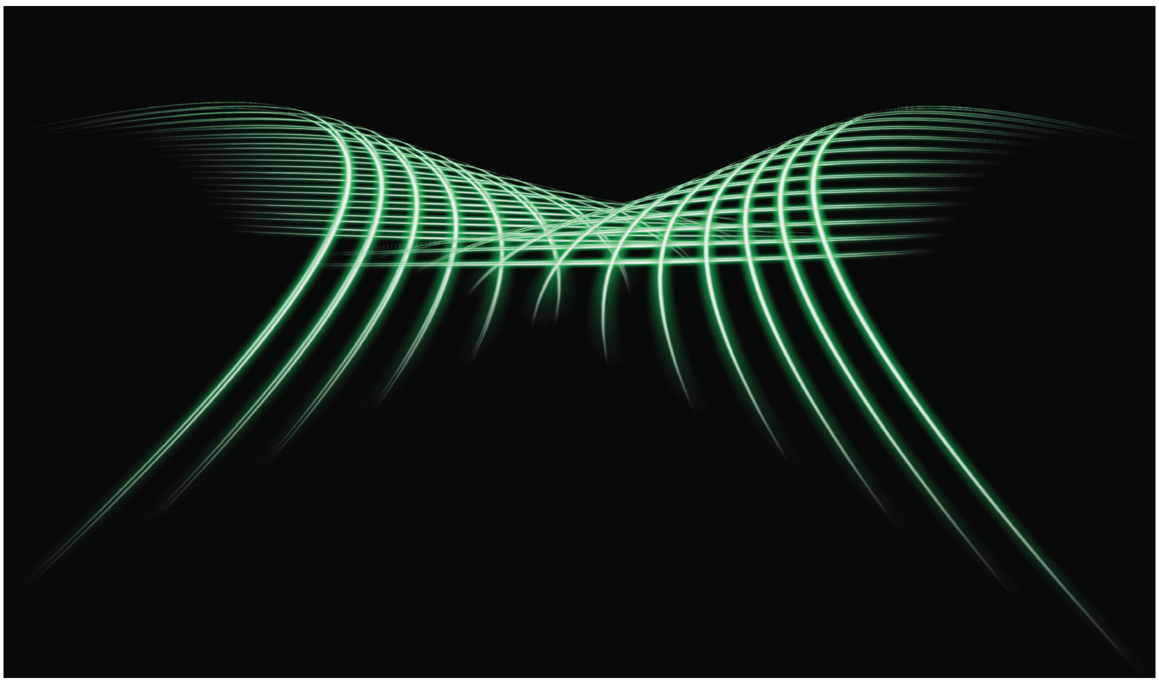
HCM2010

HIGHWAY CAPACITY MANUAL



CHAPTER 26

FREEWAY AND HIGHWAY SEGMENTS: SUPPLEMENTAL

TRB 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.

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CHAPTER 26
FREEWAY AND HIGHWAY SEGMENTS: SUPPLEMENTAL

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1. ALTERNATIVE TOOL EXAMPLES FOR BASIC FREEWAY SEGMENTS

General guidance for the use of alternative traffic analysis tools for capacity and level-of-service (LOS) analysis is provided in Chapter 6, HCM and Alternative Analysis Tools.

Chapter 11, Basic Freeway Segments, describes a methodology for analyzing basic freeway segments to estimate their capacity, speed, and density as a function of traffic demand and geometric configuration. **Chapter 26, Freeway and Highway Segments: Supplemental** includes two supplemental example problems that examine situations that are beyond the scope of the Chapter 11 methodology. A typical microsimulation-based tool is used for this purpose and some of the simulation results are compared, where appropriate, with those of the *Highway Capacity Manual* (HCM) procedures.

Both problems are based on Example Problem 3 from Chapter 11, which analyzes a six-lane freeway segment in a growing urban area. The first problem evaluates the facility when a high-occupancy-vehicle (HOV) lane is added, and the second one analyzes operations with an incident within the segment.

The need to determine performance measures based on the 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. The examples presented in Chapter 26 were applied by using versions of simulation packages available at the time of chapter development; these packages were not entirely consistent with the recommended trajectory-based measures described in Chapter 7.

EXAMPLE PROBLEM 1: DEVELOPMENT OF HOV LANE

The inputs for this problem are identical to those of Example 3 in Chapter 11. In the situation studied with that example problem, the existing six-lane freeway was projected to remain at Level of Service (LOS) D in the next 3 years, and demand was projected to exceed capacity within 7 years. An additional question, which would illustrate the use of alternative tools, is, "How would the facility operate if a fourth lane were added for use by HOVs?"

The HCM procedure does not take into consideration HOVs and therefore does not estimate performance measures related to HOV lanes. A simulation tool was used to evaluate this scenario, estimating the capacity and density of the basic freeway segment when an HOV lane is present. Exhibit 26-1 provides a graphical view of the simulated site with the leftmost lane designated as an HOV lane. It is assumed that the HOV lane is separated from the general traffic and that vehicles are not allowed to make lane changes except at designated access points.

