CHAPTER 1

GENERAL DESIGN CRITERIA

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CHAPTER 1

GENERAL DESIGN CRITERIA

1–01 GENERAL

This chapter includes a general discussion of highway types, highway systems, design designation and highway capacity. It also covers the general and geometric design requirements that are specified to insure that the design of a highway facility is consistent with its projected service.

1–02 HIGHWAY TYPES

The term highway, road or street is a general term denoting a public way for purposes of vehicular travel including the entire area within the right-of-way. For rural areas the term highway or road is used, for urban areas highway or street is used.

Control of access is the condition where the right of owners or occupants of abutting land or other persons to access, light, air or view in connection with a highway is fully or partially controlled by public authority.

Full control of access means that the authority to control access is exercised to give preference to through traffic by providing access connections with selected public highways only by prohibiting crossings at grade or private drive-way connections.

Partial control of access means that the authority to control access is exercised to give preference to a degree that, in addition to access connections with selected public highways, there may be crossings at grade and some private drive-way connections.

The following definitions of various highway types apply throughout this manual:

Expressway–An arterial highway with full or partial control of access.

Freeway–An expressway with full control of access.

Autopista–A toll freeway.

Major Highway or Major Street–An arterial highway with intersections at grade and direct access to abutting property, and on which the geometric design and traffic control measures are used to expedite the safe movement of through traffic.

Through Highway or Through Street–Every highway or portion thereof on which vehicular traffic is given preferential right-of-way, and at entrances to which vehicular traffic from intersecting highways is required by law to stop before entering or crossing the same and when stop signs are erected.

Divided Highway–A highway with separated roadways for traffic in opposite directions.

Avenue–A major street, usually a divided multilane highway, designated as such in the urban area master plan.

Principal Street–A through street, usually undivided multilane, designated as such in the urban area master plans.

Local Street or Local Road–A street or road primarily for access to residence, business or other abutting property.

Frontage Road or Street (Also called marginal road or street)–A local road or street auxiliary to and located on the side of an arterial highway for service to abutting property and adjacent areas and for control of access.

Cul-de-sac Street—A local street open at one end only and with special provision for turning around.

Dead-end Street—A local street open at one end only and without special provision for turning around.

1—03 HIGHWAY SYSTEMS

Highways in Puerto Rico have been classified and grouped into designated systems for administrative, financing and other purposes. This manual is primarily concerned with highways designated as Commonwealth highways although the design principles, policies and procedures included herein are applicable to roads and streets which fall under the jurisdiction of the respective municipalities.

1—03.01 COMMONWEALTH HIGHWAY SYSTEM

The Commonwealth Highway System includes all highways designated in the master highway plan and some additional roads and streets which are under the maintenance responsibility of the Department of Transportation and Public Works. This system is shown on an official map published by the Department which is normally updated annually. It includes both rural and urban numbered routes.

The Commonwealth Highway System is divided into three categories:

1. Primary—Includes the principal routes connecting the major population centers and some entirely intra-urban routes in the larger metropolitan areas. Primary routes at present comprise about 14% of the total Commonwealth system mileage. Numbers 1 through 99 have been reserved for primary routes.

2. Secondary—Generally serve intraregional traffic and provide together with the primary routes, and integrated network connecting all the municipal centers of the Island except the offshore municipalities of Vieques and Culebra. Secondary routes comprise about 30% of the total Commonwealth system mileage. Numbers 100 through 299 have been reserved for secondary routes.

3. Municipal—These are local access roads which have been included in the Commonwealth system and comprise about 56% of the total mileage. Numbers 300 through 9999 have been reserved for these municipal routes.

1—03.02 FEDERAL-AID HIGHWAY SYSTEM

The Federal-aid Highway System was established to designate the routes that would be eligible for improvement under the Federal-aid highway program. However, there are at present some special categories of FA highway funds which may be spent, under certain conditions, on routes not included in the FA system.

Routes on the FA highway system are classified as follows:

1. Primary—Includes most of the rural arterial highways of the Commonwealth highway system and their urban extensions. The major exceptions are the toll highways PR-22 and PR-52 which are not eligible for financing under the Federal-aid program.

2. Secondary—Includes most of the rural major collector highways in the Commonwealth highway system and their urban extensions except those in urban areas with population of 5,000 or more persons.

3. Urban—Includes principal urban arterial and collector highways located within urban areas with population of 5,000 or more persons which are not included in another FA system.

4. Forest Highways—These include highways serving the Caribbean National Forest-Luquillo Division. Forest highways may also be in other FA systems. The currently designated FH routes are PR-191 (FAS-191) and a portion of PR-186 (FAS-186).

Federal-aid projects must conform with design standards acceptable to the Federal Highway Administration which are covered in the Federal-Aid Highway Program Manual (Volume 6, Chapter 2). The FHWA accepts the standards, specifications, policies and guides of the American Association of State Highway and Transportation Officials (AASHTO). This manual is in general conformance with AASHTO standards, policies and guides; thus, projects designed under this manual will normally meet Federal-aid design requirements. However, a designer assigned a project to be built under the Federal-aid program should ascertain any special FA design requirements applicable to the projects to insure that the design will meet FHWA approval.

1–04 FUNCTIONAL HIGHWAY CLASSIFICATION

Functional highway classification is the grouping of roads and streets into classes, or systems, according to the character of service they are intended to provide. The classification process recognized that most travel involves movement through a network of roads and/or streets and should be channelized within the network in a logical and efficient manner. Under functional classification, roads and streets having similar functions and importance are grouped into connected systems. Such a classification system provides a foundation for planning and design operations.

Under a functional highway classification system, there are three basic categories of roads and streets: arterials, collectors and local. It is also recognized that urban and rural areas have different characteristics as to density and types of land use, density of street and highway networks, nature of travel patterns, and the way that all these elements are related in the definitions of highway function. Therefore, separate classification of urban and rural functional systems are made.

A complete discussion of concepts, criteria and procedures for functional classification is included in the FHWA publication "HIGHWAY FUNCTIONAL CLASSIFICATION" of July 1974. The following are generalized explanations of the three basic types:

1. Arterials—Include routes serving corridors of substantial traffic density and trip length. They are expected to provide a high degree of mobility and, therefore, should have high operating speeds, minimum interference to through movement and direct routing favoring the longer trip lengths. In rural areas, the arterial system consists of a connected network serving the larger urban areas and major traffic generators. In urban areas, the arterial system will serve the major centers of activity, the highest traffic volume corridors and the longer trips. The arterial system is further divided into principal arterials and minor arterials.

2. Collectors—These are routes intermediate between arterials and locals that serve the dual function of mobility and land access. They accommodate the shorter trip lengths and feed traffic to the arterials, and, thus, must provide some degree of mobility. In rural areas they provide service to the urban centers not directly served by the arterial system. In urban areas the collector system provides both land access service and traffic circulation within residential neighborhoods, commercial and industrial areas.

3. Local—Rural local roads serve primarily to provide access to adjacent land and provide service to travel over relatively short distances. Urban local streets serve primarily to provide direct access to abutting land and access to the higher order systems. Local roads and streets offer the lowest level of mobility and in urban areas through traffic movement is usually deliberately discouraged.

The general design criteria applicable to a particular route are directly related to its functional classification. Principal arterials are designed as freeways with high design speeds and full control of access. Minor arterials are designed for somewhat lower speeds with access to adjacent properties usually minimized through partial control of access measures. On some very high volume multilane minor arterials full freeway standards may be warranted. Since collectors are to provide both mobility and access, the applicable design standards are of a lower level than for arterials and direct access is permitted. Local roads and streets require the lowest design standards since property access is their main function and there is little need for mobility or high operating speeds.

The primary, secondary and municipal classifications of the Commonwealth Highway System, which were established many years ago, were essentially functional. The primary would correspond to principal arterials, the secondary to minor arterials and collectors, and the municipal to local. However, as the Island developed, fundamental changes have ocurred in the service requirements of many routes to the point that the Commonwealth system classification of many routes can not be directly related to their current category under a functional classification system.

Functional classification has been applied to the Puerto Rico highway system but its use has been generally limited to highway needs and transportation studies, islandwide and for the metropolitan areas. However, from such studies, the design standards for many arterial and collector routes have been established.

The general design criteria included in this chapter are presented in such a manner that they can be directly related to the functional classification established for any specific route.

