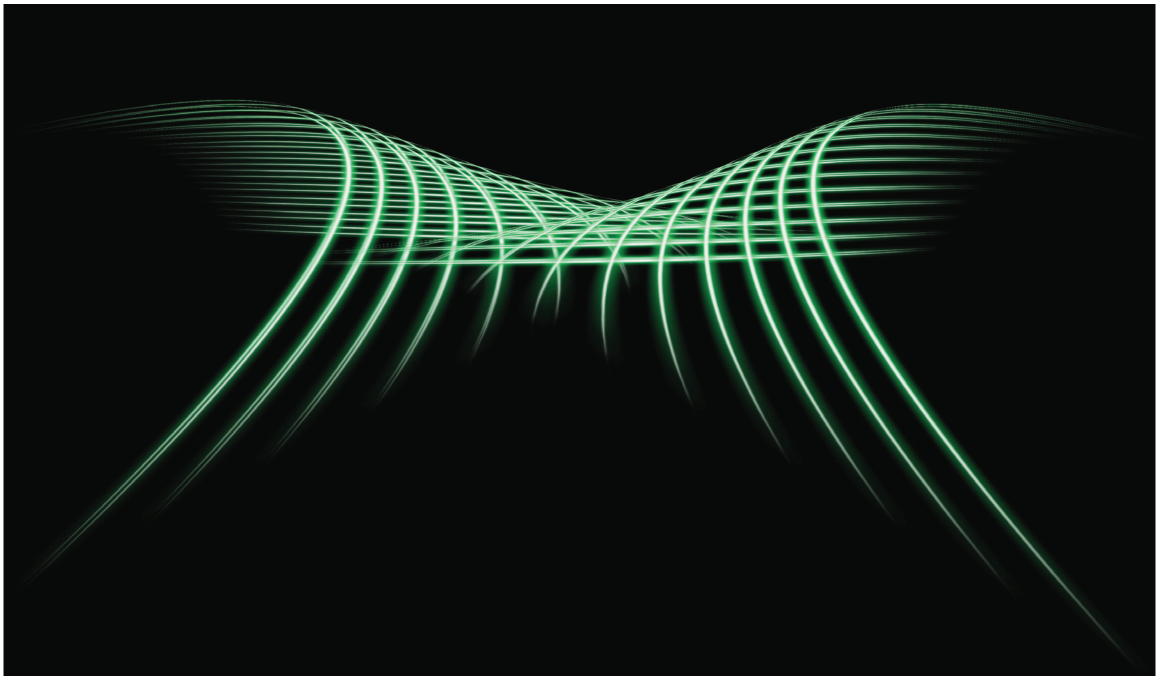
HCM2010

HIGHWAY CAPACITY MANUAL



CHAPTER 1

HCM USER'S GUIDE

TRB TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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Freeway LOS Described

LOS A describes free-flow operations. FFS prevails on the freeway, and vehicles are almost completely unimpeded in their ability to maneuver within the traffic stream. The effects of incidents or point breakdowns are easily absorbed.

LOS B represents reasonably free-flow operations, and FFS on the freeway is maintained. The ability to maneuver within the traffic stream is only slightly restricted, and the general level of physical and psychological comfort provided to drivers is still high. The effects of minor incidents and point breakdowns are still easily absorbed.

LOS C provides for flow with speeds near the FFS of the freeway. Freedom to maneuver within the traffic stream is noticeably restricted, and lane changes require more care and vigilance on the part of the driver. Minor incidents may still be absorbed, but the local deterioration in service quality will be significant. Queues may be expected to form behind any significant blockages.

LOS D is the level at which speeds begin to decline with increasing flows, with density increasing more quickly. Freedom to maneuver within the traffic stream is seriously limited and drivers experience reduced physical and psychological comfort levels. Even minor incidents can be expected to create queuing, because the traffic stream has little space to absorb disruptions.

LOS E describes operation at capacity. Operations on the freeway at this level are highly volatile because there are virtually no usable gaps within the traffic stream, leaving little room to maneuver within the traffic stream. Any disruption to the traffic stream, such as vehicles entering from a ramp or a vehicle changing lanes, can establish a disruption wave that propagates throughout the upstream traffic flow. At capacity, the traffic stream has no ability to dissipate even the most minor disruption, and any incident can be expected to produce a serious breakdown and substantial queuing. The physical and psychological comfort afforded to drivers is poor.

