

6 Segment Analysis

6.1 Purpose

For analysis purposes, roadway facilities are separated into categories that are specific to traffic flow type: Uninterrupted and Interrupted traffic flow.

This chapter presents commonly used segment (uninterrupted flow) analysis procedures and identifies specific methodologies and input parameters to be used on ODOT projects. Topics covered include:

- Freeways
- Multi-Lane Highways
- Two-Lane Highways

6.2 Freeways

The analysis of freeways is generally broken down into the major components of the freeway system including basic freeway segments, ramps and ramp junctions and weaving segments. The analysis procedures used for each of these components are described below.

6.2.1 Basic Freeway Segments

Basic freeway segments include the portions of freeway where flow is not influenced by the diverging, merging, or weaving associated with ramp/freeway connections. The common methodology used for analyzing basic freeway segment operations is from Chapter 23 of the *HCM*. The primary factors that affect operations on basic freeway segments include: lane widths, lateral clearance, the number of lanes, interchange density, heavy vehicles, grades and driver familiarity. For a complete description of the analysis methodology, refer to Chapter 23 of the *HCM*.

While the *HCM* methodology uses level of service as a performance measure (based on vehicle density in passenger cars per mile per lane), volume/capacity ratios can be calculated from this analysis for comparison against ODOT's adopted mobility standards by following the steps listed below.

1. Assuming level of service E/F threshold represents capacity, determine the segment capacity by interpolating between the values for "maximum service flow rate" at level of service E displayed in Exhibit 23-2 of the *HCM* for the appropriate free-flow speed. Free-flow speed will be either calculated by this methodology assumed to be 5 mph greater than posted, or observed in the field.
2. Divide the calculated flow rate (v_p) by the interpolated capacity to obtain a volume/capacity ratio. Note: The units are passenger cars per hour per lane (pcphpl), not vehicles per hour.

6.2.2 Ramps and Ramp Junctions

The analysis associated with operations at ramp junctions with the freeway mainline typically involves the effects of vehicles either merging onto or diverging from the mainline. The common methodologies used for analyzing these movements are those from Chapter 25 of the *HCM*. These methodologies focus on an influence area of 1,500 feet (downstream from ramp if merging and upstream from ramp if diverging). It should be noted that while the *HCM* methodology defines the influence area of merging or diverging traffic to be within 1,500 feet, the effects can extend outside of this area. The analysis for merging and diverging areas is discussed further below.

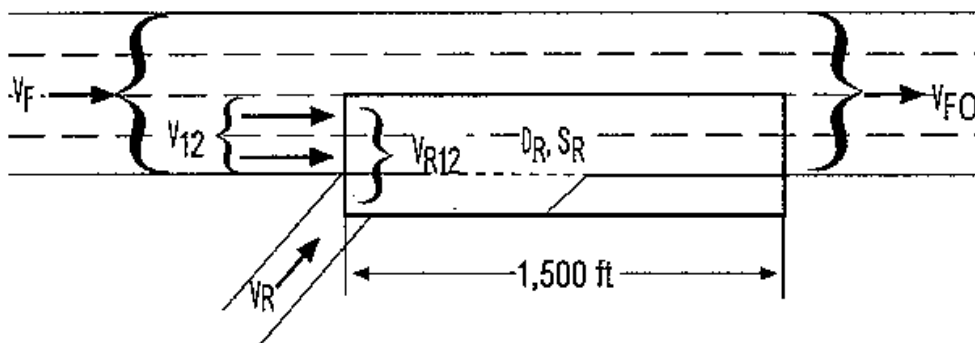
Merging Analysis

Merging analysis is often conducted at freeway on-ramps where vehicles from the ramp are entering a lane used by mainline traffic. In following the *HCM* methodology for merging analysis, there are three primary steps:

1. Predicting the flow rates entering lanes 1 and 2.
2. Determining capacity.
3. Determining level of service. Note that the performance measure of level of service is not used by ODOT and, therefore, this step will not be discussed.

The primary factors influencing the flow rates in lanes 1 and 2 (v_{12}) immediately upstream of the merge influence area are the total freeway flow rate approaching the merge area (v_F), the total ramp flow rate (v_R), the length of the acceleration lane and the ramp free-flow speed at the point of merging. The total flow rate entering the merge influence area (v_{R12}) is calculated by adding the flow rate remaining in lanes 1 and 2 (v_{12}) and the total ramp flow rate (v_R), as illustrated in Figure 6-1.