1—05 DESIGN REFERENCES

Although this manual provides specific information on design standards, policies and procedures of the Department, it does not do away with the need to consult and use other accepted design guides and throughout the manual references are made to other publications, particularly those of the American Association of State Highway and Transportation Officials.

The following is a list, by no means all inclusive, of references on geometric and structural design and traffic control features that the designer should have access to and be familiar with. These are approved references for use in conjunction with this manual; however, since some of these policies and guidelines do not always satisfy Puerto Rico conditions, the instructions in this manual shall take precedence over these references, except for Federal-aid projects. For the latter, exceptions to the standards specified in the Federal-aid Highway Program Manual (Vol. 6, Chap. 2) require approval on an individual project basis.

1. AASHTO (formerly AASHO):

(Note--AASHTO publications are subject to updating and/or revisions as changes in concepts and standards develop. Therefore, the designer should ascertain as to the latest edition of the following publications that may be in effect at the time of design.)

a. Geometric Design Standards for Highways Other Than Freeways—1969
b. Geometric Design Guide for Local Roads and Streets—1970
c. Standard Specifications for Highway Bridges—1973, as amended
d. Specifications for Design and Construction of Structural Supports for Highway Signs—1968
e. Specifications for the Design and Construction of Structural Supports for Highway Luminaries.—1970, as amended
f. Standard Specifications for Welding of Structural Steel Highway Bridges—1974
g. A Policy on Geometric Design of Rural Highways—1965

h. A Policy on Design of Urban Highways and Arterial Streets—1973
i. A Policy on the Accommondation of Utilities on Freeway Rights-of-Way—1969
j. A Policy on U-Turn Median Openings on Freeways—1960
k. A Policy on Design Standards for Stopping Sight Distances—1971
l. Highway Definitions—1968
m. Highway Design and Operational Practices Related to Highway Safety—1974
n. A Guide for Bicycle Routes—1974
o. Guide Specifications for Highway Construction—1972
p. Highway Drainage Guidelines, Volumes I, II and III—1973, and IV—1975
q. Interim Guide for Design of Pavement Structures—1972
r. A Guide for Highway Landscape and Environmental Design—1970
s. An Informational Guide for Roadway Lighting—1969
t. A Guide for Accommondating Utilities on Highway Rights-of-Way—1969
u. A Guide for Erecting Mail Boxes on Highways—1969
v. A Guide for Protective Screening of Overpass Structures—1969
w. Guide on Evaluation and Attenuation of Traffic Noise—1974
x. An Informational Guide for Fencing Controlled Access Highways—1967
y. Standard Specifications for Transportation Materials and Methods of Sampling and Testing—1974

2. Federal Highway Administration (FHWA):

a. Manual on Uniform Traffic Control Devices for Streets and Highways—1971
b. Handbook of Highway Safety Design and Operating Practices—1973, as amended
c. Capacity Analysis Techniques for Design of Signalized Intersections—1967
d. Capacity Analysis Techniques for Design and Operation of Freeway Facilities—1974
e. Corrugated Metal Pipe—1970
f. Reinforced Concrete Pipe Culverts—1963
g. Reinforced Concrete Bridge Members—1969
h. Standard Plans for Highway Bridges

Vol 1 — Concrete Superstructures—1968
Vol 2 — Structural Steel Superstructures—1968
Vol 4 — Typical Continuous Bridges—1969

i. Typical Plans for Retaining Walls—1969

3. Others:

a. Highway Capacity Manual, HRB Special Report 87—1965
b. Recommended Practices for Railroad-Highway Grade Crossing Warning Systems, Bulleting 7, Association of American Railroads—1974

Reference to other publications providing design guidance on such specific items as hydraulics, drainage, bridges, traffic barriers, lighting, aerial surveys, etc. are included in other appropriate chapters throughout this manual.

1-06 DETERMINATION OF DESIGN REQUIREMENTS

The determination of the general design requirements for a particular route or project is initially made by the Transportation Planning Area of the Department. The general standards selected result from the planning process which includes the system planning studies, corridor studies, and route location studies. This planning process is covered in detail in the ACTION PLAN which was approved in 1974.

The Transportation Planning Area is responsible for route and project development activities up to the location approval stage. However, the Design Area does participate actively during the corridor and location study stages including the furnishing of very preliminary geometric design data and construction cost estimates. The Design Area also provides during these stages information on soils, geology, drainage areas, structures and other technical data needed for the evaluation of the economic, social and environmental aspects of the alternates under consideration.

The Transportation Planning Area is responsible for route location and selection studies including the development of the alternate routes report and the final Route Location Report. The latter includes the general design criteria for the route which is based on the service to be provided and the traffic estimates that have been made.

The design traffic data is essential to the designer. This is furnished by the Transportation Planning Area in the form of traffic flow and turning movement diagrams for the design year. The normal design period used by the Department is 20 years for primary and secondary highways, both rural and urban. However, for low volume secondary highways a 10 years design period is used if the estimated annual average daily traffic (ADT) will not exceed 1,200 vehicles within that period. Commonwealth system municipal roads are designed for their current traffic volume except where the service they provide warrants a 10 or 20 years design period as determined from the highway planning studies.

After the location has been approved, the project becomes the responsibility of the Design Area and it enters the preliminary and final design phases. During the preliminary design phase the general design criteria provided in the approved Route Location Report are further evaluated and expanded to cover in more detail such items as design speed, geometrics, typical sections and structures. The end product of the preliminary design phase is the Preliminary Engineering Design Report which, after review and approval (including public hearings, if required) provides the basic design for the development of the final construction plans.

Corridor and location studies, and preliminary design reports are discussed in Chapter 18 on Route and Project Planning.

1–07 TRAFFIC ELEMENTS

The following definitions apply to traffic data elements pertinent to design which are used throughout this manual:

ADT— Average daily two-way traffic volume. The aplicable year is specified.

DHV— The design hourly volume. It is normally the estimated 30th highest hour two-way traffic volume for the design year selected. In some special cases it may be other than the 30 HV.

K— The ratio of DHV to ADT expressed as a percentage of ADT.

D— The directional distribution of traffic during the design hour. It is the one-way volume in the predominant direction of travel expressed as a percentage of DHV.

T— The proportion of trucks, exclusive of light delivery trucks, in the traffic stream expressed as a percentage of DHV.

V— The design speed in miles per hour which is determined for the design and correlation of the physical features of a highway that influence vehicle operation. It is the maximum safe speed that can be maintained over specified section of highway when conditions are so favorable that the design features of the highway govern.

When designing interchanges and major intersections it is necessary to know the volumes of all movements ocurring simultaneously. The directional DHV is determined by the use of the following formula:

$$\text{DHV (one way)} = \text{ADT} \times K \times D$$

1–08 DESIGN DESIGNATION

Design designation is an expression indicating the major controls or services for which a given highway is designed. The design designation is concise so that it can be readily understood, but complete enough to show the major design controls aplicable to a project.

The major design controls include traffic volume and composition, design speed, and control of access. These controls determine the principal geometric features to be applied. Other design controls and criteria such as topography, physical features, design vehicles, capacity, safety, parking, pedestrian services, and economics are of primary concern but these are either reflected in the major controls or have to do with the more detailed features of the design which are not considered necessary for inclusion in a concise and simple design designation.

The following items are normally included in the design designation:

Control of access— indicated as full, partial or none.

ADT— for current year.

ADT— for design year.

DHV— this ranges 9-14% of ADT for rural highways and 8-13% for urban highways in Puerto Rico.

D— ranges 50-75% of DHV.

T— ranges 3-18% of DHV for rural highways.

V— ranges 20-70 mph depending on the type of highway and character of terrain.

The design designation of each project is included in the title sheet to provide the plan users with a readily available brief reference of the major design controls applicable to the project.

1–09 DESIGN VEHICLES

There are six design vehicles used as controls in geometric design. These vehicles and their dimensions are summarized in Table 1-1. For design purposes, the largest vehicle which represents a significant percentage of the traffic for the design year is used. The design vehicles to be used on expressways and major highways are specified in the tabulations of general design requirements included in this chapter. The semitrailer-full trailer combination (WB-60) is not legal in Puerto Rico.

On most other highways accomodating truck traffic, one of the design semitrailer combinations should be considered in the design, particularly where turning roadways are bordered by curbs or islands.

