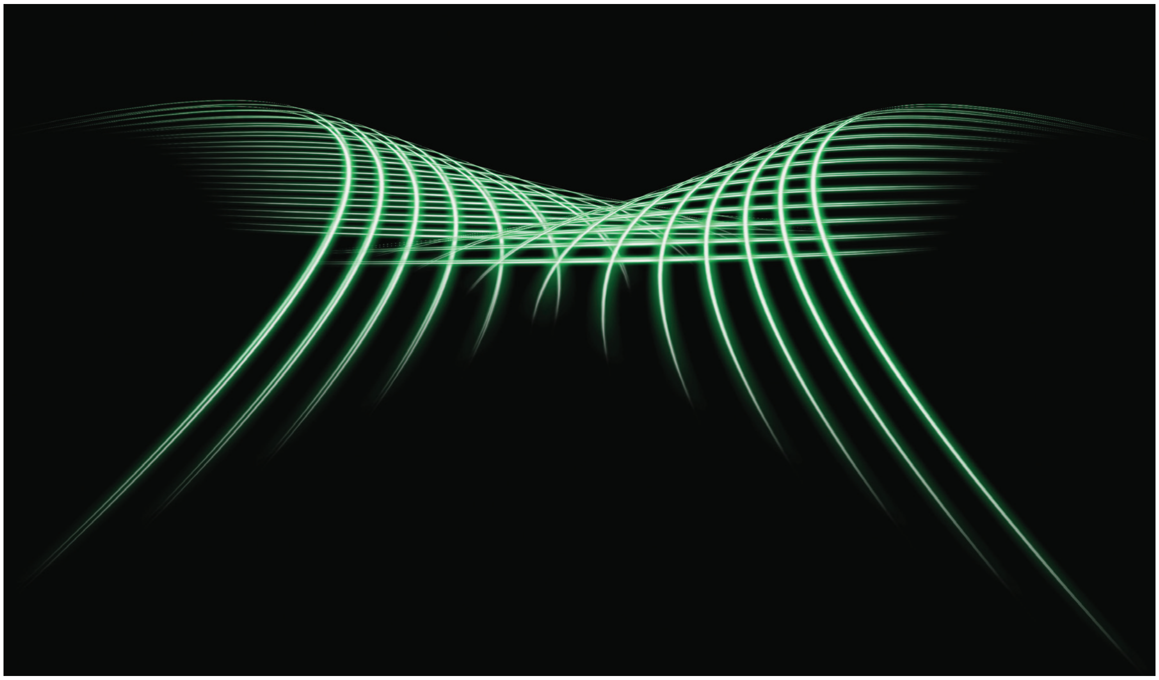
HCM2010

HIGHWAY CAPACITY MANUAL



CHAPTER 27

FREEWAY WEAVING: SUPPLEMENTAL

TRB TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

WASHINGTON, DC | WWW.TRB.ORG

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 27
FREEWAY WEAVING: SUPPLEMENTAL

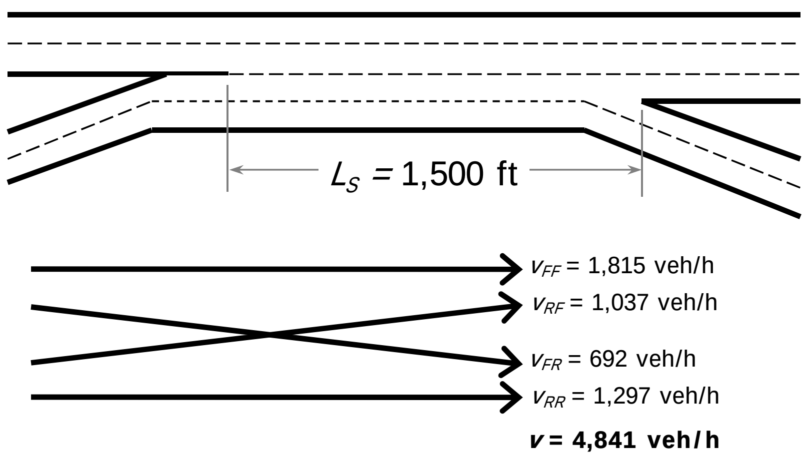
CONTENTS

LIST OF EXHIBITS

1. ALTERNATIVE TOOL EXAMPLES FOR FREEWAY WEAVING SEGMENTS

Chapter 12, Freeway Weaving Segments, described a methodology for analyzing freeway weaving segments to estimate their capacity, speed, and density as a function of traffic demand and geometric configuration. Supplemental problems involving the use of alternative tools for freeway weaving sections to address limitations of the Chapter 12 methodology are presented here. All of these examples are based on Example Problem 1 in Chapter 12. The weaving segment configuration shown in that problem is repeated here as Exhibit 27-1 for convenience.

