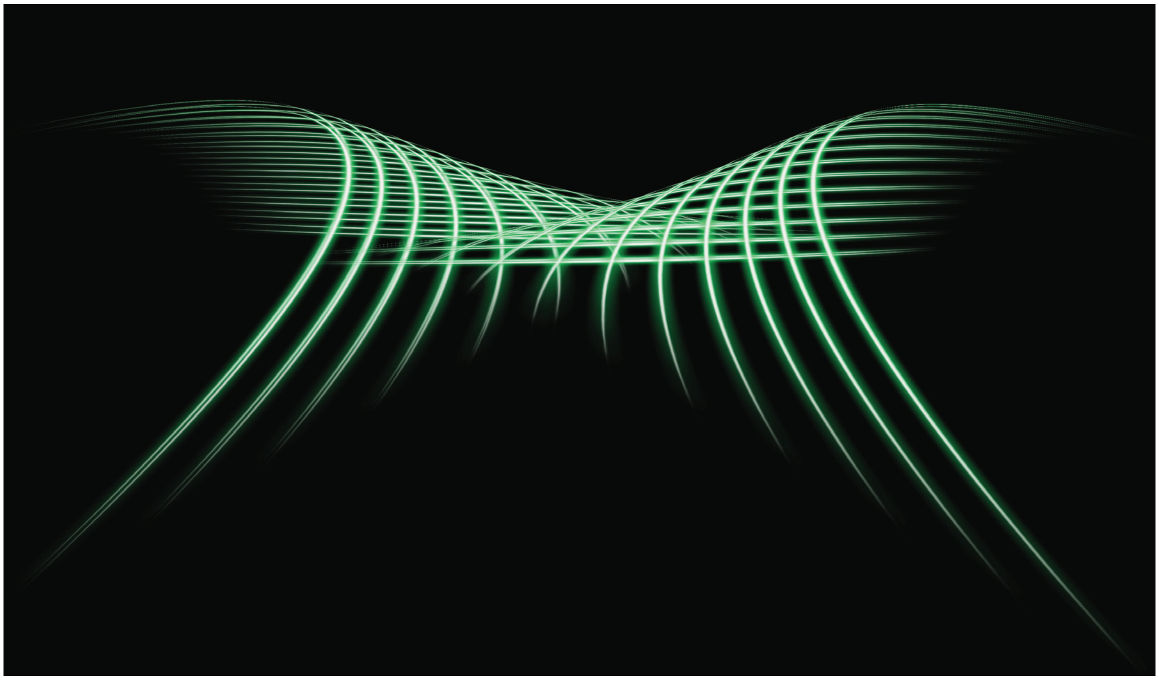
HCM2010

HIGHWAY CAPACITY MANUAL



CHAPTER 3

MODAL CHARACTERISTICS

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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HCM2010

HIGHWAY CAPACITY MANUAL

The HCM 2010 significantly enhances how engineers and planners assess the traffic and environmental effects of highway projects by

- Providing an integrated multimodal approach to the analysis and evaluation of urban streets from the points of view of automobile drivers, transit passengers, bicyclists, and pedestrians;
- Addressing the proper application of microsimulation analysis and the evaluation of the results;
- Examining active traffic management in relation to demand and capacity; and
- Exploring specific tools and generalized service volume tables to assist planners in quickly sizing future facilities.

The HCM 2010 consists of four volumes:

Volume 1: Concepts;
Volume 2: Uninterrupted Flow;
Volume 3: Interrupted Flow; and
Volume 4: Applications Guide (electronic only).

The four-volume format provides information at several levels of detail, to help users more easily apply and understand the concepts, methodologies, and potential applications.

Volumes 1, 2, and 3 are issued as a boxed set. Volume 4 is electronic only, accessible to registered HCM users via the Internet, and includes four types of content: supplemental chapters on methodological details and emerging issues; interpretations, clarifications, and corrections; comprehensive case studies; and a technical reference library.

To order HCM 2010, go to **http://books.trbbookstore.org/hcm10.aspx.**

For more information about HCM 2010 and TRB publications, contact the Transportation Research Board Business Office, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-3213; fax 202-334-2519; e-mail TRBsales@nas.edu; or through the Internet, www.trb.org).

CHAPTER 3
MODAL CHARACTERISTICS

CONTENTS

LIST OF EXHIBITS

1. INTRODUCTION

Roadways serve users of many different modes: motorists, pedestrians, bicyclists, and transit passengers. The roadway right-of-way is allocated among the modes through the provision of facilities that ideally serve each mode's needs. However, in many urban situations, the right-of-way is constrained by adjacent land development, causing transportation engineers and planners to consider trade-offs in how to allocate the right-of-way. Interactions among the modes that result from different right-of-way allocations are important to consider in analyzing a roadway, and the *Highway Capacity Manual* (HCM) provides tools for assessing these interactions. Local policies and design standards relating to roadway functional classifications are other sources of guidance on the allocation of right-of-way; safety and operational concerns should also be addressed.

Chapter 3, Modal Characteristics, introduces some basic characteristics of the four major modes addressed by the HCM. The following characteristics are considered in this chapter for each mode:

- Factors that contribute to a traveler's experience during a trip,
- Observed seasonal and daily variations in travel demand,
- Types of transportation facilities employed by a given mode,
- Notable capacity and volume observations, and
- Descriptions of the interactions that occur between modes.

Chapters 4 and 5 continue the discussion of multimodal performance. Chapter 4 discusses flow and capacity concepts and provides operational performance measures for each mode. Chapter 5 discusses quality and level-of-service (LOS) concepts and introduces the measures of effectiveness for each mode that the HCM uses to assess transportation facilities from a traveler point of view.

2. AUTOMOBILE MODE

VEHICLE AND HUMAN FACTORS

Three major elements affect driving: the vehicle, the roadway environment, and the driver. This section identifies vehicle and driver characteristics and how they are affected by the roadway's environment and physical properties.

Motor Vehicle Characteristics

Characteristics of various motorized roadway users.

This section provides a summary of the operating characteristics of motor vehicles that should be considered when a facility is analyzed. The major considerations are vehicle types and dimensions, turning radii and off-tracking, resistance to motion, power requirements, acceleration performance, and deceleration performance. Motor vehicles include passenger cars, trucks, vans, buses, recreational vehicles, and motorcycles. All of these vehicles have unique weight, length, size, and operational characteristics.

Vehicle acceleration and deceleration rates are factors that must be considered in designing traffic signal timing, computing fuel economy and travel time, and estimating how normal traffic flow resumes after a breakdown. Passenger cars accelerate after a stop at a rate ranging between 5.5 and 9 ft/s^2. Trucks, however, accelerate from a stop at rates ranging from 0.7 to 3 ft/s^2. Maximum passenger car deceleration rates range between 10 and 25 ft/s^2, depending on road surface and tire conditions, with deceleration rates of 10 ft/s^2 or less considered reasonably comfortable for passenger car occupants (*1*). Typical truck deceleration rates are 6.5 ft/s^2 or lower (*2*).

Driver Characteristics

Driving is a complex task involving a variety of skills. The most important skills are taking in and processing information and making quick decisions on the basis of this information. Driver tasks are grouped into three main categories: control, guidance, and navigation. Control involves the driver's interaction with the vehicle in terms of speed and direction (accelerating, braking, and steering). Guidance refers to maintaining a safe path and keeping the vehicle in the proper lane. Navigation means planning and executing a trip.

The way in which drivers perceive and process information is important. About 90% of information is presented to drivers visually. The speed at which drivers process information is a significant component affecting their successful use of the information. One parameter used to quantify the speed at which drivers process information is perception–reaction time, which represents how quickly drivers can respond to an emergency situation. Another parameter—sight distance—is directly associated with reaction time. There are three types of sight distance: stopping, passing, and decision. Sight distance is a parameter that helps determine appropriate geometric features of transportation facilities. Acceptance of gaps in traffic streams is associated with driver perception and influences the capacity and delay of movements at unsignalized intersections.

Factors such as nighttime driving, fatigue, driving under the influence of alcohol and drugs, the age and health of drivers, and police enforcement also contribute to driver behavior on a transportation facility. All these factors can affect the operational parameters of speed, delay, and density. However, unless otherwise specified, the HCM assumes base conditions of daylight, dry pavement, typical drivers, and so forth.

Base conditions are discussed generally in Chapter 4 and specifically in chapters in Volumes 2 and 3.

VARIATIONS IN DEMAND

The traffic volume counted at a given location on a given day is not necessarily reflective of the amount of traffic (*a*) that would be counted on another day or (*b*) that would be counted if an upstream bottleneck was removed. Traffic demand varies seasonally, by day of the week (e.g., weekdays versus weekends), and by hour of the day, as trip purposes and the number of persons desiring to travel varies. Bottlenecks—locations where the capacity provided is insufficient to meet the demand during a 15-min or hourly period—constrain the observed volume to the portion of the demand that can be served by the bottleneck. Because traffic counts only provide the portion of the demand that was served, the actual demand can be difficult to identify.

Demand relates to the number of vehicles that would like to be served by a roadway element, while volume relates to the number that can actually be served.

The following sections discuss monthly, daily, and hourly variations in traffic demand. Analysts need to account for these types of variations to ensure that the peak-hour demand volumes used in an HCM analysis are reflective of conditions on peak days of the year. Failure to account for these variations can result in an analysis that reflects peak conditions on the days counts were made, but not peak conditions over the course of the year. For example, a highway serving a beach resort area may be virtually unused during much of the year but become oversaturated during the peak summer periods.

Seasonal peaks in traffic demand must also be considered, particularly on recreational facilities.

Chapter 4, Traffic Flow and Capacity Concepts, discusses subhourly variations in demand. It is possible for a roadway's capacity to be greater than its hourly demand, yet traffic flow may still break down if the flow rate within the hour exceeds the roadway's capacity. The effects of a breakdown can extend far beyond the time during which demand exceeded capacity and may take several hours to dissipate.