LOS F describes breakdown, or unstable flow. Such conditions exist within queues forming behind bottlenecks. Breakdowns occur for a number of reasons:

- Traffic incidents can temporarily reduce the capacity of a short segment, so that the number of vehicles arriving at a point is greater than the number of vehicles that can move through it.
- Points of recurring congestion, such as merge or weaving segments and lane drops, experience very high demand in which the number of vehicles arriving is greater than the number of vehicles that can be discharged.
- In analyses using forecast volumes, the projected flow rate can exceed the estimated capacity of a given location.

Breakdown (LOS F) occurs whenever the demand-to-capacity ratio exceeds 1.00.

In all cases, breakdown occurs when the ratio of existing demand to actual capacity, or of forecast demand to estimated capacity, exceeds 1.00. Operations immediately downstream of, or even at, such a point, however, are generally at or near LOS E, and downstream operations improve (assuming that there are no additional downstream bottlenecks) as discharging vehicles move away from the bottleneck.

Multilane highways with higher FFSs will also have higher base capacities. As most highways do not operate under base conditions, observed capacities will usually be lower than the base capacity.

Capacities represent an average flow rate across all lanes. Individual lanes could have higher stable flows.

CAPACITY OF MULTILANE HIGHWAY SEGMENTS

The capacity of a multilane highway segment under base conditions varies with the FFS. For 60-mi/h FFS, the capacity is 2,200 pc/h/ln. For lesser FFSs, capacity diminishes. For 55-mi/h FFS, the capacity is 2,100 pc/h/ln; for 50-mi/h FFS, 2,000 pc/h/ln; and for 45-mi/h FFS, 1,900 pc/h/ln.

These values represent national norms. Capacity varies stochastically, and any given location could have a larger or smaller value. In addition, capacity refers to the average flow rate across all lanes. Thus, a two-lane (in one direction) multilane highway segment with a 60-mi/h FFS would have an expected capacity of 2 × 2,200 = 4,400 pc/h. This flow would not be uniformly distributed in the two lanes. Thus, one lane could have stable flows in excess of 2,200 pc/h/ln.

LOS FOR MULTILANE HIGHWAY SEGMENTS

Automobile Mode

Automobile LOS is defined by density.

Automobile LOS for multilane highway segments are defined in Exhibit 14-4. Because speeds are constant through a broad range of flow rates, LOS are defined on the basis of density, which is a measure of the proximity of vehicles to each other in the traffic stream.

Exhibit 14-4
Automobile LOS for Multilane Highway Segments

LOS	FFS (mi/h)	Density (pc/mi/ln)
A	All	>0–11
B	All	>11–18
C	All	>18–26
D	All	>26–35
E	60	>35–40
	55	>35–41
	50	>35–43
	45	>35–45
F	Demand Exceeds Capacity	
	60	>40
	55	>41
	50	>43
	45	>45

LOS thresholds for multilane highways are the same as those on freeways for LOS A–D. However, multilane highway capacity (the LOS E–F boundary) occurs at lower densities.

For LOS A through D, the criteria are the same as those for basic freeway segments. This classification is appropriate, since both represent multilane uninterrupted flow. The boundary between LOS E and F, however, represents capacity. For multilane highways, capacity occurs at varying densities, depending on the FFS. The density at capacity ranges from 40 pc/mi/ln for 60-mi/h FFS to 45 pc/mi/ln for 45-mi/h FFS.

LOS F is determined when the demand flow rate exceeds capacity. When this occurs, the methodology does not produce a density estimate. Thus, although density in such cases will be above the thresholds shown, specific values cannot be determined.

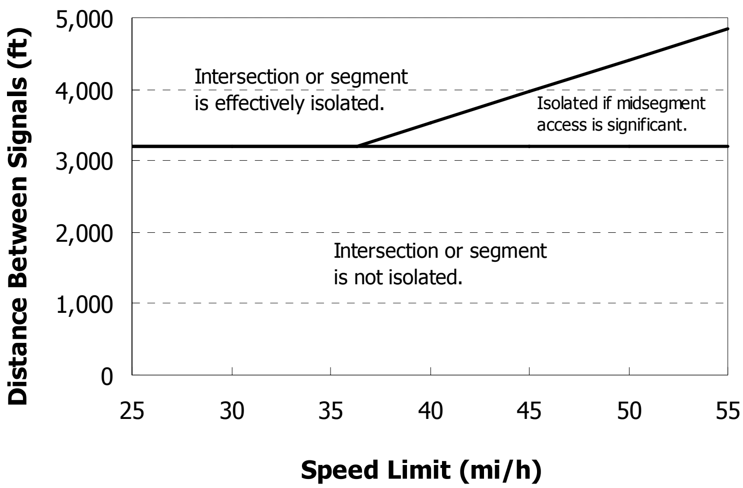
Exhibit 14-5 shows LOS thresholds in relation to the base speed–flow curves.

distance between signals is above the trend line, then the subject intersection or segment is likely to operate as effectively isolated (provided that it is not coordinated with the upstream signal).