TABLE 1-1

DESIGN VEHICLES

DESIGN VEHICLE	DIMENSIONS IN FEET						
TYPE	SYMBOL	WHEEL-BASE	Overhang Front	Overhang Rear	Overall Length	Overall Width	Height
Passenger Car	P	11	3	5	19	7	—
Single Unit Truck	SU	20	4	6	30	8.5	13.5
Single Unit Bus	BUS	25	7	8	40	8.5	13.5
Semitrailer Combination, Intermediate	WB-40	13+27=40	4	6	50	8.5	13.5
Semitrailer Combination Large	WB-50	20+30=50	3	2	55	8.5	13.5
Semitrailer-full trailer Combination	WB-60	9.7+20+9.4+20.9=60	2	3	65	8.5	13.5

1-10 HIGHWAY CAPACITY

The capacity of a highway is a measure of its ability to serve traffic. Highway capacity is considered in two general categories — uninterrupted flow or open highway conditions and interrupted flow as at intersections. Uninterrupted flow occurs in highways with control of access and to a considerable extent on highways where the influece of intersections and abutting property development is not significant.

The basic guide on highway capacity is the 1965 Highway Capacity Manual published by the Highway Research Board (now the Transportation Research Board) as Special Report 87. However, the AASHTO 1965 Policy on Geometric Design of Rural Highways, commonly referred to as the Blue Book, provides the essential working data on capacity in a more condensed, ready-to-use form. Similarly, the AASHTO 1973 Policy on Design of Urban Highways and Arterial Streets, the Red Book, includes condensed data concerning design capacity of urban highways.

This chapter includes a summary of pertinent factors and design values adapted from the above publications which can be applied by the designer to most design analysis for open highway conditions. Capacity of intersections-at-grade is discussed in Chapter 4, and of interchange ramps and weaving sections in Chapter 5.

1–10.01 DEFINITIONS

The following are definitions and explanations of the major terms and variables used in discussions of highway capacity in this manual.

CAPACITY—The maximum number of vehicles which have a reasonable expectation of passing over a section of a lane or a roadway in one direction (or in both directions for a two-lane highway) during a given time period (usually one hour) under prevailing roadway and traffic conditions. Prevailing roadway conditions refer to those that are established by the physical features of the roadway such as grades, horizontal alignment, lane width, and clearance to obstructions. Prevailing traffic conditions refer to those that are dependent upon the nature of the traffic on the roadway.

TABLE 1-2

LEVEL OF SERVICE CHARACTERISTICS BY HIGHWAY TYPE

LEVEL OF SERVICE	TWO - LANE	MULTI-LANE RURAL W/o ACCESS CONTROL	URBAN AND SUB-URBAN ARTERIALS	CONTROLLED ACCESS HIGHWAYS
A	Operating speeds of 60 m.p.h. or higher. 75% of passing maneuvers can be made with little or no delay. Under ideal conditions, a service volume of 400 passenger vehicles/ hour, two-way, can be achieved.	Operating speed 60 m.p.h. or greater. Under ideal conditions, volume is limited to 600 passenger cars per lane per hour or 30 per cent of capacity. Average speeds are likely to be influenced by speed limits.	Average over-all travel speed of 30 m.p.h. or more. Free flowing with volume/capacity ratio of 0.60. Load factor at intersections near the limit of the 0.0 range. Peak-hour factor at about 0.70.	Free flow. Operating speeds at or greater than 60 m.p.h. Service volume of 1400 passenger cars per hour on 2-lanes, one direction. Each additional lane serves volume of 1000 v.p.h./lane.
B	Operating speeds of 50 m.p.h. or higher. Volumes may reach 45% of capacity with continuous passing sight distance. Volumes of 900 passenger cars per hour, two-way, can be carried under ideal conditions.	Beginning of stable flow area. Volume at which actions of preceding vehicle will have some influence on following vehicles. Volume will not exceed 50% of capacity or 1000 passenger vehicles per lane per hour at a 55 m.p.h. Operating speed under ideal conditions.	Average over-all speeds drop due to intersection delay and intervehicular conflicts, but remain at 25 m.p.h. or above. Delay is not unreasonable. Volumes at 0.70 of capacity and peak-hour factor approximately 0.80. Load factor at intersections approx. 0.1.	Higher speed range of stable flow. Operating speed at or greater than 55 m.p.h. Service volume on 2-lanes in one direction not greater than 2000 passenger vehicles per hour. Each additional lane above two in one direction can serve 1500 v.p.h.
C	Flow still stable. Operating speeds of 40 m.p.h. or above with total volume under ideal conditions equal to 70% of capacity with continuous passing sight distance, or 1400 passenger vehicles per hour, two-way.	Stable flow to a volume not exceeding 75% of capacity or 1500 passenger cars per lane per hour, under ideal conditions, maintaining at least a 45 m.p.h. operating speed.	Service volumes about 0.80 of capacity. Average over-all travel speeds of 20 m.p.h. Operating conditions at most intersections approximate load factor of 0.3. Peak hour factor approximately 0.85. Traffic flow still stable with acceptable delays.	Operation still stable, but becoming more critical. Operating speed of 50 m.p.h. and service flow on two-lanes in one direction at 75% of capacity or not more than 5 min. flow rate of 3000 passenger cars per hour. Under ideal conditions each additional lane above two in one direction would serve 1800 v.p.h.
D	Approaching unstable flow. Operating speeds approx. 35 m.p.h. Volumes, two-direction, at 85% of capacity with continuous passing opportunity, or 1700 passenger cars per hour under ideal conditions.	Approaching unstable flow at volumes up to 90% of capacity or 1800 passenger cars per lane per hour at an operating speed of about 35 m.p.h. under ideal conditions.	Beginning to tax capabilities of street section. Approaching unstable flow. Service volumes approach 0.90 of capacity. Average over-all speeds down to 15 m.p.h. Delays at intersections may become extensive with some cars waiting two or more cycles. Peak hour factor approx. 0.90; load factor of 0.7.	Lower speed range of stable flow. Operation approaches instability and is susceptible to changing conditions. Operating speeds approx. 40 m.p.h. & service flow rates at 90% of capacity. Peak 5 min. flow under ideal conditions cannot exceed 3600 v.p.h. for 2-lanes, 1 direction; 1800 v.p.h. each added lane.
E	Operating speeds in neighborhood of 30 m.p.h. but may vary considerably. Volumes under ideal conditions, two-way, equal to 2000 passenger vehicles per hour. Level E may never be attained. Operation may go directly from Level D to Level F.	Flow at 100% of capacity or 2000 passenger cars per lane per hour under ideal conditions. Operating speeds of about 30 m.p.h. or less.	Service volumes at capacity. Average over-all traffic variable, but in area of 15 m.p.h. Unstable flow. Continuous back-up on approaches to intersections. Load factor at intersections in range between 0.7 and 1.0 Peak hour factor likely to be 0.95.	Unstable flow. Over-all operating speeds of 30-35 m.p.h. Volumes at capacity or about 2000 v.p.h./lane under ideal conditions. Traffic flow metered by design constrictions and bottlenecks, but long back-ups do not normally develop upstream.
F	Forced, congested flow with unpredictable characteristics. Operating speeds less than 30 m.p.h. Volumes under 2000 passenger cars per hour, two-way.	Forced flow, congested condition with widely varying volume characteristics. Operating speeds of less than 30 m.p.h.	Forced flow. Average over-all traffic speed below 15 m.p.h. All intersections handling traffic in excess of capacity with storage distributed throughout the section. Vehicular back-ups extend back from signalized intersections, through unsignalized intersections.	Forced flow. Freeway acts as a storage for vehicles backed-up from downstream bottleneck. Operating speeds range from near 30 m.p.h. to stop-and-go operation.

LEVEL OF SERVICE—A qualitative measure of the effect of a number of factors affecting capacity which include speed, travel time, traffic interruptions, freedom to maneuver, safety, driving comfort, convenience and operational costs. Specific levels of service range from ideal operation (Level A) to complete congestion (Level F). The various levels of service as pertain to types of highways are summarized in Table 1-2. Capacity occurs at Level E.

SERVICE VOLUME—The maximum number of vehicles that can pass over a given section of lane or roadway in one direction (or in both directions on a two-lane highway) for a specified time period (usually one hour) while operating conditions are maintained corresponding to the selected or specified level of service.

DESIGN CAPACITY—Comparable to the term service volume for a given level of service.

AVERAGE HIGHWAY SPEED—The weighted average of the design speeds within a highway section when each subsection within the section is considered to have an individual design speed.