A highway that is barely able to handle a peak-hour demand may be subject to breakdown if flow rates within the peak hour exceed capacity—a topic of Chapter 4.

The data shown in the exhibits in this section represent typical observations that can be made. The patterns illustrated, however, vary in response to local travel habits and environments, and these examples should not be used as a substitute for locally obtained data.

Data shown in these graphs represent typical observations but should not be used as a substitute for local data.

Seasonal and Monthly Variations

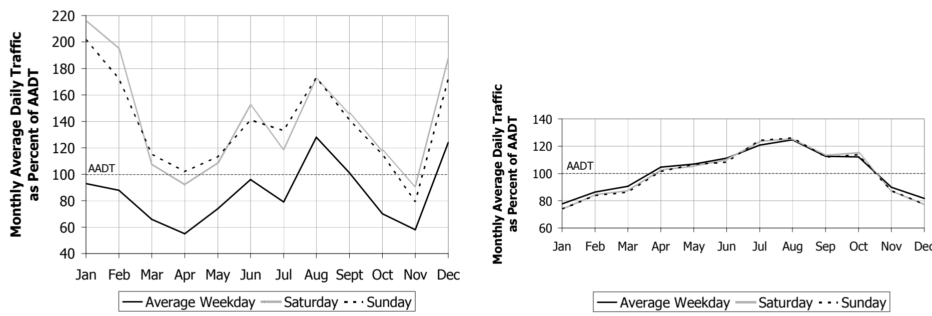
Seasonal fluctuations in traffic demand reflect the social and economic activity of the area served by the highway. Exhibit 3-1 shows monthly patterns observed in Oregon and Washington. The highway depicted in Exhibit 3-1(a) serves national forestland with both winter and summer recreational activity. The highway depicted in Exhibit 3-1(b) is a rural route serving intercity traffic. Two significant characteristics are apparent from this data set:

- The range of variation in traffic demand over the course of a year is more severe on rural routes primarily serving recreational traffic than on rural routes primarily serving intercity traffic; and
- Traffic patterns vary more severely by month on recreational routes.

Exhibit 3-1
Examples of Monthly Traffic Volume Variations for a Highway

Monthly volume variations for routes with recreational traffic show much higher seasonal peaking than for routes with predominantly intercity traffic.

The average daily traffic averaged over a full year is referred to as the annual average daily traffic, or AADT, and is often used in forecasting and planning.



(a) Routes with Significant Recreational Traffic (b) Routes with Significant Intercity Traffic

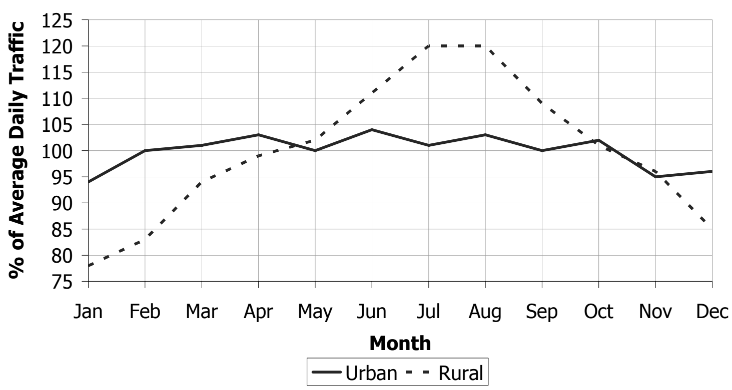
Note: (a) Highway 35 south of Parkdale, Oregon; (b) US-97 north of Wenatchee, Washington.
Source: (a) Oregon DOT, 2007; (b) Washington State DOT, 2007.

These and other similar observations lead to the conclusion that commuter- and business-oriented travel occurs in fairly uniform patterns, while recreational traffic creates the greatest variation in demand patterns.

The data for Exhibit 3-2 were collected on the same Interstate route. One segment is within 1 mi of the central business district of a large metropolitan area. The other segment is within 75 mi of the first but serves a combination of recreational and intercity travel. This exhibit illustrates that monthly variations in volume are more severe on rural routes than on urban routes. The wide variation in seasonal patterns for the two segments underscores the effect of trip purpose and may also reflect capacity restrictions on the urban section.

Exhibit 3-2
Examples of Monthly Traffic Volume Variations for the Same Interstate Highway (Rural and Urban Segments)

Monthly volume variations for rural segments of Interstate highways show much higher seasonal peaking than for urban segments of the same highway. This may reflect both recreational and agricultural traffic impacts.



Note: Urban, I-84 east of I-5 in Portland; rural, I-84 at Rowena.
Source: Oregon DOT, 2006.

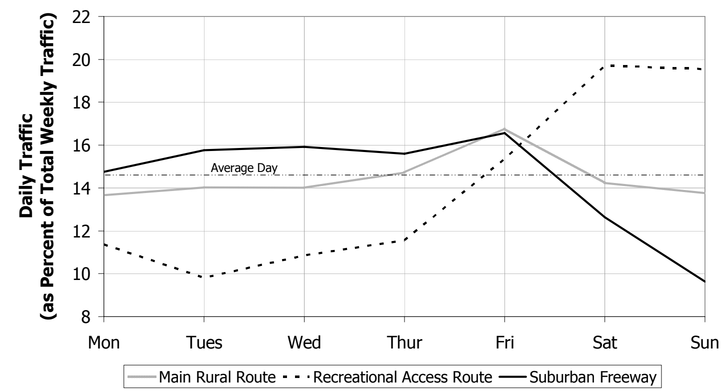
Daily Variations

Time of peak demand will vary according to highway type.

Demand variations by day of the week are also related to the type of highway. Exhibit 3-3 shows that weekend volumes are lower than weekday volumes for highways serving predominantly business travel, such as urban freeways. In comparison, peak traffic occurs on weekends on main rural and recreational highways. Furthermore, the magnitude of daily variation is highest for recreational access routes and lowest for urban commuter routes.

Exhibit 3-3
Examples of Daily Traffic Variation by Type of Route

Daily volume variations through the week show higher weekday volumes and lower weekend volumes for routes primarily serving commuter and intercity traffic, but the opposite for segments serving recreational traffic. Fridays are typically the peak weekday.

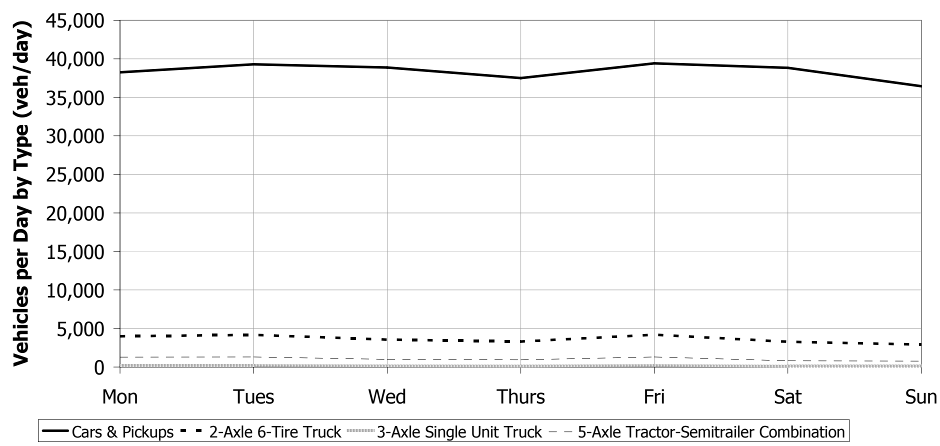


Notes: Suburban freeway, I-182 in Richland, Washington; main rural route, US-12 southeast of Pasco, Washington; recreational access route, Highway 35 south of Parkdale, Oregon.
Source: Washington State DOT, 2007, and Oregon DOT, 2007.

Exhibit 3-4 shows the variation in traffic by vehicle type for the shoulder lane of an urban freeway. Although the values shown in Exhibit 3-3 and Exhibit 3-4 are typical of patterns that may be observed, they should not be used as a substitute for local studies and analyses.

Exhibit 3-4
Daily Variation in Traffic by Vehicle Type for the Right Lane of an Urban Freeway

Daily volume variations by vehicle type through the week show higher weekday volumes and lower weekend volumes for truck traffic, with much sharper drops on the weekend for heavy truck traffic then for single-unit trucks. Car and pickup traffic peaks on Fridays and declines much more mildly on weekends on this urban freeway.



Note: Northbound Highway 16 north of I-5, Tacoma, Washington.
Source: Washington State DOT, 2007.

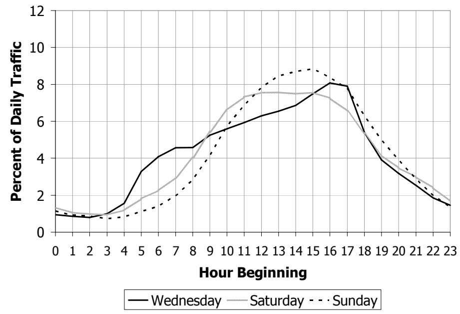
Hourly Variations

Typical hourly variation patterns for rural routes are shown in Exhibit 3-5, where the patterns are related to highway type and day of the week. Unlike urban routes, rural routes tend to have a single peak that occurs in the afternoon. A small morning peak is visible on weekdays that is much lower than the afternoon peak. The proportion of daily traffic occurring in the peak hour is much higher for recreational access routes than for intercity or local rural routes.

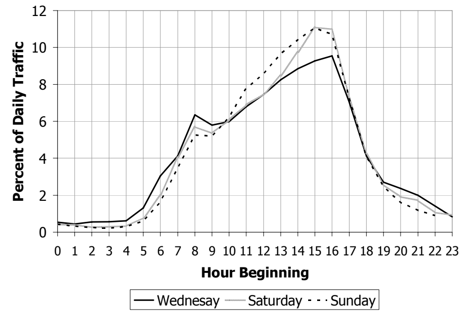
The weekend pattern for recreational routes is similar to the weekday pattern, as travelers tend to go to their recreation destination in the morning and return in the later afternoon. Weekend morning travel is considerably lower than weekday morning travel for the other types of rural routes.

