

SECOND EDITION

Guidelines for Geometric Design of Low-Volume Roads

2019

AMERICAN ASSOCIATION
OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS

AASHTO



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Documents

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FOREWORD

As road designers, engineers strive to provide for the needs of highway users while maintaining the integrity of the environment. Unique combinations of design requirements that are often conflicting result in unique solutions to design problems. The geometric design of low-volume roads presents a unique challenge because the low traffic volumes and reduced frequency of crashes make designs normally applied on higher volume roads less cost effective. The guidance supplied by this document, *Geometric Design Guidelines for Low-Volume Roads*, addresses the unique needs of such roads and the geometric designs appropriate to meet those needs. These guidelines may be used in lieu of the guidance in *A Policy on Geometric Design of Highways and Streets*, commonly known as the Green Book (5).

The first edition of these guidelines, published by AASHTO in 2001, which addressed roads with design volumes of 400 vehicles per day or less, was the result of a research and development process initiated by AASHTO in 1996. These guidelines were initially developed through two projects of the National Cooperative Highway Research Program (NCHRP), which is jointly sponsored by AASHTO and the Federal Highway Administration. After completion of the NCHRP research, these guidelines went through the normal AASHTO review process. During the development process of the first edition, representatives of other interested organizations such as the National Association of County Engineers, the American Society of Civil Engineers, the U.S. Forest Service, the American Public Works Association, and the National League of Cities participated in the review of the guidelines.

This second edition is the result of a new research and development process initiated by AASHTO in 2013 through the NCHRP program. After completion of the NCHRP research, these guidelines went through the normal AASHTO review and balloting process. AASHTO appreciates the advice of the U.S. Forest Service in the development of this edition of the guidelines. The scope of these new guidelines includes local and minor collector roads with traffic volumes of 2,000 vehicles per day or less.

Design values are presented in this document in both U.S. customary and metric units and were developed independently within each system. The relationship between the U.S. customary and metric values is neither an exact (soft) conversion nor a completely rationalized (hard) conversion. The U.S. Customary values are those that would have been used had the policy been presented exclusively in U.S. Customary units; the metric values are those that would have been used if the policy had been presented exclusively in metric units. Therefore, the user is advised to work entirely in one system and not attempt to convert directly between the two.

The fact that new design values are presented herein does not imply that existing streets and highways are unsafe, nor does it mandate the initiation of improvement projects. *A Policy on Geometric Design of Highways and Streets* (5) states that specific site investigations and crash history analysis often indicate that the existing design features are performing in a satisfactory manner. The cost of full reconstruction for these facilities, particularly where major realignment

is not needed, will often not be justified. This is especially true for low-volume roads, which experience substantially fewer crashes than roads with design volumes greater than 2,000 vehicles per day. These guidelines recommend an approach to geometric design for low-volume roads, including both new construction and projects on existing roads, that is based on research concerning the safety cost-effectiveness of geometric elements. For projects on existing roads, reviews of site-specific conditions also are a key element of the design guidance presented here.

These guidelines address issues for which appropriate geometric design guidance for low-volume roads differs from the policies normally applied to higher volume roads. For any geometric design issues not addressed by these guidelines, design professionals should consult *A Policy on Geometric Design of Highways and Streets* (5).

The intent of these guidelines is to assist the designer by referencing a recommended range of values for critical dimensions. It is not intended to be a detailed design manual that could supersede the need for the application of sound principles by the knowledgeable design professional. Flexibility in application of these guidelines is encouraged so that independent designs tailored to particular situations can be developed.

Roads, vehicles, drivers, and nonmotorized users (pedestrians and bicyclists) are all integral parts of transportation safety and efficiency. While this document primarily addresses geometric design of roads, a properly equipped and maintained vehicle and reasonable and prudent performance by the user are also needed for safe and efficient operation of the transportation facility.

PREFACE

This Guideline was developed as part of the continuing work of the AASHTO Council on Highways and Streets. The Council, then titled the Committee on Planning and Design Policies, was established in 1937 to formulate and recommend highway engineering policies. This Council has developed *A Policy on Geometric Design of Rural Highways*, 1954 and 1965 editions; *A Policy on Arterial Highways in Urban Areas*, 1957; *A Policy on Design of Urban Highways and Arterial Streets*, 1973; *Geometric Design Standards for Highways Other Than Freeways*, 1969; *A Policy on Geometric Design of Highways and Streets*, 1984, 1990, 1994, 2001, 2004, and 2011; *A Policy on Design Standards—Interstate System*, 1956, 1967, 1988, 1991, 2005, and 2016; and a number of other AASHTO policy and guide”publications.