OPERATING SPEED—The highest overall speed at which a driver can travel on a given highway under favorable weather conditions and under prevailing traffic conditions without exceeding the safe speed used for design.

RUNNING SPEED—The speed over a specified section of highway, being the distance divided by the running time. The average for all traffic is the summation of distances divided by the summation of running times.

PEAK HOUR FACTOR (PHF)—The ratio of the volume occurring during the peak hour to the maximum rate of flow during a part of the hour, usually 5 minutes for operation on freeways and 15 minutes on intersections. This factor applies for urban freeways at levels of service C and D and at intersections, but not to rural freeways. Common values are about 0.8 to 0.9.

LOAD FACTOR—The ratio of the total number of green signal intervals that are fully utilized by traffic during the peak hour to the total number of green intervals for that approach. Common values within the design range are 0.2 to 0.6.

1–10.02 UNINTERRUPTED FLOW-GENERAL

The designer should determine by analysis the design characteristics of a highway and the corresponding running speed which in combination will have a design capacity at the selected level of service which is at least as great as the design volume. Normally, highways should be so designed that the designated average running speeds can be maintained during the design hour; that is, when the design hour volume (DHV) is using the highway.

Three ranges of **average running speed** are considered appropriate for use in the design of arterial and collector highways as follows:

45—50 mph—Applicable for most main rural 2-lane, two-way highways and all rural multilane highways in level and rolling terrain. Corresponds approximately to level of service B.

40—45 mph—Applicable to highways approaching urban areas, for multilane highways in mountainous terrain, and where feasible for 2-lane highways in mountainous terrain. Corresponds approximately to level of service C.

35—40 mph—Applicable to 2-lane rural highways in mountainous terrain where design for higher speeds is not feasible, and to controlled access highways in urban areas where it is expected that during the design hour freedom to travel at high speed will be curtailed by DHV traffic. Corresponds approximately to level of service D.

It is generally not economically feasible to provide a facility that will permit running speeds during the design hour higher than those mentioned above. For low volume local roads and streets such as municipal roads in mountainous terrain, economic factors normally require the designing for even lower average running speeds.

Table 1–3 shows the capacities for highways constructed to high standards including 12–foot (3.65 M.) lanes, adequate shoulders, lateral clearances of 6 feet (1.83 M) or more, no trucks, adequate stopping sight distance throughout and no restrictive passing sight distance when the highway is 2–lane, two-way.

TABLE 1-3

POSSIBLE AND DESIGN CAPACITIES OF HIGHWAYS CONSTRUCTED TO HIGH DESIGN STANDARDS IN TERMS OF PASSENGER CARS PER HOUR

Type of Highway	Possible capacity	Design capacity for average running speed* in mph of:		
		35-40	40-45	45-50
	vph	vph	vph	vph
2-Lane, two-way (total)	2,000	1,500	1,150	900
Multilane (per lane)	2,000	1,500	1,200	1,000

*Running speed for the faster vehicles, termed "Operating Speed" in the Highway Capacity Manual, will exceed the average running speeds shown by an amount varying from about 5 mph (in the case of 35-40 mph average) to about 7 mph (in the case of the 45-50 mph average).

However, the values in Table 1–3 are seldom attainable since ideal highway conditions rarely prevail. Adjustment factors are aplied to correct for prevailing roadway and traffic conditions and derive the needed working values. The more important adjustment factors include: lane width, lateral clearance, type of terrain, composition of traffic, alignment and sight distances, and degree of access control or roadside and intersectional interference.

The effect that trucks (and buses) have on capacity is primarily a function of the difference between the average speed of the trucks and the average running speed of the passenger cars on the highway. The disparity between the speeds of the two classes of vehicles increases when the grades are sufficiently long and steep to slow down the trucks but where passenger cars are not impeded by alignment and grades. In addition, the physical dimensions of heavy trucks and their poorer accelerating characteristics also have a bearing on the space they occupy in the traffic stream. For example, the average dual-tired truck occupies about twice the space of the average passenger car when grades are nearly level and trucks can travel almost as fast as passenger cars.

The effect that trucks and buses have on capacity and the adjustment factors to be used are covered in considerable detail in the Highway Capacity Manual. Average generalized factors for converting trucks and buses to equivalent passenger cars are as follows:

Type of Highway and Vehicle	Level	Terrain Rolling	Mountainous
Two–lane Highway			
Truck	2	5	10
Bus	2	4	6
Multilane Highway			
Truck	2	4	8
Bus	1.6	3	5

Separate consideration of buses is not warranted in most capacity analyses, only where bus volumes are a significant portion of the traffic stream.

The following sections provide summarized capacity data and tabulations for direct application by the designer to capacity analyses generally under uninterrupted flow conditions. The information provided will allow the designer to arrive at practical conclusions in most cases that he will encounter. It is doubtful that greater precision will be required particularly in view of the reliability of future traffic volume forecasts. However, if greater precision is required and for more complex cases the designer should refer to the Highway Capacity Manual.

1–10.03 TWO–LANE HIGHWAYS

Tables 1–4 through 1–6 show design capacities for uninterrupted flow under various conditions on 2–lane two-way highways. Since the distribution of traffic by directions is not a factor in determining the capacity of 2–lane highways when flow is uninterrupted, the values given in these tables are in total number of vehicles per hour in both directions of travel.

Two–lane highways have a restriction not found on multilane highways resulting from the need for traffic to occupy the lane of opposing traffic when passing. Thus, the character of alignment and profile of these roads, the design speed, and the extent of restrictive sight distance have a considerable effect on their capacity.

Tables 1–4, 1–5 and 1–6 show design capacities considering five basic variables–terrain, percentage of restricted sight distance under 1500 feet (457 meters), lane width, percentage of trucks in the traffic stream and design speed. The sight distance of 1500 feet is not the safe passing sight distance which varies with design speed but is a value selected in the Highway Capacity Manual as a measurement criteria to evaluate design capacity of 2–lane highways.

Table 1–4 which shows design capacities for average running speeds of 45–50 mph corresponds approximately to volumes for a level of service B. This is the level recommended for use, wherever feasible, in the design of major rural 2–lane highways in level and rolling terrain.

The design capacities in Table 1–5, for average running speeds of 40–45 mph, correspond approximately to service level C. This is the level recommended for major 2–lane highways approaching urban areas and, whenever feasible, on rural highways in mountainous terrain. Service level "C" is also the minimum acceptable for the design of major 2–lane rural highways in level and rolling terrain.

Table 1—6 shows design capacities for average running speeds of 35—40 mph which correspond approximately to service level D. This level is acceptable for 2—lane highways with uninterrupted flow in urban areas and is the minimum acceptable level for the design of major rural roads in mountainous terrain.

Table 1—4, 1—5 and 1—6 are all based on shoulder width and lateral clearances of at least 6 feet (1.8 meters). Table 1—7 includes capacity reduction factors to be applied where shoulders and/or lateral clearances are less than 6 feet.

Tables 1—4 through 1—6, together with Table 1—7, may be used directly in design with interpolation as required to quickly evaluate design capacity. They may also be used in highway planning and in the preliminary stages of design to determine generally the extent of improvenent needed on an existing highway to serve an anticipated traffic load.

TABLE 1-4

DESIGN CAPACITIES OF 2-LANE, TWO-WAY HIGHWAYS FOR AVERAGE RUNNING SPEED OF 45-50 MPH IN VPH
Applicable for most main rural 2-lane highways in level and in rolling terrain

Terrain	Alignment: Percentage of total length of highway on which sight distance is restricted to less than 1500 feet*	Design capacity of 2-lane highway, total both directions L = width of lane and T = percentage of trucks, peak hour					
		L = 12'			L=11'		
		T= 0	10	20	T= 0	10	20
		1. Design Speed 65 or 70 mph					
Level	0	900	780	690	11-foot lanes not appropriate for high design speed with heavy volume		
	20	860	750	660			
	40	800	700	620			
Rolling	20	860	615	485			
	40	800	570	450			
	60	720	510	400			
		2. Design Speed 60 mph					
Level	0	900	780	690	775	670	590
	20	810	705	625	700	605	540
	40	700	610	540	600	525	465
	60	585	510	450	500	440	390
Rolling	20	810	580	450	700	500	390
	40	700	500	390	600	430	340
	60	585	420	325	500	360	280
	80	480	340	270	410	290	230
3. Design Speed 50 mph Highways with design speed no higher than 50 mph are not capable of providing 45-50 mph running speed except when traffic volume is very low.							