Exhibit 3-5
Examples of Hourly Traffic Variations for Rural Routes

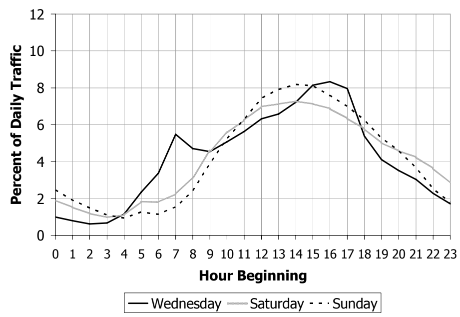
Traffic variation during the day by day of week for rural routes.



(a) Intercity Route



(b) Recreation Access Route



(c) Local Route

Notes: (a) US-395 south of Kennewick, Washington; (b) Highway 35 south of Parkdale, Oregon; (c) US-97 near Wapato, Washington.
Source: Washington State DOT, 2007, and Oregon DOT, 2007.

The repeatability of hourly variations is of great importance. The stability of peak-hour demand affects the feasibility of using such values in design and operational analyses of highways and other transportation facilities. Exhibit 3-6 shows data obtained for single directions of urban streets in metropolitan Toronto. The data were obtained from detectors measuring traffic in one direction only, as evidenced by the single peak period shown for either morning or afternoon. The area between the dotted lines indicates the range within which one can expect 95% of the observations to fall. Whereas the variations by hour of the day are typical for urban areas, the relatively narrow and parallel fluctuations among the days of the study indicate the repeatability of the basic pattern.

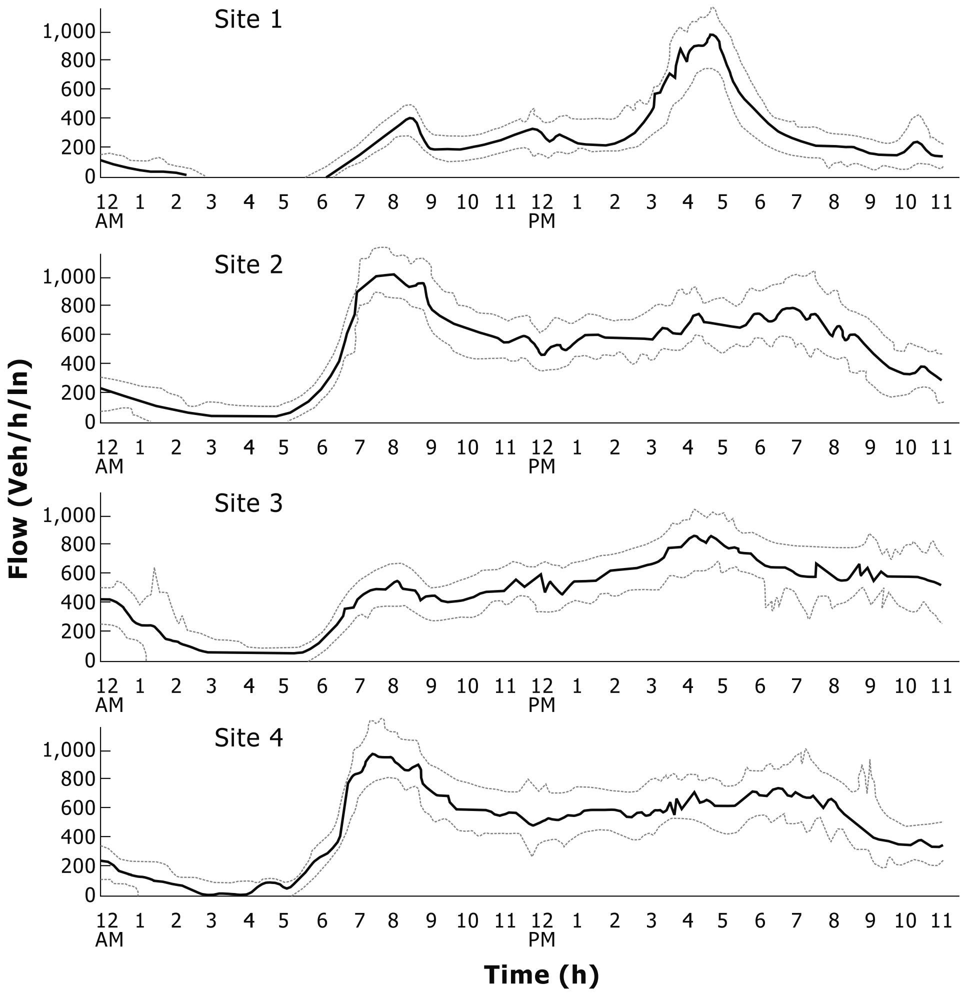


Exhibit 3-6
Repeatability of Hourly Traffic Variations for Urban Streets

Notes: Sites 2 and 4 are one block apart on the same street, in the same direction. All sites are two moving lanes in one direction.
Source: McShane and Crowley (*3*).

Repeatability of hourly patterns.

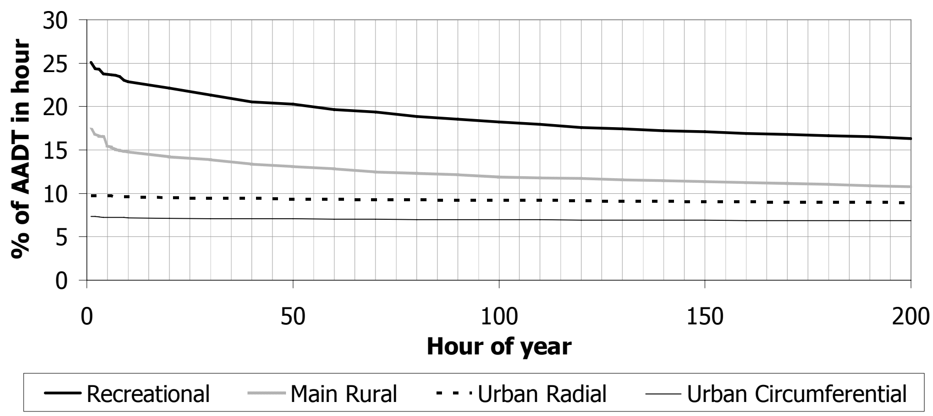
Peak Hour and Analysis Hour

Capacity and other traffic analyses typically focus on the peak-hour traffic volume because it represents the most critical period for operations and has the highest capacity requirements. However, as shown in the previous sections, the peak-hour volume is not a constant value from day to day or from season to season.

If the highest hourly volumes for a given location were listed in descending order, the data would vary greatly, depending on the type of facility. Rural and recreational routes often show a wide variation in peak-hour volumes. Several extremely high volumes occur on a few select weekends or in other peak periods, and traffic during the rest of the year flows at much lower volumes, even during the peak hour. Urban streets, on the other hand, show less variation in peak-hour traffic. Most users are daily commuters or frequent users, and occasional and special event traffic is minimal. Furthermore, many urban routes are filled to capacity during each peak hour, and variation is therefore severely constrained—an issue that will be revisited later in this section.

Exhibit 3-7 shows hourly volume relationships measured on four highway types in Washington. The recreational highway shows the widest variation in peak-hour traffic. Its values range from 25% of AADT in the highest hour of the year to about 16.3% of AADT in the 200th-highest hour of the year. The main rural freeway also varies widely, with 17.3% of the AADT in the highest hour, decreasing to 10.8% in the 200th-highest hour. The urban freeways show far less variation. The range in percent of AADT covers a narrow band, from approximately 9.7% (radial freeway) and 7.3% (circumferential freeway) for the highest hour to 8.9% and 6.9%, respectively, for the 200th-highest hour. Exhibit 3-7 is based on all hours of the year, not just peak hours of each day, and shows only the highest 200 hours of the year.

Exhibit 3-7
Ranked Hourly Volumes



Notes: Recreational, US-2 near Stevens Pass (AADT = 3,862); main rural, I-90 near Moses Lake (AADT = 10,533); urban radial, I-90 in Seattle (AADT = 120,173); urban circumferential, I-405 in Bellevue (AADT = 141,550).
Source: Washington State DOT, 2006.

Selection of an analysis hour usually implies that a small portion of the demand during a year will not be adequately served.

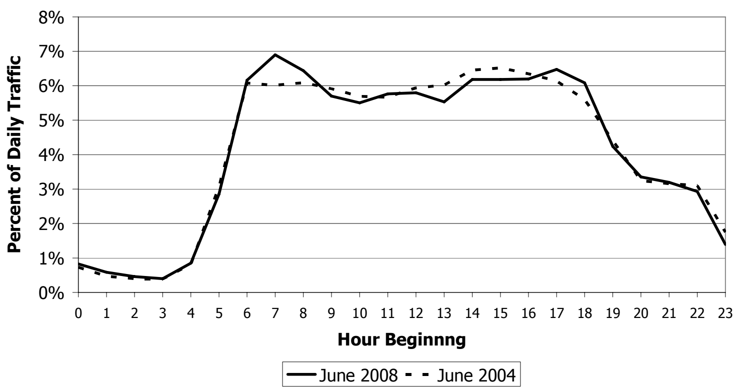
The selection of an appropriate hour for planning, design, and operational purposes is a compromise between providing an adequate LOS for every (or almost every) hour of the year and providing economic efficiency. Customary practice in the United States is to base rural highway design on the 30th-highest hour of the year. There are few hours with higher volumes than this hour, while there are many hours with volumes not much lower. In urban areas, there is usually little difference between the 30th- and 200th-highest hours of the year, because of the recurring morning and afternoon commute patterns (*4*).