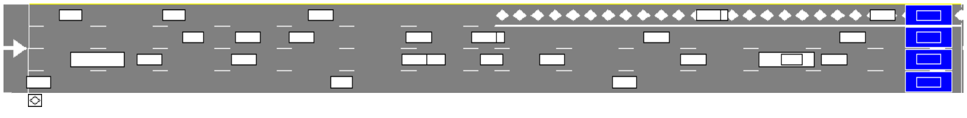


Exhibit 26-1
Graphical View of Basic Freeway Segment with HOV Lane

The subject segment and upstream segment lengths are both 1 mi. On the basis of the inputs given in Example Problem 3 from Chapter 11, it was assumed that the HOV lane would be operational in 4 years. The 3-year peak-hour demand forecast was 5,600 veh/h; thus, the hourly demand volume in the fourth year was assumed to be 4% higher (using the same growth rate as that in the example problem), or 5,824 veh/h. The peak hourly flow rate was assumed to be 5,824/0.95 = 6,131 veh/h, by using the example problem's peak hour factor of 0.95. The simulation analysis was conducted in units of vehicles per hour; simulation packages typically provide flows in vehicles per hour, and thus there was no conversion to passenger-car equivalents for this analysis.

Next, experiments were conducted to obtain the capacity and density of the subject segment as a function of (*a*) the percent of carpools in the traffic stream, (*b*) the percent of HOVs that use the HOV lane, (*c*) the distance upstream of the beginning of the HOV lane when drivers begin to react and position themselves to use (or avoid) the lane, and (*d*) the percent of HOV violators (i.e., non-HOVs that use the HOV lane). The results of these experiments are provided below. Ten runs were conducted for each experiment.

Exhibit 26-2 provides the overall density of the study segment as well as the densities of the HOV lane and the three general-purpose lanes as a function of the carpool percentage in the traffic stream. This density is estimated for a total demand flow rate of 6,131 veh/h. As expected, the average density on the link remains constant as the carpool percentage increases. When carpools increase, the density of the HOV lane increases, whereas the density of the remaining lanes decreases.

Exhibit 26-2
Density of Basic Freeway Segment with HOV Lane as a Function of Carpool Percentage

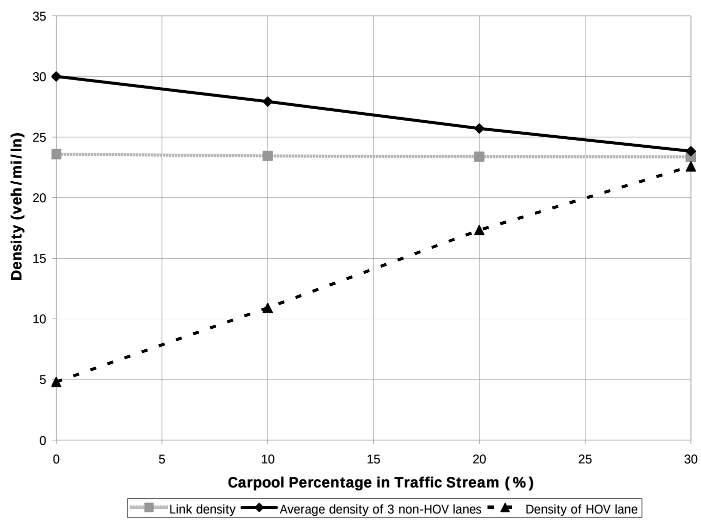


Exhibit 26-3 shows the capacity of the study segment as a function of the carpool percentage in the traffic stream. The capacity was measured as the maximum throughput of the segment when the demand was very high. As shown, the capacity increases more or less linearly as the percent of carpools increases. This increase occurs because when the carpool percentage is low, the HOV lane is underutilized. As the percent of carpools increases, more vehicles use the HOV lane, and the capacity of the entire segment increases as more vehicles shift to the HOV lane.

Exhibit 26-3
Capacity of Basic Freeway Segment with HOV Lane as a Function of Carpool Percentage