Figure 6-1 Freeway Merging Variables



Once the total flow rate entering the merge influence area (v_{R12}) has been calculated, it can be divided by the maximum desirable flow rate entering the merge influence area (4600 passenger cars per hour) to obtain a volume to capacity ratio for the merge influence area. When total flow rates for merge influence areas exceed capacity, locally high densities will occur, but freeway queuing will not always form as a result because mainline traffic will typically shift into the outermost lanes to avoid the merging traffic. Freeway queues are more likely to result in these situations where there are only two lanes for mainline traffic, forcing all vehicles to pass through the merge influence area. The *HCM* attempts to account for the amount of v_{12} traffic with the equations on *HCM* Exhibit 25-5. These equations are based on variables such as acceleration length, distance to next ramp, ramp volume, etc.

In addition to determining the volume to capacity ratio of the merge influence area, the volume to capacity of the downstream basic freeway segment should be checked to ensure the added traffic from the ramp does not create a downstream bottleneck. In cases where the total departing freeway flow rate (v_{FO}) is greater than the capacity of the downstream freeway segment (see Chapter 5.4.1: Basic Freeway Segments), queues will form immediately downstream that will result in failure at the ramp connection, regardless of the whether flow rate entering the merge influence area has exceeded its capacity or not.

Exhibit 25-7 in the *HCM* displays capacities for merge areas including downstream freeway segment capacities (taken from Basic Freeway Segment chapter), as well as merge influence area capacities (where the maximum v_{R12} is always 4600 passenger cars per hour).

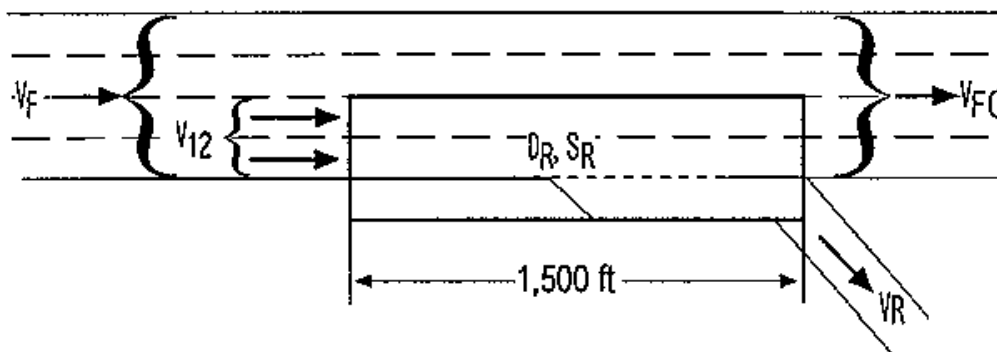
Diverging Analysis

Diverging analysis is often conducted at freeway off-ramps where vehicles from the mainline are departing to the ramp from a lane used by mainline traffic. The *HCM* methodology for diverging analysis is similar to that discussed above for merging, with three primary steps:

1. Predicting the approaching freeway flow in lanes 1 and 2.
2. Determining capacity.
3. Determining the density of flow within the ramp influence area. This step will not be discussed as the density is used to determine the performance measure of level of service, which is not used by ODOT.

For diverging analysis, the approaching flow rate in lanes 1 and 2 (v_{12}) is predicted for a point immediately upstream of the deceleration lane and includes the ramp flow rate (v_R) as illustrated in Figure 6-2. Models for predicting v_{12} can be found in Exhibit 25-12 of the *HCM*.

Figure 6-2 Freeway Diverging Variables



The primary cause of failure in diverge areas is inadequate capacity of an exit leg, whether on the freeway itself or the off-ramp. Capacities for downstream freeway legs can be obtained from Exhibit 25-14 (taken from Basic Freeway Segment chapter) from the *HCM*, and off-ramp capacities can be obtained from Exhibit 25-3. With these capacities known, volume to capacity ratios can be calculated by dividing the downstream freeway flow rate (v_{FO}) by the downstream freeway leg capacity and the ramp flow rate (v_R) by the ramp capacity.

Failure in diverge areas can also occur when the capacity of the freeway segment within the diverge area is exceeded. Capacities for upstream freeway segments can be obtained from Exhibit 25-14 (same as for downstream freeway segments) from the *HCM*. With this capacity known, a volume to capacity ratio can be calculated by dividing the freeway flow rate upstream of the diverge (v_F) by the capacity of the upstream freeway segment.

