occur and represents an issue to be addressed in the permitting process.

Also, a vehicle for which the vertical elements have been appropriately designed may encounter problems at a particular driveway. This could be due to vehicle loading condition (e.g., an overloaded vehicle) that reduces actual ground clearance to something below the design value. The vertical profile is subject to changes over time. For example, the roadway may be milled or resurfaced such that its elevations and cross slopes change. In addition, the roadway and/or driveway (and associated features such as sidewalks) may deform over time due to applied loads, the effects of weather, or construction deficiencies. As mentioned above, the vertical profile(s) used in design should be that reasonably expected to be used by the design vehicle. The possibility always exists that a design vehicle will follow an unusual or out-of-the-ordinary path in negotiating the driveway such that hang-up or dragging could result.

Exhibit 5-67 shows maximum uphill and downhill grades, as reported by transportation agencies in a survey.

Exhibit 5-67. Reported steepest allowed driveway grades.

		Normally, Use This in Most Situations			Commercial			Residential		
		Smallest reported	Average	Largest reported	Smallest reported	Average	Largest reported	Smallest reported	Average	Largest reported
Grade: maximum (+) uphill from road allowed		2.6	9.7	15	5	7.5	10	6	11	15
Grade: maximum (-) downhill from road allowed		-5	-9.4	-15	-5	-7.8	-10	-6	-11.0	-15

NOTE: These values reflect survey responses from 1 local and 16 state transportation agencies.

Maximum allowable grade, by itself, is not a sufficient control. What matters is the difference between successive grades, or the change of grade. The change of grade is what creates the crests and sags that cause the underside of a vehicle to drag. Although perhaps not widely recognized, guidance on vertical geometry applicable to driveways has been available for some time. The section on railroad-highway grade crossing design in AASHTO's policy on geometric design (*5-1*) provides recommendations on designing the vertical profile at grade crossings. AASHTO recommends that the crossing surface be in the same plane as the top of rails for a distance of 2 feet outside of the rails, and that the surface of the roadway be not more than 3 inches higher or lower than the top of the nearest rail at a point 30 feet from the rail, unless track superelevation dictates otherwise.

Similarly, a 1987 ITE guideline for driveway design discussed vertical alignment. Eck and Kang (*5-24*) used a vehicle with a 36-ft wheelbase and 5 inches of ground clearance to analyze a maximum grade change of 3 percent (for low-volume driveways on major or collector streets). This "design vehicle" had problems with the aforementioned geometry, suggesting that the ITE driveway design recommendations did not accommodate low-clearance vehicles. A similar statement can be made about the AASHTO standard railroad-highway grade crossing since French, Clawson, and Eck (*5-25*) found that car carrier trailers would hang-up on this crossing. Thus, additional research was conducted to develop driveway vertical alignment guidelines to accommodate selected design vehicles.

Operational Control

A research team made measurements at 31 driveways with visible scrapes from the undersides of vehicles, and then measured speeds and elapsed travel times for over 1500 vehicles observed turning right or left into a number of driveways. The speed and elapsed time studies were conducted at commercial driveways on built-up suburban (but not CBD) arterial multilane roadways with posted speeds of 40 and 45 mph. All of the roadways had either a raised median or a TWLTL. These data were collected at driveways with right-turn entry radii ranging from 13 to 19.5 feet, and an entry lane width of about 13 feet.

Very few vehicles about to enter a driveway exceeded 20 mph at the locations at which speeds were measured. After crossing the driveway threshold, average speeds for vehicles turning left into the driveway were around 10 mph. Vehicles that had turned right into the driveways were slightly slower, with average speeds around 7 mph. The speeds of vehicles entering driveways with breakover sag grades up to 10.5% were close to the speeds of vehicles entering flatter driveways. Scrapes on the pavement surface, presumably from the undersides of vehicles, began to be common with a sag breakover of around 10 percent, and a crest breakover of about 11 percent.

The study led to the suggestions following in Exhibit 5-68. Except where noted, these guidelines are based on observations of passenger vehicles (P-vehicle).

Where low-clearance vehicles are expected to traverse crest curves, refer to Exhibit 5-69 developed by Eck and Kang (*5-26*) that suggests vertical curve lengths for various breakover angles (i.e., algebraic difference in grades).

Drainage Control

Surface runoff from the roadway should not inundate the sidewalk or spill over onto private property. It is also undesirable for the depth of flow to cover the driveway, making it difficult for motorists to determine were the edges of the driveway are.

Exhibit 5-68. Driveway vertical profile guidelines.