Exhibit 27-1
Major Weaving Segment for Example Problem 1

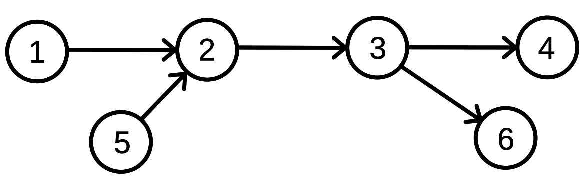


Three questions are addressed by using a typical link-node-based microscopic traffic simulation tool:

1. Can weaving segment capacity be estimated realistically by simulation by varying the demand volumes up to and beyond capacity?
2. How does demand affect performance in terms of speed and density in the weaving segment, on the basis of the default model parameters for vehicle and behavioral characteristics?
3. How would the queue backup from a signal at the end of the off-ramp affect weaving operation?

The first step is to identify the link–node structure, as shown in Exhibit 27-2.

Exhibit 27-2
Link–Node Structure for the Simulated Weaving Segment



The next step is to develop input data for various demand levels. Several demand levels ranging from 80% to 180% of the original volumes were analyzed by simulation. The demand data, adjusted for a peak hour factor of 0.91, are given in Exhibit 27-3.

Exhibit 27-3
Input Data for Various Demand Levels

Percent of specified demand	80	100	120	140	160	180
Freeway-to-freeway demand, V_{FF}	1,596	1,995	2,393	2,792	3,191	3,590
Ramp-to-freeway demand, V_{RF}	912	1,140	1,367	1,595	1,823	2,051
Freeway-to-ramp demand, V_{FR}	608	760	913	1,065	1,217	1,369
Ramp-to-ramp demand, V_{RR}	1,140	1,425	1,710	1,995	2,280	2,565
Total demand	4,256	5,320	6,384	7,448	8,512	9,576
Total freeway entry	2,204	2,755	3,306	3,857	4,408	4,959
Total freeway exit	2,507	3,134	3,761	4,388	5,015	5,641
Total ramp entry	2,052	2,565	3,078	3,591	4,104	4,617
Total ramp exit	1,749	2,186	2,623	3,060	3,497	3,934

Thirty simulation runs were made for each demand level. The results are discussed in the following sections. The need to determine performance measures from an analysis of vehicle trajectories was emphasized in Chapter 7, Interpreting HCM and Alternative Tool Results. Specific procedures for defining measures in terms of vehicle trajectories were proposed to guide the future development of alternative tools. Pending further development, the examples presented in this chapter have applied existing versions of alternative tools and therefore do not reflect the trajectory-based measures described in Chapter 7.

DETERMINING THE WEAVING SEGMENT CAPACITY

Simulation tools do not produce capacity estimates directly. The traditional way to estimate the capacity of a given system element is to overload it and determine the maximum throughput under the overloaded conditions. Care must be taken in this process because a severe overload can reduce the throughput by introducing self-aggravating phenomena upstream of the output point.

Exhibit 27-4 shows the relationship between demand volume and throughput, represented by the output of the weaving segment. As expected, throughput tracks demand precisely up to the point where no more vehicles can be accommodated. After that point it levels off and reaches a constant value that indicates the capacity of the segment. In this case, capacity was reached at approximately the same value as the HCM estimate. However, this degree of agreement between the two estimation techniques should not be expected as a general rule because of differences in the treatment of vehicle and geometric characteristics.

On the basis of observation, it is reasonable to conclude that the capacity of this weaving segment can be determined by overloading the facility and that the results are in general agreement with those of the HCM. In comparing capacity estimates, it must be remembered that the HCM expresses results in passenger car equivalent vehicles, while simulation tools express results in actual vehicles. The results will diverge as the proportion of trucks increases.