In addition to these conditions, the flow rate entering lanes 1 and 2 (v_{12}) immediately upstream of the deceleration lane should be checked to see if it exceeds the maximum desirable level. A volume to capacity ratio for this area can be calculated by dividing the approaching flow rate (v_{12}) by the maximum desirable flow rate of 4400 passenger cars per hour (Exhibit 25-14 of *HCM*). Unlike the other conditions described above, the condition where the flow rate entering lanes 1 and 2 exceeds the maximum desirable level may create locally high densities, but may not always result in freeway queuing because mainline traffic will typically shift into the outermost lanes to avoid the diverging traffic. Freeway queues are more likely to result in these situations where there are only two lanes for mainline traffic, forcing all vehicles to pass through the diverging area.

6.2.3 Weaving Segments

Weaving Configurations

Another necessary step before the analysis can be conducted is the determination of the weaving type, which is based on the number of lane changes required of each weaving movement. The *HCM* methodology identifies three types of geometric configurations for weaving areas. Each of these types of configurations is described below, with diagrams provided in Figure 6-4.

- **Type A:** Weaving vehicles in both directions must make one lane change to successfully complete a weaving maneuver.
- **Type B:** Weaving vehicles in one direction may complete a weaving maneuver without making a lane change, whereas other vehicles in the weaving segment must make one lane change to successfully complete a weaving maneuver.
- **Type C:** Weaving vehicles in one direction may complete a weaving maneuver without making a lane change, whereas other vehicles in the

weaving segment must make two or more lane change to successfully complete a weaving maneuver.

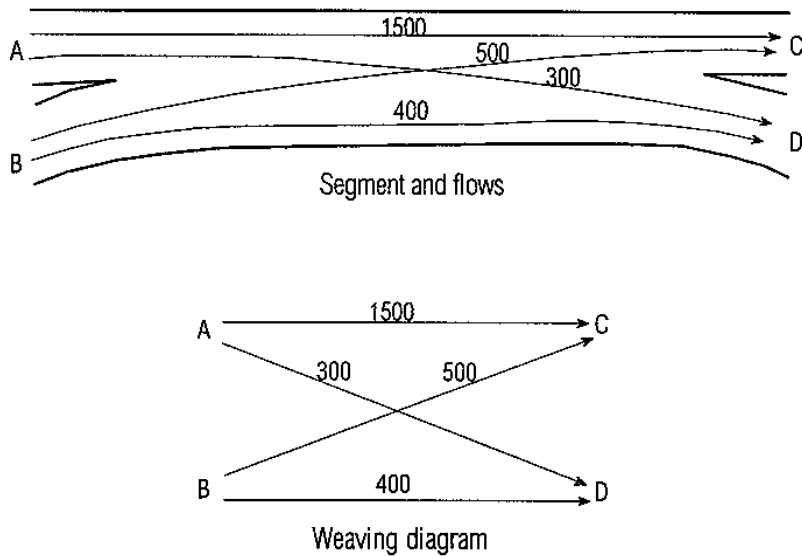
Typically weaving segments are formed when merge areas are followed closely by diverge areas (within 2,500 feet) and the two are joined by an auxiliary lane requiring the crossing of two or more traffic streams traveling in the same general direction along a significant length of highway without the aid of traffic control devices. Note that when one-lane on-ramps are followed by one-lane off-ramps and the two are not connected by an auxiliary lane, weaving analysis is not conducted and the merge and diverge areas are analyzed independently using the procedures previously described. Recognition of configurations that could result in weaving is critical in highway operations analysis, as weaving areas require intense lane changing maneuvers that create a significant amount of turbulence. ODOT prefers the use of the *HCM* methodology for analyzing weaving maneuvers, but also supports the use of the Leisch Method in cases where engineering judgment suggests *HCM* results are not accurately reflecting conditions. For weaving areas greater than 2,500 feet use the more conservative of either the merge/diverge or Leisch methods.

The *HCM* discusses weaving concepts in Chapter 13 and the analysis methodology in Chapter 24. While most analysts will take advantage of the practicality of the Highway Capacity Software (HCS), which will perform all needed calculations to analyze weaving areas, it is important to have a basic understanding of weaving characteristics and key input parameters for use with HCS.

Weaving Diagrams

With a weaving area identified for analysis, a weaving segment diagram should be created to clearly identify the traffic flow rates associated with each movement, i.e., mainline to mainline, mainline to off-ramp, on-ramp to mainline, and on-ramp to off-ramp. An example of a weaving segment diagram is shown in Figure 6-3.

