Chapter Thirty

HIGHWAY CAPACITY

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30.1 TRAFFIC VOLUME CONTROLS

30.1.1 Definitions

1. Annual Average Daily Traffic (AADT). The total yearly traffic volume in both directions of travel divided by the number of days in a year.

2. Average Daily Traffic (ADT). The total traffic volume in both directions of travel during a time period greater than one day but less than one year divided by the number of days in that time period.

3. Capacity. The maximum number of vehicles which reasonably can be expected to traverse a point or uniform roadway section during a given time period under prevailing roadway, geometric, environmental, traffic and control conditions. Capacity is usually expressed as vehicles per hour, passenger cars per hour, or persons per hour.

4. Delay. The primary performance measure on interrupted flow facilities, especially at intersections. This is determined by the additional travel time experienced by a driver, passenger or pedestrian. For intersections, average delay is measured and expressed in seconds per vehicle.

5. Density. The number of vehicles on a roadway segment averaged over space, usually expressed as vehicles per mile (km) or vehicles per mile (km) per lane.

6. Design Hourly Volume (DHV). The one-hour vehicular volume in both directions of travel in the design year selected for highway design. The DHV is typically the 30th highest hourly volume during the design year. Note that, for capacity analyses, the DHV is typically converted to an hourly flow rate based on the maximum 15 minute flow rate during the DHV.

7. Directional Design Hourly Volume (DDHV). The highest of two directional volumes which combine to form the DHV.

8. Directional Distribution (D). The distribution, by percent, of the traffic in each direction of travel during the DHV, ADT and/or AADT.

9. Flow Rate. The equivalent hourly rate at which vehicles pass over a given point or section on a lane or roadway on which the volume is collected over a time interval less than one hour. It is expressed as vehicles per hour.

10. Heavy-Vehicle Adjustment Factor. A mix of vehicle types must be adjusted to an equivalent flow rate expressed in terms of passenger cars per hour per lane (see Passenger Car Equivalent). The adjustment is made using the heavy-vehicle adjustment factor. The adjustment factor is based on the proportion of trucks, buses and RVs in the traffic stream and on the length and severity of the upgrade or downgrade. Trucks and buses are treated identically. RVs are treated separately from trucks and buses. Data on heavy vehicles are compiled and reported by the MDT Data and Statistics Bureau.

11. Level of Service (LOS). A qualitative concept that has been developed to characterize acceptable degrees of congestion as perceived by motorists. In the Highway Capacity Manual, the qualitative descriptions of each level of service (A through F) have been converted into quantitative measures for the capacity analysis for each highway element, including:

    a. basic freeway segments;
    b. freeway mainline/ramp merge/diverge;
    c. freeway weaving areas;
    d. interchange ramp terminals;
    e. 2-lane, 2-way highways;
    f. multi-lane highways;
    g. signalized intersections;
    h. urban streets;
    i. 2-way stop intersections;
    j. all-way stop intersections; and
    k. roundabouts.

    LOS-determining parameters include speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience. Chapter Twelve of the Montana Road Design Manual presents guidelines for selecting the level of service for capacity analyses in road design.

12. Passenger Car Equivalent (PCE). Compared to passenger cars, heavy vehicles (trucks, buses, RVs) are slower moving and greater in length and create longer and more frequent gaps of excessive lengths in the traffic stream. PCE represents an equivalent number of passenger cars that would use the same amount of capacity as a heavy vehicle under prevailing roadway and traffic conditions and is determined by applying an adjustment factor in the analysis (see Heavy-Vehicle Adjustment Factor). This allows capacity to be estimated

based on a consistent measure of flow in terms of passenger cars per hour per lane.

13. Peak-Hour Factor (PHF). A ratio of the volume occurring during the peak hour to the maximum rate of flow during a given time period within the peak hour (typically, 15 minutes). PHF may be expressed as follows:

$$\text{PHF} = \frac{\text{Peak Hour Volume}}{4\left(\text{Peak 15 minute Volume}\right)}$$

14. Service Flow Rate. The maximum hourly vehicular volume that can pass through a highway element at the selected level of service.

30.1.2 Design Year Selection

A highway should be designed to accommodate the traffic volume expected to occur within the life of the facility under reasonable maintenance. This involves projecting the traffic conditions for a selected future year. The following will apply:

1. New Construction/Reconstruction Projects. The roadway design will be based on a 20-year projection of traffic volume. Life-cycle analysis for pavement types may exceed this period.

2. Widening Projects. When capacity and level of service are assessed, the analysis will be based on a 20-year projection of traffic. However, it is acceptable to base the design year on the design analysis period used for pavement design, with eight years as a minimum design forecast year.

The design year is measured from the expected construction completion date. Future traffic volumes on State highways are provided by the MDT Data and Statistics Bureau.

30.1.3 Design Hourly Volume Selection

For most geometric design elements which are impacted by traffic volumes, the peaking characteristics are most significant. The highway facility should be able to accommodate the design hourly volume (adjusted for the peak-hour factor) at the selected level of service. This design hourly volume (DHV) will affect many design elements including the number of travel lanes, lane and shoulder widths and intersection geometrics.

The 30^{th} highest hourly volume in the selected design year is typically used to determine the DHV for design purposes.

For design analysis of intersections, the DHV of the intersecting roadways should be compared with the existing 30^{th} highest hourly volume. An expected percent growth should be identified. If a modeled DHV is not available, existing traffic volumes should be analyzed with respect to the ability to absorb the expected growth.