Category	Description of Common Applications*	Vertical Profile Guidelines: Suggestion	Vertical Profile Guidelines: Rationale
STANDARD DRIVEWAYS			
Very high intensity	Urban activity center, with almost constant driveway use during hours of operation.	Refer to roadway design guidelines.	These driveways are often built to the standards of and resemble public roads and streets.
FOR BOTH Higher intensity *AND* Medium intensity	Medium-size office or retail, such as community shopping center, with frequent driveway use during hours of operation. Smaller office, retail, or other sites with occasional driveway use during hours of operation.	• Limit the maximum driveway grade to +8% (except where a lesser grade is required, such as when crossing a sidewalk), and the maximum sag breakover without a vertical curve between the roadway cross slope and an uphill driveway grade to 9%. • Limit the driveway profile maximum grade change without a vertical curve for: a crest to 10% and a sag to 9%.	From observations of vehicles entering driveways with radii up to 20 ft and comparisons of Flatter (1.5-5%) and Moderate (6-9%) grades revealed (1) little difference between speeds and travel times of vehicles turning right; and (2) only slight differences between speeds and travel times of vehicles turning left. From measurements of 31 driveways with scrape marks, underside dragging became a problem at a crest of about 11%, and at a sag of about 10%.
	Apartment complexes	• May limit the sag to 7%.	Due to trailers.
Lower intensity	Single family or duplex residential, other types with very low use. May not apply to rural residential.	• Limit the driveway profile maximum grade change without a vertical curve for: a crest to 10% and a sag to 9%.	From measurements of 31 driveways with scrape marks, underside dragging became a problem at a crest of about 11%, and at a sag of about 10%.
SPECIAL SITUATION DRIVEWAYS			
CBD	Building faces are close to the street.	Refer to the guidelines above for "Higher intensity" and "Medium intensity."	
Farm or ranch; Field	A mix of design vehicles; some may be very low volume.	• Limit the driveway profile maximum grade change without a vertical curve for: a crest to 10% and a sag to 7%.	These driveways should accommodate trailers.
Industrial	Driveways are often used by large vehicles.	• Varies, depending on types of vehicles. If low-boy trailers are expected, then limit crest breakover grades without a vertical curve to 3.5%.	
Other	Motels	• Limit the driveway profile maximum grade change without a vertical curve for: a crest to 10% and a sag to 7%.	Travelers pulling a trailer may stay at a motel; therefore, motel driveways should accommodate trailers.

NOTES: Additional information on which to assess ground clearance is in Chp 3.
The sag clearance for trailers is based on Eck's evaluation; truck+trailer clearances will vary.
* These descriptions are intended to help the designer form a mental image of some of the more common examples of the category.

Exhibit 5-69. Minimum length of Type-II crest vertical curve to accommodate low-clearance vehicle.

Algebraic Difference (%)	Curve Length ft (m)
1	4 (1.2)
2	8 (2.4)
3	12 (3.7)
4	16 (4.9)
5	20 (6.1)
6	24 (7.3)
7	28 (8.5)
8	32 (9.8)
9	35 (10.7)
10	39 (11.9)

There are a number of possible design scenarios, based on combinations of curbed or uncurbed roadways with driveway profiles that extend uphill or downhill from the connection with the roadway. Among the tools to combat surface runoff are driveway profile, driveway cross slope, drainage inlets near the driveway area, and drainage grates in the driveway. Exhibit 5-70 shows how profile design can be used to prevent water in the gutter from flowing onto private property.

Roadway-Driveway Threshold Treatment

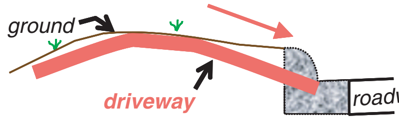
The threshold is the edge or line where the roadway and the driveway join or touch. This line is often at the curb edge. Design concerns in this area include ease of travel for users (e.g., bicycles and motor vehicles), ease of construction, and, in cases where the roadway has a curb and gutter, confining drainage to the gutter line. Exhibit 5-71 shows four common driveway threshold treatments where the roadway has curbs: rolled curb, vertical lip, counterslope, and continuous. Exhibit 5-72 suggests design guidelines for driveway threshold treatments.

The Continuous design is the preferred method. Except for single-family or duplex access on lower volume, lower speed residential streets, designers should avoid designs that create a bump at the threshold. Even in the single-family context, consider that a vertical discontinuity can be an impediment for bicyclists as well as pedestrians with disabilities (especially using wheelchairs). Vertical lip design is another topic needing additional research to assess the ability of other treatments to address drainage, to assess the detrimental effects of a pronounced lip, and to determine whether a low lip, perhaps on the magnitude of ½ inch, has any detrimental effects on users.

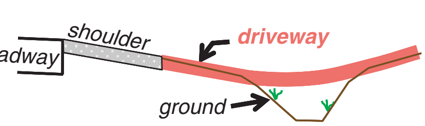
For any type of treatment, the curb and gutter should not be broken off to leave a ragged edge, but should be cut with a saw and cleanly removed.