Figure 6-3 Weaving Diagram

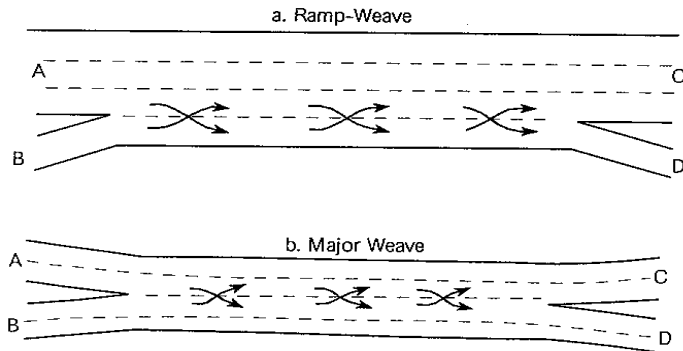


As can be seen, identifying the volume of traffic associated with each movement will require specialized data collection compared to typical counts that would only count traffic entering and leaving the area without noting its origin. Origin-destination surveys may provide the best data to use for a weaving analysis, but are not always practical to conduct and can be expensive. Some types of origin-destination studies, such as where traffic is stopped to conduct interviews, are more expensive than others such as license plate surveys. The less costly types of surveys are commonly through direct observation (usually recorded with video in the field and counted later) where all movements can be seen from one vantage point or through license plate identification. Another method sometimes available is the use of select-link output from a transportation demand model in combination with a common volume survey where a travel demand model has been created for the area. This method is especially useful for future scenarios where travel patterns may be different than current conditions. If either of these methods is not possible or practical for the particular area, the analyst may be required to apply engineering judgment in considering area characteristics such as land uses, topography and the area transportation network to create these movements from a common volume survey.

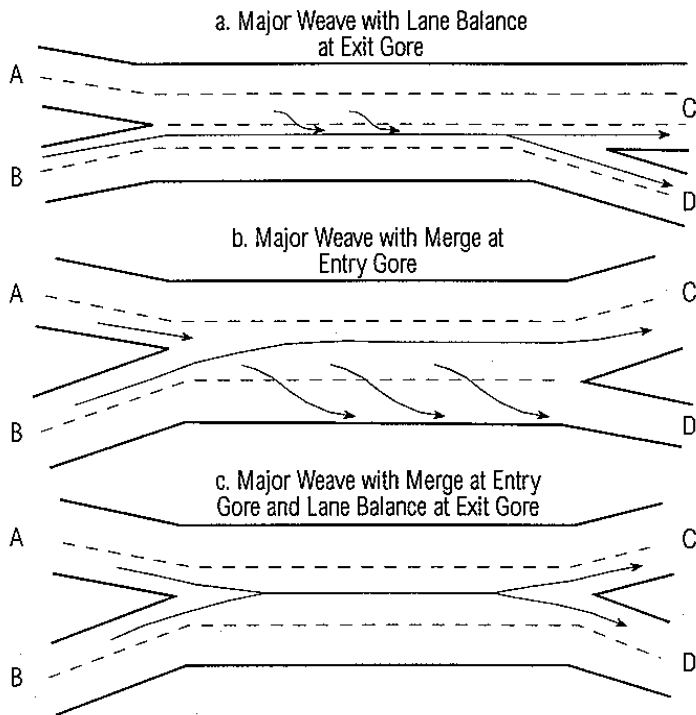
Weaving sections come in three configurations; Type A, B and C. Figure 6-4 shows the three types. Type A requires a lane change to get into or out of the auxiliary lane. Type A weaves are the most common type which occur mainly between interchanges that have a large portion of local trips that travel between them. High weaving volumes can cause Type A weaves to have poor operations. Type B weaves only require one lane change for either the mainline or ramp movement. These do not "trap" vehicles in the weaving section, so speeds are higher and operate much better than Type A weaves. Type C weaves require more than one lane change to perform the weaving maneuver and generally only

operate well if the movement that must change lanes multiple times has a small volume. Type C weaves are relatively uncommon, are generally discouraged, but may exist in older highway alignments.