*Sight distance measured from height of eye to road surface, both vertical and horizontal alignment considered.

NOTE: To obtain possible capacity, use values in table for zero sight distance restrictions and multiply by 2.22 for 12-foot lanes and 2.27 for 11-foot lanes. Tabular values are for conditions with no restrictive lateral clearances; with clearance of less than 6 feet, edge of lane to obstruction, or with shoulders narrower than 6 feet, multiply above values by factor from Table 1-7.

TABLE 1-5

DESIGN CAPACITIES OF 2-LANE, TWO-WAY HIGHWAYS FOR AVERAGE RUNNING SPEED OF 40-45 MPH IN VPH.
Applicable for highways approaching urban areas and, wherever feasible, for highways in mountainous terrain

Terrain	Alignment: Percentage of total length of highway on which sight distance is restricted to less than 1500 feet*	Design capacity of 2-lane highway, total both directions L = width of lane and T = percentage of trucks, peak hour								
		L = 12'			L = 11'			L = 10'		
		T = 0	T = 10	T = 20	T = 0	T = 10	T = 20	T = 0	T = 10	T = 20
		1. Design Speed 65 or 70 mph								
Level	0	1150	1000	880	11-foot lanes not appropriate for high design speed with heavy volume			10-foot lanes not appropriate for high design speed with heavy volume		
	20	1120	970	860						
	40	1070	930	820						
Rolling	20	1120	800	630						
	40	1070	760	600						
	60	920	650	520						
		2. Design Speed 60 mph								
Level	0	1150	1000	880	990	860	760	10-foot lanes not appropriate for 60 mph design speed with heavy volume		
	20	1050	910	810	900	780	700			
	40	930	810	720	800	700	620			
	60	810	700	620	700	600	530			
Rolling	20	1050	800	630	960	690	540			
	40	930	660	520	800	570	450			
	60	810	580	450	700	500	390			
	80	680	480	380	580	410	330			
Mountainous	40	930	490	330	800	420	280			
	60	810	430	290	700	370	250			
	80	680	360	240	580	310	210			
		3. Design Speed 50 mph**								
Level	0	1010	880	780	870	760	670	780	680	600
	20	900	780	690	770	670	590	690	600	530
	40	770	670	590	660	580	510	590	520	450
Rolling	20	900	640	500	770	550	430	690	490	380
	40	770	550	430	660	470	370	590	420	330
	60	620	440	350	530	380	300	480	340	270
	80	440	310	250	380	270	220	340	240	190
Mountainous	40	770	410	280	660	350	240	590	320	220
	60	620	330	220	530	280	190	480	250	170
	80	440	230	160	380	200	140	340	180	120

*Sight distance measured from height of eye to road surface, both vertical and horizontal alignment considered.

**Normally 50 mph is the lowest design speed suitable where a running speed of 40-45 is appropriate with volumes approaching design capacity.

NOTE: To obtain possible capacity, use values in table for zero sight distance restriction and multiply by 1.74 for 12-foot lanes; 1.78 for 11-foot lanes, and 1.83 for 10 foot lanes.

Tabular values are for conditions with no restrictive lateral clearances; with clearances of less than 6 feet, edge of lane to obstruction, or with shoulders narrower than 6 feet, multiply above values by factor from Table 1-7.

TABLE 1-6

DESIGN CAPACITIES OF 2-LANE, TWO-WAY HIGHWAYS FOR AVERAGE RUNNING SPEED OF 35-40 MPH IN VPH

Applicable for 2-lane highways with uninterrupted flow in urban areas and to 2-lane rural highways in mountainous terrain where design for higher running speed is not feasible

Terrain	Alignment: Percentage of total length of highway on which sight distance is restricted to less than 1500 feet*	Design capacity of 2-lane highway, total both directions L = width of lane and T = percentage of trucks, peak hour								
		L = 12'			L = 11'			L = 10'		
		T = 0	T = 10	T = 20	T = 0	T = 10	T = 20	T = 0	T = 10	T = 20
		1. Design Speed 65 or 70 mph								
Level	0	1500	1300	1160	11-foot lanes not appropriate for high design speed with heavy volume			10-foot lanes not appropriate for high design speed with heavy volume		
	20	1450	1260	1120						
	40	1400	1220	1080						
Rolling	20	1450	1030	820						
	40	1400	1000	780						
	60	1350	960	750						
		2. Design Speed 60 mph								
Level	0	1500	1300	1160	1290	1120	990	10-foot lanes not appropriate for 60 mph design speed with heavy volume		
	20	1410	1230	1080	1210	1050	930			
	40	1320	1150	1020	1140	990	880			
	60	1220	1060	940	1050	910	810			
Rolling	20	1410	1000	790	1210	860	680			
	40	1320	940	740	1140	810	640			
	60	1220	870	680	1050	750	590			
	80	1110	790	620	950	680	520			
Mountainous	40	1320	700	480	1140	600	410			
	60	1220	650	440	1050	560	380			
	80	1110	590	400	950	500	340			
		3. Design Speed 50 mph								
Level	0	1450	1260	1120	1250	1080	960	1120	990	860
	20	1340	1160	1040	1150	1000	890	1040	910	800
	40	1200	1040	930	1040	900	800	930	810	720
Rolling	20	1340	950	750	1150	820	640	1030	730	410
	40	1200	850	670	1040	740	580	930	660	520
	60	1050	750	590	900	640	500	810	580	450
Mountainous	40	1200	640	430	1040	550	380	930	490	330
	60	1050	560	380	900	480	320	810	430	290
	80	900	480	320	770	410	280	700	370	250
		4. Design Speed 40 mph								
Level	0	1200	1040	930	1040	900	800	930	820	720
	20	1070	930	820	920	800	710	820	720	630
	40	900	780	690	770	670	590	700	610	540
Rolling	20	1070	760	600	920	650	520	820	580	460
	40	900	640	500	770	550	430	700	500	390
	60	720	510	400	620	440	350	560	400	310
	80	460	330	260	400	280	220	350	250	200

(continues on next page)

TABLE 1-6 (Cont.)

Moun-tainous	40	900	480	320	770	410	280	700	370	250
	60	720	380	260	620	330	220	560	300	200
	80	460	240	170	400	210	140	350	180	130

*Sight distance measured from height of eye to road surface, both vertical and horizontal alignment considered.

NOTE: To obtain possible capacity, use values in table for zero sight distance restriction and multiply by 1.33 for 12-foot lanes; 1.36 for 11-foot lanes, and 1.40 for 10-foot lanes.

Tabular values are for conditions with no restrictive lateral clearances; with clearances of less than 6ft., edge of lane to obstruction, or with shoulders narrower than 6 feet, multiply above values by factor from Table 1-7.

TABLE 1–7

CAPACITY REDUCTION FACTORS FOR RESTRICTIVE LATERAL CLEARANCE BETWEEN PAVEMENT EDGE AND OBSTRUCTION ON SHOULDER OR FOR NARROW SHOULDER

(Applies to design or possible capacity values)

Clearance from pavement edge to obstruction in feet	Capacity Reduction Factor			
	Obstruction on one side		Obstruction on both sides	
	Two-lane highway	Two lanes in one direction of a four-lane highway	Two-lane highway	Two lanes in one direction of a four-lane highway
6	1.00	1.00	1.00	1.00
5	0.98	1.00	0.96	0.99
4	0.96	0.99	0.92	0.98
3	0.93	0.98	0.86	0.97
2	0.91	0.97	0.81	0.94
1	0.88	0.95	0.75	0.90
0	0.85	0.90	0.70	0.81

1-10.04 MULTILANE HIGHWAYS

The design capacity of highways with two or more lanes in each direction of travel can be related to the general conditions for 2—lane highways. However, the percentage of length with passing sight distance restriction does not apply but the degree of access control and intersectional or roadside interference assumes greater significance.

Where there is no cross or turning traffic or where crossroads are few and with low volumes that do not impede the smooth flow on the main highway, and the geometrics conform to high standards, the design capacity of multilane highways in terms of passenger cars per hour per lane approach those shown on Table 1—3. As roadside and crossroad interference with through traffic increases, as on major highways without control of access, the design capacity decreases substantially.