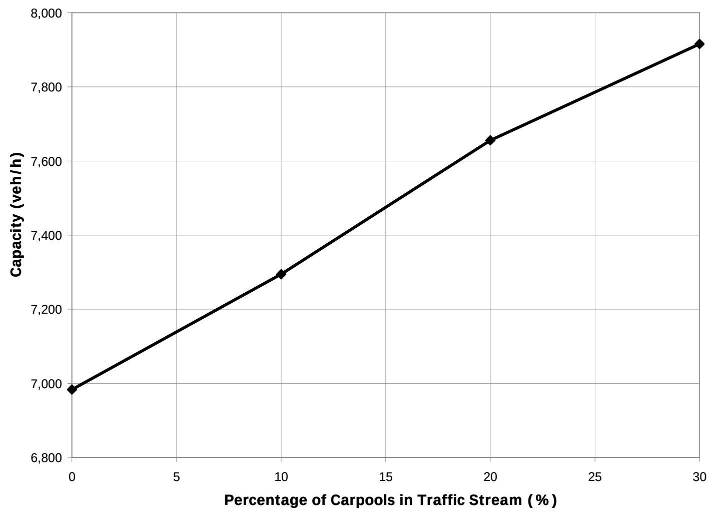


Exhibit 26-4 shows the density of the study segment as well as the density of the HOV lane and the other lanes separately as a function of the percent of HOVs using the HOV lane. The simulation package employs the percent of HOVs using the HOV lane as an input, and that number stays constant throughout the simulation, regardless of the operations of the general-use lanes. The average density of the HOV lane is relatively low even when the proportion of HOVs using the HOV lane is 100%. In this experiment, the proportion of carpools is 10%, and therefore the density of the HOV lane remains quite low even if all HOVs in the traffic stream use it.

Exhibit 26-4
Density of Basic Freeway Segment with HOV Lane as a Function of Percent of HOV Usage

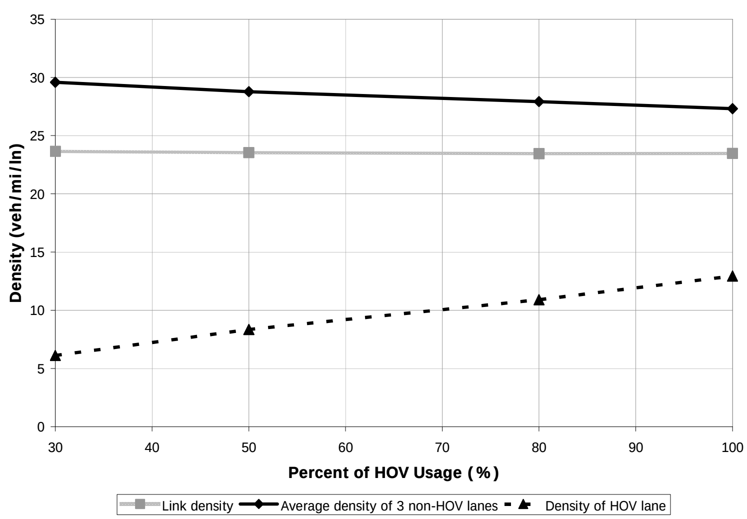


Exhibit 26-5 shows the capacity of the study segment as a function of the percent of HOVs using the HOV lane. The capacity was measured as the maximum throughput of the segment when the demand was very high.

Exhibit 26-5
Capacity of Basic Freeway Segment with HOV Lane as a Function of Percent of HOV Usage

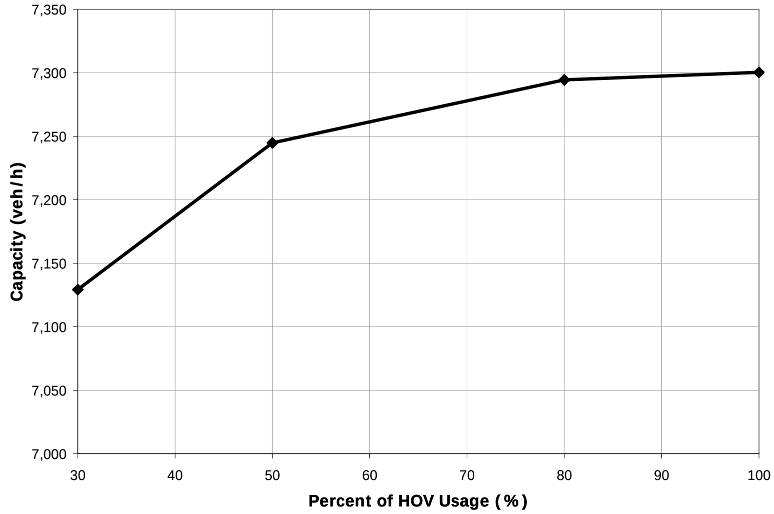
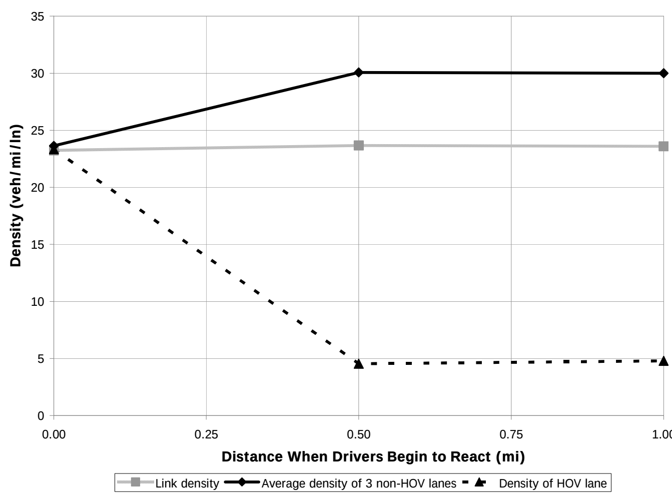


Exhibit 26-6 shows the density of the segment with the HOV lane as a function of the distance when drivers begin to react to the presence of the HOV lane. As before, the simulation package employs the percent of HOVs using the HOV lane as an input, and that number stays constant throughout the simulation regardless of whether there is congestion in the general-use lanes. In this experiment, the proportion of carpools was 10% and the proportion of HOVs using the HOV lane was 80%. As shown, when drivers are given no warning of the HOV lane, the density across all lanes is very similar. This result was surprising and somewhat unrealistic, since it indicated that once in the HOV link, the simulated vehicles do not seem to reposition themselves to use the HOV lane. However, this scenario of not providing adequate warning of the HOV lane's presence is not very realistic in the field.