The selection of the analysis hour should consider the impact on the design and operations of higher-volume hours that are not accommodated. The recreational access route curve of Exhibit 3-7 shows that the highest hours of the year have one-third more volume than the 100th-highest hour, whereas the highest hours of an urban radial route were only about 6% higher than the volume in the 100th-highest hour. Use of a design criterion set at the 100th-highest hour would create substantial congestion on a recreational access route during the highest-volume hours but would have less effect on an urban facility. Another consideration is the LOS objective. A route designed to operate at LOS C can absorb larger amounts of additional traffic than a route designed to operate at LOS D or E during the hours of the year operating with higher volumes than the design hour. As a general guide, the most frequently occurring peak volumes may be considered in the design of new or upgraded facilities. The LOS during higher-volume periods should be tested to determine the acceptability of the resulting traffic conditions.

Measured traffic volume patterns may not reflect actual demand patterns.

On roadways where oversaturation occurs during peak periods, analysts should be particularly careful in selecting a design hour, since measured traffic volumes may not reflect the changes in demand that occur once a bottleneck is removed. Exhibit 3-8 shows hourly variations in traffic on an urban freeway before and after the freeway was widened. In the before condition, the freeway's observed volumes were constrained by a bottleneck between 6 and 10 a.m., as indicated by the flat volume line. After the freeway widening, a more typical a.m. peak occurred, since travel patterns more closely reflected when travelers desired to travel rather than when the freeway could accommodate their travel.

Exhibit 3-8
Example of a Change in Travel Patterns Following Removal of a Capacity Constraint



Note: I-25 south of US-6, Denver.
Source: Colorado DOT.

As used in the HCM, the *K*-factor is the proportion of AADT that occurs during the peak hour. For many rural and urban highways, this factor falls between 0.09 and 0.10. For highway sections with high peak periods and relatively low off-peak flows, the *K*-factor may exceed 0.10. Conversely, for highways that demonstrate consistent and heavy flows for many hours of the day, the *K*-factor is likely to be lower than 0.09. In general,

- The *K*-factor decreases as the AADT on a highway increases;
- The *K*-factor decreases as development density increases; and
- The highest *K*-factors occur on recreational facilities, followed by rural, suburban, and urban facilities, in descending order.

The *K*-factor should be determined, if possible, from local data for similar facilities with similar demand characteristics.

Exhibit 3-9 demonstrates how *K*-factors decrease as AADT increases, on the basis of average data from Washington State.

Exhibit 3-9
Example *K*-Factors by AADT

AADT	Average *K*-Factor	Number of Sites Included in Average *K*-Factor: Urban	Recreational	Other Rural
0–2,500	0.151	0	6	12
2,500–5,000	0.136	1	6	8
5,000–10,000	0.118	2	2	14
10,000–20,000	0.116	1	2	15
20,000–50,000	0.107	11	5	10
50,000–100,000	0.091	14	0	4
100,000–200,000	0.082	11	0	0
>200,000	0.067	2	0	0

Note: *K*-factors are for the 30th-highest traffic volume hour of the year.
Source: Washington State DOT (*5*).

Spatial Distributions

Traffic volume varies in space as well as time. The two critical spatial characteristics used to analyze capacity are directional distribution and volume distribution by lane. Volume may also vary longitudinally along various segments of a facility, but this does not explicitly affect HCM analyses because each facility segment that serves a different traffic demand is analyzed separately.

D-Factor

Concept of D-factor or directional distribution.

The *D*-factor is the proportion of traffic moving in the peak direction of travel on a given roadway during the peak hours. A radial route serving strong directional demands into a city in the morning and out at night may display a 2:1 imbalance in directional flows. Recreational and rural routes may also be subject to significant directional imbalances, which must be considered in analyses. Circumferential routes and routes connecting two major cities within a metropolitan area may have very balanced flows during peak hours. Exhibit 3-10 provides examples of directional distributions from selected California freeways.

Exhibit 3-10
Example Directional Distribution Characteristics

Freeway Type	*D*-Factor
Rural–intercity	0.59
Rural–recreational and intercity	0.64
Suburban circumferential	0.52
Suburban radial	0.60
Urban radial	0.70
Intraurban	0.51

Notes: Rural–intercity, I-5 at Willows; rural–recreational and intercity, I-80 west of Donner Summit; suburban circumferential, I-680 in Danville; suburban radial, I-80 in Pinole; urban radial, Highway 94 at I-5, San Diego; intraurban, I-880 in Hayward.
Source: Caltrans, 2007.

Directional distribution is an important factor in highway capacity analysis. This is particularly true for two-lane rural highways. Capacity and level of service vary substantially with directional distribution because of the interactive nature of directional flows on such facilities—the flow in one direction of travel influences flow in the other direction by affecting the number of passing opportunities. Procedures for two-lane highway analyses include explicit consideration of directional distribution.

While the consideration of directional distribution is not mandated in the analysis of multilane facilities, the distribution has a dramatic effect on both design and LOS. As indicated in Exhibit 3-10, up to two-thirds of the peak-hour traffic on urban radial routes has been observed as moving in one direction. Unfortunately, this peak occurs in one direction in the morning and in the opposite direction in the evening. Thus, both directions of the facility must have adequate capacity for the peak directional flow. This characteristic has led to the use of reversible lanes on some urban streets and highways.

Directional distribution is not a static characteristic. It changes annually, hourly, daily, and seasonally. Development in the vicinity of highway facilities often changes the directional distribution.

The *D*-factor is used with the *K*-factor to estimate the peak-hour traffic volume in the peak direction, as shown by Equation 3-1:

Equation 3-1

$$DDHV = AADT \times K \times D$$

where

$DDHV$ = directional design-hour volume (veh/h),

$AADT$ = annual average daily traffic (veh/day),

K = proportion of $AADT$ occurring in the peak hour (decimal), and

D = proportion of peak-hour traffic in the peak direction (decimal).

Lane Distribution

Concept of lane distribution.

When two or more lanes are available for traffic in a single direction, the lane-use distribution varies widely. The volume distribution by lane depends on traffic regulations, traffic composition, speed and volume, the number and location of access points, the origin–destination patterns of drivers, the development environment, and local driver habits.

Because of these factors, there are no typical lane distributions. Data indicate that the peak lane on a six-lane freeway, for example, may be the shoulder, middle, or median lane, depending on local conditions.

Exhibit 3-11 gives daily lane distribution data for various vehicle types on three selected freeways. These data are illustrative and are not intended to represent typical values.

Exhibit 3-11
Lane Distribution by Vehicle Type

		Percent Distribution by Lane[a]		
Highway	**Vehicle Type**	**Lane 3**	**Lane 2**	**Lane 1**
Lodge Freeway, Detroit	Light[b]	32.4	38.4	29.2
	Single-unit trucks	7.7	61.5	30.8
	Combinations	8.6	2.9	88.5
	All vehicles	31.3	37.8	30.9
I-95, Connecticut Turnpike	Light[b]	24.5	40.9	34.6
	All vehicles	22.5	40.4	37.1
I-4, Orlando, Florida	All vehicles	38.4	31.7	29.9

Notes: [a] Lane 1 = shoulder lane; lanes numbered from right to left.
[b] Passenger cars, panel trucks, and pickup trucks.
Sources: Huber and Tracy (*6*); Florida DOT, 1993.

The trend indicated in Exhibit 3-11 is reasonably consistent throughout North America. Heavier vehicles tend to use the right-hand lanes, partially because they operate at lower speeds than other vehicles and partially because regulations may prohibit them from using the leftmost lanes.

Lane distribution must also be considered at intersections, since it affects how efficiently the demand for a particular movement can be served, as well as lane-by-lane queue lengths. Uneven lane distributions can be a result of upstream or downstream changes in the number of lanes available and the pre-positioning of traffic for downstream turning movements.

TRAVEL TIME VARIABILITY

Travelers using the same set of roadways notice that the time required to make their trip may vary from one day to the next. Depending on the importance of reaching one's destination by a given time (e.g., to start work, to pick up a child at day care, to deliver a shipment), one may budget extra time for the trip to allow for the possibility of a longer-than-usual travel time. This variability in travel times has several sources (*7*):

- *Traffic incidents* such as crashes, stalled cars, and debris in the roadway block travel lanes, reducing the roadway's capacity. Even when lanes are not physically blocked, activity on the shoulder (e.g., police action) or in the opposite direction of travel (e.g., a crash scene being cleared) can lead to changes in driver behavior that result in congestion.
- *Work zones* may provide a reduced number of lanes or reduced clearances between vehicles (e.g., due to narrower lanes) and roadside objects (e.g., due to reduced or eliminated shoulders), which affect capacity. Speed limits may also be reduced in work zones. Temporary road closures may result in a diversion of traffic to other roadways, increasing traffic volumes on those roads above typical levels.
- *Environmental conditions* such as adverse weather, bright sunlight directly in drivers' eyes, and abrupt transitions from light to dark (such as at a tunnel entrance on a sunny day) may cause drivers to slow down and increase their spacing, resulting in a drop in a roadway's capacity.
- *Fluctuations in demand* occur both in longer-term patterns (by day of the week and by month of the year, as shown in Exhibit 3-1 through Exhibit 3-5) and more randomly from day to day, as shown in Exhibit 3-6. Variable traffic demand on a roadway with fixed capacity results in variable travel times.
- *Special events* are a special case of demand fluctuation occurring at known times relatively infrequently, resulting in traffic flow patterns that vary substantially from the typical situation.
- *Traffic control devices* that intermittently disrupt traffic flow (e.g., railroad crossings and drawbridges), as well as poorly timed traffic signals, contribute to travel time variability.
- *Inadequate base capacity*, interacting with the other six factors listed above, also influences travel time variability. Depending on how close a facility

is to operating at its capacity, relatively small changes in demand can result in disproportionately large changes in travel time. Facilities with a greater base capacity are less vulnerable to disruptions: a freeway with three lanes per direction that experiences an incident blocking one lane loses at least one-third of its directional capacity, while a freeway with two lanes per direction would lose at least one-half of its directional capacity.

