

HCM2010

HIGHWAY CAPACITY MANUAL



CHAPTER 5

QUALITY AND LEVEL-OF-SERVICE CONCEPTS



TRANSPORTATION RESEARCH BOARD
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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 5

QUALITY AND LEVEL-OF-SERVICE CONCEPTS

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1. INTRODUCTION

There are many ways to measure the performance of a transportation facility or service—and many points of view that can be considered in deciding which measurements to make. The agency operating a roadway, automobile drivers, pedestrians, bicyclists, bus passengers, decision makers, and the community at large all have their own perspectives on how a roadway or service should perform and what constitutes “good” performance. As a result, there is no one right way to measure and interpret performance. **Chapter 5, Quality and Level-of-Service Concepts**, presents the concepts that the *Highway Capacity Manual* (HCM) uses to describe performance from the traveler point of view in a way that is designed to be useful to roadway operators, decision makers, and members of the community.

Quality of service describes how well a transportation facility or service operates from the traveler’s perspective. *Level of service* (LOS) is a quantitative stratification of a performance measure or measures that represent quality of service. The LOS concept facilitates the presentation of results, through the use of a familiar A (best) to F (worst) scale. LOS is defined by one or more *service measures* that both reflect the traveler perspective and are useful to operating agencies.

Three overarching concepts—quality of service, LOS, and service measures—are the subjects of this chapter.

VOLUME 1: CONCEPTS

1. HCM User’s Guide
2. Applications
3. Modal Characteristics
4. Traffic Flow and Capacity Concepts
- 5. Quality and Level-of-Service Concepts**
6. HCM and Alternative Analysis Tools
7. Interpreting HCM and Alternative Tool Results
8. HCM Primer
9. Glossary and Symbols

2. QUALITY OF SERVICE

Quality of service defined.

Quality of service describes how well a transportation facility or service operates from a traveler's perspective. Quality of service can be assessed in a number of ways. Among them are directly observing factors perceivable by and important to travelers (e.g., speed or delay), surveying travelers, tracking complaints and compliments about roadway conditions, forecasting traveler satisfaction by using models derived from past traveler surveys, and observing services not directly perceived by travelers (e.g., average time to clear an incident) that affect measures they can perceive (e.g., speed or arrival time at work).

Factors that influence traveler perceived quality of service have been found to include

- Travel time, speed, and delay;
- Number of stops incurred;
- Travel time reliability;
- Maneuverability (e.g., ease of lane changing, percent time-spent-following other vehicles);
- Comfort (e.g., bicycle and pedestrian interaction with and separation from traffic, transit vehicle crowding, ride comfort);
- Convenience (e.g., directness of route, frequency of transit service);
- Safety (actual or perceived);
- User cost;
- Availability of facilities and services;
- Facility aesthetics; and
- Information availability (e.g., highway wayfinding signage, transit route and schedule information).

The HCM provides tools to measure the multimodal operations aspects of quality of service.

The HCM's scope, measuring the multimodal performance of highway and street facilities, is narrower than the list of quality-of-service aspects listed above. As discussed in Chapter 1, HCM User's Guide, companion documents to the HCM address highway safety, roadway design, and wayfinding signage, among other topics. The HCM focuses particularly on the travel time, speed, delay, maneuverability, and comfort aspects of quality of service, although a limited number of the HCM's performance measures address some of the other aspects listed above. Federal Strategic Highway Research Program 2 research that was programmed at the time this manual was written may add measures of travel-time reliability to the HCM in the future.

LOS is an important tool used by the HCM to stratify quality of service.

The HCM provides a variety of performance measures in Volumes 2 and 3 to assess the quality of service of transportation system elements. These measures can be directly observed in the field or estimated from things observable in the field. LOS is the stratification of quality of service and is further described in the next part of this chapter.

3. LEVEL OF SERVICE

DEFINITION

LOS is a quantitative stratification of a performance measure or measures that represent quality of service. The measures used to determine LOS for transportation system elements are called *service measures*. The HCM defines six levels of service, ranging from A to F, for each service measure, or for the output from a mathematical model based on multiple performance measures. LOS A represents the best operating conditions from the traveler's perspective and LOS F the worst. For cost, environmental impact, and other reasons, roadways are not typically designed to provide LOS A conditions during peak periods, but rather some lower LOS that reflects a balance between individual travelers' desires and society's desires and financial resources. Nevertheless, during low-volume periods of the day, a system element may operate at LOS A.