An AASHTO publication is typically developed through the following steps: (1) The Council selects subjects and broad outlines of material to be covered. (2) The appropriate subcommittee and its task forces, in this case the Committee on Design and the Technical Committee on Geometric Design, assemble and analyze relevant data and prepare a tentative draft. Working meetings are held and revised drafts are prepared, as necessary, and reviewed by the Committee until agreement is reached. Standards and policies must be adopted by a two-thirds vote by the Member Departments before publication. During the developmental process, comments are sought and considered from all the states, the Federal Highway Administration, and representatives of the American Public Works Association, the National Association of County Engineers, the National League of Cities, and other interested parties.

This Guideline was first published by AASHTO in 2001 for application to very low-volume local roads and some collector roads with design average daily traffic volumes of 400 vehicles per day or less. This second edition has been updated for application to all low-volume local and minor collector roads with design average daily traffic volumes of 2,000 vehicles per day or less.

1 Introduction

1.1 INTRODUCTION

This document presents geometric design guidelines for low-volume roads. The purpose of the guidelines is to help highway designers in selecting appropriate geometric designs for roads with low traffic volumes. The design guidelines presented here may be used on low-volume local and minor collector roads in lieu of the applicable policies presented in the AASHTO publication, *A Policy on Geometric Design of Highways and Streets* (5), commonly known as the Green Book.

This chapter defines low-volume roads, describes the scope of the design guidelines, explains the relationship of the guidelines to other AASHTO policies, and presents the organization of the remainder of this document.

1.2 DEFINITION OF LOW-VOLUME ROADS

The guidelines presented in this document are applicable to low-volume roads. Low-volume roads are defined as follows:

A low-volume road is a road that is functionally classified as a local or minor collector road and has a design average daily traffic volume of 2,000 vehicles per day or less.

The preceding statement indicates that the functional classification of a road is a key element of the definition of a low-volume road in these guidelines. A *local road* is a road whose primary function is to provide access to residences, farms, businesses, or other abutting property, rather than to serve through traffic. Although some through traffic may occasionally use a local road, through traffic service is not its primary purpose. The term local road is used here to refer to the functional classification of the road and is not intended to imply that the road is necessarily under the jurisdiction of a local or municipal unit of government. *Rural minor collector roads* generally serve travel of intracounty rather than state-wide importance and constitute those routes on which predominant travel distances are shorter than major collector and arterial routes. *Urban minor collector streets* provide both land access service within residential neighborhoods and commercial and industrial areas and connections to streets of higher functional classification. Administrative arrangements for operation of the highway system vary widely and, in different parts of the United States, roads that are functionally classified as local and minor collector roads may be under Federal, state, or local control.

More than 80 percent of the roads in the United States have traffic volumes of 2,000 vehicles per day or less. The low-volume local and minor collector roads, defined above, to which the guidelines presented in this document are applicable, should include most of this extensive road mileage. Little of this road mileage would be classified as arterials. In some states, portions of the state-numbered route system meet the definition of low-volume minor collector roads and can be addressed with these guidelines.

In addition to serving motor vehicle traffic, low-volume roads also serve varying numbers of pedestrians and bicyclists. The needs of pedestrians and bicyclists should be considered in the design of each project. Some low-volume roads may serve pedestrians and bicyclists only rarely, but other low-volume roads, particularly in urban areas, serve pedestrians or bicyclists, or both, in sufficient numbers that specific pedestrian or bicycle facilities, or both, are needed.

1.3 SCOPE OF GUIDELINES

The guidelines presented in this document are intended for application in the design of low-volume roads, as defined above, including application in new construction of low-volume roads and in the improvement of existing low-volume roads. The scope of the guidelines includes roads in both rural and urban areas.