AUTOMOBILE FACILITY TYPES

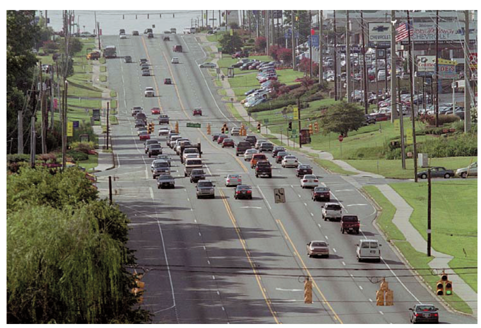
Exhibit 3-12 illustrates the kinds of automobile facilities addressed in the HCM. They are divided into two main categories: *uninterrupted-flow facilities,* where traffic has no fixed causes of delay or interruption beyond the traffic stream, and *interrupted-flow facilities,* where traffic control such as traffic signals and STOP signs introduce delay into the traffic stream.

Exhibit 3-12
Automobile Facility Types


(a) Freeway


(b) Multilane Highway


(c) Two-Lane Highway


(d) Urban Street

Uninterrupted Flow

Freeways are fully access-controlled, divided highways with a minimum of two lanes (and frequently more) in each direction. Certain lanes on freeways may be reserved for designated types of vehicles, such as high-occupancy vehicles or trucks. Some freeway facilities charge tolls, and their toll-collection facilities can create interrupted-flow conditions, such as on facilities where tolls are paid manually at toll plazas located on the freeway mainline. *Ramps* provide access to, from, and between freeways; some ramps have meters that control the flow of traffic onto a freeway segment.

Multilane highways are divided highways with a minimum of two lanes in each direction. They have zero or partial control of access. Traffic signals or roundabouts may create periodic interruptions to flow along an otherwise uninterrupted facility, but such interruptions are spaced at least 2 mi apart.

As the name implies, *two-lane highways* generally have a two-lane cross section, although passing and climbing lanes may be provided periodically. Within the two-lane sections, passing maneuvers must be made in the opposing lane. Traffic signals, STOP-controlled intersections, or roundabouts may occasionally interrupt flow, but at intervals longer than 2 mi.

Interrupted Flow

Urban streets are streets with relatively high densities of driveway and cross-street access, located within urban areas. The traffic flow of urban streets is interrupted (i.e., traffic signals, all-way stops, or roundabouts) at intervals of 2 mi or less. HCM procedures are applicable to arterial and collector urban streets, including those in downtown areas, but these procedures are not designed to address local streets.

MEASURED AND OBSERVED VOLUMES AND FLOW RATES

The direct observation of capacity is difficult to achieve for several reasons. The recording of a high, or even a maximum, volume or flow rate for a given facility does not ensure that a higher flow could not be accommodated at another time. Furthermore, capacity is sometimes an unstable operating condition. Depending on environmental factors, the mix of familiar and unfamiliar drivers in the traffic stream, and other considerations, the capacity achieved at a given location—or sets of otherwise similar locations—may vary from day to day.

HCM methodologies are based on calibrated national-average traffic characteristics observed over a range of facilities. Observations of these characteristics at specific locations will vary somewhat from national averages because of unique features of the local driving environment.

Freeways

HCM freeway capacity analysis procedures use a flow rate of 2,400 passenger cars per hour per lane (pc/h/ln) for basic freeway segments with free-flow speeds of 70 to 75 mi/h and 2,300 pc/h/ln for basic freeway segments with free-flow speeds of 65 mi/h as the capacity under base conditions.

Multilane Highways

The observation of multilane rural highways operating under capacity conditions is difficult, because such operations rarely occur. The HCM uses a flow rate of 2,200 pc/h/ln for multilane highways with free-flow speeds of 60 mi/h and 2,100 pc/h/ln for multilane highways with free-flow speeds of 55 mi/h as the capacity under base conditions.

Rural Two-Way, Two-Lane Highways

Two-way, two-lane rural highways in the United States and Canada rarely operate at volumes near capacity, and thus the observation of capacity operations for such highways in the field is difficult. The HCM methodology reports *single-direction* capacities, with a flow rate of 1,700 pc/h/ln used as the capacity under base conditions.

Urban Streets

Since flow on urban streets is uninterrupted only on segments between intersections, the interpretation of high-volume observations on urban streets is not as straightforward as for uninterrupted-flow facilities. Signal timing significantly alters the capacity of such facilities by limiting the time that is available for movement along the urban street at critical intersections. The prevailing conditions on urban streets may vary greatly, and such factors as curb parking, transit buses, lane widths, and upstream intersections may substantially affect operations and observed volumes.

INTERACTIONS WITH OTHER MODES

Each mode that uses a roadway interacts with the other modal users of that roadway. This section examines the effects of other modes on the automobile mode; the effects of the automobile mode on other modes are discussed later in the portions of the chapter addressing those modes.

Pedestrians

Pedestrians interact with the automobile mode on interrupted-flow elements of the roadway system. At signalized intersections, the minimum green time provided for an intersection approach is influenced by the need to provide adequate time for pedestrians using the parallel crosswalk to cross the roadway safely. In turn, the green time allocated to a particular vehicular movement affects the capacity of and the delay experienced by that movement. At signalized and unsignalized intersections, turning vehicles must yield to pedestrians in crosswalks, which reduces the capacity of and increases the delay to those turning movements, compared with a situation in which pedestrians are not present. The increased delays at intersections and midblock pedestrian crossings along urban streets that result from higher pedestrian crossing volumes lower vehicular speeds along the urban street.

Bicycles

At intersections, automobile capacity and delay are affected by bicycle volumes, particularly where turning vehicles conflict with through bicycle movements. However, HCM methodologies only account for these effects at signalized intersections. Bicycles may also delay automobiles on two-lane roadways, in cases where bicycles use the travel lane, causing vehicles to wait for a safe opportunity to pass. This kind of delay is not currently accounted for in the HCM two-lane roadway methodology, which only addresses delays associated with waiting to pass other automobiles.

Transit

Transit vehicles are longer than automobiles and have different performance characteristics; thus, they are treated as heavy vehicles for all types of roadway elements. At intersections, buses or streetcars that stop in the vehicular travel lane to serve passengers delay other vehicles in the lane and reduce the lane's capacity; however, this effect is only incorporated into the signalized intersection methodology. Special transit phases or bus signal priority measures at signalized intersections affect the allocation of green time to the various traffic movements, with accompanying effects on vehicular capacity and delay.

3. PEDESTRIAN MODE

OVERVIEW

Approximately 9% of all trips in the United States are accomplished by walking (2001 National Household Travel Survey). Moreover, many automobile trips and most transit trips include at least one section of the trip where the traveler is a pedestrian. Given the presence of a network of safe and convenient pedestrian facilities, as well as the availability of potential destinations within walking distance of one's trip origin, walking can be the mode of choice for a variety of shorter trips, including going to school, running errands, and recreational and exercise trips.

HUMAN FACTORS

A pedestrian is considerably more exposed than is a motorist, in both good and bad ways. A pedestrian travels much more slowly than other modal users and can therefore pay more attention to his or her surroundings. The ability to take in one's surroundings and get exercise while doing so can be part of the enjoyment of the trip. At the same time, a pedestrian interacts closely with other modal users, including other pedestrians, with potential safety, comfort, travel hindrance, and other implications. In addition, a pedestrian is exposed to the elements. As a result, a number of environmental and perceived safety factors significantly influence pedestrian quality of service. In locations with large numbers of pedestrians, pedestrian flow quality is also a consideration.

Some pedestrian flow measures are similar to those used for vehicular flow, such as the freedom to choose desired speeds and to bypass others. Others are related specifically to pedestrian flow, such as (*a*) the ability to cross a pedestrian traffic stream, to walk in the reverse direction of a major pedestrian flow, and to maneuver without conflicts or changes in walking speed and (*b*) the delay experienced by pedestrians at signalized and unsignalized intersections.

Environmental factors also contribute to the walking experience and, therefore, to the quality of service perceived by pedestrians. These factors include the comfort, convenience, safety, security, and economics of the walkway system. Comfort factors include weather protection; proximity, volume, and speed of motor vehicle traffic; pathway surface; and pedestrian amenities. Convenience factors include walking distances, intersection delays, pathway directness, grades, sidewalk ramps, wayfinding signage and maps, and other features making pedestrian travel easy and uncomplicated.

Safety is provided by separating pedestrians from vehicular traffic both horizontally, by using pedestrian zones and other vehicle-free areas, and vertically, by using overpasses and underpasses. Traffic control devices such as pedestrian signals can provide time separation of pedestrian and vehicular traffic, which improves pedestrian safety. Security features include lighting, open lines of sight, and the degree and type of street activity.