Exhibit 5-73 shows a gutter treatment used in some jurisdictions. The gutter cross slope is significantly greater than that of the adjacent traveled lanes. This treatment is believed to improve drainage; however, it also increases the profile breakover angle which motorists entering and

Exhibit 5-70. Confining surface runoff flow.



(a)



(b)

Exhibit 5-71. Driveway threshold treatment types.

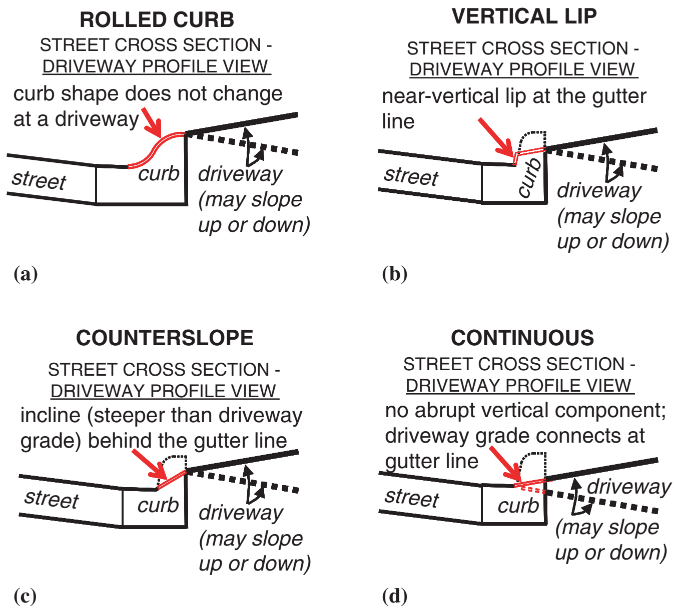


Exhibit 5-72. Driveway threshold treatment guidelines.

Method	Advantages and Disadvantages	Comments
Rolled curb	Easiest threshold to construct, because the existing curb is not modified or removed. Confines the gutter flow, since the existing curb remains intact. Vehicles entering or exiting the driveway experience a jolt while crossing a curb of typical height.	This method is generally unsuitable. It may be acceptable for single-family or duplex access on lower volume, lower speed residential streets.
Vertical lip	Construction requires curb modification or removal. Can confine very low flows in the gutter and reduce the spread of the gutter flow. Bump created by the vertical lip is a minor impediment to automobile movements and a more significant problem for turning bicyclists (i.e., bicycle tire strikes the face at a skew angle).	Is often constructed by forming the threshold with lumber that leaves a vertical face or lip of 1 to 2 inches at the threshold.
Counterslope	Construction requires curb modification or removal. Can confine very low flows in the gutter and reduce the spread of the gutter flow. Less abrupt to cross, but can still be disruptive to automobiles and bicycles.	The proportion and amount of rise and run affect the degree of disruption to automobiles and bicycles.
Continuous OR Smooth	Construction requires curb modification or removal. Is more bicycle- and automobile-friendly. If the driveway immediately slopes downward from the gutter line, this does not confine the drainage as well.	With this method, the profile slopes continuously but not abruptly upward from the gutter line. Thus the drainage objective can be suitably achieved by means that do not create problematic bumps for bicyclists or drivers.

Exhibit 5-73. Increased gutter cross slope.

exiting the driveway have to negotiate. Many scrape marks on the driveway surface from the dragging of vehicles bumpers are clearly visible. More study should be done on this type of design to weigh any drainage benefits against impediments to traffic flow.

Vertical Alignment Examples

The following examples apply some of the guidelines for designing the vertical alignment of driveways. Exhibit 5-74 shows the driveway profile rising from the gutter line up to the sidewalk, then flattening at the sidewalk before falling as the driveway continues onto the private property. This type of design will confine normal depths of water in the gutter and not allow water to flow on to private property and down the driveway.

Exhibit 5-75 shows the suggested values for driveways at which the P-vehicle is the design control. If the near edge of the sidewalk is 5.5 feet from the face-of-curb or gutter line, and the driveway is on a +7.0% grade, then the near edge of the sidewalk is 0.39 feet above the elevation of

Exhibit 5-74. Schematic showing driveway vertical alignment concepts.

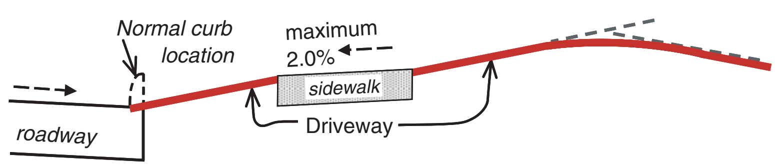


Exhibit 5-75. Example of a driveway vertical profile design.