1-10.05 FREEWAYS AND OTHER EXPRESSWAYS

Although 2—lane rural expressways are included in the Puerto Rico general design standards, the capacity analyses for these follow the procedures as for other 2—lane highways covered in Section 1-10.04 of this chapter. This section covers the capacity of multilane freeways and other expressways.

As indicated in the Highway Capacity Manual, design volumes may vary over a significant range due to three major variables — number of lanes, peak hour factor, and average highway speed. However, in most current freeway design work, they will vary within a rather narrow range. For this reason the rounded values for design capacity of freeways given in this chapter will fit most desing situations without significant error.

Table 1—8 shows design capacity average per lane under various conditions or terrain, percentage of trucks, and lane width for multilane rural and suburban highways. The values shown for suburban freeways may also be applied to freeways in mountainous terrain. With these volumes most freeways regardless of number of lanes will provide a service level C, unless the design speed is below 60 mph, in which case level D will be attained. The design capacity values for rural freeways and expressways will normally provide a service level B for 4— and 6- lane freeways with 70 mph design speeds.

Table 1-9 shows design capacity average per 12—foot lane for urban (built-up areas) and suburban freeways and other expressways for various conditions of terrain and percentages of trucks. The design capacities shown will normally provide a service level D while for the built-up area condition and a service level C for the suburban or outlying areas.

The average design capacity values per lane given in Tables 1-8 and 1—9 are for one direction of travel. Since during the design hour the directional distribution of traffic is seldom equal, it is necessary to consider the directional distribution of DHV, factor D, to determine the two-way capacity. This may be accomplished by the formula:

$$\text{Capacity (2—way)} = \frac{\text{Average lane capacity x No. of lanes in one direction}}{\text{D}}$$

1-10.06 MULTILANE HIGHWAYS WITHOUT ACCESS CONTROL

The design capacities given in the Blue Book for rural multilane highways are the same as those for rural freeways except for reductions in terms of the extent of interference from cross traffic and roadsides. These values are summarized as follows:

Extent of Interference	Maximum Design Capacity per lane — pass. cars/hour
Little or None	1000—1500
Moderate	700— 900
Considerable	500— 700

The first line may be within service level B, C or D, the same as for freeways, depending on the average running speed. The second and third lines reflect the effect of unsignalized intersections at grade and roadside interference with average running speeds of 45—50 mph and 40–45 mph respectively.

Table 1–8 shows the design capacity values for major rural multilane highways with moderate interference for various conditions of terrain, percentage of trucks and lane width.

1–10.07 ARTERIAL STREETS AND URBAN HIGHWAYS

The preceding segments of this section have covered highway facilities operating under uninterrupted flow conditions or under essentialy rural conditions with infrequent traffic interruptions. In urban areas, the adjacent development necessitates a closer control of traffic operations through the use of traffic control signals at intersections and/or low speed limits in relation to alignment. Therefore, intersection approach capacity is generally used as the primary measure of the capacity of urban facilities other than expressways. Occasionally midblock interruptions and interference are so significant that they may govern instead.

Basically, the capacity of an urban street represents the maximum utilization of that portion of the hour during which the street has a green signal indication. Although a high type urban street may carry traffic at flow rates approaching uninterrupted flow values while traffic is moving on a green signal phase, there are many periods when traffic does not move and the capacity in actual vehicles per hour will be far less than for uninterrupted flow.

Table 1–10 gives ranges of design capacity for arterial streets and urban highways which are useful as a general guide in estimating the number of lanes needed to serve the estimated design year traffic on such highways. The capacity of signalized intersections is covered in Chapter 4.

1–10.8 CAPACITY IN TERMS OF ADT

The most useful expression of capacity for design purposes is in terms of vehicles per hour. However, it is sometimes desirable to express capacity in terms of average daily traffic. Hourly design capacities may be converted to equivalent average daily traffic (ADT) through the application of the following formulas:

1. For 2–lane, two-way highways:

$$ADT = \frac{DHV}{K}$$

where DHV is the two-way hourly capacity

2. For multilane highways:

$$ADT = \frac{DHV \text{ x No. of lanes in one direction}}{K \text{ x } D}$$

where DHV is the hourly capacity per lane

Chapter II of the Blue Book includes tabulations (II–13 and II–14) showing ADT capacities for 2– lane and 4– lane rural highways for various values of K, D and T.

TABLE 1-8

DESIGN CAPACITY OF THROUGH TRAFFIC LANES ON MULTILANE RURAL AND SUBURBAN HIGHWAYS
Uninterrupted Flow

Width of lane in feet	Percent of trucks during peak hour	Design capacity, average per lane, in vph for:					
		Freeways, Suburban		Freeways and express-ways, rural		Major highways*	
		Terrain		Terrain		Terrain	
		Level	Rolling	Level	Rolling	Level	Rolling
12	0	1200	1200	1000	1000	800	800
12	10	1090	920	910	770	730	620
12	20	1000	750	830	630	670	500

NOTE: To obtain possible capacity multiply above values by 1.67 for suburban freeways and by 2 for rural expressways and major highways. For 11-foot traffic lanes reduce capacity by 3 percent; for 10-foot traffic lanes reduce capacity by 9 percent.

* The given values are representative of conditions where there is moderate interference from cross traffic and roadsides. Where there is heavy interference a reduction in these values may be appropriate.

TABLE 1-9

LANE DESIGN CAPACITIES FOR URBAN FREEWAYS AND EXPRESSWAYS

Percent of dual tire trucks during peak hour	Design capacity 1/, average per 12-foot lane, in VPH for:			
	Built-up area (Running speed 35 to 40 mph)		Suburban or outlying areas (Running speed 40 to 45 mph)	
	Level terrain	Rolling terrain	Level terrain	Rolling terrain
0	1500	1500	1200	1200
5	1430	1300	1140	1040
10	1360	1160	1090	920
15	1300	1030	1040	830
20	1250	940	1000	750

1/ Values are based on passenger car equivalents of 2 and 4, respectively, for level and rolling terrain.

1–11 GENERAL DESIGN STANDARDS

The basic general design standards for rural and urban highways used by the Department are summarized in Tables 1–11 through 1–15. These general standards are to be used in conjunction with other chapters in this manual and with the references included in Section 1–05. These standards are intended to be applied as general design controls based on functional class, level of service and design traffic but regardless of the administrative system of which the highway is a part.

Rural highways are typified by high speed (except for local rural roads), low traffic density operations with shoulders and open drainage channels as elements of the cross section. On the other hand, urban highways are typified by lower speed, high density operation with curb and gutter and underground drainage as elements of the cross section. The choice of rural or urban design shall be made on the basis of the anticipated character of the area being traversed.

Approximate ADT ranges are provided for each design class as an indication of capacity under average conditions for use in planning and project development activities. However, it is stressed that the design standards for any particular highway section shall be selected on the basis of its functional classification, proposed level of service, physical conditions, and a capacity analysis using the projected design hourly volume and traffic characteristics obtained from the highway planning studies. All arterial and collector highways, both rural and urban, are to be designed for the estimated DHV on a 20–year forecast. Design standards for local roads and streets are normally based on a 10–year traffic forecast.

Actually, right-of-way, alignment, grading, bridges and drainage structures are permanent investments which will have a service life expectancy considerably in excess of 20 years unless affected by obsolescence. Therefore, whenever the projected DHV appears to approach the capacity of the proposed design standard for a highway section, consideration should be given to providing an expandable design that will allow for constructing additional traffic lanes in the future without the necessity of acquiring additional rights-of-way and with a minimum of interference to existing traffic.

In the case of 2–lane arterial and collector highways, where it appears that four lanes will be required within 10 years after the design year, a 4–lane design should be provided with initial construction limited to two lanes but with the full 4–lane right-of-way acquired or protected.

In the case of multilane highways, expansion can normally be best accomplished by adding lanes in the median space. An expandable median width should be used on all multilane highway designs whenever feasible and shall be provided on all expressways where the traffic data indicates that the DHV is equal to or greater than 80% of the estimated capacity for a level of service "C" in the case of rural highways and "D" in the case of urban highways.

For a number of design elements, the standards specify minimum values. The use of more liberal values than these minimums is recommended where conditions are favorable and costs are not excessive.

1–11.01 RURAL HIGHWAYS

Design standards for classes R-7 and R-8 are lower than the AASHTO guides and FHWA requirements as to minimum surface widths. These minimum standards are not to be used on Federal-aid projects except when previously authorized by the FHWA on an individual project basis.