USAGE

LOS is used to translate complex numerical performance results into a simple A–F system representative of travelers' perceptions of the quality of service provided by a facility or service. The LOS letter result hides much of the complexity of facility performance. This feature is intended to simplify decision making on whether facility performance is generally acceptable and whether a future change in performance is likely to be perceived as significant by the general public. The language of LOS provides a common set of definitions that transportation engineers and planners can use to describe operating conditions; however, it is up to local policy makers to decide the appropriate LOS for a given system element in their community. One reason for the widespread adoption of the LOS concept by agencies is the concept's ability to communicate roadway performance to nontechnical decision makers. However, LOS has other strengths and weaknesses, described below, that both analysts and decision makers need to be mindful of.

Step Function Nature of LOS

LOS is a step function. An increase in average control delay of 12 s at a traffic signal, for example, may result in no change in LOS, a drop of one level, or even a drop of two levels, depending on the starting value of delay, as illustrated in Exhibit 5-1.

From a traveler perception standpoint, the condition shown in Exhibit 5-1 is not necessarily inconsistent. A change of LOS indicates that roadway performance has transitioned from one given range of traveler-perceivable conditions to another range, while no change in LOS indicates that conditions have remained within the same performance range as before. Service measure values indicate where conditions lie within a particular performance range. However, because a small change in a service measure, or the output from a mathematical model based on multiple performance measures, can sometimes result in a change from one LOS to another, the LOS result could imply a more significant effect than actually occurred.

LOS defined.

LOS is measured on an A–F scale. LOS A represents the best conditions from a traveler's perspective.

LOS is a useful and widely adopted tool for communicating roadway performance to laypersons and decision makers. However, one should also be mindful of its weaknesses.

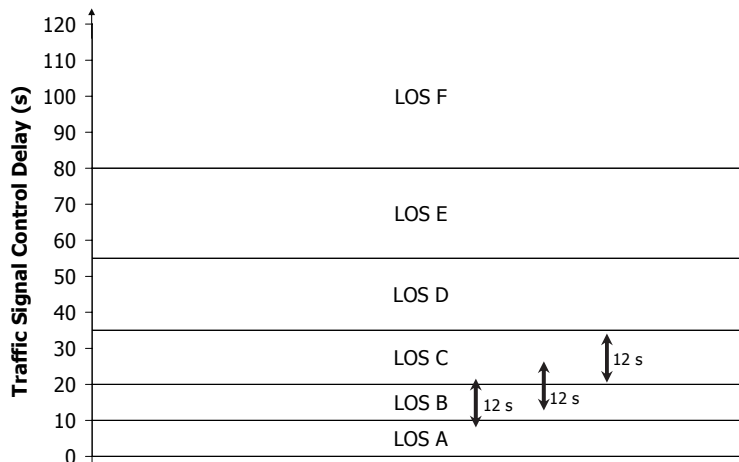
Exhibit 5-1
Example of the Step
Function Nature of LOS

Identical changes in the service measure value may result in no change in LOS or a change of one or more levels of service, depending on how close the starting value is to a LOS threshold.

Defining performance standards on the basis of LOS (or any fixed numerical value) means that small changes in performance can sometimes result in the standard being exceeded, when a facility is already operating close to the standard.

Chapter 7, Interpreting HCM and Alternative Tool Results, discusses sources of uncertainty and their impacts on analysis results in more detail.

Models provide a best estimate of service measure values, but the "true" value likely lies within a confidence interval range above or below the estimated value.



This aspect of LOS can be a particularly sensitive issue when agencies define their operational performance standards solely by using LOS. However, the definition of a fixed standard, whether numerically or as a LOS letter, always brings the possibility that a small change in performance can trigger the need for potentially costly improvements.

Variability of the Inputs to LOS

Although computer software that implements HCM methodologies can sometimes report results to many decimal places, three major sources of uncertainty influence service measure values and, thus, the LOS result:

1. The models used to estimate service measure values have confidence intervals associated with their outputs;
2. These models may, in turn, rely on the output of other models that have their own associated confidence intervals; and
3. The accuracy of input variables, such as demand flow rate, is taken to be absolute when, in fact, there is a substantial stochastic variation around the measured values.