These design guidelines enable designers for projects on low-volume roads to apply design criteria that are less restrictive than those generally used on *higher volume roads*. Where the term *higher volume roads* is used in this document, this refers to roads with design volumes of more than 2,000 vehicles per day, which are outside the scope of these guidelines. The risk assessment on which the guidelines are based shows that these less restrictive design criteria can be applied on low-volume roads without substantial effects on crash frequency and severity. The guidelines discourage widening of lanes and shoulders, changes in horizontal and vertical alignment, and roadside improvements except in situations where such improvements are likely to provide substantial reductions in crash frequency or severity. Thus, projects designed in accordance with these guidelines are less likely to negatively impact the environment, roadway and roadside aesthetics, existing development, historic and archeological sites, and endangered species. In reviewing the geometric design for sections of existing roadway, designers should strive for consistency of design between that particular section and its adjoining roadway sections. The potential effects of future development that may affect the traffic volume, vehicle mix, and presence of pedestrians or bicyclists on the roadway should also be considered.

These design guidelines are intended to encourage rational safety management practices on low-volume roads. Expenditures for highway improvements are discouraged at sites where such improvements are likely to have little effect on crash frequency or severity, but are strongly encouraged at sites where crash patterns exist that can be corrected by a roadway or roadside improvement. Designers are provided substantial flexibility to retain the existing roadway and roadside design, where that existing design is performing well, but are also provided flexibility to recommend improved designs, even designs that exceed the guidelines presented here, where needed to correct documented crash patterns or meet other agency goals.

The scope of these guidelines includes geometric design for new construction and for improvement of existing roads. Geometric design criteria for new construction apply to construction of a new road where none existed before. Projects on existing roads may involve reconstruction, resurfacing, rehabilitation, restoration, and other types of improvements.

These guidelines are limited in scope to geometric design issues and do not address the application of traffic control devices on low-volume roads. For traffic control device guidance, see the *Manual on Uniform Traffic Control Devices* (8).

1.4 RELATIONSHIP TO OTHER AASHTO POLICIES

The design guidelines presented in this document may be applied to low-volume roads in lieu of the applicable policies of the AASHTO Green Book (5) and the AASHTO *Roadside Design Guide* (3). For projects on local roads and streets, these design guidelines may be applied in place of Chapter 5 (Local Roads and Streets) of the AASHTO Green Book (5) to local roads that serve design volumes of 2,000 vehicles per day or less. For projects on minor collector roads and streets that serve design volumes of 2,000 vehicles per day or less, these design guidelines may be applied in place of the applicable policies in Chapter 6 (Collector Roads and Streets) of the AASHTO Green Book (5). The design guidelines presented here address design issues for which an explicit risk assessment has been performed. For design issues that are not addressed in these guidelines, the designer should consult the applicable sections of the AASHTO Green Book (5) and the AASHTO *Roadside Design Guide* (3). Design of facilities for nonmotorized users is addressed in the AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities* (1) and the AASHTO *Guide for the Development of Bicycle Facilities* (4).

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2 Framework for Design Guidelines

2.1 INTRODUCTION

This chapter presents a framework for the design guidelines for low-volume roads. The elements of this framework are area type, roadway functional class and subclass, design speed or operating speed, and design volume. The chapter identifies how these elements of the framework are used in identifying the appropriate design guidelines for a specific design application.

2.2 AREA TYPE

The design guidelines are applicable to both rural and urban areas. The operating characteristics, constraints, and configurations of low-volume roads in rural and urban areas differ substantially and, therefore, in many cases, the design guidelines for rural and urban roads also differ. Thus, before applying the design guidelines, the designer should determine the area type in which the site of interest is located.

Low-volume roads in rural areas are more likely than urban roads to operate at high speeds and have a cross section with open drainage (shoulders and ditches, rather than curb and gutter). Rural roads tend to have fewer right-of-way constraints, less pedestrian activity, and a broader range of uses than urban roads. Low-volume rural roads include roads in undeveloped or agricultural areas as well as roads in rural towns.

By contrast, urban and suburban roads, even those with low traffic volumes, are generally more constrained than rural roads in terms of speeds and right-of-way. The guidelines for urban roads presented in this document apply to both urban and suburban conditions.