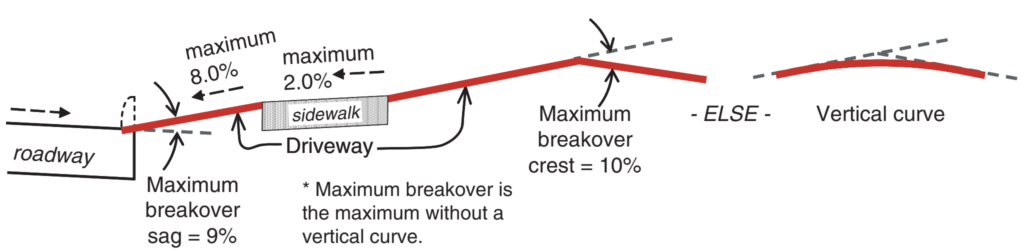
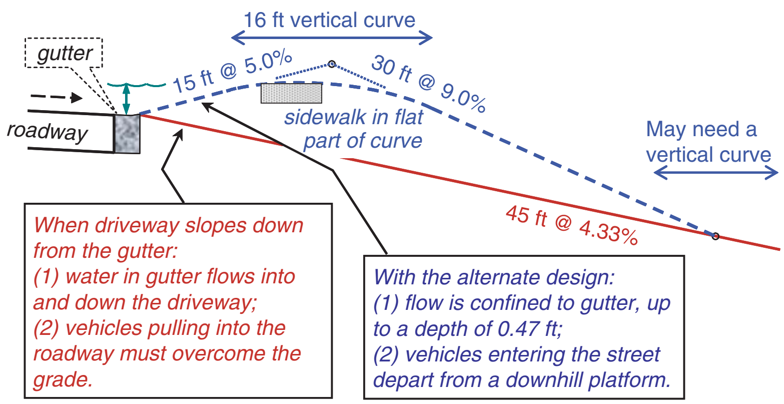


Exhibit 5-76. Example design for a downhill situation.



the gutter line. The 5-ft-wide sidewalk has a +2.0% cross slope, for a rise 0.1 foot, for total rise of 0.49 feet above the gutter line elevation.

Exhibit 5-76 shows a design for a situation where the driveway would normally slope immediately downward from the gutter line at a 4.33 percent grade. The alternate design (dashed line) allows the driveway to slope up from the gutter before sloping back down. Again, this design confines normal depths of flow to the gutter, instead of allowing the gutter flow to rush down the driveway.

Other Elements

This section discusses other aspects of driveway design, such as landscaping, right-turn lanes on the roadway in advance of the driveway, surface drainage in the area where the driveway meets the roadway and sidewalk, use of traffic control device (e.g., signs, pavement markings, and traffic signals), and other situations.

Landscaping and Business Signs

Appropriate landscaping near roadway-driveway-sidewalk intersections can produce environmental and aesthetic benefits. Landscaping can also directly or indirectly help meet some geometric design objectives for one or more user groups. Landscaping can benefit driveway users in the following ways:

- Landscaping helps reduce stormwater run-off and soil erosion.
- Tree canopies can provide shade for pedestrians.
- Trees that shade pavement can reduce asphalt temperatures by as much as 36°F and fuel tank temperatures by nearly 7°F (*5-27*).
- Well-designed landscaping can help define driveway edges and make the driveway location more conspicuous.

However, ill-chosen or ill-placed landscaping can be an inconvenience or even a hazard.

Tree selection and suitability should consider climate, maintenance requirements, susceptibility to disease, space available for root growth, ultimate tree height, and size of mature canopies. In more extreme cases, vegetation may physically interfere with one or more driveway user groups. Continuous maintenance of landscaping is essential to preserve plantings and sight lines, so the implications of budget limitations for maintenance should also affect landscaping decisions. Exhibit 5-77 presents suggested guidelines for the placement and control of vegetation (*5-28*).

Exhibit 5-77. Landscaping guidelines for driveways.