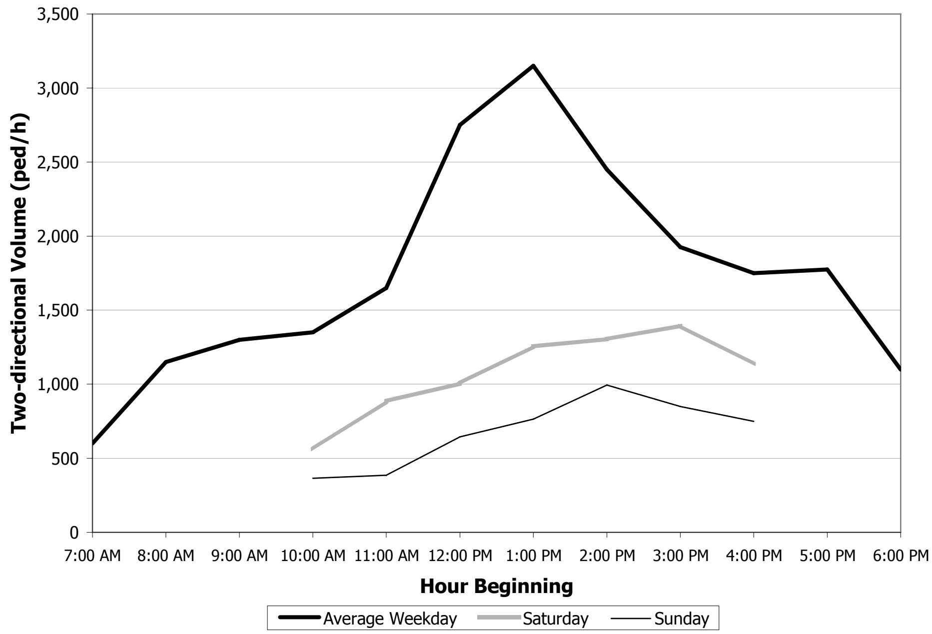
The economics of pedestrian facilities relate to user costs brought about by travel delays and inconvenience and to commercial values and retail development influenced by pedestrian accessibility.

Chapter 4, Traffic Flow and Capacity Concepts, discusses pedestrian flow measures, such as speed, space, and delay, while Chapter 5, Quality and Level-of-Service Concepts, covers the environmental factors that influence pedestrian quality of service.

VARIATIONS IN DEMAND

Pedestrian demand differs from the other modes addressed in the HCM in that the peak pedestrian demand often occurs at midday or during the early afternoon. Depending on the location, secondary peaks or plateaus in demand may also occur during the weekday a.m. and p.m. peak hours. Exhibit 3-13 shows two-directional pedestrian volume data collected in May 2004 on a sidewalk in Lower Manhattan, for an average of five weekdays in a week, Saturday, and Sunday. Although weekday demand was considerably higher than weekend demand, a single peak can be seen clearly in all three counts. Work-related trips made up the majority of a.m. peak-period pedestrian trips, while non-work-related and tourist trips made up the majority of the midday and early afternoon pedestrian trips (*8*).

Exhibit 3-13
Temporal Variations in Pedestrian Demand



Source: Adapted from New York City Department of City Planning (*8*).

PEDESTRIAN FACILITY TYPES

Exhibit 3-14 illustrates the types of pedestrian facilities addressed in the HCM. The following sections define each type of facility.

Exhibit 3-14
Pedestrian Facility Types


(a) Sidewalk


(b) Walkway


(c) Pedestrian Zone


(d) Queuing Area


(e) Crosswalk


(f) Underpass


(g) Overpass


(h) Stairway


(i) Shared Pedestrian–Bicycle Path

Sidewalks, Walkways, and Pedestrian Zones

These three facility types are separated from motor vehicle traffic and typically are not designed for bicycles or other nonpedestrian users, other than persons in wheelchairs. They accommodate the highest volumes of pedestrians and provide the best levels of service, because pedestrians do not share the facility with other modes traveling at higher speeds.

Sidewalks are located parallel and in proximity to roadways. Pedestrian walkways are similar to sidewalks in construction and may be used to connect sidewalks, but they are located well away from the influence of automobile traffic. Pedestrian zones are streets that are dedicated to pedestrian use on a full- or part-time basis.

Pedestrian walkways are also used to connect portions of transit stations and terminals. Pedestrian expectations about speed and density in a transit context are different from those in a sidewalk context; the *Transit Capacity and Quality of Service Manual* (TCQSM) (*9*) provides more information on this topic.

Queuing Areas

Queuing areas are places where pedestrians stand temporarily while waiting to be served, such as at the corner of a signalized intersection. In dense standing crowds, there is little room to move, and circulation opportunities are limited as the average space per pedestrian decreases.

Pedestrian Crosswalks

Pedestrian crosswalks, whether marked or unmarked, provide connections between pedestrian facilities across sections of roadway used by automobiles, bicycles, and transit vehicles. Depending on the type of control used for the crosswalk, local laws, and driver observance of those laws, pedestrians will experience varying levels of delay, safety, and comfort while waiting to use the crosswalk.

Stairways

Stairways are sometimes used to help provide pedestrian connectivity in areas with steep hills, employing the public right-of-way that would otherwise contain a roadway. Today they are often also used in conjunction with a ramp or elevator to provide shorter access routes to overpasses, underpasses, or walkways located at a different elevation. Even a small number of pedestrians moving in the opposite direction of the primary flow can significantly decrease a stairway's capacity to serve the primary flow.

Overpasses and Underpasses

Overpasses and underpasses provide a grade-separated route for pedestrians to cross wide or high-speed roadways, railroad tracks, busways, and topographic features. Access is typically provided by a ramp or, occasionally, an elevator, which is often supplemented with stairs. Procedures exist to assess the quality of pedestrian flow on these facilities, but not the quality of the pedestrian environment.

Shared Pedestrian–Bicycle Paths

Shared pedestrian paths typically are open to use by nonmotorized modes such as bicycles, skateboards, and inline skaters. Shared-use paths often are constructed to serve areas without city streets and to provide recreational opportunities for the public. These paths are common on university campuses, where motor vehicle traffic and parking are often restricted. In the United States, there are few paths exclusively for pedestrians; most off-street paths, therefore, are for shared use.

On shared facilities, bicycles—because of their markedly higher speeds—can have a negative effect on pedestrian capacity and quality of service. However, it is difficult to establish a bicycle–pedestrian equivalent because the relationship between the two depends on the characteristics of the cycling population and the modes' respective flows, directional splits, and other factors.

INTERACTIONS WITH OTHER MODES

Automobiles

At signalized intersections, the delay experienced by pedestrians is influenced in part by the amount of green time allocated to serve vehicular volumes on the street being crossed. The volume of cars making turns across a crosswalk at an intersection also affects a pedestrian's delay and perception of the intersection's quality of service.

At unsignalized intersections, increased major-street traffic volumes affect pedestrian crossing delay by reducing the number of opportunities for pedestrians to cross. The effect of motor vehicle volumes on pedestrian delay at unsignalized intersections also depends on local laws specifying yielding requirements to pedestrians in crosswalks and driver observation of those laws.

Automobile and heavy vehicle traffic volumes, and the extent to which pedestrians are separated from vehicular traffic, influence pedestrians' perceptions of quality of service while using a sidewalk.

Bicycles

Bicycle interaction with pedestrians is greatest on pathways shared by the two modes. Bicycles—because of their markedly higher speeds—can have a negative effect on pedestrian capacity and quality of service on such pathways.

Transit

The interaction of transit vehicles with pedestrians is similar to that of automobiles. However, because transit vehicles are larger than automobiles, the effect of a single transit vehicle is proportionately greater than that of a single automobile. The lack of pedestrian facilities in the vicinity of transit stops can be a barrier to transit access, and transit quality of service is influenced by the quality of the pedestrian environment along streets with transit service. Although it is not addressed by the HCM procedures, the pedestrian environment along the streets used to get to and from the streets with transit service also influences transit quality of service. Passengers waiting for buses at a bus stop can reduce the effective width of a sidewalk, while passengers getting off buses may create cross-flows that interact with the flow of pedestrians along a sidewalk.

4. BICYCLE MODE

OVERVIEW

Bicycles are used to make a variety of trips, including trips for recreation and exercise, commutes to work and school, and trips for errands and visiting friends. Bicycles help extend the market area of transit service, since bicyclists can travel about five times as far as an average person can walk in the same amount of time. Although bicycle trip-making in North America is lower than in the rest of the world, several large North American cities that have invested in bicycle infrastructure and programs (e.g., Portland, Oregon; Minneapolis, Minnesota; and Vancouver, Canada) have bicycle commute mode splits around 4% (2005–2007 census and local data). Some college towns like Eugene, Oregon, and Boulder, Colorado, have commute mode splits exceeding 8% (2007 census data), and Davis, California, achieved a 14% mode split (2005–2007 census data).

HUMAN FACTORS

Many of the measures of vehicular effectiveness can also describe bicycling conditions, whether on exclusive or shared facilities. As with motor vehicles, bicycle speeds remain relatively insensitive to flow rates over a wide range of flows. Delays due to traffic control affect bicycle speeds along a facility, and the additional effort required to accelerate from a stop is particularly noticeable to bicyclists. Grades, bicycle gearing, and the bicyclist's fitness level also affect bicycle speed and the level of effort required to maintain a particular speed.

Some vehicular measures are less applicable to the bicycle mode. For example, bicycle density is difficult to assess, particularly with regard to facilities shared with pedestrians and others. Because of the severe deterioration of service quality at flow levels well below capacity (e.g., freedom to maneuver around other bicyclists), the concept of capacity has little utility in the design and analysis of bicycle paths and other facilities. Capacity is rarely observed on bicycle facilities; rather, cyclists typically dismount and walk their bicycles before a facility reaches capacity. Values for capacity therefore reflect sparse data, generally from European studies or from simulation.

Hindrance as a performance measure.

Other measures of bicycle quality of service have no vehicular counterpart. For example, the concept of hindrance relates directly to bicyclists' comfort and convenience (*10*). During travel on a bicycle facility, two significant parameters can be easily observed and identified: (*a*) the number of users (other bicyclists, pedestrians, etc.) moving in the same direction and passed by the bicyclist and (*b*) the number of users moving in the opposing direction encountered by the bicyclist. Each event causes some discomfort and inconvenience to the bicyclist.

As is the case with pedestrians, environmental factors contribute significantly to the bicycling experience and, therefore, to quality of service. These factors include the volume and speed of adjacent vehicles, heavy vehicle presence, the presence of on-street parking, and the quality of the pavement. Chapter 5, Quality and Level-of-Service Concepts, discusses environmental and hindrance factors, while Chapter 4, Traffic Flow and Capacity Concepts, presents bicycle flow measures.