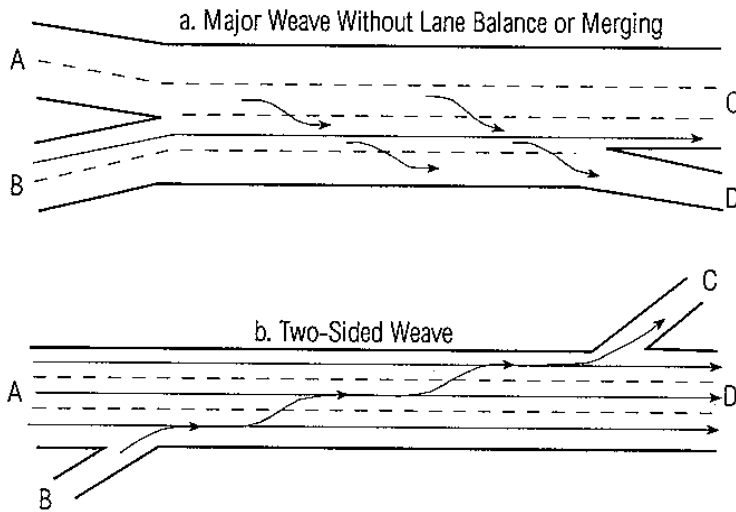
Figure 6-4 Weaving Configurations



Type A Configurations



Type B Configurations



Type C Configurations

Constrained vs. Unconstrained Conditions

Applying the weaving methodology, other geometric characteristics must be described including whether the weaving area is operating under constrained or unconstrained conditions and identifying the length of the weaving area. The determination of whether a weaving segment is operating under constrained or unconstrained conditions is based on the relationship between the number of lanes that must be used by weaving vehicles to achieve equilibrium with non-weaving vehicles (N_W) and the maximum number of lanes that can be used by weaving vehicles for a given configuration ($N_W(\max)$). Where $N_W < N_W(\max)$, conditions are described as unconstrained because there are no impediments to weaving vehicles' ability to achieve equilibrium with non-weaving traffic. Where $N_W \geq N_W(\max)$, conditions are considered to be constrained because weaving vehicles are not provided enough roadway width as would be needed to reach equilibrium. Under constrained operation weaving vehicles often experience operating conditions much worse than those experienced by non-weaving vehicles, while under unconstrained conditions weaving and non-weaving vehicles usually experience similar operating conditions.

The calculation of N_W and $N_W(\max)$ is determined by the configuration type, i.e., Type A, B, or C, and speeds of weaving and non-weaving vehicles. See Exhibit 24-7 in the *HCM*. When using the HCS to perform calculations, the analyst will only be required to determine the configuration type, free-flow speed and total number of lanes in the weaving section. However, an understanding of the characteristics of constrained and unconstrained conditions is important when analyzing weaving areas.

Weaving Length

Because weaving vehicles must execute all lane changes between the entry and exit gores, weaving lengths are measured from a point at the merge gore where

the right edge of the freeway shoulder lane and the left edge of the merging lane are 2-feet apart to a point at the diverge gore where the two edges are 12-feet apart. Weaving lengths are limited to 2,500 feet in the *HCM* methodology. For weaving areas greater than 2,500 feet, use the more conservative of either the merge/diverge or Leisch methods.

Weaving Density

The key element of the *HCM* weaving analysis methodology is the calculation of the weaving area density, which is determined by incorporating weaving characteristics such as flow rate, configuration and free-flow speed. For a complete description of the density calculation refer to Chapter 24 of the *HCM*. The *HCM* uses the performance measure of level of service to rate weaving operations, which is directly related to the density calculated according to Table 6-1.

Table 6-1 Level of Service Criteria for Weaving Segments

Level of Service	Density (Passenger Cars/Mile/Lane)	
	Freeway Weaving Segment	Multi-Lane and Collector-Distributor ⁴ Weaving Segments
A	< 10.0	<12.0
B	10.0 – 20.0	12.0 – 24.0
C	20.0 – 28.0	24.0 – 32.0
D	28.0 – 35.0	32.0 – 36.0
E	35.0 – 43.0	36.0 – 40.0
F	>43.0	>40.0

Weaving Capacity

While ODOT does not use level of service for evaluating facility performance, the density of the weaving section is still used to determine the volume to capacity ratio. If the capacity of the weaving section is equated to the level of service E/F threshold shown in Table 6-1, then the capacity of a freeway weaving section would occur at a density of 43 passenger cars per mile per lane. The capacity in passenger cars per hour at this density can be found through the following iterative process.

1. Complete the analysis using the *HCM* methodology. While this methodology will produce a level of service, which is not needed, it will also produce a density.
2. The capacity of the weaving section will be equal to the total entering flow rate that results in a calculated density of 43 passenger cars per mile per lane (for freeways). Using the flow rates from the initial analysis, begin an

⁴ See page 24-19 of the *HCM* – research is unclear on applicability of LOS criteria to collector-distributor roads.

iterative process by multiplying each movement flow rate by a common factor until the resulting density reaches, but does not exceed, 43 passenger cars per mile per lane.