Thus, any reported service measure value, whether resulting from an HCM methodology, an alternative tool, or even field measurement, potentially has a fairly wide range associated with it in which the "true" value actually lies. The LOS concept helps to downplay the implied accuracy of a numeric result by presenting a range of service measure results as being reasonably equivalent from a traveler's point of view. Nevertheless, the same variability issues also mean that the "true" LOS value may be different from the one predicted by a methodology. In addition, for any given set of conditions, different travelers may perceive their LOS to be different from one another, as well as different from the LOS estimated by an HCM method. One way of thinking about reported service measure values and the corresponding LOS result is that they are the statistical "best estimators" of conditions and aggregate traveler perception.

Beyond LOS F

The HCM uses LOS F to define operations that have either broken down (i.e., demand exceeds capacity) or have exceeded a specified service measure value (or combination of service measure values) that most users would consider unsatisfactory. However, particularly for planning applications where different alternatives may be compared, analysts may be interested in knowing just how bad the LOS F condition is. Several measures are available to describe individually, or in combination, the severity of a LOS F condition:

- *Demand-to-capacity ratios* describe the extent to which capacity is exceeded during the analysis period (e.g., by 1%, 15%, etc.).
- *Duration of LOS F* describes how long the condition persists (e.g., 15 min, 1 h, 3 h).
- *Spatial extent measures* describe the areas affected by LOS F conditions. These include measures such as the back of queue and the identification of the specific intersection approaches or system elements experiencing LOS F conditions.

The HCM does not subdivide LOS F, but several measures are available to describe the severity of a LOS F condition.

Separate LOS Reporting by Mode and System Element

LOS is reported separately for each mode operating on a given system element [although some other modes, such as large trucks, recreational vehicles (RVs), and motorcycles are currently considered members of the automobile model for HCM analysis purposes]. Each mode's travelers have different perspectives and potentially experience very different conditions while traveling along a particular roadway. Using a blended LOS risks overlooking quality of service deficiencies for nonautomobile travelers that discourage the use of those modes, particularly if the blended LOS is weighted by the number of modal travelers. Other measures, such as person-delay, can be used when an analysis requires a combined measure.

LOS is reported separately, by mode, for a given system element.

Identical values of some service measures (e.g., delay) can produce different LOS results, depending on the system element to which the service measure is applied. The TRB Committee on Highway Capacity and Quality of Service (HCQS Committee) believes that travelers' expectation of performance varies at different system elements (e.g., unsignalized intersections versus signalized intersections) but realizes that further research is needed to understand fully the variation in traveler perceptions of LOS across facility types.

LOS as Part of a Bigger Picture

Neither LOS nor any other single performance measure tells the full story of roadway performance. Depending on the particulars of a given analysis, queue lengths, demand-to-capacity ratios, average travel speeds, indicators of safety, quantities of persons and vehicles served, and other performance measures may be just as or even more important to consider, whether or not they are specifically called out in an agency standard. For this reason, the HCM provides methods for estimating a variety of useful roadway operations performance measures, and not just methods for determining LOS. Chapter 7, Interpreting

No single performance measure tells the full story of roadway performance.

HCM and Alternative Tool Results, lists the major performance measures available from each chapter of Volumes 2 and 3.

Duration of an operating condition can be important to know, since it helps describe the severity of the condition (e.g., the duration of a LOS F condition). In cases where demand exceeds capacity, duration *must* be known in order to set the analysis period long enough so that all demand is served and all relevant performance measures can be calculated properly. Frequency and probability of a particular condition occurring (e.g., likelihood or frequency of queue storage being exceeded during an analysis period) are also useful descriptors.

4. SERVICE MEASURES

DEFINITION AND CHARACTERISTICS

Service measures are performance measures used to define LOS for transportation system elements.