Design standards R-9, 10 and 11 are also lower than the AASHTO guides and FHWA requirements. These standards are normally used on low volume municipal and local roads not on the Federal-aid system. Use of these standards on any Federal-aid project requires prior approval of an exception by the FHWA.

The following notes apply to the general design standards for rural highways shown on Tables 1—11, 1—12 and 1—13.

1. The approximate ADT ranges shown for major highways are based on design capacities for average conditions of K=12%, D=60%, and T=10%; and 40% passing sight distance restrictions on 2—lane highways. Specific highway sections may have capacities outside the ranges shown depending on the variables of traffic characteristics, terrain, roadway conditions and level of service provided.

2. Terrain conditions are defined as follows:

Level (L)—generally flat terrain where sight distances, as governed by both horizontal and vertical restrictions, are generally long or could be made to be so without construction difficulty or major expense.

Rolling (R)—terrain where the natural slopes consistently rise above and fall below the highway grade line and where occasional steep slopes offer some restriction to normal highway horizontal and vertical alignment.

Mountainous (M)—terrain where longitudinal and transverse changes in elevation of the ground with respect to the highway are abrupt and where the roadbed is obtained by frequent benching or side hill excavation.

3. On rural expressways with partial control of access, design classes RE—3 and RE—4, intersections with major highways carrying high traffic volumes should be grade separated to attain essentially uninterrupted flow conditions and retain expressway capacity levels.

4. Desirable lane width for all arterial and collectors is 3.65 meters: therefore, wherever feasible this width should be used on design classes R—7 and R—8 (Table 1—12).

5. The minimum pavement width shown on Table 1—13 for local rural roads, design classes R—9, R—10 and R—11, should be increased by 1.2 meters wherever feasible.

6. Median width is a critical safety item on high-speed multilane highways. The minimum median width values shown are bare minimums and the designer should strive for wider medians whenever economically feasible. Medians wider than 9.0 meters normally do not require a median barrier, see Chapter 8.

7. Minimum surfaced or paved shoulder widths are indicated. Total shoulders width shall be as shown in the typical sections, see Chapter 2.

8. Right-of-way width provided for expressways shall be sufficient to accomodate the full cross section plus an additional two meters (preferably three) on each side when this requirement exceeds the minimum ROW widths shown on Table 1—11. On long structures the minimum right-of-way width may be limited to the out to out width of the structure plus an additional three meters on each side.

9. The minimum curve radius indicated for the main line in Tables 1—11 and 1—12 are based on Table III-5 of the AASHTO Policy on Geometric Design of Rural Highways (Blue Book). The minimum curve radius for interchange ramps and loops for expressways in Table 1—11 and for local rural roads with design speeds of 30 mph or less in Table 1—13, are derived from Table IX—2 of the Blue Book.

10. The maximum superelevation rate for expressways is 8%; however, on interchange down ramps a maximum rate of 10% may be authorized if required by site conditions.

11. Steep long grades have a marked influence on the operating speeds and capacity of highways, particularly 2—lane highways, because of the reduction in truck speeds. Grades of 4% or steeper and in excess of 200 meters in length on major highways should be analyzed for "critical length" as per Chapter 3 procedures to determine the possible need for climbing lanes.

12. Pavement widening on sharp curves shall be provided on all 2—lane rural roads with pavement width of less than 7.30 meters (Design Classes R—7 through R—11) as per Chapter 3 procedures.

1—11.02 URBAN HIGHWAYS

The following notes apply to the general design standards for urban highways shown on Tables 1—14 and 1—15.

1. The approximate ADT ranges shown for multilane highways are based on design capacities for average conditions of K=10%, T=5% and D=67%. Specific highway sections may have capacities outside of the ranges shown depending on the variables of traffic characteristics, roadway conditions, intersectional or roadside interference, and level of service provided.

2. A level of service C should be provided on all urban expressways unless costs are excessive.

3. On urban expressways with partial control of access, design classes UE—4 and UE—5, provision should be made for frontage roads.

4. Minimum design speeds for urban interchange ramps and loops shall be as provided in Table 1—11 for rural expressways.

5. Minimum median widths indicated for urban freeways (Design classes UE—1, 2, 3) in Table 1—14 are bare minimums which provide space for a median barrier (0.6 m) plus the median side shoulder. Whenever right-of-way and cost restrictions permit it, a wider median should be used, preferably 9.0 m for non-expandable and 16.3 m for expandable medians.

6. On non-controlled access urban highways, Table 1—15, the border includes a planting strip and sidewalk; however, in commercial areas the planting strip is normally paved for additional sidewalk width.

7. The width of pavement on local streets, design classes U-9 and U-10, will depend on whether one-way or two-way operation is proposed, and whether parking on one or two sides will be permitted.

TABLE 1-10

DESIGN CAPACITIES FOR ARTERIAL STREETS AND URBAN HIGHWAYS

Type of Highway	Design capacity, passengers cars per hour per 12-foot lane
Major suburban highway with moderate interference from cross traffic and roadsides; level of service "C"	700-900
Major suburban highway, considerable interference from cross traffic and roadsides; level of service "C"	500-700
Arterial street, traffic signals average one mile or more apart, parking prohibited and refuge provided for stalled vehicles; level of service "C"	400-600
Arterial street, traffic signals average less than one mile apart, parking prohibited	As governed by capacity of critical intersections

TABLE I-11

GENERAL DESIGN STANDARDS FOR RURAL EXPRESSWAYS[1]

DESIGN CLASS CODE		RE-1			RE-2			RE-3			RE-4		
APPROXIMATE ADT RANGE		OVER 25,000			15,000 - 25,000			5,000 - 15,000			UNDER 5,000		
MIN. LEVEL OF SERVICE		C			C			C			C		
TERRAIN[2]		L	R	M	L	R	M	L	R	M	L	R	M
CONTROL OF ACCESS		FULL			FULL			PARTIAL			PARTIAL		
CROSS ROAD TREATMENT		GRADE SEPARATED			GRADE SEPARATED			AS DETERMINED			AS DETERMINED		
RAILROAD CROSSING		GRADE SEPARATED			GRADE SEPARATED			GRADE SEPARATED			GRADE SEPARATED		
MINIMUM DESIGN SPEED (MPH)	MAIN LINE	70	60	50	70	60	50	70	60	50	60	60	50
	DIR. RAMPS	40	30	30	40	30	30	40	30	30	40	30	30
	LOOPS	30	30	25	30	30	25	30	30	25	30	30	25
	CROSS ROADS	AS REQUIRED			AS REQUIRED			AS REQUIRED			AS REQUIRED		
	FRONTAGE RDS.	40	30	30	40	30	30	40	30	30	40	30	30
NUMBER OF LANES		6			4			4			2		
LANE WIDTH		3.65			3.65			3.65			3.65		
PAVEMENT		SEE CHAPTER 7											
MIN. MEDIAN WIDTH		4.2[3]			4.2[3]			6.0			NONE		
EXPANDABLE MED. WIDTH		11.5			11.5			13.3			—		
MIN. SHOULDER WIDTH (SURFACED)	RIGHT	3.0			3.0			3.0			3.0		
	LEFT	1.8			1.2			1.2			NONE		
MIN. ROW WIDTH[4]		60			50			50			30		
MAX. SUPERELEVATION		8%			8%			8%			8%		
MINIMUM CURVE RADIUS	MAIN LINE	500	350	230	500	350	230	500	350	230	350	350	230
	DIR. RAMPS	140	65	65	140	65	65	140	65	65	140	65	65
	LOOPS	65	65	45	65	65	45	65	65	45	65	65	45
	CROSS ROADS	AS REQUIRED			AS REQUIRED			AS REQUIRED			AS REQUIRED		
	FRONTAGE RDS.	140	75	75	140	75	75	140	75	75	140	75	75
MIN. STOP. SIGHT DISTANCE		185	145	110	185	145	110	185	145	110	145	145	110
MIN. PASS. SIGHT DISTANCE		—			—			—			640	640	550
MAXIMUM GRADE PERCENT (%)	MAIN LINE	3	4	7	3	4	7	3	4	7	3	4	7
	DIR. RAMPS	6	7	7	6	7	7	6	7	7	6	7	7
	LOOPS	6	7	7	6	7	7	6	7	7	6	7	7
	CROSS ROADS	AS REQUIRED			AS REQUIRED			AS REQUIRED			AS REQUIRED		
	FRONTAGE RDS.	5	7	9	5	7	9	5	7	9	5	7	9
MINIMUM GRADE (%)		0.5			0.5			0.5			0.5		
DESIGN VEHICLE		WB-50			WB-50			WB-50			WB-50		
BRIDGES		SEE CHAPTER 6											

(1) ALL DIMENSIONS IN METERS UNLESS OTHERWISE SPECIFIED.
(2) L = LEVEL, R = ROLLING, M = MOUNTAINOUS.
(3) MINIMUM WIDTH FOR PAVED MEDIAN WITH BARRIER, SEE CHAPTER 8.
(4) MINIMUM WIDTH EXCLUSIVE OF ANY ROW REQUIRED FOR FRONTAGE ROADS.