VARIATIONS IN DEMAND

Bicycle travel demand varies by time of day, day of the week, and month of the year. All of these variations in demand are related to trip-making demands in general (e.g., bicycle demand is highest during weekday a.m. and p.m. peak periods, just as with motor vehicles). Bicyclists are more exposed than motorists to the elements and other roadway users. Dutch research has shown that weather explains up to 80% of annual variation in bicycle travel, with higher rainfall and lower temperatures resulting in lower rates of bicycling (*11*).

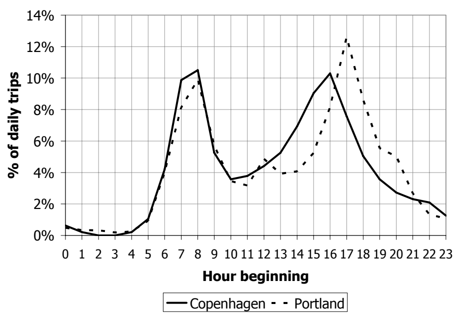
Therefore, monthly variations in bicycle demands are also weather- and daylight-related. Exhibit 3-15 shows variations in bicycle demand hourly, daily, and monthly, on the basis of data from Copenhagen, Denmark, and Portland, Oregon. Exhibit 3-16 shows observations of bicycle demand compared with variations in daily high temperature along a bicycle path in Boulder, Colorado.

Exhibit 3-15
Temporal Variations in Bicycle Demand

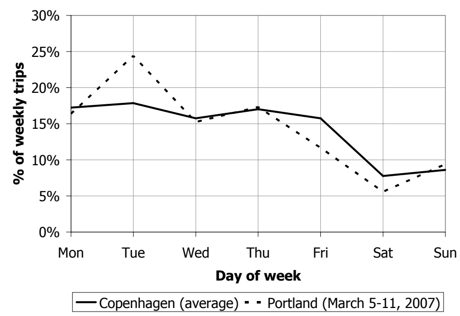
Copenhagen and Portland hourly demand patterns are nearly identical through noon. In the afternoon, Copenhagen peaks an hour earlier (due to a shorter workday length). The Portland p.m. peak is noticeably higher than the a.m. peak, unlike Copenhagen.

Bicycle volumes can fluctuate significantly from day to day, as suggested by the Portland line on the weekly variation chart. The Portland volumes may reflect the effects of rain on Wednesday, Friday, Saturday, and Sunday of that week.

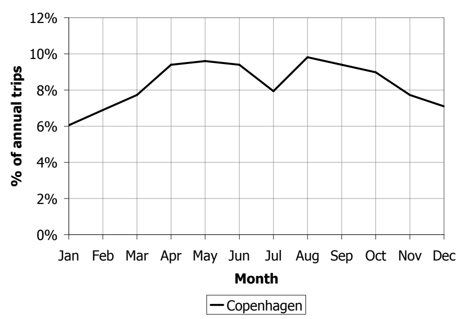
Automobile volumes also drop in July in Copenhagen, when many people go on vacation. Except for July, months with higher temperatures and more daylight have higher bicycle volumes in Copenhagen.



(a) Hourly Variations



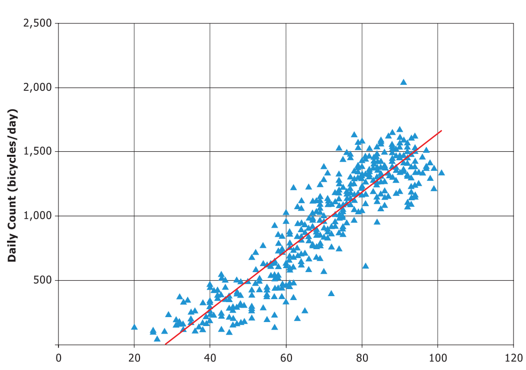
(b) Weekly Variations



(c) Monthly Variations

Source: Municipality of Copenhagen (*12*); Portland Office of Transportation, 2007.

Exhibit 3-16
Example Variations in Bicycle Demand due to Temperature

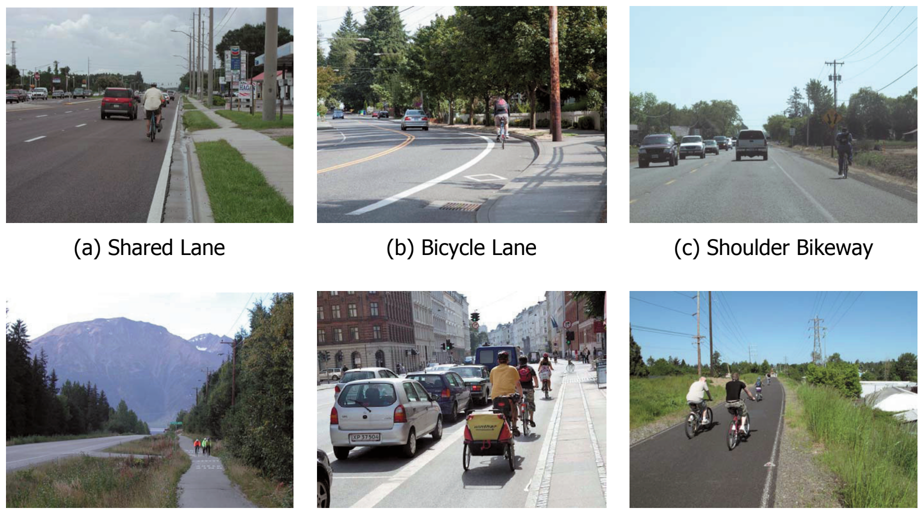


Source: Lewin (*13*).

BICYCLE FACILITY TYPES

Exhibit 3-17 illustrates the types of bicycle facilities addressed in the HCM. The facilities are divided into two types, on-street and off-street, and include situations where a facility is shared with users of another mode (e.g., a lane shared by bicyclists and motor vehicle traffic or a pathway shared by bicyclists and pedestrians).

Exhibit 3-17
Bicycle Facility Types



(a) Shared Lane (b) Bicycle Lane (c) Shoulder Bikeway

(d) Sidepath (e) Bicycle Track (f) Exclusive Pathway

On-Street Bicycle Facilities

On-street bicycle facilities include roadways on which bicycles share a travel lane with motorized vehicular traffic, dedicated on-street bicycle lanes, paved roadway shoulders available for use by bicyclists, and bicycle tracks—mainly seen in Europe—located between the roadway and the sidewalk and separated from each by low curbs. For each facility type, bicycle flow is one-way. The quality of bicycle flow, safety, and the bicycling environment are all considerations for these types of facilities.

Off-Street Bicycle Facilities

Off-street bicycle facilities consist of pathways dedicated to the exclusive use of bicyclists and pathways shared with pedestrians and other types of users. These types of facilities may be located parallel and in proximity to roadways (*sidepaths*), or they may be completely independent facilities, such as recreational trails along former railroad rights-of-way and off-street pathways of the kind found in city parks and on college campuses. Bicycle flow along these types of facilities is typically two-way and is often shared with users of other modes. The number of meeting and passing events between cyclists and other path users affects the quality of service for bicyclists using these facility types. The presence and design of driveways and intersections may affect the quality of service of bicyclists on side paths but is not addressed by HCM procedures.

MEASURED AND OBSERVED VOLUMES

Exhibit 3-18 provides daily two-directional bicycle volumes on selected U.S. roadways and bicycle facilities. Data were collected on weekdays, generally in late spring or summer, so these volumes represent peak conditions for the year. In comparison, the highest-volume roadways in Copenhagen, Denmark, have two-directional daily bicycle volumes exceeding 30,000 on spring and fall weekdays with good weather (*12*).

Exhibit 3-18
Daily Weekday Bicycle Volumes on Selected U.S. Bicycle Facilities (2006–2008)

Facility	Location	Facility Type	Daily Bicycle Volume
Hawthorne Bridge	Portland, OR	Shared pedestrian–bicycle path	7,400
Russell Boulevard	Davis, CA	Shared pedestrian–bicycle path	6,700
Broadway Bridge	Portland, OR	Shared pedestrian–bicycle path	4,300
North Vancouver Street	Portland, OR	Bicycle lane	3,500
Hudson River Greenway	New York, NY	Shared pedestrian–bicycle path	3,500
Steel Bridge	Portland, OR	Shared pedestrian–bicycle path	3,000
Waterfront Park	Portland, OR	Shared pedestrian–bicycle path	3,000
Williamsburg Bridge	New York, NY	Shared pedestrian–bicycle path	3,000
Springwater Trail	Portland, OR	Shared pedestrian–bicycle path	2,800

Source: City of Davis, Portland Office of Transportation, New York City DOT.

INTERACTIONS WITH OTHER MODES

Automobiles

Vehicular and heavy vehicle traffic volumes and speeds, the presence of on-street parking (which presents the potential for bicyclists to hit or be hit by car doors), and the degree to which bicyclists are separated from automobile traffic all influence bicyclists' perceptions of the quality of service received while using an on-street bicycle facility. Turning vehicles, particularly right-turning vehicles that cross the path of bicyclists, also affect quality of service.

Pedestrians

The effect of pedestrians on bicycles is greatest on pathways shared by the two modes. Pedestrians—because of their markedly lower speeds and tendency to travel in groups several abreast—can have a negative effect on bicycle quality of service on such pathways. Similar to pedestrian impacts on motor vehicles, bicyclists must yield to crossing pedestrians, and the signal timing at intersections reflects, in part, the time required for pedestrians to cross the street.

Transit

Transit vehicles interact with bicycles in much the same way as automobiles. However, because transit vehicles are heavy vehicles, the effect of a single transit vehicle is proportionately greater than that of a single automobile. Buses can also affect bicyclists when they pull over into a bicycle lane or paved shoulder to serve a bus stop; however, this impact is not accounted for in HCM procedures. Although not addressed by HCM procedures, the availability of good bicycle access extends the capture shed of a transit stop or station, and when bicycles can be transported by transit vehicles, transit service can greatly extend the range of a bicycle trip.