Concern or Issue	Design Response	Specific Procedure and/or Information
Provide unobstructed lines-of-sight among bicyclists, pedestrians, and vehicles in the area	Do not install landscaping that blocks needed sight lines. Trees should be set back a sufficient distance from the driveway – public road intersections to avoid obstructing sight lines. In urban settings, trees generally should be set back at least 20 to 30 ft on the approach to intersections and 10 to 20 ft on the far side. However, in higher speed environments, greater setbacks may be required (*5-29*). The top of ground cover in driveway and street medians should not exceed 2 feet. This is 18 in. below the clear sight line of 42 in. The bottom of the tree canopy should be at least 5 ft (60 in. high).	Refer to the latest edition of the AASHTO Green Book for the procedure to calculate the needed distance.
Landscaping should not obscure or interfere with traffic control devices or other roadside fixed objects	Vegetation should be sufficiently removed from traffic signs. Vegetation should be sufficiently removed from utility lines.	
Landscaping should not create conflicts in the paths of users	Limbs or branches that overhang any pedestrian path should be at least 7 ft above the surface of the path. Vegetation should be sufficiently removed from pavement surfaces to prevent roots from damaging sidewalks. Vegetation should be sufficiently removed from pavement edges to avoid scraping vehicles. Planting arrangements should not create concealed spaces.	The ADA requires at least an 80 in. clearance above the pedestrian path (*5-30*).
Landscaping should not interfere with adequate artificial illumination	Trees should be set back at least 40 ft from luminaries.	
Preserve an adequate roadside clear zone	Along major highways, the clear zone should normally extend at least 10 ft beyond the edge of the shoulder.	See AASHTO *Roadside Design Guide* (*5-31*). More study is needed to better define the needed clear zone in lower speed, built-up urban street environments.

Business signs may be present outside of the roadway right-of-way, along driveways, or within parking areas. These signs should be placed so that they do not compete with traffic signs or obstruct sight lines of the various users.

Along a busy roadway, a business sign may help identify a driveway location. If placed close to the driveway, a sign can help motorists who are scanning the upcoming roadside to detect the location of the driveway they are searching for. Conversely, a business sign located far from the driveway may actually divert a motorist's view from the driveway location and be misleading and confusing.

Auxiliary Right-Turn Lanes

Right-turn deceleration lanes are frequently constructed to remove the slower right-turning vehicles from the through travel lanes when right-turn volumes into a driveway are heavy and/or could have a significant adverse effect on through traffic. The benefits that accrue from having right-turn lanes include increased capacity, reduced speed differentials and brake applications, and reduced rear-end collisions.

When a pedestrian is crossing a driveway, a right-turn auxiliary lane on the public highway allows a driver to wait without blocking a through traffic lane. A right-turn lane also removes turning vehicles from the through traffic lane, thus limiting interference with traffic progression through a coordinated traffic signal system.

Right-turn lanes may be desirable, but, where provided, should not be continuous, to avoid additional conflicts that would be introduced with both vehicular and bicycle traffic.

Installation Guidelines

The decision to provide an auxiliary right-turn deceleration lane on the roadway approach to a driveway intersection is usually made by the governing transportation agency. Although the driveway designer may not be in a position to make a decision as to whether a right-turn deceleration lane should be installed, it is important for the designer to have some background information as to how a decision is made and on how provision of a right-turn deceleration lane may affect the driveway. Considerations in the decision making process generally include roadway volumes and speeds, driveway volumes, right-turn volumes, type of traffic control at the driveway intersection, and property availability.

Some states have established application and design criteria for right-turn deceleration lanes for driveways and intersections on roadways under their jurisdiction, but the criteria vary widely from state to state (*5-32*)—two examples follow.

Colorado DOT has warrants for right-turn decelerations based on roadway classification and posted speed (*5-33*). For example, on a roadway classified as an Expressway, Major Bypass (Category E-X), a projected peak-hour right-turn ingress turning volume greater than 10 vph would warrant a right-turn lane. For a Non-Rural Arterial (Category NR-A), a right-turn lane would be warranted for any access with a projected peak-hour right-turn ingress turning volume greater than 50 vph; if the posted speed is greater than 40 mph, a right-turn deceleration lane would be warranted for any access with a projected peak-hour right-turn ingress turning volume greater than 25 vph.

Florida DOT has guidelines based on posted speed and volume (*5-9,* p.60). For roadways with a posted speed of greater than 45 mph, 35 to 55 or more right turns per hour would warrant a right-turn lane. For roadways with a posted speed of less than or equal to 45 mph, 80 to 125 or more right turns per hour would warrant a right-turn lane. The lower thresholds would be most appropriate on higher volume roadways or on two-lane roadways where lateral movement is restricted.

The research in *NCHRP Report 420* may be applied to assess the effects of right turns on curb lane operations (*5-12*).

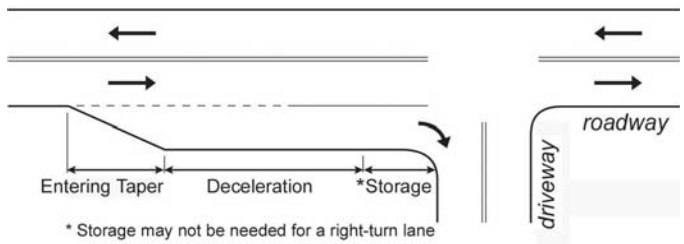
The installation of a right-turn deceleration lane has implications in terms of potential conflicts with pedestrian movements. The objective of NCHRP Project 3-89, "Design Guidance for Channelized Right-Turn Lanes," is to develop design guidance for channelized right-turn lanes, based on balancing the needs of passenger cars, trucks, buses, pedestrians (including pedestrians with disabilities), and bicycles.