TABLE 1-12

GENERAL DESIGN STANDARDS FOR OTHER RURAL ARTERIALS AND COLLECTORS[1]

(NON-CONTROLLED ACCESS)

DESIGN CLASS CODE	R - 5			R - 6			R - 7			R - 8		
APPROXIMATE ADT RANGE	OVER 6,000			2,000 - 6,000			1,000-2,000			UNDER 1,000		
MIN. LEVEL OF SERVICE	C			C			D			D		
TERRAIN[2]	L	R	M	L	R	M	L	R	M	L	R	M
MIN. DESIGN SPEED (MPH)	60	60	50	60	50	40	50	40	30	40	40	30
NUMBER OF LANES	4			2			2			2		
LANE WIDTH	3.65			3.65			3.35			3.05		
PAVEMENT	SEE CHAPTER 7											
MIN. MEDIAN WIDTH	6.0			NONE			NONE			NONE		
EXPANDABLE MED. WIDTH	13.3			—			—			—		
MIN. SHOULDER WIDTH	3.0	3.0	2.4	3.0	3.0	2.4	2.4	2.4	1.8	1.8	1.8	1.8
MIN. ROW WIDTH	50			30			22			20		
MAX. SUPERELEVATION	8 %			8 %			8 %			6 %		
MIN. CURVE RADIUS	350	350	230	350	230	140	230	140	75	150	150	70
MIN. STOP. SIGHT DISTANCE	145	145	110	145	110	85	110	85	60	85	85	60
MIN. PASS. SIGHT DISTANCE	—			640	550	460	550	460	335	460	460	335
MAX. GRADE (%)	3	4	7	3	5	8	4	6	9	5	6	9
MIN. GRADE (%)	0.5			0.5			0.5			0.5		
DESIGN VEHICLE	WB-50			WB-50			WB-40			WB-40		
BRIDGES	SEE CHAPTER 6											

(1) ALL DIMENSIONS IN METERS UNLESS OTHERWISE SPECIFIED.

(2) L = LEVEL , R = ROLLING , M = MOUNTAINOUS .

TABLE 1-13

GENERAL DESIGN STANDARDS FOR LOCAL RURAL ROADS[1]

DESIGN CLASS CODE	R-9			R-10			R-11		
APPROXIMATE ADT RANGE	OVER 400			100-400			UNDER 100		
TERRAIN[2]	L	R	M	L	R	M	L	R	M
MIN. DESIGN SPEED (MPH)	40	30	25	35	25	20	30	25	20
PAVEMENT WIDTH	5.5			4.9			4.0		
PAVEMENT	SEE CHAPTER 7								
MIN. SHOULDER WIDTH	1.25			1.25			1.25		
MIN. ROW WIDTH[3]	14.0			13.4			12.5		
MAX. SUPERELEVATION	6 %			6 %			6 %		
MIN. CURVE RADIUS	150	70	50	100	50	30	70	50	30
MIN. STOP. SIGHT DISTANCE	85	60	50	75	50	40	60	50	40
MIN. PASS. SIGHT DISTANCE	460	335	—	400	—	—	335	—	—
MAX. GRADE (%)	7	8	10	8	10	12	8	12	15
MIN. GRADE (%)	0.5			0.5			0.5		
DESIGN VEHICLE	SU			SU			SU		
BRIDGES	SEE CHAPTER 6								

(1) ALL DIMENSIONS IN METERS UNLESS OTHERWISE SPECIFIED.
(2) L = LEVEL, R = ROLLING, M = MOUNTAINOUS.
(3) ABSOLUTE MINIMUM. DESIRABLE MINIMUM IS 20 METERS TO ALLOW FOR FUTURE WIDENING.

TABLE 1-14

GENERAL DESIGN STANDARDS FOR URBAN EXPRESSWAYS[1]

DESIGN CLASS CODE	UE-1	UE-2	UE-3	UE-4	UE-5
APPROXIMATE ADT RANGE	OVER 60,000	40-60,000	UNDER 40,000	OVER 30,000	UNDER 30,000
MIN. LEVEL OF SERVICE	D	D	D	D	D
TOTAL LANES	8	6	4	6	4
CONTROL OF ACCESS	FULL			PARTIAL	
CROSS STREET TREATMENT	GRADE SEPARATED			AS DETERMINED	
MINIMUM DESIGN SPEED (MPH)	60	60	60	50	50
LANE WIDTH	3.65	3.65	3.65	3.65	3.65
MINIMUM MEDIAN WIDTH	6.6	5.4	4.2	6.0	6.0
EXPANDABLE MEDIAN WIDTH	—	13.9	11.5	13.3	13.3
MIN. SURFACED SHOULDER WIDTH — RIGHT	3.0	3.0	3.0	3.0	3.0
MIN. SURFACED SHOULDER WIDTH — LEFT	3.0	2.4	1.8	1.8	1.2
OUTER SEPARATOR	9.0 FOR 2-WAY FRONTAGE, 6.0 FOR ONE-WAY			6.0	6.0
FRONTAGE STREETS	AS REQUIRED - SEE CHAPTER 2			AS REQUIRED	
RIGHT-OF-WAY WIDTH	AS REQUIRED FOR TOTAL SECTION			AS REQUIRED	
MAXIMUM SUPERELEVATION	8%	8%	8%	8%	8%
MINIMUM CURVE RADIUS	350	350	350	230	230
MIN. STOPPING SIGHT DISTANCE	145	145	145	110	110
MAXIMUM GRADE (%)	4	5	5	5	5
MINIMUM GRADE (%)	0.35	0.35	0.35	0.35	0.35
DESIGN VEHICLE	WB-50	WB-50	WB-50	WB-50	WB-50
BRIDGES	SEE CHAPTER 6				

(1) ALL DIMENSIONS IN METERS UNLESS OTHERWISE SPECIFIED.

TABLE 1-15

GENERAL DESIGN STANDARDS FOR OTHER URBAN HIGHWAYS[1]

(NON-CONTROLLED ACCESS)

DESIGN CLASS CODE	U-6 AVENUE	U-7 PRINCIPAL ST.	U-8 PRINCIPAL ST.	U-9 LOCAL-COMM.	U-10 LOCAL-RES.
APPROXIMATE ADT RANGE	20-30,000	10-20,000	10-20,000	UNDER 8,000	—
MIN. LEVEL OF SERVICE	D	D	—	—	—
TOTAL TRAVEL LANES	6 DIVIDED	4 DIVIDED	4	2	2
MIN. DESIGN SPEED (MPH)	40	40	30	30	30
PAVEMENT WIDTH	2 @ 11.0 (NO PARKING)	2 @ 7.3 W/O PARK. 2 @ 10.3 W. PARK.	14.6 W/O PARK. 20.6 W. PARK.	8.0 - 12.0	8.0 - 11.0
MIN. MEDIAN WIDTH	6.0	4.25	NONE	NONE	NONE
MIN. ROW WIDTH	36	FULL ROADWAY PLUS BORDERS			
MAX. SUPERELEVATION	6%	6%	—	—	—
MIN. CURVE RADIUS	150	150	70	70	70
MIN. STOP. SIGHT DISTANCE	85	85	60	60	60
MAX. GRADE (%)	7	7	7	10	12
MIN. BORDER WIDTH	4.0	3.0	2.5	2.5	2.5
SIDE WALK WIDTH	1.5 - 4.0	1.5 - 3.0	1.5 - 2.5	2.5	1.25
DESIGN VEHICLE	WB-50	WB-50	WB-50	SU	SU
BRIDGES	SEE CHAPTER 6				

(1) ALL DIMENSIONS IN METERS UNLESS OTHERWISE SPECIFIED.