2.3 FUNCTIONAL CLASSIFICATION

The concept of functional classification is fundamental to the criteria used in the geometric design of highways and streets. The functional classification of a roadway identifies the relative importance of the mobility and access functions for that roadway. Roadways in the highest functional class are freeways. Freeways are intended primarily to serve through traffic traveling relatively long distances and provide no access to adjacent land except by way of interchanges spaced at appropriate intervals. Arterials and major collectors provide progressively less emphasis on mobility for through traffic and more emphasis on access to adjacent land. Local roads are intended to provide access to residences,

businesses, farms, or other abutting property and are not intended to serve through traffic, although a limited amount of through traffic may use some local roads.

The design guidelines presented in this document are applicable to local and minor collector roads with design volumes of 2,000 vehicles per day or less. Some highway agencies distinguish between major and minor collectors only in rural areas, although Federal guidelines now permit this distinction in urban areas as well. If an agency does not formally use the minor collector classification in urban areas, designers should exercise judgment in applying the guidelines to low-volume roads that are classified as collectors and are closer in character to local roads than to arterials.

For purposes of the design guidelines, low-volume roads are further subdivided into six functional subclasses for rural facilities and three functional subclasses for urban facilities as follows:

Rural Roads:

- rural major access roads,
- rural minor access roads,
- rural industrial or commercial access roads,
- rural agricultural access roads,
- rural recreational and scenic roads, and
- rural resource recovery roads.

Urban Roads:

- urban major access streets,
- urban residential streets, and
- urban industrial or commercial access streets.

Each of these functional subclasses is defined below.

Figures 2-1 and 2-2 present photographs of typical rural and urban low-volume roads.



Figure 2-1. Typical Rural Low-Volume Roads (Source: CH2M Hill/Jacobs Engineering)



Figure 2-2. Typical Urban Low-Volume Streets (Source: MRIGlobal)

2.3.1 Rural Major Access Roads

Rural major access roads serve a dual function of providing access to abutting properties as well as providing through or connecting service between other local roads or higher type facilities. In rural areas, major access roads may have significant local continuity and may operate at relatively high speeds. Because of the possibility of through traffic, there may be a meaningful segment of traffic that includes unfamiliar drivers. Major access roads classified as local roads may thus, in some respects, function like collector or even minor arterial roads. Major access roads are usually paved, but may be unpaved in some rural areas. Minor collector roads should be treated as major access roads for purposes of these guidelines. Traffic on rural major access roads is largely composed of passenger vehicles or other smaller vehicle types. However, such roads need to be accessible to school buses, fire trucks, other emergency vehicles, and maintenance vehicles such as snow plows and garbage trucks. Access roads serving commercial or industrial land uses are described below in a separate functional subclass.

2.3.2 Rural Minor Access Roads

Rural minor access roads serve almost exclusively to provide access to adjacent property. Many of these roads are cul de sacs or loop roads with no through continuity. The length of minor access roads is typically short. Because their sole function is to provide access, such roads are used predominantly by familiar drivers.

Minor access roads generally serve residential or other non-commercial land uses. Speeds are generally low for the local environment, given the purpose of the road and short trip lengths. As noted above, many minor access roads end in cul de sacs or dead ends, thus limiting the opportunity for high travel speeds. Minor access roads are frequently narrow, and in some rural areas may function as one lane roads. Minor access roads can be either paved or unpaved. Traffic is largely composed of passenger vehicles or other smaller vehicle types. However, such roads need to be accessible to school buses, fire trucks, other emergency vehicles, and maintenance vehicles such as snow plows and garbage trucks. Access roads serving commercial or industrial land uses are described below in a separate functional subclass.

2.3.3 Rural Industrial or Commercial Access Roads

Industrial or commercial access roads serve developments that may generate a significant proportion of truck or other heavy vehicle traffic. The primary or sole function of such roads is generally to provide access from a factory or another commercial land use to the local or regional highway network. Typical industrial or commercial access roads are very short and, in many cases, they do not serve any through traffic. Industrial or commercial access roads may be either paved or unpaved. Such industrial or commercial access roads are addressed in their own functional subclass, separately from minor access roads, which they otherwise resemble, because consideration of trucks and other heavy vehicles is important in their design.

2.3.4 Rural Agricultural Access Roads

Certain roads in rural areas serve primarily to provide access to fields and farming operations. Vehicle types that use such roads include combines, tractors, trucks that haul agricultural products, and other large and slow-moving vehicles with unique operating characteristics. The driving population generally consists of repeat users who are familiar with the road and its characteristics. Such roads are often unpaved.