Ideally, service measures should exhibit the following characteristics:

- Service measures should reflect travelers' perceptions (i.e., measures should reflect things travelers can perceive during their journey);
- Service measures should be useful to operating agencies (e.g., agency actions should be able to influence future LOS);
- Service measures should be directly measurable in the field (e.g., an analyst wishing to determine LOS for a two-lane highway used for recreational access can go into the field and directly measure average travel speed); and
- Service measures should be estimable given a set of known or forecast conditions (e.g., a method is provided in Chapter 15 to estimate the average travel speed for a two-lane highway, given inputs for roadway and traffic conditions).

SERVICE MEASURE SELECTION

Historically, the selection of a service measure or measures for an analysis methodology has been based on the collective opinion and judgment of TRB's HCQS Committee. The service measure threshold values that identify the breakpoints between each level of service have also been determined by the HCQS Committee. This approach was necessary, because until recently little information was available on the subject of how travelers evaluate operating conditions. However, it has been the intent of the committee to select service measures that it felt would be highly correlated with travelers' personal assessments of the operating conditions. Since 1993, there has been considerably more research focused on determining appropriate service measures based directly on traveler input. While this area of research was still immature at the time of publication of this edition of the HCM, the HCQS Committee intends to monitor and evaluate future research in this area for potential inclusion in subsequent editions of the HCM.

Studies that seek to determine service measures and thresholds based on traveler perceptions obviously use research approaches that directly involve a sample of travelers. Some of the methods used to obtain this direct traveler input include in-field experiments (e.g., driving or riding courses), simulated in-field experiments (such as through the use of video presentations), focus groups, and surveys. The study participants are typically asked to rate the conditions they are presented with on a scale of "very good" to "very poor," or something similar. The qualitative ratings are later converted to numeric values for analysis purposes. Some challenges to these types of studies include designing the instrument (field experiment, focus group, etc.) to capture all of the roadway, traffic, and control factors that might affect travelers' perceptions of operating

Service measures reflect traveler perceptions and can be influenced by agency actions.

Service measure selection.

conditions; excluding factors that may not be relevant but could distract study subjects; recruiting an adequate sample of study participants from both a quantity and a diversity perspective; replicating desired conditions (for in-field experiments) for repeated observations; and accounting for the distribution of LOS responses that will result from each test scenario in the analysis methodology.

The advantage of this type of research approach is that, with application of an appropriate analysis methodology, multiple variables can be considered simultaneously, consistent with the high likelihood that travelers consider multiple factors when they evaluate the operating conditions. Including multiple factors also gives agencies more options in seeking to achieve a desired LOS for a given mode or in balancing the needs of various modes. All variables found to be statistically significant are incorporated into a mathematical function (hereinafter referred to as a *model*). In the model, the coefficients (i.e., weighting factors) associated with each of the variables are determined directly through the statistical analysis. The output from such a model is a value often referred to as a LOS score. The LOS score value generally represents the average score that travelers would give a facility or service. Furthermore, some of the methodologies can directly estimate the threshold values that are used to distinguish between the LOS categories, again, on the basis of traveler input. To determine the LOS, the LOS score value is compared with the statistically estimated threshold values.

While variables representing any number of things can be included in this type of model, for models to be useful from a practical perspective, only variables representing operational or design conditions are usually included. Operational conditions refer to variables such as delay and speed (i.e., performance measures), while design conditions refer to variables such as median type and sidewalk presence. Traveler characteristics (e.g., age, gender, income) can certainly affect LOS perceptions; however, these data are difficult to collect in a transportation engineering situation. Thus, their utility in a LOS model is limited.

Several methodological approaches have been applied to relate traveler perceptions directly to LOS, including regression-based methods (1–4), ordered probit models (5, 6), and fuzzy clustering (7). These studies have addressed facilities such as urban and rural freeways, arterial streets, and signalized intersections. LOS methods resulting from some of these studies have been included in the HCM 2010, while others have been studied by the HCQS Committee to improve the understanding of techniques used in estimating traveler-based LOS.

This edition of the HCM is the first to incorporate LOS methodologies that are based directly on results from traveler perceptions of LOS. As the field of traveler perception of LOS research continues to mature and results from regional studies are validated nationally, the HCQS Committee expects to continue to include these new LOS methodologies in future editions of the HCM. When research is not available to support traveler-perceived LOS methodologies,

HCQS Committee–selected service measures and thresholds continue to be used in this edition of the HCM.