3. Add the individual movement flow rates that produced the target density to obtain the total entering flow rate, which will be taken as the weaving section capacity.

The volume to capacity ratio for the section can now be calculated by dividing the original total entering flow rate by the capacity (total entering flow rate resulting in target density). This process of iteration will typically require fewer than ten attempts. The same procedure can be used for weaving analysis of non-freeway facilities, but a different target density for the capacity will be required, as shown in Table 6-1 for multi-lane and collector-distributor roadways.

In addition to v/c ratio, the weaving section volume ration (VR) and speeds should be reported. The VR is the ratio of the weaving flow rate to the total flow rate. The *HCM* provides recommended upper limits on volume ratios. The difference between weaving and non-weaving speeds is a form of speed differential, which is preferred to be 10 mph or less for safety. Conditions exceeding these values should be examined using more detailed analysis methods such as simulation.

Example 6-1

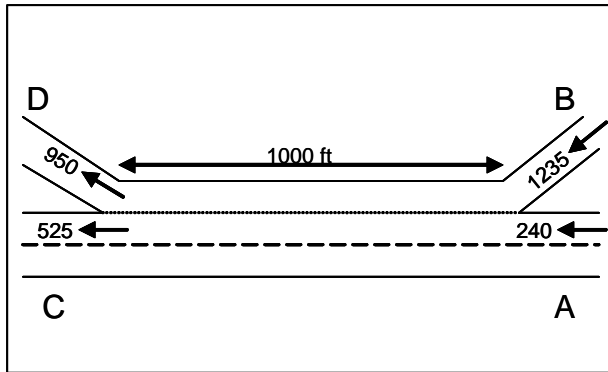
Given: Type A weave

- 12 ft lanes
- 6 ft lateral clearance
- 1000 ft weaving distance
- 35 mph posted speed
- Multilane highway segment
- 5% Trucks
- PHF = 0.95
- Driver population factor = 0.95
- Volumes in vehicles per hour
- Weaving and non-weaving flow distributions

Find: Volume-to-Capacity ratio for weaving section

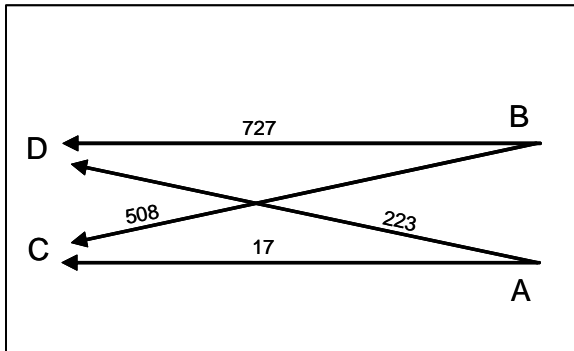
This example problem is based off of an actual project alternative. The lane and volume diagram (Figure 6-5) shows the layout of the Type A weaving section and the volumes in vehicles per hour. The weaving section was created between a free-right turn at “B” and a loop off-ramp at “D” on a multilane roadway at an interchange.

Figure 6-5 Lane and Volume Diagram



The lane volumes were converted into weaving (A-D and B-C) and non-weaving (B-D and A-C) volumes as shown on Figure 6-6. In this case, future distributions were available from a cumulative analysis procedure.

Figure 6-6 Weaving Flow Diagram



The given information is then input into the *HCM* weaving procedure. The *HCM* result is a flow rate (in passenger cars per hour) of 1673 pc/h with a corresponding density of 17.41 pc/mi. The target density is 40 pc/mi, which is the density at capacity ($v/c = 1.00$) for a multilane or collector-distributor roadway. Table 6-2 was then iteratively created by multiplying the flow rates by a common factor until the density was as close as possible to 40 pc/mi.