Design Considerations

An auxiliary lane for either right- or left-turn lanes should be at least 10 feet wide and, ideally, should equal that of the through lanes. If the lane has curbs, the curb face should be appropriately offset from the lane edge (*5-1*).

As shown in Exhibit 5-78, the length of the auxiliary lanes for turning vehicles consists of three components: entering taper, deceleration length, and storage length (*5-1*). Ideally, the total length of the auxiliary lane should be the sum of the length for these three components; however,

Exhibit 5-78. Parts of a deceleration lane.



common practice is to accept a moderate amount of deceleration within the through lanes and to consider the taper length as part of the deceleration length.

The following paragraphs summarize each component of the auxiliary lane length, based on information in the AASHTO *A Policy on Geometric Design of Highways and Streets* (*5-1*). Additional information is available in this AASHTO document.

Taper. On high-speed rural roadways, a common practice has been to use a taper rate between 8:1 and 15:1 (longitudinal-to-transverse). In urban areas, some use a standard taper ranging in length from 50 to 100 feet. The following numbers provide an example from an agency that varies the taper length according to the posted speed:

Posted speed (mph)	30	35	40	45	50	55
Straight line ratios	6:1	8:1	10.5:1	12.5:1	14.5:1	16.5:1

Source: New Mexico DOT, *State Access Management Manual,* Ch. 8, Sec. 18, p. 92, Sep. 2001

Some considerations favor shorter tapers over longer tapers at urban intersections, including driveways:

1. Shorter tapers appear to produce better "targets" for approaching drivers and to give more positive identification to an added auxiliary lane.
2. A longer taper may cause some drivers to incorrectly think that the deceleration lane is a through lane, especially when the taper is on a horizontal curve.
3. For the same total length of taper and deceleration, a shorter taper allows the storage length to be longer. This results in a longer length of full-width pavement for the auxiliary lane. The additional storage length helps to avoid turning traffic backing up in the through travel lanes and the slower speeds during peak periods would have a shorter taper needed. However, at higher vehicle speeds, this would involve deceleration in the through or turn lane.
4. During peak periods, when the queue length in the auxiliary lane is longer, speeds may decrease, which will make a shorter taper adequate.

Deceleration Length. Provision for deceleration clear of the through traffic lanes is desirable on arterial roadways. Exhibit 5-79 lists turn lane deceleration distances from different sources. The braking distance component of stopping sight distance is included for comparison.

On many urban facilities, an auxiliary turn lane is not long enough to accommodate the storage and all of the deceleration within its limits. Therefore, the initial part of the deceleration takes place in the through lanes, before the vehicle enters the auxiliary lane. In some higher volume and speed environments, significant deceleration in the through lanes may affect safety and operations adversely, so deceleration in the through lanes should be minimized.

For steep upgrades, a shorter deceleration length may be acceptable. For significant downgrades, the deceleration distances need to be extended.

Exhibit 5-79. Example deceleration lengths.

Design Speed (mph)	Deceleration Length (ft) AASHTO Braking[a] Value	AASHTO Comfortable[b] Value	Fla (Urban)[c] Values	Fla (Rural)[d]	NM Stop[e]	NM 15mph[f]	Wis d2[g]
30	86	170	--	--	200	175	160
35	118	--	145	--	250	230	--
40	154	275	155	--	325	300	275
45	194	340	185	--	400	370	--
50	240	410	240	290	475	450	425
55	290	485	--	350	550	525	--

-- indicates no value given for this speed
a. braking distance (2004, p. 112)
b. deceleration (2004, p. 714)
c, d. assumes 10 mph speed difference (from Std. Index 301, rev. 2005). The FDOT Driveway Handbook (2005, p. 63) says "Right turn lane tapers and distances are identical to left turn lanes under stop conditions."
e, f. New Mexico State Access Mgmt. Manual, Ch. 8, Sec. 18, p. 92, Sep. 2001. One condition is deceleration to 0 mph, the other is to 15 mph.
g. Wisconsin Facilities Development Manual, 11-25-1, p. 1-3, May 2006. Distance d2 is the distance traveled while the driver maneuvers laterally and stops. The values allow a 10 mph speed difference when the turning vehicle clears the through lane.

Storage Length for Left-Turn Lanes. At unsignalized driveway intersections, the storage length, may be based on the number of turning vehicles likely to arrive in an average 2-min period within the peak hour. Storage for at least two passenger vehicles should be provided. Where trucks represent more than 10 percent of the traffic, storage should be sufficient for at least one car and one truck.