DETERMINATION OF LOS F

The threshold between LOS E and LOS F is based on the judgment of the HCQS Committee in some instances and is determined directly from research on traveler perceptions of LOS in others. One example of where the service measure and LOS thresholds were determined by the HCQS Committee is basic freeway segments; density was selected as the service measure and the LOS E–F density threshold value was selected as the density at which traffic flow transitions from uncongested to congested. Bicycling on urban streets is an example of where the service measures were determined from traveler perception of LOS research; the LOS E–F threshold was chosen as a value that represents the transition to a totally unacceptable condition (i.e., an average rider will not ride under these conditions). Thresholds between LOS A and E may be based on ranges of values that define particular operating conditions or may simply provide an even gradation of values from LOS A to E. As mentioned previously, in some studies on traveler perceptions of LOS, the methodological approach explicitly yields the model variables (e.g., speed, median presence) as well as the specific LOS thresholds. However, these thresholds are still a function of the total number of LOS categories originally included in the study.

The volume-to-capacity (v/c) ratio (or, more correctly, the demand-to-capacity, d/c , ratio) is a special-case service measure. It cannot be directly measured in the field, nor is it a measure of traveler perceptions. Until capacity is reached (i.e., when flow breaks down on uninterrupted-flow facilities and when queues build on interrupted- or uninterrupted-flow facilities), the v/c ratio is not perceivable by travelers. Therefore, the HCM often uses the v/c ratio to define the LOS E–F threshold, but not to define other LOS thresholds.

The v/c ratio is often used to define the LOS E–F threshold, but not other LOS thresholds.

SERVICE MEASURES FOR SPECIFIC SYSTEM ELEMENTS

Cross-Cutting Issues

Automobile Mode

A facility's capacity to serve the automobile mode reflects the effects of all motorized vehicles using the facility, including trucks, RVs, motorcycles, and intercity buses. In contrast, LOS for the automobile mode reflects the perspective of automobile drivers and passengers, but not necessarily the perspectives of other motorized vehicle users. Although automobiles are usually the dominant motorized vehicle type on roadways, analysts should use care in interpreting LOS results in special cases, such as intermodal-terminal access routes, where trucks may dominate.

LOS for the automobile mode is reflective of automobile driver and passenger perspectives, but not necessarily those of other motorized vehicle users.

Pedestrian and Bicycle Modes

Depending on local regulations, pedestrians and bicycles may be allowed on all types of uninterrupted-flow facilities, including sections of freeways. However, research is only available to support LOS estimation methods for bicyclists traveling on two-lane and multilane highways. Pathways that are

Pathways parallel to freeways and multilane highways are analyzed by using the off-street facility procedures.

Transit service measures are provided only for urban streets. Consult the TCQSM for service measures for other situations.

Density is the automobile service measure for all freeway and multilane highway system elements.

parallel to freeways and multilane highways use the service measures for off-street pedestrian and bicycle facilities. Of the various types of interrupted-flow system elements, pedestrian and bicycle service measures are provided for urban street facilities, urban street segments, signalized intersections, and off-street pedestrian and bicycle facilities. Pedestrian LOS can also be calculated for two-way STOP-controlled intersections and roundabouts.

Transit Mode

Bus service on uninterrupted-flow facilities typically serves longer-distance trips, with few (if any) stops. The transit service measures provided in the *Transit Capacity and Quality of Service Manual (TCQSM)* (8) can be used to evaluate bus service along uninterrupted-flow facilities, as well as rail service operating within an uninterrupted-flow facility's right-of-way.

The HCM provides transit service measures for urban street facilities and segments to facilitate multimodal comparisons of urban-street LOS. The TCQSM's service measures can be used to evaluate transit LOS at specific bus stops, for specific routes, for specific origin–destination pairs, and for specific areas. Some of the HCM's performance measures, such as delay, may also be useful in multimodal comparisons—for example, in comparing person-delay at an intersection with and without a transit preferential treatment, such as a queue-jump lane.

Freeways and Multilane Highways

Automobile Mode

Although travel speed is a major concern of drivers that relates to service quality, freedom to maneuver within the traffic stream and proximity to other vehicles are equally noticeable concerns. These qualities are related to the *density* of the traffic stream. Unlike speed, density increases as flow increases up to capacity, resulting in a service measure that is both perceivable by motorists and is sensitive to a broad range of flows. Density is used as the service measure for freeway facilities, basic freeway segments, ramp junctions, weaving segments, and multilane highways.