Exhibit 26-6
Density of Basic Freeway Segment with HOV Lane as a Function of HOV Warning Sign Distance



As the distance when drivers begin to react increases, the density at each group of lanes changes significantly. When vehicles are given a warning at least ½ mi upstream of the HOV lane, the density among the lanes is changed accordingly and does not change when the warning distance increases to farther than ½ mi.

Exhibit 26-7 shows the capacity of the study segment as a function of the distance when drivers begin to react to the presence of the HOV lane. The proportion of carpools for this experiment is 10%. As shown, the capacity decreases when this distance increases. The drop occurs because for the longer distances vehicles have had the opportunity to redistribute themselves among the four lanes, and the HOV lane is used only by carpools. Because the percent of carpools is relatively low, the HOV lane is not as effectively used as when all vehicles were using it, and the overall throughput drops.

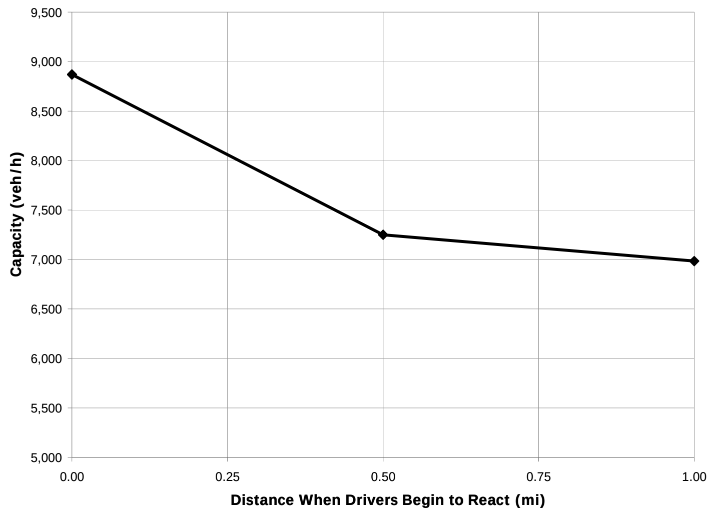


Exhibit 26-7
Capacity of Basic Freeway Segment with HOV Lane as a Function of HOV Warning Sign Distance

Exhibit 26-8 shows the density as a function of HOV violators (i.e., non-HOVs using the HOV lane). The proportion of carpools is 10%, the distance to warning is 1 mi, and the proportion of HOV usage is 80%. As expected, the density of the HOV lane increases as the percent of violators increases.

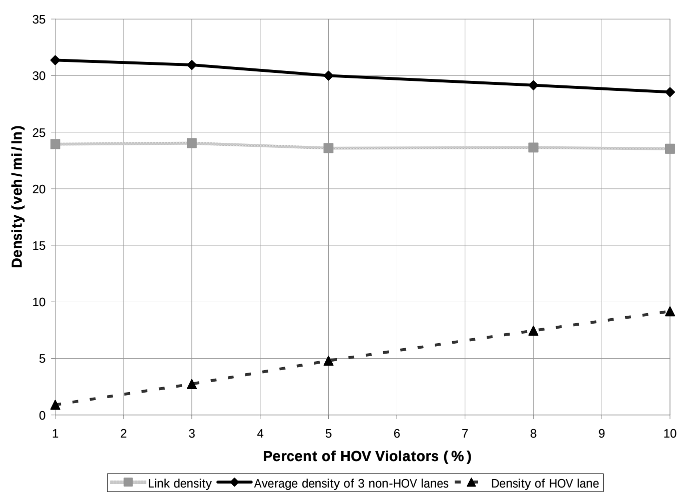
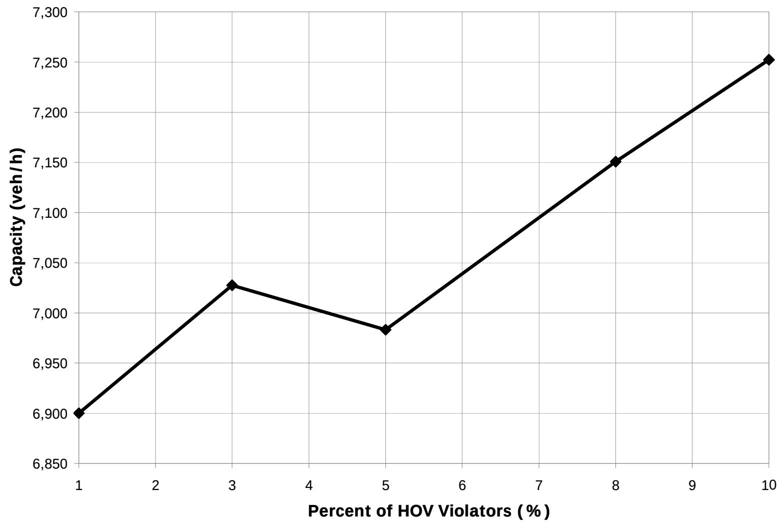