Storage Length for Right-Turn Lanes. At unsignalized driveways, if the turn lane does not stop or yield to other motor vehicles, and pedestrians seldom cross the driveway, no storage may be needed. If pedestrians often cross the driveway, then storage for at least one vehicle may be desirable.

Drainage of Surfaces Occupied by User Groups

When there is deep standing or flowing water, the following undesirable scenarios can occur:

- A passing motor vehicle will splash nearby bicyclists, pedestrians, or persons waiting at a transit stop. In the more extreme cases, it may adversely affect a driver's ability to control a vehicle.
- Bicyclists and pedestrians are forced to wade through the water.

A good driveway design considers and accommodates the flow of water that results from surface runoff in a way that minimizes inconvenience to users.

Surface runoff water should flow toward a gutter, an inlet, a flume, a ditch, or other suitable destination and not stand and pond in the roadway-driveway-sidewalk intersection area. Although it may be impossible to totally eliminate runoff, depths can be minimized and flows directed away from pedestrian users, the most vulnerable of the user groups.

To achieve suitable drainage and avoid creating problems, the designer should examine the amount of and direction of surface flows in and near the intersection of the driveway with the roadway and sidewalk. The designer should specify the elevations of the surfaces of the driveway, the sidewalk, and the border on the design sheets.

Drainage grates in the driveway can help intercept the surface runoff. As Exhibit 5-80 shows, if installed, grates do need to be inspected and maintained periodically to avoid creating potentially hazardous situations.

Exhibit 5-80. Damaged grates in driveway need repair.

Designing to avoid directing roadway gutter flow into a driveway and onto private property was discussed in the Vertical Alignment section.

Traffic Controls

Signs, pavement markings, and traffic signals are called traffic control devices (TCDs). Strictly speaking, they are not geometric design elements, but TCDs may be used to complement a geometric design.

Because of low volumes and speeds, TCDs are not needed on many driveways. Driveways with moderate to high traffic volumes are more likely to need some form of traffic control, such as signs and/or pavement markings.

Where TCDs are installed, they should be consistent with the signs and markings that motorists and pedestrians are familiar with, the ones they see on the surrounding roadway system. The *Manual on Uniform Traffic Control Devices* (MUTCD) (*5-34*) for streets and highways sets forth the guidelines for the application of traffic signs, pavement markings, signals, and other TCDs.

Sign Considerations

Among the many situations that call for signs, the following are likely to be found at driveways and perhaps overlooked by some designers:

- Along an undivided roadway, when triangular islands (pork chops) are constructed in the driveway entry throat to prohibit one or both left turns, installation of No Left Turn (R3-2) sign(s) in conformance with the MUTCD is needed.
- If a driveway has a wide median, drivers may find that the R4-7 Keep Right (of the median nose) sign is helpful.
- Driveways intended for one-way operation should be accompanied by appropriate signs, so motorists will not proceed in the wrong direction. Refer to the MUTCD for information about the use of One-Way, turn prohibition, and Do Not Enter signs.

If a driveway connects with a narrow roadway, motorists may find parked cars make turning into or out of the driveway difficult or impossible. Some situations may call for parking

Exhibit 5-81. Wider driveways without and with pavement markings.

(a)

(b)

prohibitions in advance of and past the connection and on the other side of the roadway opposite the connection.

Marking Considerations

The MUTCD requires that pavement markings separating opposite directions of travel, such as a center line, be yellow. Markings separating the same direction of travel (e.g., lane lines) and the outer edge lines are white, as are stop lines, crosswalk markings, and directional turn arrows.

Where driveways are wide enough to accommodate three or more lanes of traffic, pavement markings to delineate the intended lanes should be provided. Exhibit 5-81 shows two driveways wide enough for three lanes of traffic. On the driveway without the pavement markings, motorists are much more likely to position their vehicles so as to create problems and conflicts with other vehicles.

Some driveways with multiple exit lanes are marked with slightly offset stop lines, as shown in Exhibit 5-82. This is done so that when both left-turning and right-turning vehicles are trying to exit the driveway at the same time, the left-turning vehicle does not block the needed line-of-sight of the right-turning driver. The right-turning vehicle is given preference because a safe right-turn maneuver requires only an adequate size gap from the left, while a safe left-turn maneuver requires adequate size gaps from both the left and the right. This offset also accommodates the path of a vehicle turning left from the roadway into the driveway.

Channelizing devices, such as tubular markers, have been used to enhance delineation and to reinforce turn prohibitions. They are sometimes part of a driveway triangular island installation. The MUTCD provides detailed instructions for using channelization devices, including that, if used at night, they are to be retroreflective. Exhibit 5-83 shows tubular markers used to discourage unwanted left turns.