Bicycle Mode

Bicycle LOS for multilane highways is based on a *bicycle LOS score* model. The model uses variables determined from research that relate to bicyclists' comfort and perceived exposure while riding on multilane highways, such as separation from traffic, motorized traffic volumes and speeds, heavy-vehicle percentage, and pavement quality.

Higher vehicle volumes, a greater proportion of trucks and buses, and higher vehicle speeds all act to decrease a bicyclist's perceived comfort and traffic exposure. Striped bicycle lanes or roadway shoulders add to the perceived sense of traffic separation and improve the LOS. Pavement quality affects bicyclists' ride comfort: the better the pavement quality, the better the LOS.

Two-Lane-Highway Measures

Automobile Mode

Traffic operations on two-lane, two-way highways differ from those on other uninterrupted-flow facilities. Lane changing and passing are possible only in the face of oncoming traffic. Passing demand increases rapidly as traffic volumes increase, and passing capacity in the opposing lane declines as volumes increase. Therefore, on two-lane highways, unlike other types of uninterrupted-flow facilities, normal traffic flow in one direction influences flow in the other direction. Motorists must adjust their travel speeds as volume increases and the ability to pass declines.

Efficient mobility is the principal function of major two-lane highways that connect major traffic generators or that serve as primary links in state and national highway networks. These routes tend to serve long-distance commercial and recreational travelers, and long sections may pass through rural areas without traffic-control interruptions. Consistent high-speed operations and infrequent passing delays are desirable for these facilities.

Other paved, two-lane rural highways are intended to serve primarily an accessibility function. Although beneficial, high speed is not the principal concern. Delay—as indicated by the formation of platoons—is more relevant as a measure of service quality.

Two-lane roads also serve scenic and recreational areas in which the vista and environment are meant to be experienced and enjoyed without traffic interruption or delay. A safe roadway is desired, but high-speed operation is neither expected nor desired. For these reasons, three service measures are used for two-lane highways: *percent time-spent-following*, *average travel speed*, and *percent free-flow speed*.

Percent time-spent-following represents the freedom to maneuver and the comfort and convenience of travel. It is the average percentage of travel time that vehicles must travel in platoons behind slower vehicles because of the inability to pass. Percent time-spent-following is difficult to measure in the field. However, the percentage of vehicles traveling with headways of less than 3 s at a representative location can be used as a surrogate measure.

Average travel speed reflects the mobility on a two-lane highway: it is the length of the highway segment divided by the average travel time of all vehicles traversing the segment in both directions during a designated interval.

Percent of free-flow speed represents the ability of vehicles to travel at or near the posted speed limit.

LOS criteria use one or two of these measures. On major two-lane highways, for which efficient mobility is paramount, both percent time-spent-following and average travel speed define LOS. However, roadway alignments with reduced design speeds will limit the LOS that can be achieved. On highways for which accessibility is paramount and mobility less critical, LOS is defined only in terms of percent time-spent-following, without consideration of average travel speed. On two-lane highways in developed rural areas, LOS is defined in terms of percent of free-flow speed.

Traveler expectations for and travel conditions on two-lane highways are different from those for other uninterrupted-flow facilities.

Percent time-spent-following defined.

Average travel speed defined.

Percent of free-flow speed defined.

Bicycle Mode

Bicycle LOS for two-lane highways is determined by a *bicycle LOS score* model in the same manner as described above for multilane highways, with the addition of on-highway parking as a factor that may exist on two-lane highways. The presence of on-highway parking negatively affects bicycle LOS because bicyclists tend to leave a buffer between themselves and parked vehicles, resulting in less separation between themselves and moving vehicles.

Urban Street Facility and Segment Measures

Automobile Mode

The service measure for the automobile mode on an urban street is the percent of base free-flow speed. Motorists traveling along arterial streets expect to be able to travel at or near the posted speed limit between intersections and to have to stop only infrequently. As delay due to traffic control devices and to other roadway users (e.g., vehicles stopped in a travel lane waiting to turn, buses stopping to serve passengers, or pedestrian crossings) increases, the lower the average speed and the lower the perceived LOS.