LOS CRITERIA

This subsection describes the LOS criteria for the automobile, pedestrian, bicycle, and transit modes. The criteria for the automobile mode are different from the criteria used for the nonautomobile modes. Specifically, the automobile mode criteria are based on performance measures that are field-measurable and perceivable by travelers. The criteria for the pedestrian and bike modes are based on scores reported by travelers indicating their perception of service quality. The criteria for the transit mode are based on measured changes in transit patronage due to changes in service quality.

Exhibit 16-3
Signal Spacing Associated with Effectively Isolated Operation



Automobile Mode

All uses of the word "volume" or the phrase "volume-to-capacity ratio" in this chapter refer to demand volume or demand-volume-to-capacity ratio.

Through-vehicle travel speed is used to characterize vehicular LOS for a given direction of travel along an urban street facility. This speed reflects the factors that influence running time along each link and the delay incurred by through vehicles at each boundary intersection. This performance measure indicates the degree of mobility provided by the facility. The following paragraphs characterize each service level.

LOS A describes primarily free-flow operation. Vehicles are completely unimpeded in their ability to maneuver within the traffic stream. Control delay at the boundary intersections is minimal. The travel speed exceeds 85% of the base free-flow speed.

LOS B describes reasonably unimpeded operation. The ability to maneuver within the traffic stream is only slightly restricted and control delay at the boundary intersections is not significant. The travel speed is between 67% and 85% of the base free-flow speed.

LOS C describes stable operation. The ability to maneuver and change lanes at midsegment locations may be more restricted than at LOS B. Longer queues at the boundary intersections may contribute to lower travel speeds. The travel speed is between 50% and 67% of the base free-flow speed.

LOS D indicates a less stable condition in which small increases in flow may cause substantial increases in delay and decreases in travel speed. This operation may be due to adverse signal progression, high volume, or inappropriate signal timing at the boundary intersections. The travel speed is between 40% and 50% of the base free-flow speed.

LOS E is characterized by unstable operation and significant delay. Such operations may be due to some combination of adverse progression, high volume, and inappropriate signal timing at the boundary intersections. The travel speed is between 30% and 40% of the base free-flow speed.

LOS F is characterized by flow at extremely low speed. Congestion is likely occurring at the boundary intersections, as indicated by high delay and extensive queuing. The travel speed is 30% or less of the base free-flow speed. Also, LOS F is assigned to the subject direction of travel if the through movement at one or more boundary intersections has a volume-to-capacity ratio greater than 1.0.

Exhibit 16-4 lists the LOS thresholds established for the automobile mode on urban streets.

Exhibit 16-4
LOS Criteria: Automobile Mode

Travel Speed as a Percentage of Base Free-Flow Speed (%)	**LOS by Critical Volume-to-Capacity Ratio[a]**	
	≤ 1.0	**> 1.0**
>85	A	F
>67–85	B	F
>50–67	C	F
>40–50	D	F
>30–40	E	F
≤30	F	F

Note: [a] The critical volume-to-capacity ratio is based on consideration of the through movement volume-to-capacity ratio at each boundary intersection in the subject direction of travel. The critical volume-to-capacity ratio is the largest ratio of those considered.

Nonautomobile Modes

Historically, this manual has used a single performance measure as the basis for defining LOS. However, research documented in Chapter 5, Quality and Level-of-Service Concepts, indicates that travelers consider a wide variety of factors in assessing the quality of service provided to them. Some of these factors can be described as performance measures (e.g., speed), and others can be described as basic descriptors of the urban street character (e.g., sidewalk width). The methodologies in Chapter 17, Urban Street Segments, and Chapter 18, Signalized Intersections, provide procedures for mathematically combining these factors into a score for the segment or intersection, respectively. This score is then used in this chapter to determine the LOS that is provided for a given direction of travel along a facility.

Exhibit 16-5 lists the range of scores associated with each LOS for the pedestrian travel mode. The LOS for this particular mode is determined by consideration of both the LOS score and the average pedestrian space on the sidewalk. The applicable LOS for an evaluation is determined from the table by

It is difficult to define specific conditions under which a segment is short. However, two general rules apply in making this determination. First, a segment is considered to be short if the queue frequently extends back from one intersection into the other intersection (i.e., spills back) during the analysis period. Second, a segment is considered to be short if the through signal phase duration at the downstream intersection is longer than that needed to serve all the vehicles that store on the segment plus any vehicles that can enter it from the upstream signalized intersection while the downstream phase is green. This situation results in "demand starvation." It leads to the inefficient use of the downstream through phase and the retention of unserved vehicles on the approaches to the upstream intersection. In general, segments that are bounded by signalized intersections and are shorter than 400 ft may experience one or both of these conditions.