Consideration of the unique vehicle types that use agricultural access roads is important in their design. For purposes of these guidelines, rural agricultural access roads consist of roads that are used regularly or seasonally for access to farms by agricultural equipment, such as combines, that are wider than a typical 8.5-ft [2.6-m] truck. Roads that provide frequent access to farms for conventional trucks, but not for wider equipment, should be treated as rural commercial or industrial access roads. Roads that provide access to farms but are used only occasionally by conventional trucks and are not used by

wider equipment, should be treated as either rural major access or rural minor access roads depending upon the function and characteristics of the road.

2.3.5 Rural Recreational and Scenic Roads

Recreational and scenic roads serve specialized land uses, including parks, tourist attractions, and recreational facilities, such as campsites or boat-launch ramps, and are found primarily in rural areas. Traffic is open to the general public, and their users are more likely than users of other functional subclasses of local roads to consist of unfamiliar drivers. Recreational and scenic roads do not generally carry significant volumes of truck traffic, but do serve recreational vehicles including motor homes, campers, and passenger cars pulling boats and other trailers. In many cases, these roads may carry highly seasonal traffic volumes. Recreational and scenic roads may accommodate a wide range of speeds and trip lengths may be fairly long. Such roads can be either paved or unpaved. Additional design guidance for this category of roadway is available in the U.S. Forest Service *Road Preconstruction Handbook* (17).

2.3.6 Rural Resource Recovery Roads

Resource recovery roads are local roads serving logging, mining, oilfield, or similar operations. Such roads are typically found only in rural areas, and frequently in very remote areas. Resource recovery roads are distinctly different from the other functional subclasses of low-volume roads in that they are used primarily by vehicles involved with the resource recovery activities and the driving population consists primarily or exclusively of professional drivers with large vehicles. In some cases, traffic operations on resource recovery roads are enhanced through radio communication between drivers, enabling such roads to be built and to operate as single-lane roads. Most resource recovery roads are unpaved. The design guidelines for this category of road take into account the remoteness of their setting, the types of vehicles that generally use such a road, and the professional experience of the drivers of those vehicles. Additional design guidance for this category of roadway is available in the U.S. Forest Service *Road Preconstruction Handbook* (17).

2.3.7 Urban Major Access Streets

Urban major access streets, like major access roads in rural areas, serve a dual function of providing access to adjacent property as well as providing through or connecting service between other local roads or higher type facilities. Urban major access roads are generally shorter than major access roads in rural areas, but their function in serving more through traffic than most local roads is much the same. Thus, urban major access streets that are functionally classified as local roads often approach the status of a minor collector. Minor collector streets in urban and suburban areas should be treated as urban major access streets for purposes of the guidelines. Any specific role assigned to particular urban major access streets in local pedestrian and bicycle planning should be considered in their design.

2.3.8 Urban Residential Streets

Urban residential streets typically serve to provide access to single- and multiple-family residences in urban areas. Motorists, pedestrians, and bicyclists using such streets generally include only residents and their visitors. Use of such streets by large trucks and other heavy vehicles is rare, except for occasional use by delivery and maintenance vehicles. Accessibility for school buses, fire trucks, other emergency vehicles, and maintenance vehicles such as snow plows and garbage trucks is an important consideration in the design of residential streets.

2.3.9 Urban Industrial or Commercial Access Streets

Urban industrial or commercial access streets, like their rural counterparts, serve development that may generate a substantial volume of trucks or other heavy vehicles. The primary function of such a street is typically to provide access from a factory or another industrial or commercial site to the local or regional highway network. Pedestrian and bicycle usage may be expected on some industrial or commercial access streets. Industrial or commercial access streets are typically quite short, can be paved or unpaved, and may or may not carry traffic from smaller streets. The main defining characteristic of an industrial or commercial street is that its design is influenced by the heavy vehicles using the street.

2.3.10 Other Urban Facilities

Urban agricultural access roads, recreational and scenic roads, and resource recovery roads are rare, but where they occur, they should be designed like their rural counterparts.

2.3.11 Roads that Meet the Definition of More than One Functional Subclass

Some roads meet the definition of more than one of the functional subclasses defined above. For example, a given road might be considered both a rural minor access road and a rural agricultural access road. Another road might be considered both a rural major access road and a recreational and scenic road. In such cases, the road should be evaluated using the design guidelines applicable to each functional class, as presented in Chapter 4, and the higher of the applicable design guidelines should be applied.