Table 6-2 Multiplied Flow Rates

Iteration	Factor	A-C (pc/h)	B-D (pc/h)	A-D (pc/h)	B-C (pc/h)	Flow rate (pc/h)	Density (pc/h)
1	1x	19	825	253	576	1673	17.41
2	2x	38	1650	506	1152	3346	47.83
3	1.5x	57	1238	380	864	2539	33.76
4	1.8x	34	1485	455	1037	3011	41.92
5	1.7x	32	1402	430	979	2843	39.04
6	1.74x	33	1436	440	1002	2911	40.20
7	1.73x	33	1427	438	996	2894	39.91
8	1.735x	33	1431	439	999	2902	40.05
9	1.733x	33	1430	438	993	2899	39.99

As can be seen from the last line in the table, the target density was reached at a flow rate of (rounded) 2900 pc/h. The 2900 pc/h flow rate is taken as the capacity in the v/c calculation. The sum of the original weaving and non-weaving flow rates is taken as the volume in the v/c calculation. The resulting v/c ratio would be:

$$\text{Weaving v/c} = 1673 / 2900 = 0.58$$

This v/c ratio is of an acceptable level. However, in doing the calculations it was found that the VR of 0.50 exceeds the maximum allowed by the methodology (0.45). Note: “c” at the end of HCM Exhibit 24-8 indicates that 3-lane type A segments do not operate well at volume ratios above .45, and may have poor operations and localized queuing. In addition, the difference between the weaving speeds (27 mph) and the non-weaving speeds (40 mph) is greater than 10 mph, which indicates a much greater potential crash risk. Simulation afterwards confirmed the poor operations as predicted even though the v/c ratio was acceptable.

It should also be noted, if using the HCS to perform calculations, that this program will provide warnings on the output sheet regarding limitations of this methodology that may not be reflected in the analysis results. It is the analyst's responsibility to check these conditions to be sure the analysis results are valid. In addition, as with all types of analysis procedures, the analyst should verify that the results obtained appear to be reasonable for the given scenario. If they are not, the assumptions and input parameters should be reevaluated for errors. Should the results continue to appear inaccurate after making these types of adjustment, the analyst may consider applying a different methodology.

6.3 Multi-Lane Highways

Analysis procedures for uninterrupted-flow multi-lane highways are provided in Chapter 21 of the *HCM*. Highways analyzed with this procedure must maintain a minimum of two travel lanes in each direction, would typically have direct access allowed through driveways and at-grade intersections, and must maintain uninterrupted flow. Highways with access limited to on-ramps and off-ramps should be analyzed using the Basic Freeway Segment methodology. In addition, highways experiencing interrupted flow from influences such as traffic signals and on-street parking should be analyzed using a different methodology, such as the Urban Streets methodology from the *HCM*.

These procedures are very similar to those previously described for basic freeway segments, with slightly different input data needs. The most notable differences include the need to account for median type and access density. For a complete description of the analysis methodology, refer to Chapter 21 of the *HCM*.

While the *HCM* methodology uses level of service as a performance measure (based on vehicle density in passenger cars per mile per lane), volume/capacity ratios can be calculated from this analysis for comparison against ODOT's adopted mobility standards by following the steps listed below. Note that separate volume/capacity ratios must be calculated for each direction of travel.

1. Assuming level of service E/F threshold represents capacity, determine the segment capacity by interpolating between the values for "maximum service flow rate" at level of service E displayed in Exhibit 21-2 of the *HCM* for the appropriate free-flow speed. Free-flow speed will be either calculated by this methodology or assumed.
2. Divide the calculated flow rate (v_p) by the interpolated capacity to obtain a volume/capacity ratio.

6.4 Two-Lane Highways

The *HCM* provides procedures for the operational analysis of two-lane highways modeled as two-way or directional segments, using level of service (LOS) and volume to capacity (v/c) ratios as performance measures. The application of these procedures on ODOT facilities is discussed below. For a complete description of the methodology, refer to Chapter 20 of the *HCM*.

6.4.1 Two-Way vs. Directional Analysis

While the ability to analyze two-lane highways as two-way or directional segments is offered by the *HCM*, only the analysis of ODOT facilities as directional segments is considered acceptable. The two-way analysis averages the two directions together, which can result in a combined v/c ratio that is within the adopted standard where the v/c ratio for one of the directions fails to meet the standard. In reality the v/c ratio of the highway is controlled by the highest direction, and should be reported as such.

Furthermore, the two-way analysis is not compatible with the multi-lane analysis. Because of this, it is possible to analyze a two-lane highway before and after widening to four lanes and obtain a higher v/c ratio for the four-lane condition. This inconsistency is corrected if the two-lane highway is analyzed by direction.