5. TRANSIT MODE

OVERVIEW

Transit plays two major roles in North America. First, it accommodates choice riders—those who choose transit for their mode of travel even though they have other means available. These riders choose transit to avoid congestion, save money on fuel and parking, use their travel time productively for other activities, and reduce the impact of automobile driving on the environment, among other reasons. Transit is essential for mobility in the central business districts (CBDs) of some major cities, which could not survive without it.

The other major role of transit is to provide basic mobility for segments of the population that are unable to drive for age, physical, mental, or financial reasons. About 11% of the adult population in the United States does not have a driver's license (*14*) and must depend on others to transport them in automobiles, on transit, or via other modes, including walking, bicycling, and taxis. These transit users have been termed captive riders.

Exhibit 3-19 provides examples of peak-hour trips by transit to the downtowns of selected U.S. cities. The variations in transit use reflect differences in population, CBD employment, extent of bus and rail transit services, and geographic characteristics.

Exhibit 3-19
Transit Commuting to Downtowns (2000)

Area	Transit Share of Downtown Commuters	Area	Transit Share of Downtown Commuters
New York	76.5%	Los Angeles	20.3%
Chicago	61.7%	Houston	16.7%
Boston	50.9%	Dallas	13.6%
San Francisco	49.0%	Sacramento	12.3%
Philadelphia	45.7%	San Diego	11.4%
Washington, DC	37.8%	San Antonio	7.2%
Seattle	36.8%	Austin	3.8%
Portland	27.5%		

Source: *Commuting in America III* (*15*), adapted from "Commuting to Downtown in America: Census 2000," report to the Transportation Research Board Subcommittee on Census Data for Transportation Planning, Jan. 10, 2005.

HUMAN FACTORS

Transit passengers frequently rely on other modes to gain access to transit. Transit use is greater where population densities are higher and pedestrian access is good. Typical transit users do not have transit service available at the door and must walk, bicycle, or drive to a transit stop and walk or bicycle from the transit discharge point to their destination. In contrast, suburban areas are mainly automobile-oriented, with employment and residences dispersed, often without sidewalks or direct access to transit lines. If potential passengers cannot access service at both ends of their trip, transit is not an option for that trip.

Unlike the other modes addressed in the HCM, transit is primarily focused on a service rather than a facility. Roadways, bicycle lanes, and sidewalks, once constructed, are generally available at all times to users. Transit service, in contrast, is only available at designated times and places. Another important difference is that transit users are passengers, rather than drivers, and not in direct control of their travel. Thus, the frequency and reliability of service are important quality-of-service factors for transit users. Travel speed and comfort while making a trip are also important to transit users.

Transit is about moving people rather than vehicles. Transit operations at their most efficient level involve relatively few vehicles, each carrying a large number of passengers. In contrast, roadway capacity analysis typically involves relatively large numbers of vehicles, most carrying only a single occupant. In evaluating priority measures for transit and automobile users, the number of people affected is often more relevant than the number of vehicles.

ON-STREET TRANSIT CHARACTERISTICS

The TCQSM comprehensively addresses transit modes.

The HCM addresses only those major transit modes (in terms of passengers carried) that operate on streets and interact with other users of streets and highways. These modes are buses, streetcars, and light rail, illustrated in Exhibit 3-20 and described briefly in the following sections.

Exhibit 3-20
Transit Modes Addressed in the HCM

(a) Bus (b) Streetcar (c) Light Rail

Bus

Demand-responsive transit (with flexible schedules or routes, or both) is not addressed by the HCM but is addressed in the TCQSM.

The bus mode is operated by rubber-tired vehicles that follow fixed routes and schedules along roadways. Although the electric trolleybus (a bus receiving its power from overhead wires) is classified as a separate mode by the Federal Transit Administration (FTA), for the purposes of the HCM, it is also considered a bus. In 2007, more than 53% of all transit passenger boardings in the United States occurred on buses (*16*).

The bus mode offers considerable operational flexibility. Service can range from local buses stopping every two to three blocks along a street, to limited-stop service stopping every ½ to 1 mi, to express service that travels along a roadway without stopping. Buses may stop in the travel lane (*on-line)* or in a parking lane or pullout (*off-line*). On-line stops reduce bus delay but may increase vehicle and bicycle delay. Because buses frequently carry more people than the vehicles stopped behind them, on-line stops may help reduce overall person delay.

Streetcar

The streetcar mode is operated by vehicles that receive power from overhead wires and run on tracks. For FTA reporting purposes, streetcars are considered to be a form of light rail. For HCM purposes, the following operating and physical characteristics distinguish streetcars from light rail:

- Generally shorter (typically one-car) trains, with slightly narrower cars;
- Greater potential for onboard fare payment, which may affect dwell times;

- Greater prevalence of mixed-traffic operation; and
- More frequent stops.

Streetcars make on-line stops, which minimizes their delay leaving a station, but may increase delay to vehicles and bicycles stopped behind the streetcar.

Light Rail

As is streetcar, light rail is a mode operated by vehicles that receive power from overhead wires and that run on tracks. Trains typically consist of multiple cars; fares are typically paid to a machine on the station platform (thus allowing passengers to board through all doors, reducing dwell time); station spacing tends to be relatively long, particularly outside downtown areas; and traffic signal preemption or priority is frequently employed.

The HCM only addresses light rail operations along roadways. Consult the TCQSM for a more comprehensive treatment of light rail.

When light rail operates along a roadway, it typically does so in an exclusive lane or in a segregated right-of-way in the street median or along the side of the street. Most light rail routes include lengthy sections where tracks are located in a separate, potentially grade-separated right-of-way and any interaction with traffic occurs at gate-controlled grade crossings.

TRAVEL TIME VARIABILITY

As do motorists, transit riders often allow extra time for time-sensitive trips. Sources of bus travel time variability include all of the factors listed in the automobile section of this chapter, plus bus-specific factors such as variations in passenger demands (day-to-day and bus-to-bus), traffic signal delays after stopping to serve passengers, wheelchair lift and bicycle rack usage, differences in bus operator experience, route length, and the number of stops (*9*).

ON-STREET TRANSIT FACILITY TYPES

Mixed Traffic

More than 99% of the bus route miles in the United States are operated in mixed traffic. In contrast, most rail route miles—other than portions of streetcar lines—operate in some form of segregated right-of-way. In mixed traffic, transit vehicles are subject to the same causes of delay as are automobiles, and they need to stop periodically to serve passengers. These stops can cause transit vehicles to fall out of any traffic signal progression that might be provided along the street, causing them to incur greater amounts of signal delay than other vehicles.

Exclusive Lanes

Exclusive lanes are on-street lanes dedicated for use by transit vehicles, on either a full-time or part-time basis. They are generally separated from other lanes by just a stripe, and buses may be able to leave the exclusive lane to pass buses or obstructions such as delivery trucks. Right-turning traffic, bicycles, carpools, and taxis are sometimes allowed in exclusive bus lanes. Generally, no other traffic, with the possible exception of transit buses, is allowed in exclusive lanes provided for rail transit vehicles. Exclusive lanes allow transit vehicles to bypass queues of vehicles in the general traffic lanes and reduce or eliminate delays to transit vehicles caused by right-turning traffic. Therefore, these lanes can provide faster, more reliable transit operations.

On-Street Transitways

Buses and trains sometimes operate within a portion of the street right-of-way that is physically segregated from other traffic: in the median or adjacent to one side of the street. No other traffic is allowed in the transitway. The amount of green time allocated to transit vehicles may be different from the amount of time allocated to the parallel through movements—for example, it might be reduced to provide time to serve conflicting vehicular turning movements.

MEASURED AND OBSERVED VOLUMES

Exhibit 3-21 provides examples of observed peak-direction, peak-hour bus and passenger flows along selected roadways in the United States and Canada. Higher bus volumes have been observed on busways in South America; they require a combination of passing lanes at stations for express services and multiple-platform stations at major transfer points and downtown terminals.

Exhibit 3-21
Observed On-Street, Peak-Direction, Peak-Hour Bus and Passenger Volumes (1995–2000)

		Peak-Hour Peak-Direction	
Location	**Facility**	**Buses**	**Passengers**
Ottawa	Albert St./Slater St.	190	10,000
New York City	Madison Ave.	180	10,000
Portland	5th Ave./6th Ave.	175	8,500
Newark	Broad St.	150	6,000
Denver	Broadway/Lincoln St.	90	2,300
Boston	South St./High St.	50	2,000
Vancouver	Granville Mall	70	1,800

Source: *TCRP Report 26* (*17*), *TCRP Report 90, Volume 2* (*18*), TCQSM (*9*).

INTERACTIONS WITH OTHER MODES

Automobiles

Higher automobile volumes result in greater delays for all motorized traffic, including buses. In locations where buses pull out of the travel lane to serve bus stops and yield-to-bus laws are not in place (or generally observed), buses experience delay waiting for a gap to pull back into traffic after serving a stop. Day-to-day variations in roadway congestion and trip-to-trip variations in making or missing green phases at signalized intersections affect bus schedule reliability, although no HCM techniques exist to predict this impact.

Pedestrians

Transit users are typically pedestrians immediately before and after their trip aboard a transit vehicle, so the quality of the pedestrian environment along access routes to transit stops also affects the quality of the transit trip. Pedestrians can also delay buses in the same way that they delay automobiles, as described earlier in this chapter.

Bicycles

In locations where buses pull out of the travel lane to serve bus stops, bicycles may delay buses waiting for a gap to pull back into traffic, similar to automobiles. Transit users may be bicyclists before or after their trip, so the quality of the bicycling environment along access routes to transit stops also influences the quality of the transit trip.

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