Exhibit 26-8
Density of Basic Freeway Segment with HOV Lane as a Function of Percent of HOV Violators

Exhibit 26-9 shows the capacity of the study segment as a function of the percent of HOV violators. The capacity generally increases as the percent of violators increases, because the HOV lane is generally underutilized, and thus when non-HOVs use it, its throughput increases.

Exhibit 26-9
Capacity of Basic Freeway Segment with HOV Lane as a Function of Percent of HOV Violators



This type of analysis cannot be conducted by using the HCM, since the HCM method does not estimate the HOV-lane density separately. The experiments shown in this example evaluating the potential installation of an HOV lane cannot be conducted with the HCM methods. Variables such as the impact of the distance of the HOV warning sign cannot be evaluated, because they pertain to driver behavior attributes and their impact on density and capacity. The impact of the percent of carpools and the percent of violators could perhaps be estimated with appropriate modifications to the HCM method.

EXAMPLE PROBLEM 2: INCIDENT OCCURRENCE

Example Problem 2 is also based on Example Problem 3 of Chapter 11. It evaluates the operating conditions that would result if a lane-blocking incident occurred along the segment. The HCM procedure for basic freeway segments cannot estimate the impacts of the presence of an incident. A typical simulation tool was used to evaluate this scenario and to estimate the capacity and density of the basic freeway segment when an incident occurs.

The subject segment length is 1 mi, and the upstream segment is also 1 mi. Each simulation run was for 1 full hour, and it was assumed that the incident started 15 min after the beginning of the simulation and—where not varied as part of the experiment—the duration of the incident was 15 min. It was assumed that the demand flow rate was 6,131 veh/h and that one lane would be blocked during the incident. The incident was assumed to occur in the middle of the link, with the rightmost lane blocked.

A series of experiments obtained the subject segment's capacity and density as a function of (*a*) the incident duration and (*b*) the length of the segment affected. Exhibit 26-10 presents the density as a function of the incident duration, and Exhibit 26-11 presents the hourly capacity. As shown, as the incident duration increases, the average density increases, whereas the capacity decreases.