2.4 DESIGN SPEED OR OPERATING SPEED

Speed has always been a primary defining variable in the development and presentation of geometric design criteria. Current AASHTO policy specifies design criteria in increments of 5 mph [10 km/h]. Designers select a design speed which is appropriate for the roadway and that speed is used to correlate the various features of the design. The selected design speed should be a logical one with respect to the anticipated operating speed, topography, adjacent land use, and functional classification of the road. In selection of design speed, every effort should be made to attain a desired level of safety, mobility, and efficiency within the constraints of environmental quality, economics, aesthetics, and social or political impacts. The selected design speed should be consistent with the speeds that drivers are likely to expect

on a given road. Where a reason for limiting speed is obvious to approaching drivers or bicyclists, they are more apt to accept lower speed operation than where there is no apparent reason.

One of the design guidelines presented in Chapter 4 varies as a function of speed, as follows:

- Low speed—0 to 45 mph [0 to 70 km/h], and
- High speed—more than 45 mph [70 km/h].

2.5 TRAFFIC VOLUMES

The projected average daily traffic volume (ADT) should be used as the basis for design. Usually, the year for which traffic is projected is 20 years from the date of completion of construction, but may range from the current year to more than 20 years in the future depending upon the nature of the improvement. Where traffic volumes vary substantially from season to season, design should be based on the ADT during the peak season. Traffic volume growth rates on low-volume roads are generally modest, and some roads may experience future traffic volume decreases. However, the designer should be alert to the possibility of future development that might affect traffic volume growth, especially in or near urban areas. If new development that would increase the design volume above 2,000 vehicles per day is anticipated on a local or minor collector road within the period for which traffic volumes are projected, then Chapter 5 or 6 of the AASHTO Green Book (5) should be used instead of the design guidelines presented here. Where future development is uncertain, a project with a projected volume of 2,000 vehicles per day or less may be designed in accordance with the design guidelines presented in Chapter 4, but the basis for this decision should be documented.

For some design criteria for new construction in Chapter 4, traffic volumes on low-volume roads (2,000 vehicles per day or less) are stratified into several levels. The volume ranges used for specific new construction design criteria may include:

- 100 vehicles per day or less,
- 101 to 250 vehicles per day,
- 251 to 400 vehicles per day, or
- 401 to 2,000 vehicles per day.

3 Rationale for Development of Design Guidelines

3.1 INTRODUCTION

This chapter explains the rationale for and approach to development of the design guidelines presented in Chapter 4. The rationale includes a discussion of the unique characteristics of low-volume roads, a discussion of the basis for the design guidelines, an explanation of the risk-assessment approach used to develop the guidelines, an explanation of the differences between the guidelines for new construction and for improvement of existing roads, and a discussion of the need for flexibility in applying the design guidelines.

3.2 UNIQUE CHARACTERISTICS OF LOW-VOLUME ROADS

The design guidelines presented in Chapter 4 are based on the unique characteristics of low-volume roads. The fundamental characteristics of low-volume roads that distinguish them from other types of roads are:

- The traffic volumes of such roads are, by definition, low. All low-volume roads have average daily traffic volumes of 2,000 vehicles per day or less, and many such roads have volumes that are much less than the 2,000-vehicle-per-day threshold value. These low traffic volumes mean that encounters between vehicles that represent opportunities for crashes to occur are rare events and that multiple-vehicle collisions of any kind are extremely rare events.
- The limitation of the scope of these guidelines to local and minor collector roads means that many motorists using the road have traveled it before and are familiar with its features. Geometric design features that might surprise an unfamiliar driver will be anticipated by the familiar driver.

Because of these unique characteristics, design guidelines for low-volume roads can be less stringent than those used for higher volume roads or roads that serve primarily unfamiliar drivers. The functional subclasses of low-volume roads presented in Chapter 2 permit the design guidelines to vary with the expected proportion of unfamiliar drivers. Similarly, design guidelines for low-volume roads also vary with the expected design traffic volume level.

3.3 BASIS FOR DESIGN RECOMMENDATIONS

Design criteria for streets, roads, and highways are based on a wide range of considerations. Operational efficiency, low crash frequency and severity, constructability, and maintainability are of primary im-