30.2 CAPACITY ANALYSES

The highway mainline or intersection should be designed to accommodate the selected design hourly volume (DHV) at the selected level of service (LOS). This may involve adjusting the various highway factors that affect capacity until a design is found that will accommodate the DHV. The detailed calculations, factors and methodologies are presented in the Highway Capacity Manual (HCM). During the analysis, the design service volume (or flow rate) of the facility is calculated. Capacity assumes a LOS E; the design service volume is the maximum volume of traffic that a highway of designed dimensions is able to serve without the degree of congestion falling below a preselected level. This is always higher than LOS E.

For various types of highway facilities, the HCM documents the measures of effectiveness that should be used in capacity analyses to determine level of service. These measures are presented in Figure 30.2A. For each facility type, the HCM provides the analytical tools necessary to calculate the numerical value of its respective measure of effectiveness.

The following presents the simplified procedure for conducting a capacity analysis for the highway mainline:

1. Select the design year.
2. Determine the DHV.
3. Select the target level of service (see Figure 30.2B).
4. Identify and document the proposed highway geometric design (e.g., lane width, clearance to obstructions, number and width of approach lanes at intersections).
5. Using the HCM, analyze the capacity of the highway element for the proposed design:
    a. determine the maximum flow rate under ideal conditions;
    b. identify the adjustments for prevailing roadway, traffic and control conditions; and
    c. calculate the service flow rate for the selected level of service.

TYPE OF FACILITY	MEASURE OF EFFECTIVENESS	
	US Customary	Metric
Uninterrupted Flow		
Freeways		
Basic freeway segments	Density (pce/mi/ln)	Density (pce/km/ln)
Weaving areas	Speed (mph)	Speed (km/h)
Ramp merge	Density (pce/mi/ln)	Density (pce/km/ln)
Ramp diverge	Density (pce/mi/ln)	Density (pce/km/ln)
Multilane highways	Density (pce/mi/ln)	Density (pce/km/ln)
Two-lane highways	Time delay (%) Speed (mph)	Time delay (%) Speed (km/h)
Interrupted Flow		
Signalized Intersections	Average stopped delay (s/veh)	Average stopped delay (s/veh)
Urban streets	Speed (mph)	Speed (km/h)
Two-way stop intersections	Average stopped delay (s/veh)	Average stopped delay (s/veh)
All-way stop intersections	Average stopped delay (s/veh)	Average stopped delay (s/veh)
Roundabouts	(1)	(1)
Interchange Ramp Terminals	Average stopped delay (s/veh)	Averaged stopped delay (s/veh)

(1) HCM does not include a method for estimating performance measures for roundabouts. Non-HCM models that produce a delay estimate should be used.

MEASURES OF EFFECTIVENESS FOR LEVEL OF SERVICE

Figure 30.2A

6. Compare the calculated service flow rate to the DHV. If the DHV is less than or equal to the service flow rate, the proposed design will meet the objectives of the capacity analysis. If the DHV exceeds the service flow rate, the proposed design will be inadequate. The various elements in the capacity analysis will help the designer assess where excess or deficient design parameters exist.

The default values in the HCM will apply unless reliable local data is available (e.g., the peak-hour factor). Use the criteria presented in Figure 30.2B when selecting the level of service for the facility.

TYPE OF FACILITY	LEVEL-OF-SERVICE CRITERIA	
Freeways (NHS — Interstate)	Rural: B	Urban: B
Principal Arterials (NHS — Non-Interstate)	Level/Rolling: B	Mountainous: C
Minor Arterials (Non-NHS — Primary)	Level/Rolling: B	Mountainous: C
Rural Collector Roads (Non-NHS — Secondary)	Desirable: B	Minimum: C
Urban Principle Arterials (NHS — Non-Interstate) 2-Lane and Multi-Lane	Desirable: B	Minimum: C
Urban Minor Arterials (Non-NHS) 2-Lane and Multi-Lane	Desirable: B	Minimum: C
Urban Collector Streets (Non-NHS)	Desirable: C	Minimum: D

LEVEL-OF-SERVICE CRITERIA

Figure 30.2B

30.3 TRUCK-CLIMBING LANES

The Traffic Engineering Section typically determines the need for truck-climbing lanes and will provide the design details for the lanes where they are justified.

In general, the following conditions and criteria should be satisfied to justify a truck-climbing lane on a two-lane highway:

1. the upgrade traffic flow rate is in excess of 200 veh/h; and

2. the upgrade heavy vehicle (e.g., trucks, buses, recreational vehicles) flow rate is in excess of 20 veh/h; and

3. the critical length of grade speed reduction is 10 mph (15 km/h) or greater (see Figure 26.2A); and

4. one of the following conditions exists:

    a. the level of service (LOS) on the upgrade is D or worse, or

    b. a reduction of two or more LOS is experienced when moving from the approach segment to the upgrade.

Note that these guidelines do not apply to truck-climbing lanes on multilane highways. Criteria for multilane facilities can be found in the HCM.

In addition to above guidelines, the designer should consider the following when determining whether or not to provide a climbing lane:

1. construction costs,
2. right-of-way impacts,
3. environmental impacts,
4. downstream passing opportunities to break up platoons caused by slow trucks,
5. adverse crash experience on the upgrade relative to slow-moving vehicles, and
6. engineering judgment.

The objective of the capacity analysis is to determine if the above guidelines are met for two-lane facilities. This is accomplished by calculating the service flow rate for each LOS level (A through D) and comparing this to the actual flow rate on the upgrade. Because a LOS worse than D justifies the consideration of a truck-climbing lane, it is not necessary to calculate the service flow rate for LOS E. The HCM provides examples of this procedure.