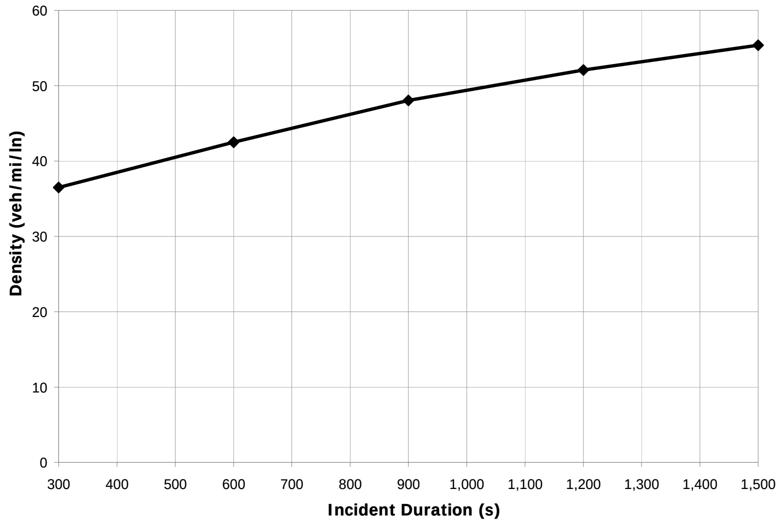


Exhibit 26-10
Density of Basic Freeway Segment for Varying Incident Duration

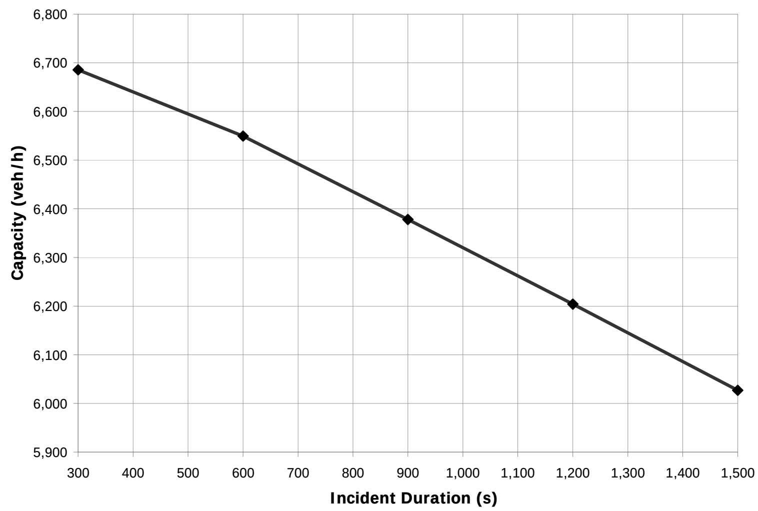


Exhibit 26-11
Capacity of Basic Freeway Segment for Varying Incident Duration

Exhibit 26-12 presents the density of a basic freeway segment as a function of the length of the segment affected during the incident. The graph provides density based on link statistics (i.e., the density of the link with the incident). As expected, the greater the length of the segment affected, the higher the link density. The change, however, is relatively small—on the order of less than 0.5 veh/mi/ln. The results would be different if density were based on detector output. For example, if detectors were placed downstream of the incident, the density recorded there would not be affected by the length of the segment affected, and the relationship would be flat.

Exhibit 26-12
Link Density of Basic Freeway Segment for Varying Length of Segment Affected

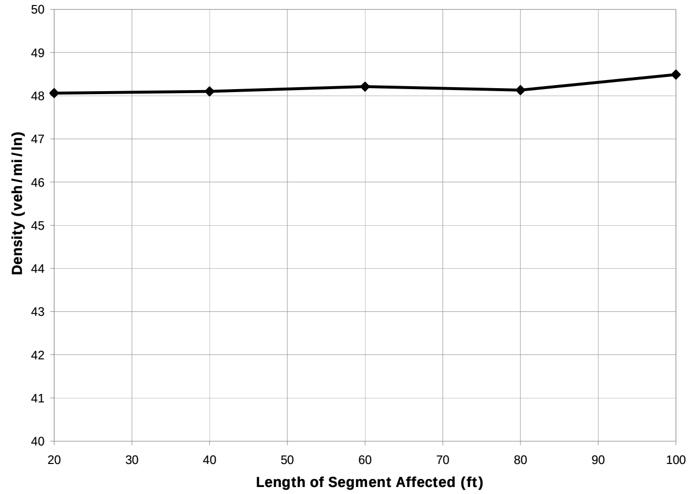


Exhibit 26-13 plots the capacity as a function of the length of the segment affected during the incident. In this graph, capacity is measured at detectors downstream of the incident. As shown, there is a slight increase in capacity as the length of the segment affected increases. This finding may be because the distance from the end of the incident area to the detectors decreases as the length of the segment affected by the incident increases.

Exhibit 26-13
Capacity of Basic Freeway Segment for Varying Length of Segment Affected

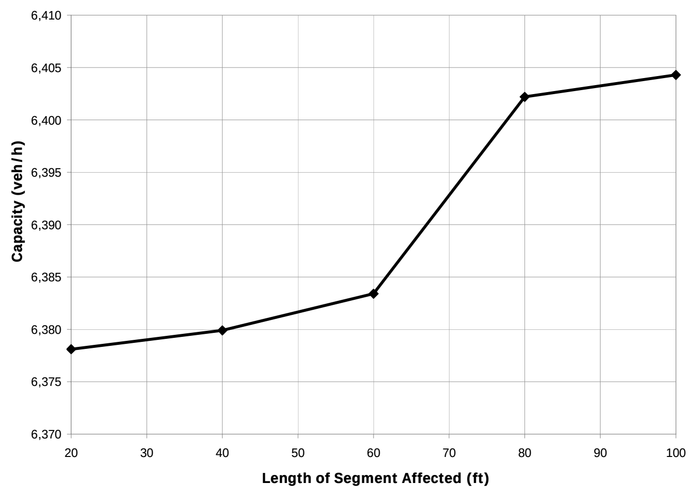


Exhibit 26-14 plots the density of the basic freeway segment as a function of the location of the warning sign upstream of the incident. As shown, the density fluctuates within 1.5 veh/mi/ln, and the general trend for the entire range tested is for the density to decrease as the distance between the warning sign and the incident increases. However, the magnitude of the change is very small. Generally, the presence of the warning sign results in a speed drop as vehicles attempt to change lanes in anticipation of the lane blockage ahead.

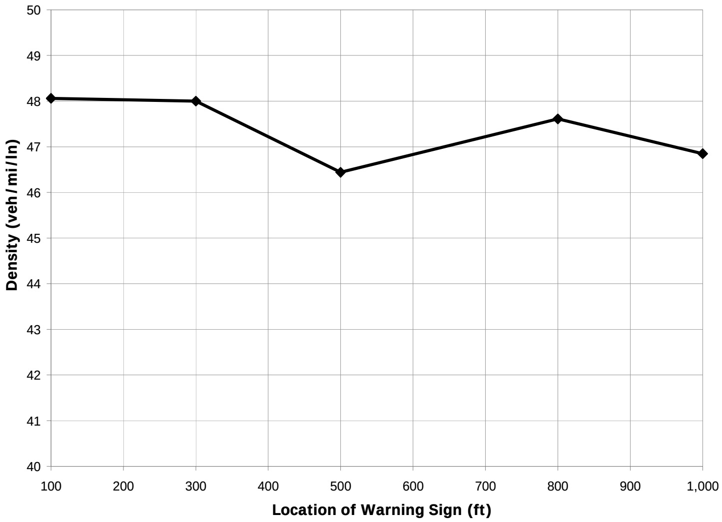


Exhibit 26-14
Density of Basic Freeway Segment for Varying Location of Warning Sign