Research on automobile travelers' perceptions of LOS, as part of the National Cooperative Highway Research Program (NCHRP) 3-70 project, revealed that a combination of stops per mile and left-turn lane presence at signalized intersections had the highest statistical significance for predicting automobile LOS. However, the HCQS Committee elected to retain usage of a time-based service measure to analyze automobile LOS on urban streets for this edition of the HCM. The alternative NCHRP 3-70 methodology is also presented in Chapter 17, Urban Street Segments, since it is well suited for applications with a focus on determining multimodal LOS trade-offs and designing complete streets.

Pedestrian Mode

Pedestrian LOS for urban streets is based on a *pedestrian LOS score* model that includes variables determined from research on pedestrians' perceptions of LOS. These variables relate to pedestrians' experiences walking along street segments between signalized intersections, crossing side streets at signalized intersections, and crossing the street between signalized intersections.

The segment component relates to both the density of pedestrians along the street and to pedestrian comfort and perceived exposure to traffic. The pedestrian-density indicator is a function of pedestrian volumes and sidewalk width, while the nondensity indicator is a function of separation from traffic due to distance and physical objects, sidewalk presence and width, and motorized traffic volumes and speeds. The worse of the two indicators is used to determine pedestrian-perceived segment LOS. The nondensity indicator is predominately used in suburban and rural settings.

The signalized-intersection component relates to pedestrian delay and perceived exposure to or interaction with traffic. The exposure elements of the indicator include potentially conflicting traffic volumes, parallel traffic volumes, parallel traffic speed, crossing width, and channelizing-island presence.

Urban street pedestrian LOS combines the quality of walking along a street, crossing at signalized intersections, and crossing the street between traffic signals.

The roadway-crossing component is a function of the lesser of the delay in waiting for a gap to cross the street and the delay involved in diverting to the nearest signalized intersection. It also incorporates the segment and signalized-intersection components, which relate to the quality of the pedestrian environment experienced when pedestrians divert to a signal, either because of lower delay or a prohibition on crossings between signalized intersections.

Overall, pedestrian LOS is improved by the provision of sidewalks, wider sidewalks, a greater degree of separation from traffic, and reduced delays crossing the street at both signalized and unsignalized locations. Higher traffic volumes, higher traffic speeds, and wider streets all tend to reduce pedestrian LOS.

Bicycle Mode

Bicycle LOS for urban streets is based on a *bicycle LOS score* model that includes variables determined from research on bicycle riders' perceptions of LOS. These variables relate to bicyclists' experiences at signalized intersections and their experiences on street segments between signalized intersections. The intersection component relates to bicyclist comfort and perceived exposure to traffic and is a function of separation from traffic, cross-street width, and motorized traffic volumes. The segment component similarly relates to comfort and perceived exposure. It is a function of separation from traffic, motorized traffic volumes, traffic speeds, heavy-vehicle percentage, presence of parking, and pavement quality. The frequency of unsignalized intersections and driveways between traffic signals is also a factor in the LOS score value.

Higher vehicle volumes, a greater proportion of trucks and buses, higher vehicle speeds, and presence of parking all act to decrease a bicyclist's perceived comfort and traffic exposure. Striped bicycle lanes or roadway shoulders add to the perceived sense of traffic separation and improve the LOS. Pavement quality affects bicyclists' ride comfort: the better the pavement quality, the better the LOS.

Transit Mode

Transit LOS for urban streets is based on a *transit LOS score* model that includes variables determined from research on transit riders' perceptions of LOS. These variables relate to passengers' experiences walking to a transit stop on the street, waiting for the transit vehicle, and riding on the transit vehicle. The walking-to-the-stop component is based on the street's pedestrian LOS score: transit passengers are usually pedestrians before and after their transit trip—and improvements to the pedestrian environment along streets with transit service contribute to a better LOS. The waiting component is a function of the transit vehicle frequency (relating to wait time and trip-making convenience), service reliability (unplanned passenger waiting time at the stop), and the presence of shelters and benches (which make waiting time more comfortable). Finally, the riding-on-the-vehicle satisfaction is a function of average travel speed (a convenience factor) and passenger loads (a comfort factor).