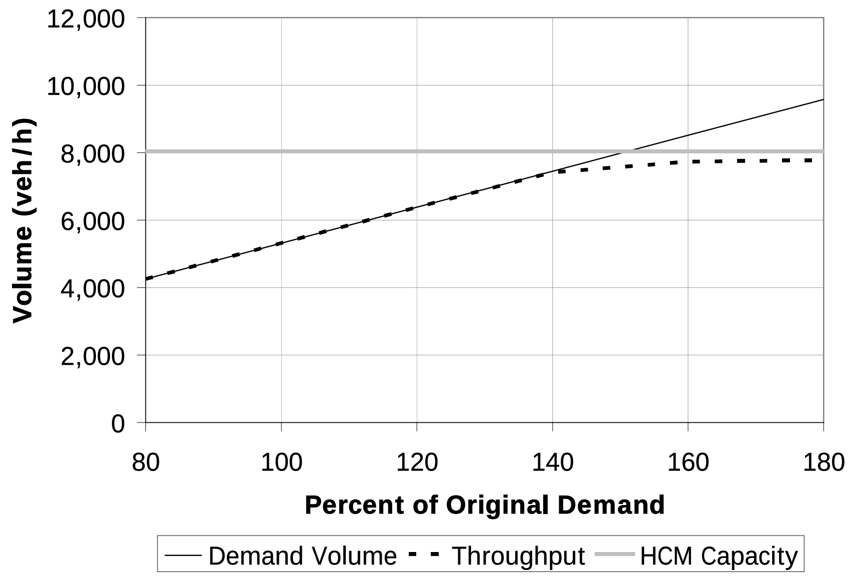


Exhibit 27-4
Determining the Capacity of a Weaving Segment by Simulation

EFFECT OF DEMAND ON PERFORMANCE

Exhibit 27-5 shows the effect of demand on density and speed. Density increases with demand volume up to the segment capacity and then levels off at a constant value of approximately 75 veh/ln/mi, which represents very dense conditions. The speed remains close to the free-flow speed at lower demand volumes. It then drops in a more or less linear fashion and eventually levels off when capacity is reached. The minimum speed is approximately 26 mi/h.

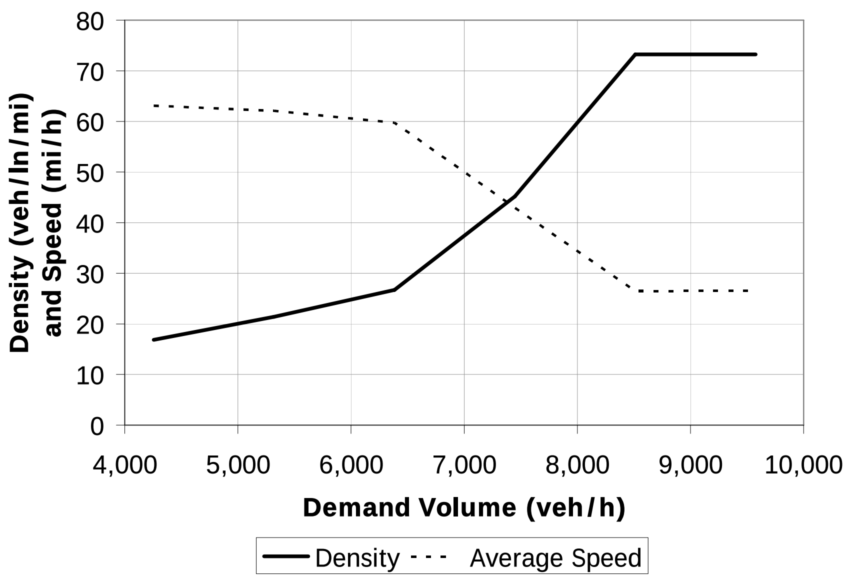


Exhibit 27-5
Simulated Effect of Demand Volume on Weaving Segment Capacity and Speed

At the originally specified demand volume level of 5,320 veh/h (peak hour adjusted), the estimated speed was 62.0 mi/h and the density was 21.4 veh/ln/mi. The corresponding values from simulation were 53.1 mi/h and 26.3 pc/ln/mi. Because of differences in definition, these results are not easy to compare. These differences illustrate the pitfalls of applying level of service (LOS) thresholds to directly simulated density to determine the segment LOS.