Platoons formed at a signalized intersection are typically dispersed by the time they reach a point about 0.6 mi downstream of the signal. This distance can vary depending on the amount of access point activity along the street and the speed of the traffic stream. Regardless, the influence of platoons on urban street operation is very likely to be negligible when segment length exceeds 2 mi. Therefore, if a segment exceeds 2 mi in length and its boundary points are signalized, then the analyst should evaluate the segment as an uninterrupted-flow highway segment with isolated intersections.

LOS CRITERIA

This subsection describes the LOS criteria for the automobile, pedestrian, bicycle, and transit modes. The criteria for the automobile mode are different from the criteria used for the nonautomobile modes. Specifically, the automobile mode criteria are based on performance measures that are field-measurable and perceivable by travelers. The criteria for the pedestrian and bicycle modes are based on scores reported by travelers indicating their perception of service quality. The criteria for the transit mode are based on measured changes in transit patronage due to changes in service quality.

Automobile Mode

All uses of the word "volume" or the phrase "volume-to-capacity ratio" in this chapter refer to demand volume or demand-volume-to-capacity ratio.

Two performance measures are used to characterize vehicular LOS for a given direction of travel along an urban street segment. One measure is travel speed for through vehicles. This speed reflects the factors that influence running time along the link and the delay incurred by through vehicles at the boundary intersection. The second measure is the volume-to-capacity ratio for the through movement at the downstream boundary intersection. These performance measures indicate the degree of mobility provided by the segment. The following paragraphs characterize each service level.

LOS A describes primarily free-flow operation. Vehicles are completely unimpeded in their ability to maneuver within the traffic stream. Control delay at the boundary intersection is minimal. The travel speed exceeds 85% of the base free-flow speed, and the volume-to-capacity ratio is no greater than 1.0.

LOS B describes reasonably unimpeded operation. The ability to maneuver within the traffic stream is only slightly restricted, and control delay at the boundary intersection is not significant. The travel speed is between 67% and 85% of the base free-flow speed, and the volume-to-capacity ratio is no greater than 1.0.

LOS C describes stable operation. The ability to maneuver and change lanes at midsegment locations may be more restricted than at LOS B. Longer queues at the boundary intersection may contribute to lower travel speeds. The travel speed is between 50% and 67% of the base free-flow speed, and the volume-to-capacity ratio is no greater than 1.0.

LOS D indicates a less stable condition in which small increases in flow may cause substantial increases in delay and decreases in travel speed. This operation may be due to adverse signal progression, high volume, or inappropriate signal timing at the boundary intersection. The travel speed is between 40% and 50% of the base free-flow speed, and the volume-to-capacity ratio is no greater than 1.0.

LOS E is characterized by unstable operation and significant delay. Such operations may be due to some combination of adverse progression, high volume, and inappropriate signal timing at the boundary intersection. The travel speed is between 30% and 40% of the base free-flow speed, and the volume-to-capacity ratio is no greater than 1.0.

LOS F is characterized by flow at extremely low speed. Congestion is likely occurring at the boundary intersection, as indicated by high delay and extensive queuing. The travel speed is 30% or less of the base free-flow speed, or the volume-to-capacity ratio is greater than 1.0.

Exhibit 17-2 lists the LOS thresholds established for the automobile mode on urban streets.

Exhibit 17-2
LOS Criteria: Automobile Mode

Travel Speed as a Percentage of Base Free-Flow Speed (%)	LOS by Volume-to-Capacity Ratio[a] ≤1.0	> 1.0
>85	A	F
>67–85	B	F
>50–67	C	F
>40–50	D	F
>30–40	E	F
≤30	F	F

Note: [a] Volume-to-capacity ratio of through movement at downstream boundary intersection.

Nonautomobile Modes

Historically, this manual has used a single performance measure as the basis for defining LOS. However, research documented in Chapter 5, Quality and Level-of-Service Concepts, indicates that travelers consider a wide variety of factors when they assess the quality of service provided to them. Some of these factors can be described as performance measures (e.g., speed), and others can be described as basic descriptors of the urban street character (e.g., sidewalk width). The methodology for evaluating each mode provides a procedure for mathematically combining these factors into a score. This score is then used to determine the LOS that is provided for a given direction of travel along a segment.