Urban street bicycle LOS combines the quality of bicycling along the street between traffic signals and the quality of passing through signalized intersections.

The transit service measure applies to bus, streetcar, and at-grade light rail services that make stops along an urban street.

The service measure combines traveler perceptions walking to a transit stop, waiting for a transit vehicle, and riding on the vehicle.

Control delay is the automobile service measure for urban street intersections.

Urban Street Intersections

Automobile Mode

The service measure for the automobile mode at all urban-street intersections—including signalized intersections, all-way STOP-controlled intersections, two-way STOP-controlled intersections, roundabouts, and interchange ramp terminals—is *control delay*.

Control delay, which was defined in Chapter 4, Traffic Flow and Capacity Concepts, is a measure of driver discomfort, frustration, fuel consumption, and increased travel time. It depends on a number of variables, which are different depending on whether the intersection is signalized or unsignalized. As control delay increases, LOS worsens. The maximum control delay allowed for a given LOS at unsignalized intersections is lower than for signalized intersections due to differing driver expectations. In the HCQS Committee's opinion, the expectation of drivers is that a signalized intersection is designed to carry higher traffic volumes and experience greater delay than an unsignalized intersection.

Pedestrian, Bicycle, and Transit Modes

At the time of publication, there was insufficient research to be able to provide pedestrian and bicycle LOS for urban street intersections, except for signalized intersections and—for pedestrians only—two-way STOP-controlled intersections. The HCM provides transit LOS measures only at the urban street segment and facility levels.

Signalized Intersections

Pedestrian LOS at signalized intersections is based on a *pedestrian LOS score* model that incorporates conflicting motorized vehicle volumes and speeds, crosswalk length, average pedestrian delay, and the presence of right-turn channelizing islands. Pedestrian LOS improves with lower motorized vehicle volumes and speeds, shorter crosswalk lengths, lower delay, and the provision of right-turn channelizing islands.

Bicycle LOS at signalized intersections is based on a *bicycle LOS score* model that incorporates perceived separation from motorized vehicle traffic, motorized vehicle volumes, cross-street width, and presence and utilization of on-street parking. Bicycle LOS improves with greater perceived separation from motorized vehicle traffic, lower motorized vehicle volumes, shorter cross-street widths, and reduced on-street parking conflicts.

Two-Way STOP-Controlled Intersections

Pedestrian LOS at two-way STOP-controlled intersections is based on average pedestrian *control delay* crossing the major street. Lower vehicle volumes, presence of a median, and provision of pedestrian crossing treatments that improve motorist yielding rates all help to improve pedestrian LOS.

Off-Street Pedestrian and Bicycle Facilities

Pedestrian Mode

Off-street facilities used exclusively by pedestrians (e.g., pedestrian pathways, plazas, and stairways) use *pedestrian space* as the service measure. As the space available to pedestrians increases, the ability to move at one's desired speed along one's desired line of travel increases. Therefore, as the space available to a pedestrian on an off-street facility increases, so does the LOS.

When an off-street facility is shared by pedestrians and bicycles, pedestrian quality of service is much more affected by the bicyclists using the facility than by other pedestrians because of the speed differential between the two types of travelers. Therefore, the pedestrian service measure for shared off-street facilities is based on *events*, the number of times per hour that a pedestrian is met by or passed by bicyclists. The greater the number of bicyclists on a shared facility, the lower the pedestrian LOS.

Bicycle Mode

Bicycle LOS for off-street bicycle facilities, both exclusive and shared, is based on a *bicycle LOS score* model that includes variables determined from research on bicycle riders' perceptions of LOS. These variables consist of the number of times a bicyclist meets other path users per minute, the number of times per minute on average that a bicyclist passes or is delayed in passing other path users, the presence of a centerline, and the path width. As the number of other path users (including bicyclists) increases, the LOS declines. Wider paths and the presence of a centerline contribute to better LOS.

The service measure for off-street exclusive pedestrian facilities is pedestrian space.

The pedestrian service measure for shared off-street facilities is the number of times per hour a pedestrian meets or is passed by bicyclists.

The bicycle service measure for all off-street facilities is a bicycle LOS score.

Many of these references can be found in the Technical Reference Library in Volume 4.

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