The densities produced when demand exceeded capacity were greater than 70 veh/ln/mi. This level of density is usually associated with queues that back up from downstream bottlenecks; however, in this case, no such bottlenecks were present. Inspection of the animated graphics suggests that the increase in density within the weaving segment is caused by vehicles that are not able to get into the required lane for their chosen exit. Some vehicles were forced to stop and wait for a lane-changing opportunity, and the reduction in average speed produced a corresponding increase in the average density.

For purposes of illustration, this example focuses on a single link containing the weaving segment. The overloading of demand prevented all of the vehicles from entering the link and would have increased the delay substantially if the vehicles denied entry were considered. For this reason, the delay measures from the simulation were not included in this discussion.

EFFECT OF QUEUE BACKUP FROM A DOWNSTREAM SIGNAL ON THE EXIT RAMP

The operation of a weaving segment may be expected to deteriorate when congestion on the exit ramp causes a queue to back up into the weaving segment. This condition was one of the stated limitations of the methodology in Chapter 12, Freeway Weaving Segments.

Signal Operation

To create this condition, a pretimed signal with a slightly oversaturated operation is added 700 ft from the exit point. The operating parameters for the signal are given in Exhibit 27-6. Note that the right-turn capacity estimated by the Chapter 18, Signalized Intersections, procedure is slightly lower than the left-turn capacity because of the adjustment factors applied to turns by that procedure.

Exhibit 27-6
Exit Ramp Signal Operating Parameters

Cycle length	150 s
Green interval	95 s
Yellow interval	4 s
All-red clearance	1 s
Saturation flow rate	1,800 veh/hg/ln
g/C ratio	0.633
Left-turn movement	
• Lanes	1
• Capacity (by HCM Chapter 18)	1,083 veh/h
Right-turn movement	
• Lanes	1
• Capacity (by HCM Chapter 18)	969 veh/h
Link capacity (by HCM Chapter 18)	2,052 veh/h

Capacity Calibration

To ensure that the simulation model is properly calibrated to the HCM, the simulation tool's operating parameters for the link were modified by trial and error to match the HCM estimate of the link capacity by overloading the link to determine its throughput. With a start-up lost time of 2.0 s and a steady-state headway of 1.8 s/veh, the simulated capacity for the link was 2,040 veh/h, which compares well with the HCM's estimate of 2,052 veh/h.

Results with the Specified Demand

An initial run with the demand levels specified in the original example problem indicated severe problems on the freeway caused by the backup of vehicles from the signal. Two adverse conditions are observed in the graphics capture shown in Exhibit 27-7:

1. Some vehicles in the freeway mainline through lanes were unable to access the auxiliary lane for the exit ramp because of blockage in the lane.
2. The resulting use of the exit ramp lanes prevented the signal operation from reaching its full capacity. This caused a self-aggravating condition in which the queue backed up farther onto the freeway.

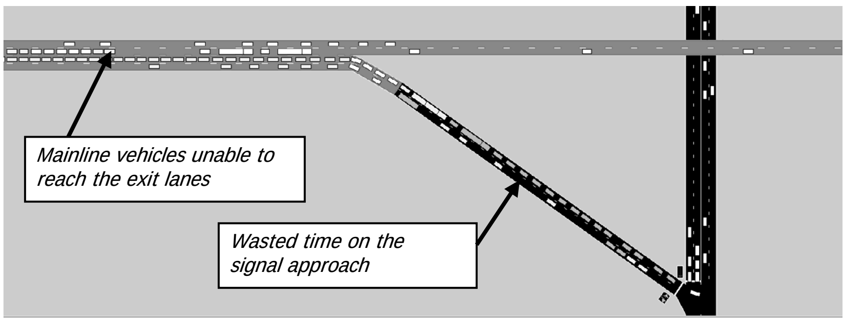


Exhibit 27-7
Deterioration of Weaving Segment Operation due to Queue Backup from a Traffic Signal