Exhibit 26-15 plots the capacity of a basic freeway segment as a function of the location of the warning sign. The results are consistent with those in Exhibit 26-14, indicating that capacity generally is reduced as the distance between the warning sign and the incident increases. Again, this result is potentially related to a speed drop in the traffic stream associated with the presence of a warning sign.

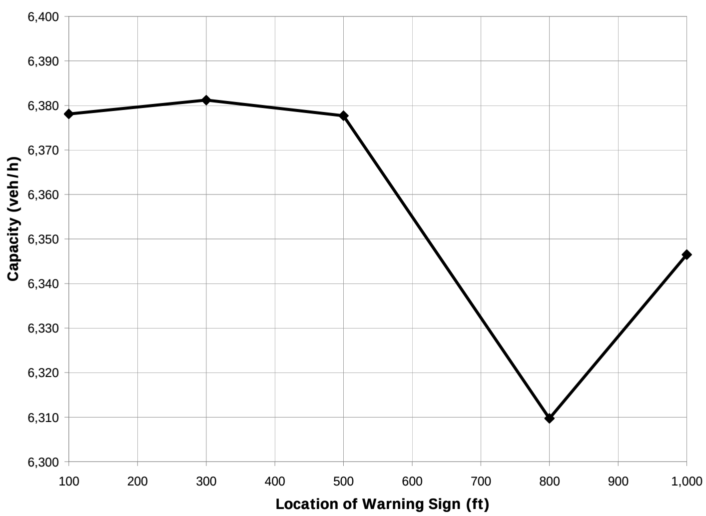


Exhibit 26-15
Capacity of Basic Freeway Segment for Varying Location of Warning Sign

As indicated earlier, the presence of incidents cannot be evaluated by using the HCM. The freeway facilities methodology in Chapter 10 can handle changes in the segment capacity; however, variables related to driver behavioral aspects cannot be analyzed. In addition, the segment capacity is an input to the freeway facilities methodology, and thus a tool is needed to estimate the segment capacity when an incident occurs.

2. STATE-SPECIFIC HEAVY-VEHICLE DEFAULT VALUES

Research into the percentage of heavy vehicles on uninterrupted-flow facilities (*1*) found a wide range of average values from state to state, so much so that not even regional default values could be developed. Exhibit 26-16 presents default values for the percentage of heavy vehicles on freeways by state and area population, based on data from the 2004 Highway Performance Monitoring System (HPMS). Exhibit 26-17 presents similar default values for multilane and two-lane highways. Where states or local jurisdictions have developed their own values, these may be substituted. Analysts may also wish to develop their own default values based on more recent data.

Exhibit 26-16
State-Specific Default Values for Percentage of Heavy Vehicles on Freeways

State	Rural	Small Urban	Medium Urban	Large Urban	State	Rural	Small Urban	Medium Urban	Large Urban
AL[*]	14[a]	7	7	7[a]	MT	22[c]	16[c]	12[c]	NA
AK	4	5[b]	5	3[b]	NC[*]	19[b]	12[b]	12	10[a]
AR	30	24	13	14	ND	21[c]	22[c]	10[c]	NA
AZ	21	19	18	11	NE	36	37	11	8
CA	16	10	7	6	NH	15[b]	12[b]	6[b]	7[b]
CO	12	10	8	7	NJ	8	6	6	9
CT	13	6	6	5	NM	26	12	21	12
DC	NA	NA	NA	4[b]	NV	34[b]	26	18[b]	11[b]
DE	—	—	9[b]	8[b]	NY	18	11	11	7
FL[*]	11	7	12	6	OH	24	13	10	8
GA[*]	19[b]	7[b]	12	8[b]	OK	28	27	12	10
HI	5	19[b]	2	3	OR	26	19	10	7
IA	20[c]	24[c]	11[c]	10[c]	PA	16	13	9	8
ID	29[c]	28[b]	12[b]	7[b]	PR[*]	6	7[b]	7	4[b]
IL	21	23	16	9	RI	3	—	NA	4
IN	26	25	23	14	SC[*]	19[b]	7[b]	7	8[b]
KS	21[c]	17[c]	8[c]	9[b]	SD	20[c]	14[c]	9[c]	NA
KY[*]	20[a]	16	12	10[a]	TN[*]	19	12	12	8
LA[*]	12[c]	7[b]	12	10[c]	TX	16	28[c]	8	5
MA	7[a]	5	4[a]	4	UT	34[c]	—	18	13
MD	18	14	17	8	VA[*]	9	7	7	4
ME	5	5	5	NA	VT	15	12	6	NA
MI	18	12	13	8	WA	11	10	7	6
MN	11	10	6	4	WI	6	6	6	6
MO	29[b]	23[b]	13[b]	10[b]	WV	16[b]	13[b]	9[b]	NA
MS[*]	9[b]	7[b]	7	6[b]	WY	33[c]	36[a]	28[c,d]	NA