6.4.2 Performance Measures

The *HCM* defines the LOS for two-lane highway analysis by the percent time-spent-following and average travel speed. However, ODOT has no established standard for the amount of time-spent-following that is acceptable, or how such a standard might be different for various classifications of highways. Time spent following can be used for relative comparisons among alternatives. These measures can also understate performance in developed areas where driver expectations may be consistent with slower travel speeds and restricted passing opportunities. In addition, the calculation of the performance measures of percent time-spent-following and average travel speed have a large amount of uncertainty and error and, therefore, should not be considered reliable. As a result, only the v/c ratio will be considered as an acceptable measure of performance for two-lane highway segments.

The capacity of a two-lane highway is generally assumed to be 1,700 passenger cars per hour per direction of travel, with a maximum of 3,200 passenger cars per hour per direction of travel for both directions combined. To calculate the v/c ratio for a directional segment, the passenger car equivalent peak 15-minute flow rate is divided by the appropriate capacity.

6.4.3 Passing and Climbing Lanes

Both passing and climbing lanes are low-cost improvements that can be very effective in improving the operation of two-lane highways and can reduce the need to widen highways to four lanes. The *HCM* includes methodologies for analyzing these types of facilities in Chapter 20.

When analyzing either passing or climbing lanes it must be determined whether a no-passing restriction will be placed on opposing traffic in the area of the added lane. If passing by opposing traffic will not be allowed, the operations of opposing traffic must be reanalyzed to include this restriction.

While the methodologies described below can be used to evaluate the operations of passing and climbing lanes, the appropriate locations and lengths to use for design should be determined through the use of ODOT's *HDM*.

Passing Lanes

Passing lanes are typically used where there may be inadequate passing opportunities, either because of sight distance limitations or as traffic volumes approach capacity. By providing a safe place to pass, passing lanes tend to reduce unsafe passing maneuvers. In addition to improving operations in the segment containing the passing lane, operations of the highway downstream of the passing lane may also be improved for up to several miles before queues begin to reform. Exhibit 20-23 in the *HCM* shows the general relationship between the directional flow rate and the length of the downstream roadway affected. The *HCM* methodology is applicable to directional segments of two-lane highways that include the entire passing lane, and should also include the full effective downstream length (Exhibit 20-23), if possible.

A critical part of passing lane analysis using the *HCM* methodology includes dividing the analysis segment into four regions.

1. Upstream of the passing lane.
2. The passing lane, including tapers.
3. Downstream of the passing lane, but within its effective length.
4. Downstream of the passing lane, but beyond its effective length.

When using the Highway Capacity Software (HCS) to perform calculations, only the total segment length, length upstream of the passing lane and length of the passing lane are needed for input. The program will automatically calculate the other lengths based on these lengths and the directional flow rate.

As with the Two-Lane Highway analysis, a volume to capacity ratio for a directional segment must be obtained by dividing the passenger car equivalent peak 15-minute flow rate by the appropriate capacity. For a complete description

of the remaining analysis assumptions and methodology, see Chapter 20 in the *HCM*.

The analysis methodology in the *HCM* for passing lanes is intended to be applied to highways on level or rolling terrain only. Added lanes on mountainous terrain or on specific grades should be analyzed as climbing lanes.

Climbing Lanes

Climbing lanes are similar to passing lanes, but are generally used where grades cause unreasonable reductions in operating speeds of some vehicles. An unreasonable reduction in operating speeds is typically considered to occur where speed differentials of more than 10 mph are created. These lanes increase the capacity of a two-lane highway by providing a specific lane for slower vehicles to travel in while climbing an extended grade. This enables faster vehicles to pass these slower vehicles safely without having to leave the main travel lane. While climbing lanes are typically thought of as being associated with upgrades, they can also be applied to downgrades where heavy vehicles must drive in a low gear to avoid speeding out of control.

When analyzing the downgrade direction, passenger car equivalents for trucks operating at crawl speeds are available in Exhibit 20-18 of the *HCM*. For all other heavy vehicles, the passenger car equivalents in the *HCM* for level terrain should be used (Exhibit 20-9).

6.4.4 Other Analysis Procedures

Because of the deficiencies in the *HCM* procedures noted above, and the fact that volume to capacity ratios do not describe two-lane highway operations very well on their own, new methods and performance measures for evaluating two-lane highway operations are being considered. As an example, the Florida Department of Transportation has developed a modified version of the *HCM* methodology that more accurately reflects performance in developed areas by creating a unique class (Class III) for two-lane highways through developed areas, selecting percent free-flow speed as the performance measure and establishing new LOS thresholds to better reflect driver expectations in these areas. While ODOT has not accepted this methodology, it does represent one possible approach that will require further research.