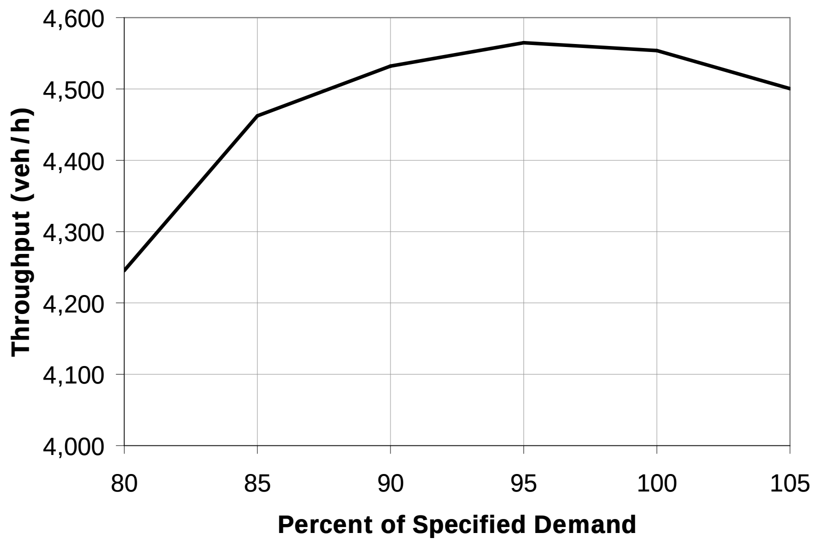
A reasonable conclusion is that the weaving segment would not operate properly at the specified demand levels. The logical solution to the problem would be to improve signal capacity. To support a recommendation for such an improvement, varying the demand levels to gain further insight into the operation might be desirable. Since it has already been discovered that the specified demand is too high, the original levels of 80% to 180% of the specified demand are clearly inappropriate. The new demand range will therefore be reduced to a level of 80% to 105%.

Effect of Reducing Demand on Throughput

Exhibit 27-8 illustrates the self-aggravating effect of too much demand. Throughput is generally expected to increase with demand up to the capacity of the facility and to level off at that point. Notice that the anticipated relationship was observed without the signal, as was shown in Exhibit 27-4.

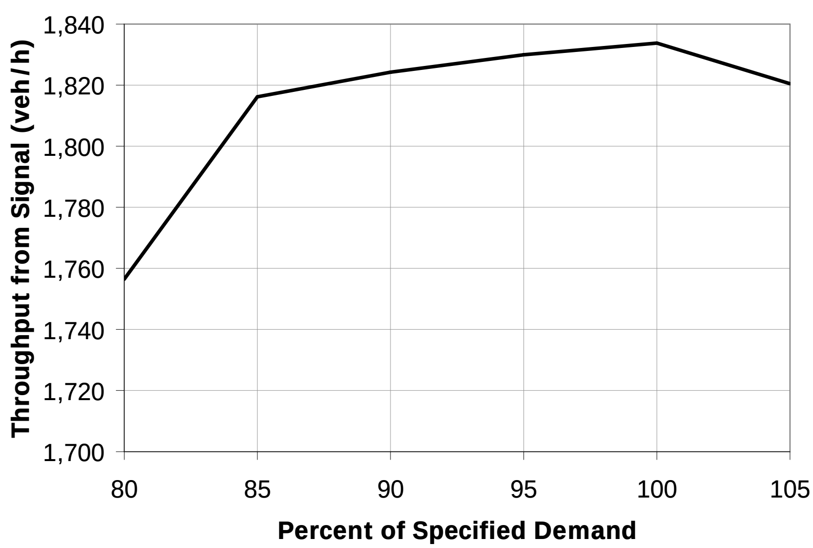
When the signal was added, the situation changed significantly. The throughput peaked at about 95% of the specified demand and declined noticeably as more vehicles were allowed to enter the freeway. Another useful observation is that the peak throughput of approximately 4,560 veh/h is considerably below the estimated capacity of nearly 8,000 veh/h.

Exhibit 27-8
Effect of Demand on Weaving Segment Throughput with Exit Ramp Backup



The same phenomenon is observed on the exit ramp approach to the signal, as shown in Exhibit 27-9. The throughput declined with added demand after reaching its peak value of about 1,835 veh/h. Note that the peak throughput is also well below the capacity of 2,040 to 2,050 veh/h estimated by both the HCM and the simulation tool in the absence of upstream congestion.

Exhibit 27-9
Effect of Demand on Exit Ramp Throughput with Signal Queuing



This example illustrates the potential benefits of using simulation tools to address conditions that are beyond the scope of the HCM methodology. It also points out the need to consider conditions outside of the facility under study in making a performance assessment. Finally, it demonstrates that care must be taken in estimating the capacity of a facility through an arbitrary amount of demand overload.