Notes: Rural: <5,000 pop.; small urban: 5,000–50,000; medium urban: 50,000–250,000; large urban: >250,000.
NA = population group does not exist within the state; —, data not available.
Values shown represent mean values for the state for each population type except where noted otherwise.
* Because of limited data, small urban values were combined for these groups of states: AL, MS, PR, SC, and VA and FL, GA, KY, LA, NC, and TN. Medium urban values were combined for AL, FL, and VA.
[a] Reported values appeared to be a mix of field observations and statewide values. The latter were discounted, such that the averages shown here are based primarily on values deemed to be field observations, with some consideration given to nearby states and the value state personnel thought was statewide.
[b] The default value was estimated from field observations from nearby states, because of insufficient field data, a lack of data for this road type, or too-heavy reliance on statewide values.
[c] The peak-period percentage is identical to the daily average percentage for nearly all observations in the HPMS data set. Default values were estimated primarily from the daily average value but took into account the results from nearby states, particularly the difference between peak and daily values in those states.
[d] This distribution was bimodal, with one group centered on 19% and the other on 44%.
Source: *NCHRP Report 599* (*1*).

Exhibit 26-17
State-Specific Default Values for Percentage of Heavy Vehicles on Multilane and Two-Lane Highways

State	Two-Lane Highways		Multilane Highways		State	Two-Lane Highways		Multilane Highways	
	Rural	Small Urban	Rural	Small Urban		Rural	Small Urban	Rural	Small Urban
AL	6[a]	6[a]	4[a]	6[a]	MT	10*	4*	6*	3*
AK	10	2	6	3	NC	8[b]	4[b]	6[b]	6[b]
AR	14	7	11	12	ND	14*	3*	12*	7*
AZ	9	11	9	9	NE	10	3	12	5
CA	9	5	9	6	NH	6[b]	6[a]	6[b]	6[b]
CO	11	4	5	5	NJ	8	7	8	6[b]
CT	3	3	2	6[b]	NM	17	7	23	12
DC	NA	NA	NA	NA	NV	17[b]	5*	10*	6*
DE	7	6	9	8	NY	8	5	8	5
FL	8	4	7	7	OH	11	4	14	9
GA	8[b]	5[b]	6[b]	6[b]	OK	14[a]	5	17	11
HI	3	3	2	2	OR	12	5	6	9
IA	4*	5*	5*	4*	PA	6	3	5	4
ID	12*	7*	16*	9*	PR	5	5[b]	5	6
IL	8	5	8	6	RI	2	1	2	6[b]
IN	10	6[a]	12	10	SC	8[b]	5[b]	6[b]	6[b]
KS	15[a]	3	12*	6*	SD	13*	4*	12*	7*
KY	16[a]	6[a]	9[a]	6[a]	TN	5	4[a]	6	4
LA	16*	10*	6[b]	16	TX	13	9	12	9
MA	3[a]	3[a]	7[b]	6[b]	UT	20*	9*	22*	14*
MD	10	6	12	8	VA	4	2	5	2
ME	5	3	4	3	VT	8	5[a]	7	6[b]
MI	9	7[a]	8	4	WA	15	8[a]	10	7
MN	9	8[a]	8	6	WI	4	5[a]	4	5[a]
MO	9*	6*	12[b]	10*	WV	6[b]	6[b]	5[b]	6[b]
MS	14[a]	5[a]	6[b]	6[a]	WY	15*	6*	10*	9*

Notes: Rural: <5,000 pop.; small urban: 5,000–50,000.

NA: Population group does not exist within the state

Values shown represent mean values for the state for each population type except where noted otherwise.

* The peak-period percentage is identical to the daily average percentage for all or almost all observations in the HPMS data set for this cell. Default values were estimated primarily from the daily average value for this cell, taking into account the results for other similar states in the same region, and in particular the difference between peak and daily average values in those states.

[a] Reported values appeared to be a mix of field observations and statewide values. The latter were discounted, such that the averages shown here are based primarily on values deemed to be field observations, with some consideration given to nearby states and the value the state personnel thought was statewide.

[b] Either there are insufficient field data, such that regional averages were used, or there are no usable field data, either because there are no data in the state for this road type or because there is too heavy a reliance on statewide values for both the peak period and the daily average. In these cases, the default value was estimated from field observations for nearby states.

Source: *NCHRP Report 599* (*1*).

3. REFERENCE

This report can be found in the Technical Reference Library in Volume 4.

1. Zegeer, J. D., M. A. Vandehey, M. Blogg, K. Nguyen, and M. Ereti. *NCHRP Report 599: Default Values for Highway Capacity and Level of Service Analyses*. Transportation Research Board of the National Academies, Washington, D.C., 2008.