Signal Considerations

Where high-volume driveways intersect public roadways, traffic signals may be necessary. Considerations are listed in Exhibit 5-84.

Driveways sometimes essentially form the fourth leg of a signalized intersection. The current MUTCD does allow a driveway that forms the fourth approach or leg of an otherwise signalized intersection to be unsignalized. Before deciding to exercise this option, the designer should ascertain that volumes and speeds on the other three approaches as well as on the driveway are low enough so that vehicles from the unsignalized driveway can safely enter the intersection.

Exhibit 5-82. Offset stop line markings.

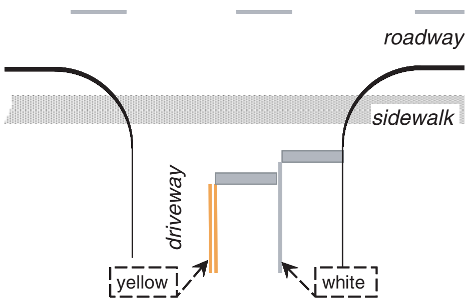


Exhibit 5-83. Example of tubular markers to prohibit a movement.

Railroad Grade Crossings

Where there is a practical alternate route, it is desirable that a driveway not cross railroad tracks at grade. However, in some cases, the only access to a public road may be across a railroad track.

The guidance in the *Railroad-Highway Grade Crossing Handbook* (*5-35*) for design of rail-highway crossings also applies to the design of driveway-rail crossings. Exhibit 5-85 lists some design considerations for driveways crossing railroad tracks.

Track maintenance can result in raising the track as new ballast is added to the track structure. The *Handbook* cautions that "unless the highway profile is properly adjusted, this practice will result in a 'humped' profile that may adversely affect the safety and operation of highway traffic over the railroad." The greatest risk of becoming hung up at railroad-highway grade crossings because of contact with the track or highway surface is posed by low-clearance, long-wheelbase vehicles. A similar problem can occur where the crossing is in a sag vertical curve. In this case, the front or rear overhangs on certain vehicles can strike or drag the pavement.

When a road parallels a railroad and an intersecting driveway crosses the railroad, a railroad grade crossing near the roadway intersection results. The *Railroad-Highway Grade*

Exhibit 5-84. Traffic signal considerations.

Traffic Signal Design Element	Suggested Practice
Minimum green time	To accommodate pedestrians crossing either the driveway or the roadway, the designer can either establish a minimum green time that is adequate for crossing or provide pedestrian pushbuttons.
Users with disabilities	Many situations, especially in urban areas, call for features such as detectable warnings to accommodate pedestrians with disabilities.
Actuation	In most cases, want an actuated signal, so will not take away green from the through roadway unless there is actual driveway demand. Semi-actuated may be adequate.
Progression	If the driveway traffic signal is one of a series along the roadway, then time and coordinate the signal to minimize interference with progression along the through roadway. Semi-actuated traffic signals may help minimize interruptions to through traffic on the public road.

Exhibit 5-85. Considerations for driveways crossing railroad tracks.

Design Element	Suggested Practice	Reason
Intersection angle	Driveway and railroad tracks intersect at 90 degrees	Enhance the driver's view of the crossing
Horizontal alignment - curvature	Crossings should not be located on either driveway or railroad curves	Driveway curvature limits a driver's view of the crossing ahead and the driver's attention may be directed toward negotiating the curve rather than looking for a train. Railroad curvature restricts a driver's view down the tracks from both a stopped position at the crossing and on approach to the crossing
Vertical alignment	Driveway-rail crossing should be as level as possible. AASHTO (*5-1*, pp. 731-733) recommends that the crossing surface be in the same plane as the top of rails for a distance of 2 feet outside the rails, and that the surface of the roadway be not more than 3 inches higher or lower than the top of the nearest rail at a point 30 feet from the rail, unless track superelevation dictates otherwise.	Improved sight distance, rideability, and braking and acceleration distances

Crossing Handbook points out that the higher occurrence of collisions at these intersections is due in part to a short storage area for vehicles waiting to move through the crossing and the intersection. "If the intersection is signalized or if the driveway approach from the crossing is controlled by a STOP sign, queues may develop across the crossing, leading to the possibility of a vehicle becoming 'trapped' on the crossing. Also, there are more distractions to the motorist, leading to the possibility of vehicle-vehicle conflicts." The critical distance between a driveway-rail crossing and a driveway-highway intersection is a function of the number and type of vehicles expected to be queued up by the intersection traffic control. If other viable driveway locations are available, consider routing the driveway so that it does not cross the railroad track.

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Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation