



**HCS™**  
Freeways Module

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# USER GUIDE

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# Introduction

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Effective Date: 10/15/2024

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## Acknowledgements

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# Getting Started

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## System Requirements

HCS is designed for standard Windows installations. For optimal performance, the system should be Windows 10 or newer. While HCS may be compatible with older versions of Windows, any installation and operational issues arising from using these older versions will be the sole responsibility of the end user.

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## Getting Started

To begin, click on File then New (or the "New File..." button on the Start page).

Normal Windows keyboard and mouse functions are available. Tabbing, clicking to a new field, or pressing the Enter key will trigger a recalculation and update the report.

### Freeways Analysis

Freeways analyses will estimate Capacity and Level of Service (LOS) for a given set of traffic and geometric conditions. This type of analysis is oriented toward the evaluation of an existing or planned segment or facility. The methodology and procedures of application use the HCM Chapter 10, 12, 13, and 14 procedures.

### Freeway Facility Reliability Analysis

Freeway Facility Reliability analyses evaluate the travel time reliability experiences by motorists on an urban or rural freeway facility. Travel time reliability reflects the distribution of trip travel time over an extended period of time. The distribution arises from the occurrence of a number of factors that influence travel time (e.g., weather events, incidents, work zone presence, etc.). The distribution describes *how often* these factors occur and *how bad* operations are as a result. The methodology of the application uses the HCM Chapters 11 and 25 procedures.



# General Controls

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## Menu Items

**New** – Creates a new Freeways or Freeways Reliability file (\*.xuf or \*.xfr) and starts a new analysis project; shortcut is Ctrl+N

**Basic Freeway Segment** – Creates a new Freeways file (\*.xuf) and starts a new Basic Segment analysis project

**Freeway Merge Segment** – Creates a new Freeways file (\*.xuf) and starts a new Merge Segment analysis project

**Freeway Diverge Segment** – Creates a new Freeways file (\*.xuf) and starts a new Diverge Segment analysis project

**Freeway Weaving Segment** – Creates a new Freeways file (\*.xuf) and starts a new Weaving Segment analysis project

**Freeway Facility** – Creates a new Freeways file (\*.xuf) and starts a new Facility analysis project

**Planning-Level Freeway Facility Analysis** – Creates a new Freeways file (\*.xuf) and starts a new Facility Planning analysis project

**Freeway Reliability Analysis** – Creates a new Freeways Reliability file (\*.xfr) and starts a new Reliability analysis project

**Open** – Opens an existing Freeways or Freeways Reliability file (\*.xuf, \*.xfr, \*.xff, \*.xhf, \*.xhr, \*.xhw, or \*.csv); shortcut is Ctrl+O

**Example Folder** – Opens folder with all HCS examples in File Explorer

**Save** – Saves an open Freeways or Freeways Reliability file (\*.xuf or \*.xfr) using the current file name; shortcut is Ctrl+S

**Save As...** – Saves an open Freeways or Freeways Reliability file (\*.xuf or \*.xfr) using a specified file name; shortcut is F12

**Close** – Closes an open Freeways or Freeways Reliability file (\*.xuf or \*.xfr); shortcut is Ctrl+W

### Units

**USC Units** – Changes the units of the current file to U.S. Customary

**Metric Units** – Changes the units of the current file to Metric

**Print** – Brings up printer selection and prints a Freeways report to the printer or specified file type; shortcut is Ctrl+P

**Print Preview** – Displays preview of current report before printing; shortcut is Ctrl+F2

**View** – View menu items are only available for Freeways analyses, not Reliability analyses

**Page View** – Changes the view to display inputs and report by pages; shortcut is F9

## Full View

**Report -> Right** – Changes the view to display both the input screen and report simultaneously; the report is displayed on the right portion of the screen; shortcut is F10

**Report -> Bottom** – Changes the view to display both the input screen and report simultaneously; the report is displayed on the bottom portion of the screen; this function is only available for single segment analyses; shortcut is F11

## Report

**Formatted Report** – Displays formatted report including the most important values; shortcut is F4

**Text Report** – Displays text report with input, intermediary, and final results; shortcut is F6

**Heat Map Report** – Displays graphical representation of data where the individual values contained in a matrix are represented as colors; Density, LOS, v/c, and d/c ratios are included as heat maps; this report is only available for a Freeway Facility analysis; shortcut is F7

**Import From CSV** – Imports the facility inputs of each segment and analysis period from a CSV file into the \*.xuf file; this function is only available for a Freeway Facility analysis

**Export** – Export menu items are only available for a Freeway Facility analysis

**Facility -> CSV** – Exports the inputs of each segment and analysis period from the \*.xuf file into a CSV file with segments in ascending order; this function is only available for a Freeway Facility analysis

**Facility -> Graph** – Exports the facility graphic found on the Segments page to a PNG image file

**Default Settings** – Opens a dialog box for the user to input defaults for Analyst, Agency, and Jurisdiction, which will be applied to all new files; also allows selection of USC or SI units, which will be applied to all new files; other options for Export to CSV, Reports, and Safety Analysis are provided for selection and will be applied to all newly opened files; shortcut is Alt+F

**Reliability Analysis** – Opens Freeways Reliability and loads current Freeways file as the base file in the Reliability analysis; this is only available for a Freeway Facility analysis

**Reliability Planning** – Opens the Reliability Planning Calculator for the user to input all the necessary information to calculate results using the planning procedure; this is only available for a Reliability analysis

## Help

**Contents** – Provides access to glossary, acknowledgements, copyrights, and information on the HCM procedures; shortcut is Ctrl+F1

**Index** – Allows user to search keywords within the glossary

**Search** – Allows the user to search for any word within the glossary

**User Guide** – Opens a comprehensive user guide in PDF format; shortcut is Ctrl+G

**HCM Reference Guide** – Opens a reference guide for the HCM in PDF format

**HCS Updates** – Sends the HCS version number anonymously without any personally identifiable information to McTrans to check for a newer version

**HCM/HCS Training** – Opens the McTrans Training Page in the default web browser to view the latest training opportunities

**HCQS Web Page** – Opens the TRB Highway Capacity and Quality of Service Committee page in the default web browser

## Support

**Frequently Asked Questions** – Opens the McTrans support page for HCS in the default web browser

**HCS Overview** – Opens the McTrans HCS Overview page in the default web browser

**McTrans Website** – Opens the McTrans home page in the default web browser

**E-mail McTrans** – Composes a new e-mail addressed to McTrans in the default e-mail client with registration number, serial key, module, and version number already populated in the Subject field

**About HCS** – Opens an about window with software version information, EULA, general acknowledgements, and other relevant links

## CORSIM

**View Animation** – Sends data to the TSIS-CORSIM program for simulation and/or animation purposes, TRAFVU can be opened within TSIS-CORSIM case to allow user to view animation; shortcut is Ctrl+Shift+A

**Generate TRF File** – Saves an open Freeways file (\*.xuf) as a CORSIM file (\*.trf), which is a file that contains the input data used to define a CORSIM network and to drive the CORSIM simulation for a single simulation case; shortcut is Ctrl+Shift+T

**Exit** – Exits the *HCS* Freeways module; shortcut is Alt+F4

# Freeway Facilities

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## HCM Chapter 10

The Highway Capacity Software (*HCS*) faithfully implements the methodology prescribed in the Highway Capacity Manual (HCM) for analyzing Freeway Facilities. This chapter's methodology relies on the freeway segment methodologies in Chapters 12, 13, and 14. These methods focus on a single analysis period of interest, generally the peak 15 minutes within a peak hour. This chapter's methodology allows for the analysis of multiple and contiguous 15-min analysis periods and is capable of identifying breakdowns and the impact of such breakdowns over space and time. In essence, the methodology amalgamates hundreds or even thousands of individual segment/analysis period analyses into a single facility analysis. It also allows for managed lanes and work zone analysis.

A freeway is a separated highway with full control of access having two or more lanes in each direction dedicated to the exclusive use of motorized traffic. Freeway facilities are composed of various uniform segments that may be analyzed to determine capacity and LOS. Three types of segments are found on freeways:

- *Basic freeway segments*: All segments that are not merge, diverge, or weaving segments—whether general purpose or managed lanes. Those are described in more detail in Chapter 12.
- *Freeway weaving segments*: Segments in which two or more traffic streams traveling in the same general direction cross paths along a significant length of freeway without the aid of traffic control devices (except for guide signs). Weaving segments are formed when a diverge segment closely follows a merge segment or when a one-lane off-ramp closely follows a one-lane on-ramp and the two are connected by a continuous auxiliary lane. These segment types occur on both general purpose and managed lane (ML) facilities. In the latter case, and depending on the geometry, that segment could be labeled as an ML Weaving or an ML Access segment. Details for those designations are provided in Chapter 13.
- *Freeway merge and diverge segments*: Segments in which two or more traffic streams combine to form a single traffic stream (merge) or a single traffic stream divides to form two or more separate traffic streams (diverge). These segment types occur on both general purpose and managed lane facilities. Details for those segments are provided in Chapter 14.

This chapter covers the core freeway facilities methodology, which may include managed lanes as part of the facility. The analysis is limited to a single study period not to exceed 24 h. Extensions of the core method to longer study periods are covered in Chapter 11, Freeway Reliability Analysis. Those extensions are intended to account for (a) the longer-term effects of both recurring (i.e., bottlenecks) and nonrecurring (e.g., due to weather, incidents, or work zones) congestion on freeway facility operations, and (b) the effects of ATDM strategies in mitigating some of those negative impacts.

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## HCM Chapter 25

Chapter 25 is the supplemental chapter for Chapter 10, which describes the core methodology for freeway facilities, and Chapter 11, which presents a methodology for evaluating freeway reliability and active traffic and demand management (ATDM) strategies. The computations used by these methodologies are detailed in this supplemental chapter. The documentation is closely tied to FREEVAL, the computational engine for Chapter 10 and Chapter 11.

Chapter 25 presents a glossary of all relevant variables used in the procedures and the computational engine, provides details of the undersaturated and oversaturated procedures, describes details for work zone analysis, develops the planning-level methodology for freeway facilities, discusses the mixed-flow model for composite grades, develops the freeway calibration methodology at three levels, discusses freeway scenario generation, presents an overview of the computational engine structure, and presents example problems.

## LIMITATIONS OF THE METHODOLOGIES

The completeness of the analysis will be limited if freeway segment cells in the first time interval, the last time interval, and the first freeway segment do not have demand-to-capacity ratios of 1.00 or less. The methodology can handle congestion in the first interval properly, although it will not quantify any congestion that could have occurred before the first time interval. To ensure a complete quantification of the effects of congestion, it is recommended that the analysis contain an initial undersaturated time interval. If all freeway segments in the last time interval do not exhibit demand-to-capacity ratios less than 1.00, congestion will continue beyond the last time interval, and additional time intervals should be added. This fact will be noted as a difference between the vehicle miles of travel desired at the end of the analysis (demand flow) and the corresponding vehicle miles of travel flow generated (volume served). If queues extend upstream of the first segment, the analysis will not account for the congestion outside the freeway facility but will store the vehicles vertically until the congestions clears the first segment. The same process is followed for queues on on-ramp segments.

The methodology for oversaturated conditions described in this chapter is based on concepts of traffic flow theory and assumes a linear speed-flow relationship for densities greater than 45 passenger cars per mile per lane (pc/mi/ln). This relationship has not been extensively calibrated for field observations on U.S. freeways, and analysts should therefore perform their own validation from local data to obtain additional confidence in the results of this procedure.

The procedure described here becomes extremely complex when the queue from a downstream bottleneck extends into an upstream bottleneck, causing a queue interaction. When such cases arise, the reliability of the methodology is questionable, and the user is cautioned about the validity of the results. For heavily congested directional freeway facilities with interacting bottleneck queues, a traffic simulation model might be more applicable. Noninteracting bottlenecks are addressed by the methodology.

The procedure focuses on analyzing a directional series of freeway segments. It described the performance of a facility but falls short of addressing the broader transportation network. The analyst is cautioned that severe congestion on a freeway—especially freeway on-ramps—is likely to affect the adjacent surface street network. Similarly, the procedure is limited in its ability to predict the impacts of an oversaturated off-ramp and the associated queues that may spill back onto the freeway. Alternative tools are suitable to evaluate these impacts.

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## Operational Data

First, the user enters the General Information into the respective fields: Analyst, Agency, Date, and Time Analyzed. Then, the user enters the Site Information into the respective fields: Jurisdiction, Analysis Year, and Project Description. Facility-wide values are also provided on the General page under Facility Global Inputs to specify Jam Density, Density at Capacity, Queue Discharge Capacity Drop, Area Type, presence of Managed Lanes, Demand Factor, and application of the Mixed Flow Model. The 'Mixed Flow Model' checkbox is enabled only when the facility has Basic segments coded. If any other segment type is added to the facility, the checkbox will be disabled, and the mixed flow model will not be applied. If 'Mixed Flow Model' is checked and applied, two new inputs will be added to the Details page of the Basic segment(s). A Segments Global Inputs section is provided for the user to apply inputs to all segments within the coded facility to simplify inputting values throughout the whole facility. These fields include Freeway Lanes, Freeway FFS, Freeway Terrain Type, Freeway Peak Hour Factor, Freeway Total Trucks, Ramp Lanes, Ramp FFS, Ramp Terrain Type, Ramp Peak Hour Factor, and Ramp Total Trucks. There are checkboxes by each of these fields for the user to specify if they want to apply the inputs to each of the segments within the facility. For example, if one Freeway FFS is desired for every segment within the facility, the user can enter the value in the Freeway FFS textbox, check the checkbox next to it, and then click the Apply Global Inputs button. The value entered in the Freeway FFS textbox will then be applied to the Freeway FFS of each segment within the facility.

## Segments and Analysis Periods

On the Segments page, the user can add, insert, or remove segments by clicking the appropriate buttons at the top of the screen. Adding a segment will add a row of inputs with the Segment Type of 'Basic' along with the values from the previous Basic segment or default values if following a Merge, Diverge, or Weaving segment. The user can add an unlimited number of segments and can manually change the inputs to the desired values. When inserting a segment, the user must select a segment first before clicking the 'Insert Segment' button. When a segment is inserted, it will be added to the facility before the selected segment. To remove a segment, select one or more segments and then click the 'Delete Segment' button to remove the desired segments. Analysis periods can also be added or deleted. Similar to inserting a segment, inserting an analysis period will add an analysis period before the selected analysis period. To remove an analysis period, select the desired analysis period and then click the 'Delete Analysis Period' button.

## General Segment Inputs

On the Segments page, each segment has a row of editable inputs. These include: Segment Type, Segment Name, Segment Length, Number of Lanes, and Demand. There are two additional columns for each row that are not user inputs. These include Volume and Segment Analysis Details, which includes a link that leads to the corresponding Details page.

## Detailed Segment Inputs

On the Details page, the user can switch between each coded segment. Each segment has inputs for Geometric Data, Demand Data, and Adjustment Factors.

The Details page of a Basic or Overlap segment is the same as the input screen of an individual Basic segment. Inputs required for Geometric Data include: Number of Lanes, Base Free Flow Speed or Free Flow Speed If Measured FFS is checked, Segment Length, Lane Width, Terrain Type, Percent Grade and Grade Length if the Terrain Type selected is Specific Grade, Right Side Clearance, and Total Ramp Density. Inputs required for Demand Data include: Demand, Peak Hour Factor, Percent Total Trucks, Percent Single-Unit Trucks, and Percent Tractor-Trailers. Inputs required for Adjustment Factors include: Driver Population, Weather Type, Speed Adjustment Factor, Capacity Adjustment Factor, Incident Type, and Demand Adjustment Factor. There is also a checkbox to indicate if there is a work zone included for that analysis period. Checking this box will enable a Work Zone Data section with additional inputs including: Lane Closure Type, Area Type, Daylight or Night, Percent Drop in Capacity, Barrier Type, Lateral Distance, and Work Zone Speed Limit. If the 'Mixed Flow Model' checkbox from the Details page is checked and the model is applied, two new inputs will be added to the Demand Data section of the Details page of the Basic segment(s). These include: SUT Kinematic End Spot Rate and TT Kinematic End Spot Rate.

The Details page of a Merge or Diverge segment is the same as the input screen of an individual Merge or Diverge segment, respectively. Inputs are separated with freeway data on the left and ramp data on the right. Both the freeway and ramp data require Number of Lanes, Free Flow Speed, Terrain Type, Percent Grade and Grade Length if Terrain Type is Specific Grade, Demand, Peak Hour Factor, Percent Total Trucks, Percent Single-Unit Trucks, Percent Tractor-Trailers, Driver Population, Weather Type, Speed Adjustment Factor, Capacity Adjustment Factor, and Demand Adjustment Factor. Data specifically for ramps include the acceleration/deceleration lane lengths and the side of junction or location of ramp. Data specifically for the freeway include the freeway segment length and indication if it is a Highway or C-D Roadway. There is also an input to indicate Incident Type.

The Details page of a Weaving segment is the same as the input screen of an individual Weaving segment. Inputs required for Geometric Data include: Number of Lanes, Freeway Free-Flow Speed, Weaving Configuration, Number of Maneuver Lanes, Short Length, Interchange Density, Terrain Type, Percent Grade and Grade Length if the Terrain Type is Specific Grade, Minimum Freeway-to-Ramp Lane Changes, Minimum Ramp-to-Freeway Lane Changes, and Minimum Ramp-to-Ramp Lane Changes. There are also checkboxes included to indicate if it is a Highway or C-D Roadway and to indicate if there is a Cross Weaving Managed Lane. If a cross weaving managed lane is present, then a new section of cross weaving inputs will enable. Inputs required for Cross Weaving include: General Purpose Segment Type, Minimum Cross Weaving Length, Free-Flow Speed of the Managed Lane, Cross-



Weave Demand, Ramp Terrain Type, Percent Ramp Total Trucks, and Ramp Peak Hour Factor. Inputs required for Freeway Demand Data include: Freeway-to-Freeway Demand, Demand Adjustment Factor, Peak Hour Factor, Percent Total Trucks, Percent Single-Unit Trucks, and Percent Tractor-Trailers. Inputs required for Freeway Adjustment Factors include: Driver Population, Weather Type, Incident Type, Speed Adjustment Factor, and Capacity Adjustment Factor. Inputs required for On-Ramp Data include: On-Ramp Number of Lanes, On-Ramp Free-Flow Speed, Ramp-to-Freeway Demand, Ramp-to-Freeway Demand Adjustment Factor, Percent Ramp-to-Freeway Total Trucks, Ramp-to-Freeway Peak Hour Factor, Ramp-to-Ramp Demand, Ramp-to-Ramp Demand Adjustment Factor, Percent Ramp-to-Ramp Total Trucks, and Ramp-to-Ramp Peak Hour Factor. Inputs required for Off-Ramp Data include: Off-Ramp Number of Lanes, Off-Ramp Free-Flow Speed, Freeway-to-Ramp Demand, Freeway-to-Ramp Demand Adjustment Factor, Percent Freeway-to-Ramp Total Trucks, and Freeway-to-Ramp Peak Hour Factor.

If Managed Lane was checked on the General page, a new set of inputs will be enabled for Managed Lanes on each of the segments within the facility. Inputs required for Managed Lane Geometric Data include: Number of Managed Lanes, Managed Lane Type, Free-Flow Speed of the Managed Lane, Terrain Type, and Percent Grade and Grade Length if the Terrain Type is Specific Grade. Inputs required for Managed Lane Demand Data include: Managed Lane Demand, Peak Hour Factor, Percent Total Trucks, Percent Single-Unit Trucks, and Percent Tractor-Trailers. Inputs required for Managed Lane Adjustment Factors include: Driver Population, Demand Adjustment Factor, Speed Adjustment Factor, and Capacity Adjustment Factor.

### **Calibration Inputs**

A calibration table is provided on the Calibration page. The number of cells in the table is dependent on the number of segments and analysis periods in the facility analysis. There are two drop-down menus provided to adjust what is shown in the table. These include Cell Values and Cell Background Color. The Cell Values drop-down selection is provided to establish which values are shown in the cells of the calibration table. Choices include the following: Mainline Demand (veh/h), Entry Demand (veh/h), Exit Demand (veh/h), Ramp-to-Ramp Demand (veh/h), Mainline Free Flow Speed, Capacity Adjustment Factor, and Speed Adjustment Factor. The values can be edited within the table to adjust for calibration. Adjusting values in the table will also automatically update the same values on the Details page. The Cell Background Color drop-down selection is provided to establish a heat map by associating a chosen performance measure with background colors of the cells in the calibration table. Choices include the following: Per-Lane Demand; Speed; Density; Density-Based LOS; Demand-Based LOS; Demand - Capacity Ratio (D/C); Volume - Capacity Ratio (V/C); and Queue, %. Editing the cell values in the table can show the effect it has on the chosen performance measure.

### **Facility Graphic**

A facility graphic can be found on the Segments, Details, and Results pages to better visualize the facility being analyzed. Included in the graphic is a table listing the segment type, segment length in feet, Segment ID, number of general purpose lanes, and if applicable, the number of managed lanes for each segment. Underneath this information, is a drawing of the actual facility. On the Segments page, clicking on a particular segment, will bring the user to the Details page of the selected segment. Hovering over each segment will show a tooltip that provides information on the segment number, analyzed type, FFS, and terrain type. On both the Details page and Results page, the currently viewed segment will be highlighted. The user can switch the currently viewed segment by clicking on another segment. There are also options to change the color of the graph based on different performance measures, which include Flow, Speed, Density, and LOS. Selecting 'None' will leave the graphic white. A legend for the different colors appears to the side of the graphic when any of the other options are selected. Hovering over each segment on the Details page will show a tooltip that provides information on the segment number, analyzed type, FFS, and terrain type. Hovering over each segment on the Results page will show a tooltip that provides information on the segment number, analysis period number, flow, density, speed, and LOS.

## Results

### Level of Service (LOS) Criteria for Urban Freeway Facilities:

	Density (pc/mi/ln) [USC]	Density (pc/km/ln) [SI]
LOS A	≤11	≤7
LOS B	>11 - 18	>7 - 11
LOS C	>18 - 26	>11 - 16
LOS D	>26 - 35	>16 - 22
LOS E	>35 - 45	>22 - 28
LOS F	>45 or $a_d/c > 1.0$	>28 or $v_d/c > 1.0$

### Level of Service (LOS) Criteria for Rural Freeway Facilities:

	Density (pc/mi/ln) [USC]	Density (pc/km/ln) [SI]
LOS A	≤6	≤4
LOS B	>6 - 14	>4 - 9
LOS C	>14 - 22	>9 - 14
LOS D	>22 - 29	>14 - 18
LOS E	>29 - 39	>18 - 24
LOS F	>39 or $v_d/c > 1.0$	>24 or $v_d/c > 1.0$

### Level of Service (LOS) Criteria for Basic Freeway Segments:

	Density (pc/mi/ln) [USC]	Density (pc/km/ln) [SI]
LOS A	≤11	≤7
LOS B	>11 - 18	>7 - 11
LOS C	>18 - 26	>11 - 16
LOS D	>26 - 35	>16 - 22
LOS E	>35 - 45	>22 - 28
LOS F	>45 or $v/c > 1.0$	>28 or $v/c > 1.0$

### Level of Service (LOS) Criteria for Freeway Weaving Segments:

	Density (pc/mi/ln) [USC]	Density (pc/km/ln) [SI]
LOS A	0 - 10	0 - 6
LOS B	>10 - 20	>6 - 12
LOS C	>20 - 28	>12 - 17
LOS D	>28 - 35	>17 - 22
LOS E	>35	>22
LOS F	>43 or $v/c > 1.0$	>27 or $v/c > 1.0$

### Level of Service (LOS) Criteria for Freeway Merge and Diverge Segments:

	Density (pc/mi/ln) [USC]	Density (pc/km/ln) [SI]
LOS A	≤10	≤6
LOS B	>10 - 20	>6 - 12
LOS C	>20 - 28	>12 - 17
LOS D	>28 - 35	>17 - 22
LOS E	>35	>22
LOS F	$v/c > 1.0$	$v/c > 1.0$

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## Safety Results

When 'Show Safety Analysis Results in Reports' is checked in the *Default Settings*, predicted crashes will be computed based on the Highway Safety Manual (HSM) methods for the corresponding road type.

Due to structural differences between the HCM and HSM methods, certain transformations are required to convert HCM inputs into HSM inputs. Additionally, not all HSM-required data is available from HCM. Therefore, certain assumptions are included in the calculations.

The next section lists the conversion process of internal parameters, default values, and assumptions used to compute safety results in the *Freeways* module.

The following *HCS Freeways* inputs are internally converted to *HSS* as shown:

- Directional Volume (veh/h): The 'Directional Volume' is converted to 'AADT (veh/day)' by applying 'K-Factor' and 'D-Factor'. These factors can be defined by the user in the *Default Settings*.
- Number of Lanes: Since *HSS* analysis approach is bi-directional, it is assumed that the number of directional lanes entered in *Freeways* applies to both directions in *HSS*.
- Segment Length (ft): Lengths in feet are internally converted to miles.
- Lane Width: If 'Lane Width' is entered in *Freeways*, no conversion is needed. Otherwise, a base condition value of 12 ft is applied.
- Grade: No conversion is needed.

The following inputs are required in *HSS* are not used in *HCS Freeways*. Therefore, the base conditions are assumed in the calculation of safety results, represented by the following values:

- Area Type: Urban
- Inside/Outside Shoulder Width: 6 ft
- Median Width: 60 ft
- Proportion of Median Barrier Length: 0.00
- Proportion of Rumble Strips on Inside/Outside Shoulders: 0.0
- Proportion of AADT During High Volume Hours: 0.0
- Distance from Inside/Outside Shoulder to Barrier: 10 ft
- Clear Zone Width: 0 ft
- Horizontal Curvature: None
- Shoulder Width: 6 ft
- Shoulder Configuration: Paved Shoulder
- Centerline Rumble Strips: None
- Two-Way Left Turn Lanes: None
- Lighting: None

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## Planning Analysis

Facilities Planning is based off of HCM Chapter 25 Section 6. This procedure reduces the data requirements for freeway facilities by assuming default values for some inputs found in operational calculations. Facility planning is no longer based on the segment level of the operational analysis, but instead on a section level. Sections are typically from ramp gore to gore, but may include only one ramp or no ramp.

Demand is no longer input per analysis period, but 4 analysis periods of demand are estimated based on AADT and K-factor. The AADT input should be a single direction of data. This can be found from a two-direction AADT value by multiplying by the D-factor. The HCM recommends sections stay below 2 miles, particularly if they are ramp sections, to avoid the ramp adjustment applying for too long of a distance.

In comparison to Freeway Facilities operational analysis, facility planning does not have section specific inputs. All inputs can be found on the facility page with ramp FFS, truck percent, and other factors applying to the entire facility. A growth factor is provided to dynamically grow or reduce the demand input.

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## Facilities Report

The report page shows a formatted version of the analysis in a dynamic form, reacting to changes in the General, Segments, and Details pages. All or a portion can be copied to the Windows clipboard for insertion into other files by right-clicking into the report and selecting Copy.

Both formatted and text reports are available for viewing and printing. The formatted report provides data and results that are most important to the user, and are displayed in a clean and more presentable fashion. There are three graphs at the bottom of the report which show Volume Distribution, Speed Distribution, and Density Distribution. The text report provides more details to the user, rather than a summary.

The user can switch between Text and Formatted reports, Segment and Facility reports, and the Heat Map Report by clicking on the buttons found at the bottom of the Report page.

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## Import/Export Facility

### Import Facility

To properly import facility inputs, a new Freeway Facility XUF file must be created or an existing Freeway Facility XUF file must be opened. The number of segments, number of analysis periods, and segment types must be coded beforehand for the demand and other inputs to be properly imported. For example, if demand for 3 segments is desired but only 1 segment is available in the XUF file, then the information stored in the CSV file cannot be imported. A popup will appear in Freeways saying “Cannot import demand file, number of segments is not consistent with XUF file.” The same is applied for inconsistent number of analysis periods and segment types. Once the number of segments, number of analysis periods, and segment types are consistent between the CSV file and XUF file, then the ‘Import > Facility From CSV’ option can be selected from the menu items.

The first value of each line consists of the input label. Only the brackets with identifiers are required for properly importing. For example, it is not necessary for “Number of Segments” to be included in the label, but it is necessary for “[F1]” to be included for the number of segments to be properly read for importing. Import Facility also supports reading of partial files so not all labels are required for importing. Number of Segments, Number of Analysis Periods, and Segment Type are the three inputs required. All other inputs can be included, but are not necessary for importing to take place. The following list includes all the available labels with identifiers for the CSV file to be imported:

Version

Number of Segments [F1]

Number of Analysis Periods [F2]

Run Mixed Flow Model [F3]

Managed Lane [F4]

Jam Density [F5]

Queue Discharge Capacity [F6]

Density at Capacity [F7]

Area Type [F8]

Demand Factor [F10]

Start Time [F10]

Analyst [P1]

Jurisdiction [P2]

Agency [P3]

Time Analyzed [P4]

Analysis Year [P5]

Date [P6]

Segment Number [GB1]

Segment Name [GB14]

Segment Type [GB2]  
Lanes [GB3]  
Measured FFS [GB4]  
FFS [GB5]  
Length [GB6]  
Terrain Type [GB7]  
Grade [GB8]  
Grade Length [GB9]  
Right Side Clearance [GB10]  
Lane Width [GB11]  
Total Ramp Density [GB12]  
Managed Lane Type [GML1]  
Number of Managed Lanes [GML2]  
Managed Lane FFS [GML3]  
Managed Lane Terrain Type [GML4]  
Managed Lane Grade [GML5]  
Managed Lane Grade Length [GML6]  
Ramp Lanes [RB1]  
Ramp FFS [RB2]  
Ramp Side [RB3]  
Length of First Accel/Decel Lane [RB4]  
Length of Second Accel/Decel Lane [RB5]  
Ramp Terrain [RB6]  
Ramp Grade [RB7]  
Ramp Grade Length [RB8]  
Cross Weaving Effect [RB9]  
Min Cross Weaving Length [RB10]  
Highway or C-D Roadway [RB11]  
Number of Maneuver Lanes [WB1]  
Weaving Configuration [WB2]  
Short Length [WB3]  
Freeway-to-Ramp Lane Changes [WB4]  
Ramp-to-Freeway Lane Changes [WB5]  
Ramp-to-Ramp Lane Changes [WB6]  
On-Ramp Terrain [WB7]  
Off-Ramp Terrain [WB8]  
On-Ramp Grade [WB9]  
Off-Ramp Grade [WB10]  
On-Ramp Grade Length [WB11]  
Off-Ramp Grade Length [WB12]  
Interchange Density [WB13]  
Highway or C-D Roadway [WB14]  
On-Ramp FFS [WB16]  
Off-Ramp FFS [WB17]  
Mainline Demand [TB1]  
Mainline Peak Hour Factor [TB2]  
Mainline Total Trucks [TB3]  
Mainline Single-Unit Trucks [TB4]  
Mainline Driver Population [TB6]  
Mainline Weather Type [TB7]  
Mainline Incident [TB8]  
Mainline Speed Adjustment Factor [TB9]  
Mainline Capacity Adjustment Factor [TB10]  
Mainline Demand Adjustment Factor [TB11]

Mainline SUT Kinematic End Spot Rate [TB12]  
Mainline TT Kinematic End Spot Rate [TB13]  
Mainline Include Work Zone [TB14]  
Managed Lane Demand [TML1]  
Managed Lane Peak Hour Factor [TML2]  
Managed Lane Total Trucks [TML3]  
Managed Lane Single-Unit Truck [TML4]  
Managed Lane Driver Population [TML6]  
Managed Lane Speed Adjustment Factor [TML9]  
Managed Lane Capacity Adjustment Factor [TML10]  
Managed Lane Demand Adjustment Factor [TML11]  
Access Demand ML to GP [TML12]  
Access Demand GP to ML [TML13]  
Work Zone Lane Closure Type [TWZ1]  
Work Zone Barrier Type [TWZ2]  
Work Zone Area Type [TWZ3]  
Work Zone Lateral Distance [TWZ4]  
Work Zone Daylight or Night [TWZ5]  
Work Zone Speed Limit [TWZ6]  
Work Zone Percent Drop Capacity [TWZ7]  
Ramp Demand [TR1]  
Ramp Peak Hour Factor [TR2]  
Ramp Total Trucks [TR3]  
Ramp Single-Unit Trucks [TR4]  
Ramp Driver Population [TR6]  
Ramp Weather Type [TR7]  
Ramp Incident [TR8]  
Ramp Speed Adjustment Factor [TR9]  
Ramp Capacity Adjustment Factor [TR10]  
Ramp Demand Adjustment Factor [TR11]  
Cross Weaving Demand [TR12]  
Proportion of Flow Outside 4th Lane [TR13]  
Ramp-to-Freeway Demand [TW1]  
Freeway-to-Ramp Demand [TW2]  
Ramp-to-Ramp Demand [TW3]  
Ramp-to-Freeway Peak Hour Factor [TW4]  
Freeway-to-Ramp Peak Hour Factor [TW5]  
Ramp-to-Ramp Peak Hour Factor [TW6]  
Ramp-to-Freeway Total Trucks [TW7]  
Freeway-to-Ramp Total Trucks [TW8]  
Ramp-to-Ramp Total Trucks [TW9]  
Ramp-to-Freeway Demand Adjustment Factor [TW10]  
Freeway-to-Ramp Demand Adjustment Factor [TW11]  
Ramp-to-Ramp Demand Adjustment Factor [TW12]  
Ramp-to-Freeway Single-Unit Trucks [TW13]  
Freeway-to-Ramp Single-Unit Trucks [TW14]  
Ramp-to-Ramp Single-Unit Trucks [TW15]



From the labels *Mainline Demand [TB1]* and onward, additional rows are added underneath each label depending on the number of analysis periods included in a dataset. They are labeled as “TP#”. For example, if there are 4 analysis periods in a dataset, there would be 4 rows under each of these labels and they would be labeled as follows:

TP1  
TP2  
TP3  
TP4

With the exception of Number of Segments, Number of Analysis Periods, and the labels that come before the TP# rows, every row should have a value for each segment in the dataset. If a value is not applicable for a certain segment, then that value for that segment is “-”. For example, if there are 11 segments and only the sixth segment is a weaving segment, then the row for weaving configuration would look like the following:

Weaving Configuration [WB2],-,-,-,-,One-Sided,-,-,-,-

If using excel, each value would be in its own cell.

Number of Segments and Number of Analysis Periods should each have only one value following the label. For example, if there are 11 segments and 4 analysis periods in a dataset, the rows would be as follows:

Number of Segments [F1],11  
Number of Analysis Periods [F2],4

To ensure proper labeling, it is suggested to export a facility first and then make changes to the inputs within the CSV file for importing.

## **Export Facility**

To properly export facility inputs, a Freeway Facility XUF file must be opened. In the menu items, there is an ‘Export > Facility To CSV’ option. There are two options for exporting: Ascending Order and Descending Order. If the ‘Ascending Order’ option is chosen, then the inputs of each segment and analysis period will be exported with segments in ascending order. Likewise, if the ‘Descending Order’ option is chosen, then the inputs of each segment and analysis period will be exported with segments in descending order. If either of these are selected, a Save As dialog box will appear with the default file name of ‘export.csv’ already populated. The name can be edited if necessary. Once saved, the CSV file can be opened from the file location in whichever default CSV application is set for the current computer.

# Basic Freeway Segments

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## HCM Chapter 12

The Highway Capacity Software (*HCS*) faithfully implements the methodology prescribed in the Highway Capacity Manual (HCM) for analyzing Basic Freeway and Multilane Highway Segments. These segments are outside the influence of merging, diverging, and weaving maneuvers. In the case of multilane highways, they are also outside the influence of signalized intersections. Because of the similar operational characteristics of basic freeway and multilane highway segments, they are analyzed with the same methodology.

Chapter 12 focuses on *uninterrupted flow*, which refers to access-controlled facilities, with access and egress being controlled through grade-separated cross streets and ramp movements to access the facility.

The methodologies in this chapter are limited to *uncongested flow* conditions. Uncongested flow conditions require that the demand-to-capacity ratio for the segment is less than or equal to 1.0. Uncongested flow on freeways and multilane highways further means that there are no queuing impacts on the segment from downstream bottlenecks. Chapter 10, Freeway Facilities Core Methodology, provides an evaluation method for analyzing oversaturated basic freeway segments.

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## HCM Chapter 26

Chapter 26 is the supplemental chapter for Chapter 12, Basic Freeway and Multilane Highway Segments, and Chapter 15, Two-Lane Highways, which are found in Volume 2 of the *Highway Capacity Manual* (HCM). The chapter provides state-specific heavy-vehicle default values that can be applied to freeway, multilane, and two-lane highway analyses; presents a supplemental procedure for basic freeway segments that can be used to assess their operating performance under mixed-flow conditions when significant truck presence, a prolonged single upgrade, or both exist; provides travel time versus distance curves for single-unit trucks (SUTs) or tractor-trailers (TTs) for a range of free-flow speeds (FFS) for use with this procedure; presents an extension of this method for composite grades on freeway facilities; provides suggested capacity and FFS adjustments to account for the effects of different proportions of motorists on a freeway or multilane highway who are not regular users of the facility; presents freeway capacity definitions, guidance on locating sensors for use in measuring freeway capacity, and guidance on estimating capacity from the collected sensor data; and provides example problems.

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# Operational Data

## Project Properties

The following inputs are general information involving the analysis and are available under the Project Properties section: Analyst, Jurisdiction, Agency, Time Analyzed, Analysis Year, Date, and Project Description. A checkbox for Design Analysis is provided. When checked, a table will be added to both the formatted and text reports, listing the results for the current freeway segment with different numbers of lanes. A checkbox for Service Volumes is also provided. Checking this will enable the D-factor and K-factor fields and will add a service volume table to the end of both the formatted and text reports.

## Geometric Data

For Basic freeway segments, the number of lanes in the analysis direction is entered. The user chooses the type of Terrain (Level, Rolling, or Specific Grade). If Specific Grade is chosen, fields for Percent Grade and Grade Length will enable for the user to change. Lane Width, Base Free Flow Speed or Free-Flow Speed if Measured FFS is indicated, and Right Side Clearance are also available as inputs. Total Ramp Density is an input included for basic freeway segments.

A checkbox is provided for Measured FFS to indicate if Free-Flow Speed was measured for the current analysis. When Measured FFS is checked for basic freeway segments, the following fields are disabled: Lane Width, Right Side Clearance, and Total Ramp Density.

For basic freeways segments, a checkbox for Managed Lane is provided. When 'Managed Lane' is checked, three new sections are added to the bottom of the input screen: Managed Lane Geometric Data, Managed Lane Demand Data, and Managed Lane Adjustment Factors. Inputs for Managed Lane Geometric Data include: Number of Managed Lanes, Managed Lane Type, Free-Flow Speed of the Managed Lane, Terrain Type, and Percent Grade and Grade Length if the Terrain Type is Specific Grade. Inputs for Managed Lane Demand Data include: Managed Lane Demand, Peak Hour Factor, Percent Total Trucks, Percent Single-Unit Trucks, and Percent Tractor-Trailers. Inputs for Managed Lane Adjustment Factors include: Driver Population, Demand Adjustment Factor, Speed Adjustment Factor, and Capacity Adjustment Factor.

## Demand Data

Demand, Peak Hour Factor, Percent Total Trucks, Percent Single-Unit Trucks, and Percent Tractor-Trailers are included as inputs for basic freeway segments. A checkbox for Mixed Flow Model is also provided and is only enabled when the Terrain Type is coded as Specific Grade. If 'Mixed Flow Model' is checked, the mixed-flow model will be used to assess capacity, speed, and density in addition to the traditional passenger-car-equivalent (PCE) method. Results of both methods will be provided in the reports.

## Adjustment Factors

Both Driver Population and Weather Type are taken into account. These affect the Speed and Capacity Adjustment Factors. If the user chooses to override the default values based on driver population and weather type, they can change the adjustment factors.

In addition to these inputs, there are inputs for Incident Type, Demand Adjustment Factor, and Work Zone. If a Work Zone is indicated, a new Work Zone Data section will be enabled with the following inputs: Lane Closure Type, Area Type, Daylight or Night, Percent Drop in Capacity, Barrier Type, Lateral Distance, and Work Zone Speed Limit.

## Results

A basic freeway segment can be characterized by three performance measures: density in passenger cars per mile per lane (pc/mi/ln), space mean speed in miles per hour (mi/h), and the ratio of demand flow rate to capacity (v/c). Since speed is constant through a broad range of flows and the v/c ratio is not directly discernible to road users (except at capacity), the service measure for basic freeway segments is density.

Level of Service (LOS) Criteria for Basic Freeway Segments:

	Density (pc/mi/ln) [USC]	Density (pc/km/ln) [SI]
LOS A	≤11	≤7
LOS B	>11 - 18	>7 – 11
LOS C	>18 - 26	>11 – 16
LOS D	>26 - 35	>16 – 22
LOS E	>35 - 45	>22 – 28
LOS F	>45 or v/c>1.0	>28 or v/c>1.0

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## Safety Results

Please see *Safety Results* section under *Freeway Facilities*.

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## Design Analysis

The design mode of HCS Freeways can be used to determine the number of lanes required for a particular target LOS. Simply select the 'Design Analysis' checkbox and a table will be added to the report, listing the density and LOS for each number of lanes (2-5 for Basic and Ramp segments, and 3-6 for Weaving segments). For ramp segments, both 1 ramp lane and 2 ramp lanes are evaluated.

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## Basic Freeway Report

The report can be displayed in either Page or Full View. If displayed in Page View, the results will automatically update when the user switches to the Report page. From the Report page, the user can switch between the formatted report and text report using the button found at the bottom of the page. The formatted report shows the most important results in a presentable format, while the text report shows a detailed step-by-step analysis in plain text.

If displayed in Full View, the report can be displayed along with the input screen. The user has the choice of displaying the report to the right of the input screen or below the input screen. The report is dynamic and reacts to changes in the input screen. Like the Report page in Page View, the user can switch between the formatted report and the text report using the button found at the bottom of the report.

All or a portion can be copied to the Windows clipboard for insertion into other files by right-clicking into the report and selecting Copy. The user can also change the display of the report through File Menu or with the user of shortcuts. See *General Controls*.

# Freeway Weaving Segments

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## HCM Chapter 13

The Highway Capacity Software (*HCS*) faithfully implements the methodology prescribed in the Highway Capacity Manual (HCM) for analyzing Freeway Weaving Segments. The chapter describes how the methodology can be applied to planning, operations, and design applications. The methodology can further be used to estimate the effects of weather and incidents on weaving segment computations, and includes extension to apply concepts to weaving segments on managed lanes.

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## HCM Chapter 27

Chapter 27 is the supplemental chapter for Chapter 13, Freeway Weaving Segments, which is found in Volume 2 of the *Highway Capacity Manual* (HCM). This chapter provides example problems demonstrating the application of the Chapter 13 core methodology and its extension to freeway managed lanes.

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## Operational Data

### Project Properties

The following inputs are general information involving the analysis and are available under the Project Properties section: Analyst, Jurisdiction, Agency, Time Analyzed, Analysis Year, Date, and Project Description. A checkbox for Design Analysis is provided. When checked, a table will be added to both the formatted and text reports, listing the results for the current freeway segment with different numbers of lanes. A checkbox for Service Volumes is also provided. Checking this will enable the D-factor and K-factor fields and will add a service volume table to the end of both the formatted and text reports.

### Geometric Data

For Weaving Segments, inputs required for Geometric Data include: Number of Lanes, Freeway Free-Flow Speed, Weaving Configuration, Number of Maneuver Lanes, Short Length, Interchange Density, Terrain Type, Percent Grade and Grade Length if Terrain Type is Specific Grade, Minimum Freeway-to-Ramp Lane Changes, Minimum Ramp-to-Freeway Lane Changes, and Minimum Ramp-to-Ramp Lane Changes.

There are also checkboxes included to indicate if it is a Highway or C-D Roadway, to indicate if there is a Cross Weaving Managed Lane, and to indicate if there is a Managed Lane. If a cross weaving managed lane is present, then a new section of cross weaving inputs will enable. Inputs required for Cross Weaving include: General Purpose Segment Type, Minimum Cross Weaving Length, Free-Flow Speed of the Managed Lane, Cross-Weave Demand, Ramp Terrain Type, Percent Ramp Total Trucks, and Ramp Peak Hour Factor. If 'Managed Lane' is checked, a new set of inputs will be enabled for Managed. Inputs required for Managed Lane Geometric Data include: Number of Managed Lanes, Managed Lane Type, Free-Flow Speed of the Managed Lane, Terrain Type, and Percent Grade and Grade Length if the Terrain Type is Specific Grade. Inputs required for Managed Lane Demand Data include: Managed Lane Demand, Peak Hour Factor, Percent Total Trucks, Percent Single-Unit Trucks, and Percent Tractor-Trailers. Inputs required for Managed Lane Adjustment Factors include: Driver Population, Demand Adjustment Factor, Speed Adjustment Factor, and Capacity Adjustment Factor.

## Freeway Demand Data

Inputs required for Freeway Demand Data include: Freeway-to-Freeway Demand, Demand Adjustment Factor, Peak Hour Factor, Percent Total Trucks, Percent Single-Unit Trucks, and Percent Tractor-Trailers.

## Freeway Adjustment Factors

Driver Population and Weather Type are also taken into account. This affects the Speed and Capacity Adjustment Factors. However, if the user chooses to override the default values based on driver population and weather type, they can change the adjustment factors. In addition to these inputs, there is an input for Incident Type, which also affects Capacity Adjustment Factor.

## On-Ramp Data

Inputs required for On-Ramp Data include: On-Ramp Number of Lanes, On-Ramp Free-Flow Speed, Ramp-to-Freeway Demand, Ramp-to-Freeway Demand Adjustment Factor, Percent Ramp-to-Freeway Total Trucks, Ramp-to-Freeway Peak Hour Factor, Ramp-to-Ramp Demand, Ramp-to-Ramp Demand Adjustment Factor, Percent Ramp-to-Ramp Total Trucks, and Ramp-to-Ramp Peak Hour Factor.

## Off-Ramp Data

Inputs required for Off-Ramp Data include: Off-Ramp Number of Lanes, Off-Ramp Free-Flow Speed, Freeway-to-Ramp Demand, Freeway-to-Ramp Demand Adjustment Factor, Percent Freeway-to-Ramp Total Trucks, and Freeway-to-Ramp Peak Hour Factor.

## Results

LOS criteria is provided for weaving segments on freeways, collector-distributor (C-D) roads, and multilane highways.

Level of Service (LOS) Criteria for Freeway Weaving Segments:

	Density (pc/mi/ln) [USC]	Density (pc/km/ln) [SI]
LOS A	0 - 10	0 - 6
LOS B	>10 - 20	>6 - 12
LOS C	>20 - 28	>12 - 17
LOS D	>28 - 35	>17 - 22
LOS E	>35	>22
LOS F	>43 or $v/c > 1.0$	>27 or $v/c > 1.0$

Level of Service (LOS) Criteria for Weaving Segments on Multilane Highways or C-D Roads:

	Density (pc/mi/ln) [USC]	Density (pc/km/ln) [SI]
LOS A	0 - 12	0 - 7
LOS B	>12 - 24	>7 - 15
LOS C	>24 - 32	>15 - 20
LOS D	>32 - 36	>20 - 22
LOS E	>36 - 40	>22 - 25
LOS F	>40 or $v/c > 1.0$	>25 or $v/c > 1.0$

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## Safety Results

Please see *Safety Results* section under *Freeway Facilities*.



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## Design Analysis

The design mode of HCS Freeways can be used to determine the number of lanes required for a particular target LOS. Simply select the 'Design Analysis' checkbox and a table will be added to the report, listing the density and LOS for each number of lanes (2-5 for Basic and Ramp segments, and 3-6 for Weaving segments). For ramp segments, both 1 ramp lane and 2 ramp lanes are evaluated.

Note that for weaving segments, some configurations may lead to LOS F for all numbers of lanes due to HCM equations creating a capacity less than the demand. To solve this problem, reconfigure the weaving segment to change  $N_{WL}$  to 3. If this is infeasible, or  $N_{WL}$  is already 3, the weaving segment will always be LOS F. To improve the LOS, adjust the demand (specifically the weaving demand) or increase the length of the segment past the maximum weaving length to cause the segment to be analyzed as a basic segment.

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## Weaving Report

The report can be displayed in either Page or Full View. If displayed in Page View, the results will automatically update when the user switches to the Report page. From the Report page, the user can switch between the formatted report and text report using the button found at the bottom of the page. The formatted report shows the most important results in a presentable format, while the text report shows a detailed step-by-step analysis in plain text.

If displayed in Full View, the report can be displayed along with the input screen. The user has the choice of displaying the report to the right of the input screen or below the input screen. The report is dynamic and reacts to changes in the input screen. Like the Report page in Page View, the user can switch between the formatted report and the text report using the button found at the bottom of the report.

All or a portion can be copied to the Windows clipboard for insertion into other files by right-clicking into the report and selecting Copy. The user can also change the display of the report through File Menu or with the user of shortcuts. See *General Controls*.

# Freeway Merge and Diverge Segments

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## HCM Chapter 14

The Highway Capacity Software (*HCS*) faithfully implements the methodology prescribed in the Highway Capacity Manual (HCM) for analyzing Freeway Merge and Diverge Segments. The procedures in this chapter focus on ramp-freeway junctions, but guidance is also provided to allow approximate use of such procedures on multilane highway and on collector-distributor roadways.

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## HCM Chapter 28

Chapter 28 is the supplemental chapter for Chapter 14, Freeway Merge and Diverge Segments, which is found in Volume 2 of the *Highway Capacity Manual* (HCM). The chapter provides example problems for demonstrating the application of Chapter 14 methodology and its extension to freeway managed lanes.

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## Operational Data

### Project Properties

The following inputs are general information involving the analysis and are available under the Project Properties section: Analyst, Jurisdiction, Agency, Time Analyzed, Analysis Year, Date, and Project Description. A checkbox for Design Analysis is provided. When checked, a table will be added to both the formatted and text reports, listing the results for the current freeway segment with different numbers of lanes. A checkbox for Service Volumes is also provided. Checking this will enable the D-factor and K-factor fields and will add service volume tables to the end of both the formatted and text reports.

### Geometric Data

For merge and diverge segments, inputs are separated with freeway data on the left and ramp data on the right. Both the freeway and ramp data require Number of Lanes, Free Flow Speed, Terrain Type, and Percent Grade and Grade Length if Terrain Type is Specific Grade.

Data specifically for ramps include the acceleration/deceleration lane lengths and the side of junction or location of ramp. Data specifically for the freeway include the freeway length and indication if it is a Highway or C-D Roadway.

There is also a checkbox to indicate the presence of a Managed Lane. When 'Managed Lane' is checked, three new sections are added to the bottom of the input screen: Managed Lane Geometric Data, Managed Lane Demand Data, and Managed Lane Adjustment Factors. Inputs for Managed Lane Geometric Data include: Number of Managed Lanes, Managed Lane Type, Free-Flow Speed of the Managed Lane, Terrain Type, and Percent Grade and Grade Length if the Terrain Type is Specific Grade. Inputs for Managed Lane Demand Data include: Managed Lane Demand, Peak Hour Factor, Percent Total Trucks, Percent Single-Unit Trucks, and Percent Tractor-Trailers. Inputs for Managed Lane Adjustment Factors include: Driver Population, Demand Adjustment Factor, Speed Adjustment Factor, and Capacity Adjustment Factor.

For an individual diverge segment, a checkbox for Major Diverge is provided when the number of ramp lanes is 2. This checkbox is hidden when the number of ramp lanes is 1.

### Demand Data

Demand, Peak Hour Factor, Percent Total Trucks, Percent Single-Unit Trucks, and Percent Tractor-Trailers are necessary inputs for both the subject ramp and freeway.

### Adjustment Factors

Driver Population and Weather Type are also taken into account and inputs are provided for both the ramp and the freeway. These fields affect the Speed and Capacity Adjustment Factors. However, if the user chooses to override the default values based on driver population and weather type, they can change the adjustment factors. In addition to these inputs, there are inputs for Demand Adjustment Factor and Incident Type.

### Adjacent Ramps

Fields are provided for adjacent ramps if they exist in an analysis. This section is only enabled when Number of Freeway Lanes is 3. There are inputs for both upstream and downstream adjacent ramps; the user can specify if the adjacent ramp is a merge or a diverge, the distance from the subject ramp to the adjacent ramp, the Terrain of the adjacent ramp, the Demand of the adjacent ramp, the Peak Hour Factor of the adjacent ramp, and the Percent Trucks of the adjacent ramp.

### Results

LOS criteria applies to all ramp-freeway junctions and may also be applied to major merges and diverges; high-speed, uncontrolled merge or diverge ramps on multilane highway sections; and merges and diverges on freeway C-D roadways. LOS is not defined for ramp roadways.

Level of Service (LOS) Criteria for Freeway Merge and Diverge Segments:

	Density (pc/mi/ln) [USC]	Density (pc/km/ln) [SI]
LOS A	≤10	≤6
LOS B	>10 - 20	>6 – 12
LOS C	>20 - 28	>12 – 17
LOS D	>28 - 35	>17 – 22
LOS E	>35	>22
LOS F	v/c>1.0	v/c>1.0

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## Safety Results

Please see *Safety Results* section under *Freeway Facilities*.

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## Design Analysis

The design mode of HCS Freeways can be used to determine the number of lanes required for a particular target LOS. Simply select the 'Design Analysis' checkbox and a table will be added to the report, listing the density and LOS for each number of lanes (2-5 for Basic and Ramp segments, and 3-6 for Weaving segments). For ramp segments, both 1 ramp lane and 2 ramp lanes are evaluated.

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## Merge Report

The report can be displayed in either Page or Full View. If displayed in Page View, the results will automatically update when the user switches to the Report page. From the Report page, the user can switch between the formatted report and text report using the button found at the bottom of the page. The formatted report shows the most important results in a presentable format, while the text report shows a detailed step-by-step analysis in plain text.

If displayed in Full View, the report can be displayed along with the input screen. The user has the choice of displaying the report to the right of the input screen or below the input screen. The report is dynamic and reacts to changes in the input screen. Like the Report page in Page View, the user can switch between the formatted report and the text report using the button found at the bottom of the report.

All or a portion can be copied to the Windows clipboard for insertion into other files by right-clicking into the report and selecting Copy. The user can also change the display of the report through File Menu or with the user of shortcuts. See *General Controls*.

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## Diverge Report

The report can be displayed in either Page or Full View. If displayed in Page View, the results will automatically update when the user switches to the Report page. From the Report page, the user can switch between the formatted report and text report using the button found at the bottom of the page. The formatted report shows the most important results in a presentable format, while the text report shows a detailed step-by-step analysis in plain text.

If displayed in Full View, the report can be displayed along with the input screen. The user has the choice of displaying the report to the right of the input screen or below the input screen. The report is dynamic and reacts to changes in the input screen. Like the Report page in Page View, the user can switch between the formatted report and the text report using the button found at the bottom of the report.

All or a portion can be copied to the Windows clipboard for insertion into other files by right-clicking into the report and selecting Copy. The user can also change the display of the report through File Menu or with the user of shortcuts. See *General Controls*.

# Freeway Reliability

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## HCM Chapter 11

The Highway Capacity Software (*HCS*) faithfully implements the methodology prescribed in the Highway Capacity Manual (HCM) for analyzing a freeway's travel time reliability over a multiday or multimonth *reliability reporting period* (RRP). The methodology estimates the impacts of recurring and non-recurring congestions (i.e., demand variations and fluctuations, incidents, weather, work zones, and special events) on the travel time distribution over the course of the RRP. As an extension, the methodology can be used to estimate the impacts of Active Traffic and Demand Management (ATDM) strategies on the travel time distribution.

This chapter's methodology relies on the freeway facilities core methodology presented in Chapter 10, which in turn applies the freeway segment methodologies in Chapters 12, 13, and 14. The freeway facilities core methodology focuses the analysis on a single day or less, while the segment methodologies are limited to the analysis of one 15-min period. In contrast, this chapter's methodology is capable of repeatedly applying the core method across multiple days, weeks, months, up to a one-year RRP. A one-year RRP is the most common application, although shorter periods are possible for specific applications (e.g., reliability of summer tourist traffic, a focus on the construction season). RRP's longer than one year are uncommon, as most typical variations in travel time (day-of-week, month-of-year, weather, and incidents) are encapsulated in a single year.

### STRENGTHS OF THE METHODOLOGY

The methodology is capable of estimating the impacts of non-recurring congestion (due to demand variability, weather, incidents, work zones, and special events) on the operational performance of a freeway facility over an extended reliability reporting period—up to one year. Due to the computational efficiency of the HCM freeway facility core methodology, compared to an analysis of a freeway facility in simulation, for example, a whole-year analysis can be performed relatively quickly. Specific strengths of the methodology are:

- An efficient method to estimate travel time reliability, which can be applied quickly several hundred times to derive a travel time distribution over a reliability reporting period up to one year.
- A core methodology that is less computationally intensive than microsimulation.
- A core methodology that can be directly calibrated on the basis of local or regional capacity defaults to replicate recurring bottlenecks.
- The consideration of local and regional weather defaults for the 101 largest U.S. metropolitan areas based on a ten-year average.
- A method to estimate incident and crash rates in the absence of detailed local incident logs.
- The ability to extend the method for evaluating ATDM strategies.

In addition, the strength of the core methodology described in HCM Chapter 10 also apply to the reliability and strategy assessment methods presented here.

## LIMITATIONS OF THE METHODOLOGY

Because the reliability method applies the freeway facility core methodology multiple times, it inherits the core methodology's limitations. These limitations were described in HCM Chapter 10. For example, one limitation of the core method is its use of 15-min analysis periods. Therefore, all event durations (e.g., weather, incidents) used by the reliability method must be expressed as integer numbers of 15-min analysis periods. The reliability method has the following additional limitations:

- The method assumes a multiplicative effect when two or more factors (weather and incident) affect speed or capacity. This assumption has not been sufficiently tested empirically, and may overstate the deleterious effects of combined non-recurring congestion effects.
- Weather events that have a small effect (<4%) on segment capacity reduction are not addressed. A given weather event (e.g., rain, snow) is always assumed to occur at its mean duration value. Sun glare is not accounted for.
- The method assumes that incident occurrence and traffic demand are independent of weather conditions, although all are indirectly tied to each other through the specification of demand, incident, and weather probabilities on a calendar basis. However, the analyst is able to adjust incident frequencies by month on the basis of local data.
- The method estimates incident occurrence as a function of segment demand and month of the year. It does not consider potentially elevated incident rates in segments with low demands. Some segments may be overly prone to incidents due to poor visibility, poor geometry, a short weaving segment, or a host of other factors that are not considered by the reliability method.
- The method does not consider full facility closures in the scenarios. In the course of assigning incidents to the segments, at least one lane should therefore remain open. The scenario generation methodology does not assign incidents that result in full-segment closure, but reassigns those probabilities to other (less severe) incidents. This is also true for work zones, where at least one travel lane has to remain open.
- The travel time reliability analysis assumes similar effects of demand variation and weather conditions on general purpose and managed lanes, when a managed lane facility is included in the analysis.
- Work-zone events are only allowed to be modeled in general purpose lanes; no managed-lane work zone effects are considered.
- The traffic-demand adjustment assumes a proportional demand effect across the entire facility, meaning that all inputs and outputs (across time and space in the base scenario) are increased or decreased by the same factors.

## CALIBRATION AT THE TRAVEL TIME RELIABILITY LEVEL

After calibrating the core freeway facility methodology and fixing the value of its parameters, a comprehensive travel time reliability calibration is performed. The process includes three major steps: whole-year demand calibration, incident calibration, and weather calibration.

To calibrate the methodology for a particular site, it is recommended that the analyst perform an initial comprehensive reliability run using default values for all input parameters and subsequently compare the predicted travel time index (TTI) cumulative distribution to the observed distribution.

The comprehensive reliability calibration steps include:

- Step 1: Gather input data (demand, weather, incident, distribution, and work zone data)
- Step 2: Determine demand multipliers
- Step 3: Calibrate incident probabilities
- Step 4: Calibrate weather probabilities
- Step 5: Validate parameters

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# Operational Data

## BASE

On the Base page, the user is required to load a base dataset to run a Freeways Reliability analysis. There are two options when using a base dataset: *Load Base Dataset* and *Create Base Dataset*. The program requires the HCS Freeways module for both these options. The *Load Base Dataset* button opens a dialog that allows users to open an existing HCS Freeways (\*.xuf) file. The *Create Base Dataset* button launches the Freeways module where a user can create a new HCS Freeways (\*.xuf) file. If HCS is already installed on the computer, then the Freeways module should open when this button is clicked. If HCS is not installed, an error will pop up and HCS will need to be installed on the computer to continue with the Freeway Reliability analysis.

The Base page shows a summary of the data from the Freeways file. When a Freeways file is loaded, the required information from the dataset is extracted for reliability analysis. Two sections appear when the Freeways file is loaded: *Base Dataset Facility* and *Base Dataset General Information*. The number of segments in the facility, along with the segment type, segment length, and number of lanes on each segment are displayed graphically in the first section. The second section lists out the Analyst Name, Agency, Jurisdiction, Year, Date, File Name, and Project Description taken directly from the Freeways file.

## ANALYSIS

On the Analysis page, there are fields for the user to specify project properties. These include: Analyst, Agency, Analysis Year, Jurisdiction, Time Analyzed, Date, and Project Description. The Analysis page is further used to specify the duration of the reliability reporting period. There are three main sections in the analysis page: *Reporting Period*, *Study Period*, and *Number of Replications*.

The reliability reporting period represents the specific days over which the travel time distribution is to be computed, for example, all nonholiday weekdays in a year. The period is specified by start and end dates as well as by the days of week being considered. The start and end dates can be selected by clicking the calendar in the respective textbox and selecting the date on the calendar or by typing the date in the format MM/DD/YYYY. The days of week to be considered in a reliability analysis can be selected by clicking the checkboxes provided for each day of the week.

If these values are not changed by the user, the following defaults will be used:

- Start Date: Today's date
- End Date: Today's date, a year later
- Days of Week: Mon, Tue, Wed, Thu, Fri (all weekdays)

The number of days should be reflected under each month based on the information input for reporting period. The reliability reporting period is used with the study period to describe the temporal representation of the performance measure fully (e.g., average travel time on nonholiday weekdays from 4:00 to 6:00 p.m. for the current year).

The *Study Period* is based on information pulled from the Freeways Base Dataset. Listed in the *Study Period* box is the *Start Time*, *End Time*, and *Duration (min)*.

The user can specify the number of times the methodology is applied changing the *Number of Replications*. For a one-year reliability reporting period, the methodology is typically applied with four replications for each of five weekdays (Monday through Friday) and 12 months in the year, for a total of 240 scenarios. This approach roughly corresponds to 250 work days in a typical calendar year. A reliability analysis that includes weekend effects would result in an increased number of scenarios. For reliability reporting periods that are significantly shorter than one year, the analyst should increase the number of replications to ensure a sufficient sample size for scenario generation. HCM Exhibit 11-9, found below, provides guidance on the recommended number of replications in such cases.

RRP Duration (months)	Number of Days Considered	Recommended Number of Replications	Resulting Number of Scenarios
1	5 (all weekdays)	48	240
2	5	24	240
4	5	12	240
6	5	8	240
9	5	6	270
12*	5	4*	240*
12	2 (weekend only)	10	240
12	7 (all days)**	3	252

Notes: RRP = reliability reporting period.

\*Default value.

\*\*Not desirable; separating weekday and weekend reliability analysis is preferred.

## WEATHER

On the Weather page, a drop-down list is located at the top of the screen where a city with available weather data can be chosen. A city can also be typed into the search bar, which will then match and select the city from the drop-down list.

Once a city is selected, the first table displayed will show the defaults of Weather Event Probability and Weather Event Duration. The probability of a weather event happening is displayed for each month based on the location and the study period start time and end time. The default probabilities are based on the Metropolitan Weather Database for Freeway Reliability Analysis in Volume 4 of the HCM. The duration associated with each weather event is the length of time of the weather event in minutes. The default duration for each weather event is the same for each location. If any of the probability defaults or duration is changed, the weather location originally selected will change to 'Custom'. To restore the default values, the user can set the location again.

Based on weather conditions and free-flow speeds, the second table displayed shows the Demand Adjustment Factors, Capacity Adjustment Factors, or Speed Adjustment Factors by switching between the DAF, CAF, and SAF tabs. Demand Adjustment Factor default values are 1.000 for all. Capacity Adjustment Factor and Speed Adjustment Factor default values can be found in the tables below.

Default CAFs by Weather Condition:

Weather Type	Weather Event Definition	Capacity Adjustment Factors				
		55 mi/h	60 mi/h	65 mi/h	70 mi/h	75 mi/h
Medium rain	> 0.10-0.25 in/h	0.94	0.93	0.92	0.91	0.90
Heavy rain	> 0.25 in/h	0.89	0.88	0.86	0.84	0.82
Light snow	>0.00 – 0.05 in/h	0.97	0.96	0.96	0.95	0.95
Light-medium snow	>0.05 – 0.10 in/h	0.95	0.94	0.92	0.90	0.88
Medium-heavy snow	>0.10 – 0.50 in/h	0.93	0.91	0.90	0.88	0.87
Heavy snow	>0.50 in/h	0.80	0.78	0.76	0.74	0.72
Severe cold	< -4°F	0.93	0.92	0.92	0.91	0.90
Low visibility	0.50 – 0.99 mi	0.90	0.90	0.90	0.90	0.90
Very low visibility	0.25 – 0.49 mi	0.88	0.88	0.88	0.88	0.88
Minimal visibility	< 0.25 mi	0.90	0.90	0.90	0.90	0.90
Non-severe weather	All conditions not listed above	1.00	1.00	1.00	1.00	1.00

Source: Zegeer et al. (1).

Note: Speeds given in column heads are free-flow speeds.



Default SAFs by Weather Condition:

Weather Type	Weather Event Definition	Speed Adjustment Factors				
		55 mi/h	60 mi/h	65 mi/h	70 mi/h	75 mi/h
Medium rain	> 0.10-0.25 in/h	0.96	0.95	0.94	0.93	0.93
Heavy rain	> 0.25 in/h	0.94	0.93	0.93	0.92	0.91
Light snow	>0.00 – 0.05 in/h	0.94	0.92	0.89	0.87	0.84
Light-medium snow	>0.05 – 0.10 in/h	0.92	0.90	0.88	0.86	0.83
Medium-heavy snow	>0.10 – 0.50 in/h	0.90	0.88	0.86	0.84	0.82
Heavy snow	>0.50 in/h	0.88	0.86	0.85	0.83	0.81
Severe cold	<-4°F	0.95	0.95	0.94	0.93	0.92
Low visibility	0.50 – 0.99 mi	0.96	0.95	0.94	0.94	0.93
Very low visibility	0.25 – 0.49 mi	0.95	0.94	0.93	0.92	0.91
Minimal visibility	< 0.25 mi	0.95	0.94	0.93	0.92	0.91
Non-severe weather	All conditions not listed above	1.00	1.00	1.00	1.00	1.00

Source: Zegeer et al. (1).

Note: Speeds given in column heads are free-flow speeds.

**DEMAND**

The Demand page is used to display user inputs related to demand to specify demand ratios.

One of the required inputs is the *Freeway Area Type*. There are two freeway area types considered: *Urban Freeway* and *Rural Freeway*. The default in the program is *Urban Freeway*. Once selected, the defaults for *Default Freeway Demand Ratios* and *Demand Ratios Relative To Base Dataset* are displayed. Similar to the table on the Weather page, the fields in the *Default Freeway Demand Ratios* table can be edited if necessary. The ratios were derived from a national freeway dataset developed by SHRP 2 Project L03. All ratios reflect demand relative to a Monday in January. Where possible, analysts should obtain local or regional estimates of demand variability to account for facility-specific and seasonal trends on the subject facility.

Default Urban Freeway Demand Ratios (ADT/Mondays in January):

Month	Day of Week						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
January	1.00	1.00	1.02	1.05	1.17	1.01	0.89
February	1.03	1.03	1.05	1.08	1.21	1.04	0.92
March	1.12	1.12	1.14	1.18	1.31	1.13	0.99
April	1.19	1.19	1.21	1.25	1.39	1.20	1.05
May	1.18	1.18	1.21	1.24	1.39	1.20	1.05
June	1.24	1.24	1.27	1.31	1.46	1.26	1.10
July	1.38	1.38	1.41	1.45	1.62	1.39	1.22
August	1.26	1.26	1.28	1.32	1.47	1.27	1.12
September	1.29	1.29	1.32	1.36	1.52	1.31	1.15
October	1.21	1.21	1.24	1.27	1.42	1.22	1.07
November	1.21	1.21	1.24	1.27	1.42	1.22	1.07
December	1.19	1.19	1.21	1.25	1.40	1.20	1.06

Source: Derived from data presented by Cambridge Systematics et al. (2).

Note: Ratios represent demand relative to a Monday in January.

Default Rural Freeway Demand Ratios (ADT/Mondays in January):

Directional Lanes	No Incident	Shoulder Closed	1 Lane Closed	2 Lanes Closed	3 Lanes Closed	4 Lanes Closed
2	1.00	0.81	0.70	N/A	N/A	N/A
3	1.00	0.83	0.74	0.51	N/A	N/A
4	1.00	0.85	0.77	0.50	0.50	N/A
5	1.00	0.87	0.81	0.67	0.50	0.50
6	1.00	0.89	0.85	<u>0.75</u>	0.52	0.52
7	1.00	0.91	0.88	0.80	0.63	0.63
8	1.00	0.93	0.89	0.84	0.66	0.66

Source: Zegeer et al. (1).

Notes: N/A = not applicable — the number of lanes closed equals or exceeds the number of directional lanes. The methodology does not permit all directional lanes of a facility to be closed.

The *Demand Ratios Relative To Base Dataset* table displays the demand ratios relative to the base dataset. The values in the *Default Freeway Demand Ratios* table can be edited, if necessary, and the corresponding values in the *Demand Ratios Relative To Base Dataset* table will change based on the edited values.

## INCIDENT

The Incident page is used to display user inputs related to incident and crash frequency data, distribution and duration, and adjustment factors based on incident type.

Incidents are generated on the basis of their expected frequency of occurrence per study period (analysis hours in a day) in a given month on the facility. The analyst may opt to use default expected incident frequencies, may supply a facility-specific incident or crash rate, or may supply a 12-month table of facility-specific expected frequencies of any incident type.

The first table displayed on the Incident page is the incident distribution and duration. It provides mean distributions of freeway incidents by severity and default incident duration parameters by incident type.

Parameter	Incident Severity Type				
	Shoulder Closed	1 Lane Closed	2 Lanes Closed	3 Lanes Closed	4+ Lanes Closed
Distribution %	75.4%	19.6%	3.1%	1.9%	0%
Duration (Mean)	34	34.6	53.6	67.9	67.9
Duration (Std Dev)	15.1	13.8	13.9	21.9	21.9
Duration (Min)	8.7	16	30.5	36	36
Duration (Max)	58	58.2	66.9	93.3	93.3

Source: Zegeer et al. (1).

The second table displayed on the incident page can display either values for Demand Adjustment Factor (DAF), Capacity Adjustment Factor (CAF), or Speed Adjustment Factor (SAF) by clicking on the corresponding tabs. The defaults for DAF and SAF are 1.000 for all incident severities. The table below shows the default CAFs associated with each incident severity. The values shown in the table reflect the *remaining relative capacity per open lane*. For example, a two-lane closure incident on a six-lane directional facility (underscored) results in a loss of two full-lane capacities, in addition to maintaining only 75% of the remaining four open lanes' capacities. The result is that only three lanes worth (50%) of the facility's original six lane capacity is maintained. No information is currently available on the effect of incidents on free-flow speed, so this effect is not accounted for at this time.

Directional Lanes	No Incident	Shoulder Closed	1 Lane Closed	2 Lanes Closed	3 Lanes Closed	4 Lanes Closed
2	1.00	0.81	0.70	N/A	N/A	N/A
3	1.00	0.83	0.74	0.51	N/A	N/A
4	1.00	0.85	0.77	0.50	0.52	N/A
5	1.00	0.87	0.81	0.67	0.50	0.50
6	1.00	0.89	0.85	0.75	0.52	0.52
7	1.00	0.91	0.88	0.80	0.63	0.63
8	1.00	0.93	0.89	0.84	0.66	0.66

Source: Zegeer et al. (1).

Notes: N/A: not applicable, the number of lanes closed equals or exceeds the number of directional lanes. The methodology does not permit all directional lanes of a facility to be closed.

Incident Frequency Data is also provided, with three choices: Local Incident Frequency, Local Crash Frequency, and Calculated Crash Frequency. Choosing Local Incident Frequency will enable a table with fields for Incident Frequency (per 100 million VMT) that by month. Defaults are provided but can be edited if the user is aware of recurring incident occurrences. If, for example, incidents are more likely in winter months (despite potentially lower demands), the user should adjust the incident rate defaults and calibrate for local conditions. Choosing Local Crash Frequency will enable a table with defaults for Crash Frequency (per 100 million VMT) that vary by month. Similar to Local Incident Frequency, the values are editable for the user to calibrate for local conditions. In addition to this table, a field is provided for the user to specify the Incident-to-Crash Ratio (ICR). Choosing Calculated Crash Frequency will cause the Highway Economic Requirements System (HERS) model to be used to calculate crash rate. Fields for ICR, ACR, and Lane Width will also be provided for the user to specify.

## WORK ZONE

The Work Zone page is used to add scheduled work zones to the analysis. The user can add work zone events by clicking the 'Add Work Zone Event' button. If there are already work zone events present in a dataset, the user can add more by using either the 'Add Work Zone Event' button or the 'Insert Work Zone Event' button. When the 'Add Work Zone Event' button is used, a new work zone event will be added to the end of the list of work zone events. When the 'Insert Work Zone Event' button is used, a new work zone will be added before the work zone event that is currently selected in the list of work zone events. To delete work zone events, the user can select one or more work zone events and then click the 'Delete Work Zone Event' button.

When a work zone event is added, the following inputs are provided for the user to change: Segment ID, Start Date, End Date, Start Analysis Period, Duration Analysis Period, Lane Closure Type, Barrier Type, Area Type, Lateral Distance, Daylight or Night, Speed Limit, and Percent Drop in Capacity. Segment ID allows the user to specify which segment in the analysis is affected by a work zone. Start Date and End Date provides the date boundaries for when the work zone event takes place. Start Analysis Period provides a drop-down menu for the user to select between the analysis periods set from the base dataset. Duration Analysis Period specifies how many analysis periods the work zone event lasts. Based on the geometry of the facility being analyzed, Lane Closure Type can have up to five options: Shoulder Closed, 1 Lane Closed, 2 Lanes Closed, 3 Lanes Closed, and 4 Lanes Closed. Barrier Type has two options: Hard Barrier Separation and Soft Barrier Separation. Area Type also has two options: urban areas and rural areas. Urban areas are typified by high development densities or concentrations of population. Rural areas are areas with widely scattered development and low housing and employment densities. Lateral distance is specified in feet and is the distance from the edge of the travel lane adjacent to the work zone to the barrier, barricades, or cones. Daylight or Night is used to determine whether daytime or nighttime operations are considered. Speed Limit is used to specify the speed limit, in miles per hour, of the work zone. Higher work zone speed limits and higher speed ratios result in higher work zone FFS. Percent Drop in Capacity refers to the percentage drop in pre-breakdown capacity at the work zone due to queuing conditions. Research shows an average queue discharge drop of 7% in non-work zone conditions, and an average value of 13.4% in freeway work zones.

## SPECIAL EVENT

The Special Event page is used to add special events, such as football games or concerts, to the analysis. The user can add special events by clicking the 'Add Special Event' button. When the 'Add Special Event' button is used, a new special event will be added to the end of the list of special events. A textbox for 'Scenario ID for Special Event' is provided for the user to enter the appropriate scenario for the special event to be added. To delete special events, the user can select one or more special events and then click the 'Delete Special Event' button.

When a special event is added, a row of the following inputs/information are included: Scenario ID, Analysis Period, Demand Ratio, Weather Event Count, Incident Event Count, Work Zone Event Count, Import from XUF File, and Overwritten by Imported File.

## EVENTS

The Events page lays out the events found in each of the scenarios generated from the reliability analysis. There are three tabs to choose what is displayed on the page. These include: Summary, Incident, and Work Zone. The Summary tab displays the Scenario ID, Analysis Period, Demand Ratio, Weather Event Count, Incident Event Count, and Work Zone Event Count. The Incident tab displays the Event ID, Incident Event Type, Scenario ID, Segment ID, Start Analysis Period, and Duration (Analysis Periods). The Work Zone tab displays the Segment ID, Start Date, End Date, Lane Closure Type, and Assigned Scenarios. All three tabs allows the user to specify how many items are shown per page by providing a drop-down menu in the upper left-hand corner. The user can specify 10, 20, 50, or 100 items per page to be shown. Navigation buttons are provided below the tables to allow the user to easily jump between the first, previous, next, or last page of items. All three tabs also provide an 'Export to CSV' button in the upper right-hand corner. This will export the entire table of the corresponding tab to a CSV file.

## SUMMARY

The Summary page provides a summary of each of the scenarios generated by the reliability analysis. The Scenario ID, Demand-Combination, Travel Time in minutes, Average Speed in miles per hour, and Average Density in vehicle per mile per lane are provided for each scenario. Similar to the Events page, a drop-down menu is provided in the upper left-hand corner to allow the user to specify how many items to be displayed per page. Again, the choices for number of scenarios per page are 10, 20, 50, and 100. Navigation buttons are provided below the table to allow the user to easily jump between the first, previous, next, or last page of scenarios. There are also three export buttons provided above the table. These include: Export Summary Results to CSV, Export to XUF, and Export Facility to CSV. Clicking the 'Export Summary Results to CSV' button will allow the user to save the summary results displayed in the table to be saved in CSV format. 'Export to XUF' will allow the user to save all the scenarios generated in the Freeways XUF format. Clicking this button will open a dialog box allowing the user to browse folders or create a folder which will save a folder with all the scenarios generated. The folder holding all the scenarios will be titled the same as the Freeways Reliability XFR file and all the scenarios will be titled Scenario#, with # being the corresponding scenario number. 'Export Facility to CSV' will export the inputs of each scenario into corresponding CSV files.

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## Freeways Reliability Report

The Report page displays the results of the analysis in the form of tables and graphs. There are two reports available to the user: the formatted report and the text report. The formatted report is initially displayed, but the user can switch to the text report by clicking the *Switch to Text Report* button located at the bottom of the screen. Similarly, if the user has the text report displayed, the *Switch to Formatted Report* button located at the bottom of the screen can be used to display the formatted report instead.

The report page shows a formatted version of the analysis in a dynamic form, reacting to changes in the Base, Analysis, Weather, Demand, Incident, and Work Zone pages. All or a portion can be copied to the Windows clipboard for insertion into other files by right-clicking into the report and selecting Copy.

The formatted report provides an overview of the results in the table. There are five sections in the table: Project Information, Base Dataset Analysis, Reliability Input Summary, Average Performance Measure Results, and graphs for TTI (TTI Probability Density Distribution and TTI Cumulative Distribution). Project Information provides information on the Analyst, Agency Jurisdiction, Date, Analysis Year, Time Analyzed, and Project Description. Base Dataset Analysis provides general information that can be found in the base dataset. These include: the base dataset file name, the data collection date, the start and end times of the study period, the number of analysis periods, and the number of segments. Reliability Input Summary provides general information on the reliability analysis and the random seed summary. These include: Reporting Start Date, Reporting End Date, Reliability Reporting Period Duration in months, Number of Days Considered, Number of Replications, Number of Scenarios, what is included in the Reliability analysis (Weather Events, Incident Events, Demand Ratios, and Work Zone Events) and the random seed numbers for Weather and Incident. Average Performance Measure Results include: Average Speed in miles per hour, Average Density in passenger cars per mile per lane, Average Travel Time in minutes, 50<sup>th</sup> Percentile Travel Time Index (TTI<sub>50</sub>), Mean Travel Time Index (TTI<sub>mean</sub>), maximum observed facility TTI (TTI<sub>max</sub>), Misery Index, Reliability Rating as a percentage, semi-standard deviation, and Percent VMT at TTI >2. The four graphs at the bottom of the report show the TTI Probability Distribution Function, TTI Cumulative Distribution Function, Density Distribution, and Speed Distribution.

The text report also provides the general project information and base dataset information but provides more Average Performance Results. These include: Average Speed in miles per hour, Average Density in both vehicles per mile per lane and passenger cars per mile per lane, Average Travel Time in minutes, Mean Travel Time Index (TTI<sub>mean</sub>), 50<sup>th</sup> Percentile Travel Time Index (TTI<sub>50</sub>), 80<sup>th</sup> Percentile Travel Time Index (TTI<sub>80</sub>), Planning Time Index (PTI) or 95<sup>th</sup> Percentile Travel Time Index (TTI<sub>95</sub>), Maximum Observed Facility TTI (TTI<sub>max</sub>), Misery Index, Semi-Standard Deviation, Reliability Rating as a percentage, and Percent VMT at TTI >2.

Both formatted and text reports are available for viewing and printing.

# How To

## Create a New File

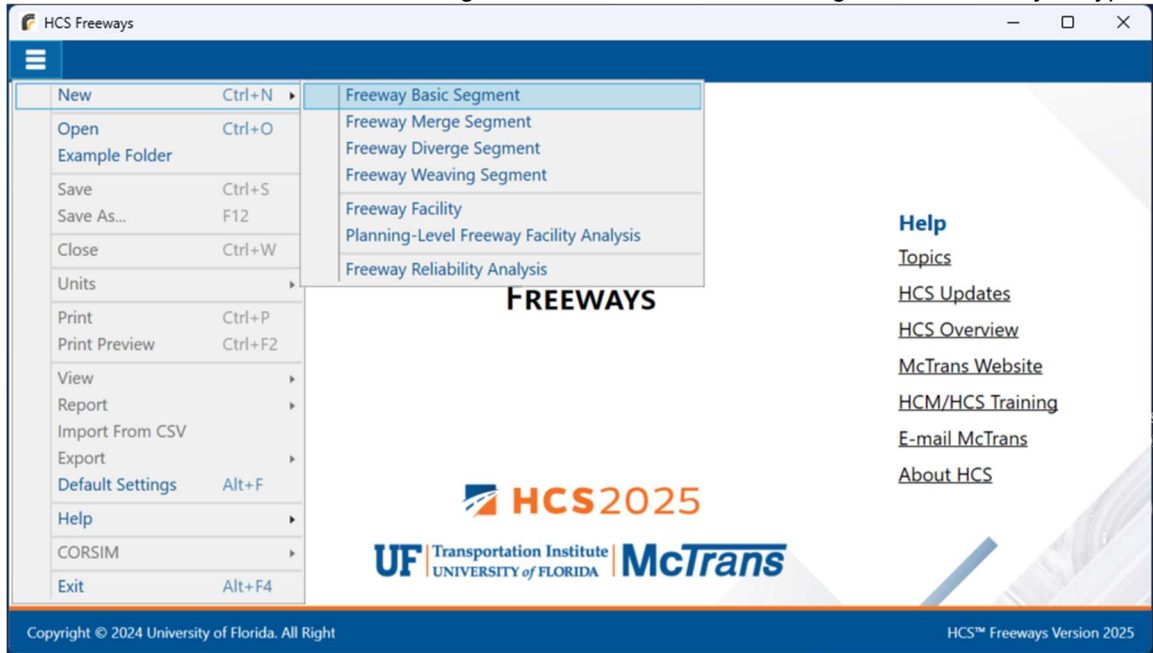
1. From the Start screen, there are three options for creating a new file:



*Note: A new file can be created if an existing file is already open; you do not need to start from the Start screen.*



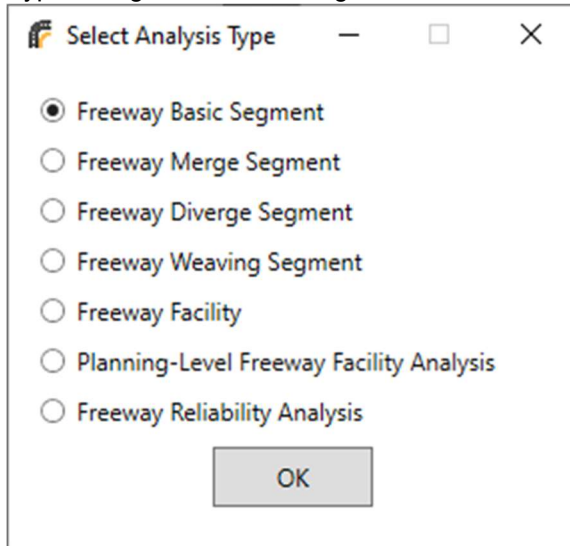
- a. Selecting *File > New* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen, hovering over “New”, and then selecting one of the analysis types.



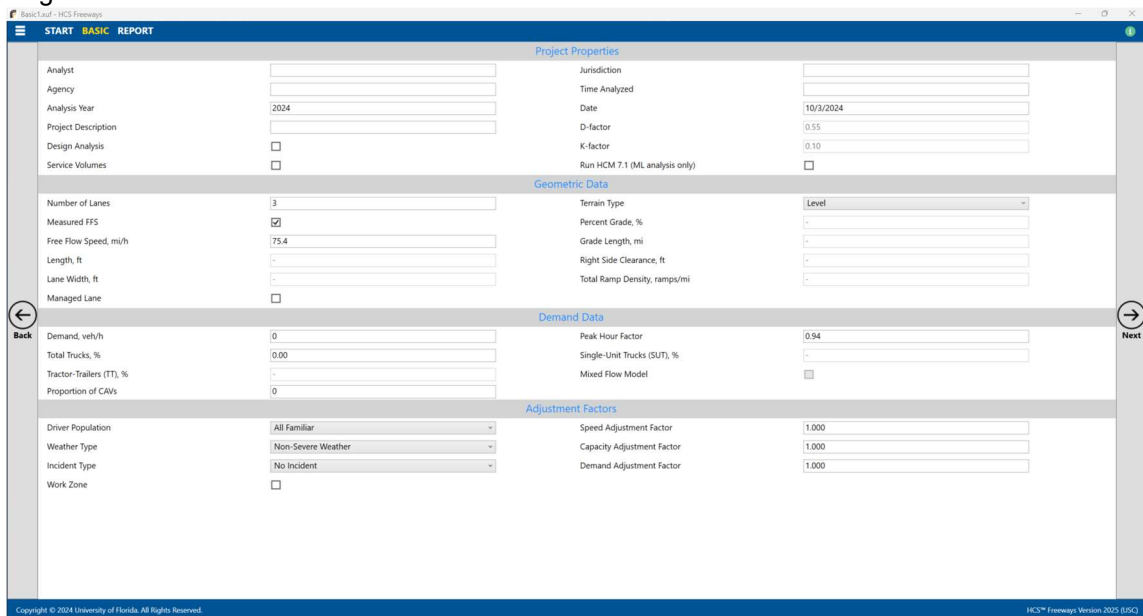
- b. Selecting “New File...” from the Start screen; this can be found below in the red box. A Select New File Type dialog box will pop up after selecting “New File...” which allows you to choose the desired analysis type.



- c. Using the keyboard shortcut “Ctrl+N”, selecting one of the analysis types from the Select New File Type dialog box, and clicking “OK”



2. Once a new file is created, you will be brought to the input page of the selected analysis type if in Page View or the input screen split with the report on either the right or the bottom of the screen if in Full View.
  - a. Page View



- i. If Freeway Basic Segment was selected, you will be brought to the Basic page.
- ii. If Freeway Merge Segment was selected, you will be brought to the Merge page.
- iii. If Freeway Diverge Segment was selected, you will be brought to the Diverge page.
- iv. If Freeway Weaving Segment was selected, you will be brought to the Weaving page.
- v. If Freeway Facility was selected, you will be brought to the General page.
- vi. If Planning-Level Freeway Facility Analysis was selected, you will be brought to the Facility page.
- vii. If Freeway Reliability Analysis was selected, you will be brought to the Base page.



b. Full View

The screenshot displays the 'Full View' of the HCS Freeways software. The interface is split into two main panels. The left panel contains input fields for project information, geometric data, demand data, and adjustment factors. The right panel displays a detailed 'HCS Basic Freeway Report' with various data points and tables.

**Project Properties**

Analyst		Jurisdiction	
Agency		Time Analyzed	
Analysis Year	2024	Date	10/3/2024
Project Description		D-factor	0.55
Design Analysis	<input type="checkbox"/>	K-factor	0.10
Service Volumes	<input type="checkbox"/>	Run HCM 7.1 (ML analysis only)	<input type="checkbox"/>

**Geometric Data**

Number of Lanes	3	Terrain Type	Level
Measured FFS	<input checked="" type="checkbox"/>	Percent Grade, %	-
Free Flow Speed, mi/h	75.4	Grade Length, mi	-
Length, ft	-	Right Side Clearance, ft	-
Lane Width, ft	-	Total Ramp Density, ramps/mi	-
Managed Lane	<input type="checkbox"/>		

**Demand Data**

Demand, veh/h	0	Peak Hour Factor	0.94
Total Trucks, %	0.00	Single-Unit Trucks (SUT), %	-
Tractor-Trailers (TT), %	-	Mixed Flow Model	<input type="checkbox"/>
Proportion of CAVs	0		

**Adjustment Factors**

Driver Population	All Familiar	Speed Adjustment Factor	1.000
Weather Type	Non-Severe Weather	Capacity Adjustment Factor	1.000
Incident Type	No Incident	Demand Adjustment Factor	1.000
Work Zone	<input type="checkbox"/>		

**HCS Basic Freeway Report**

Project Information		
Analyst		Date: 10/3/2024
Agency		Analysis Year: 2024
Jurisdiction		Time Analyzed
Project Description		Units: U.S. Customary
Geometric Data		
Number of Lanes (N), In	3	Terrain Type
Segment Length (L), ft	-	Level
Measured or Base Free-Flow Speed	Measured	Percent Grade, %
Base Free-Flow Speed (BFFS), mi/h	-	Grade Length, mi
Lane Width, ft	-	Total Ramp Density (TRD), ramps/mi
-	-	Free-Flow Speed (FFS), mi/h
-	-	75.4
Right-Side Lateral Clearance, ft	-	
Adjustment Factors		
Driver Population	All Familiar	Final Speed Adjustment Factor (SAF)
Weather Type	Non-Severe Weather	Demand Adjustment Factor (DMF)
Incident Type	No Incident	Final Capacity Adjustment Factor (CAF)
Proportion of CAVs in Traffic Stream	0	Capacity Adj. Factor for CAVs (CAF <sub>CAV</sub> )
1.000		1.000
Demand and Capacity		
Demand Volume (V), veh/h	0	Heavy Vehicle Adjustment Factor (Hv)
Peak Hour Factor (PHF)	0.94	Flow Rate (q), pc/h/ln
Total Trucks, %	0.00	Capacity (c), pc/h/ln
Single-Unit Trucks (SUT), %	-	Initial Adjusted Capacity (c <sub>adj</sub> ), pc/h/ln
Tractor-Trailers (TT), %	-	Final Adjusted Capacity (c <sub>adj</sub> ), pc/h/ln
Passenger Car Equivalent (ET)	2.00	Volume-to-Capacity Ratio (v/c)
0.000		0.000
Speed and Density		
Lane Width Adjustment (Lw)	-	Average Speed (S), mi/h
Right-Side Lateral Clearance Adj. (RLC)	-	Density (D), pc/mi/ln
Total Ramp Density Adjustment	-	Level of Service (LOS)
Adjusted Free-Flow Speed (FFS <sub>adj</sub> ), mi/h	75.4	A
Highway Safety Manual - Predicted Crashes		
	Single-vehicle crashes	Multi-vehicle crashes
Fatal and Injury - FI, crashes/year	0.000	0.000
Property Dmg Only - PDO, crashes/year	0.000	0.000
Total crashes/year	0.000	0.000

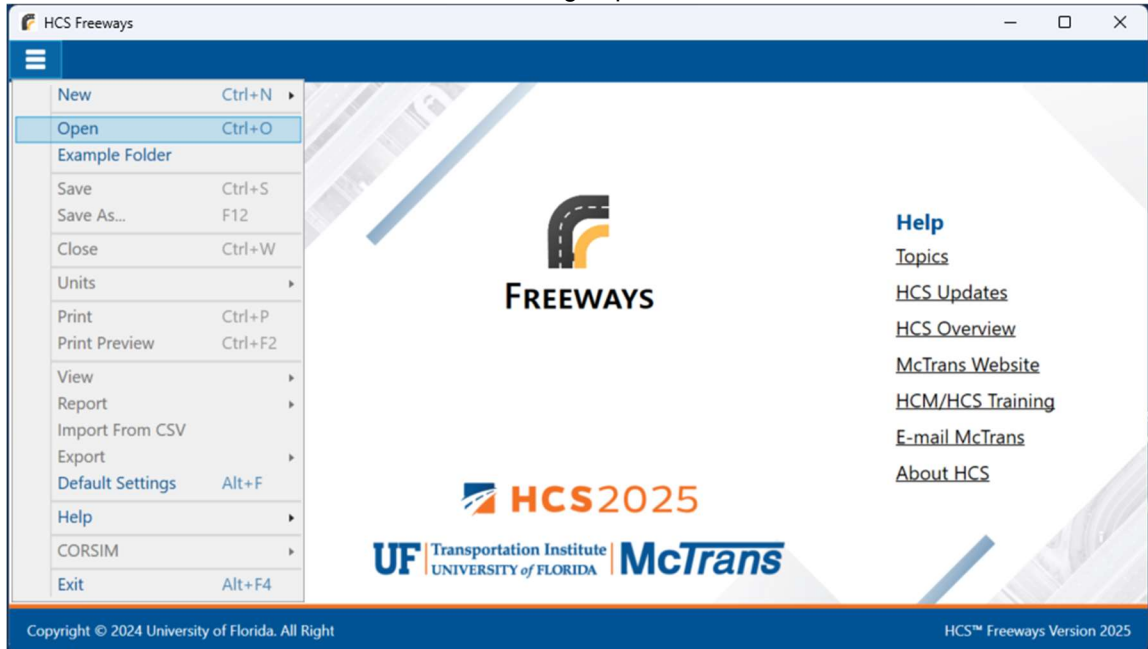
# Open an Existing File

1. From the Start screen, there are six options for opening an existing file:

The screenshot shows the 'Start' screen of the HCS Freeways software. The interface features a central logo for 'FREWAYS' and 'HCS2025' with the 'UF Transportation Institute' and 'McTrans' logos below it. On the left side, there are six options for opening an existing file: 'New File...', 'Open File...', 'Example Folder...', and 'Recent'. On the right side, there is a 'Help' section with links to 'Topics', 'HCS Updates', 'HCS Overview', 'McTrans Website', 'HCM/HCS Training', 'E-mail McTrans', and 'About HCS'. The bottom of the screen displays the copyright information: 'Copyright © 2024 University of Florida. All Right' and 'HCS™ Freeways Version 2025'.

*Note: A file can be opened even if another file is currently open; you do not need to start from the Start screen.*

- a. Selecting *File > Open* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting “Open”



- b. Selecting “Open File...” from the Start screen; this can be found below in the red box

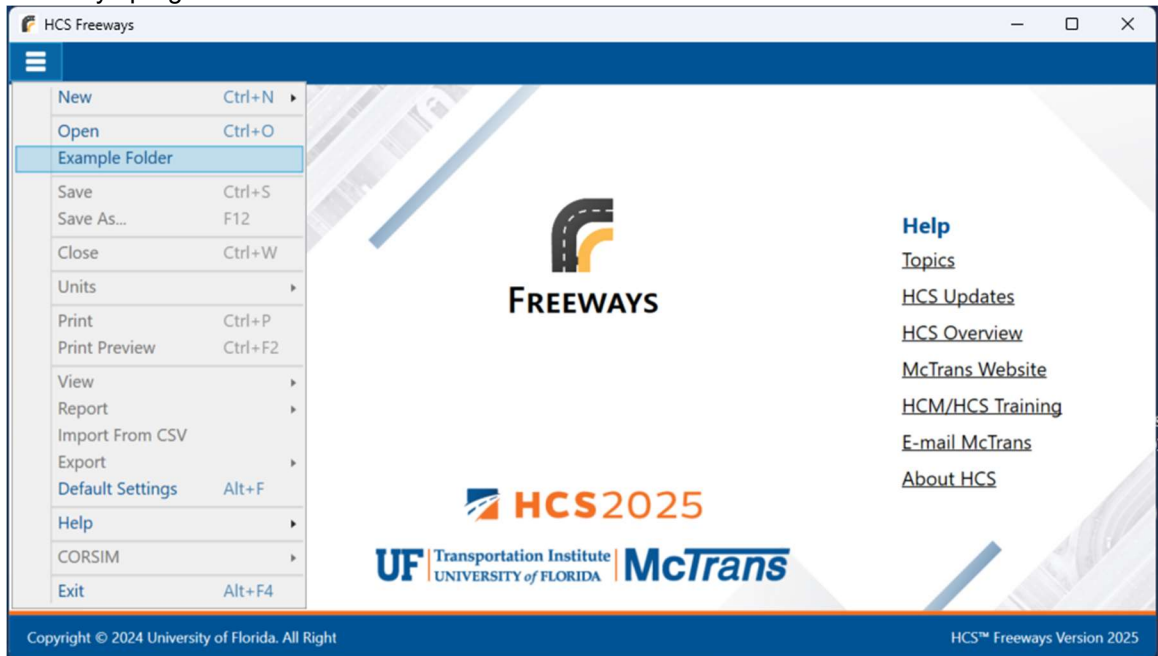


- c. Using the keyboard shortcut “Ctrl+O”

- d. Selecting a file under the Recent files list from the Start screen; this can be found below in the red box



- e. Selecting *File > Example Folder* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting “Example Folder”. Opening the example folder will open the path of the HCS example files in File Explorer. The desired example file can be double-clicked or right-clicked and selecting ‘Open’, which will open the example file in the Freeways program.

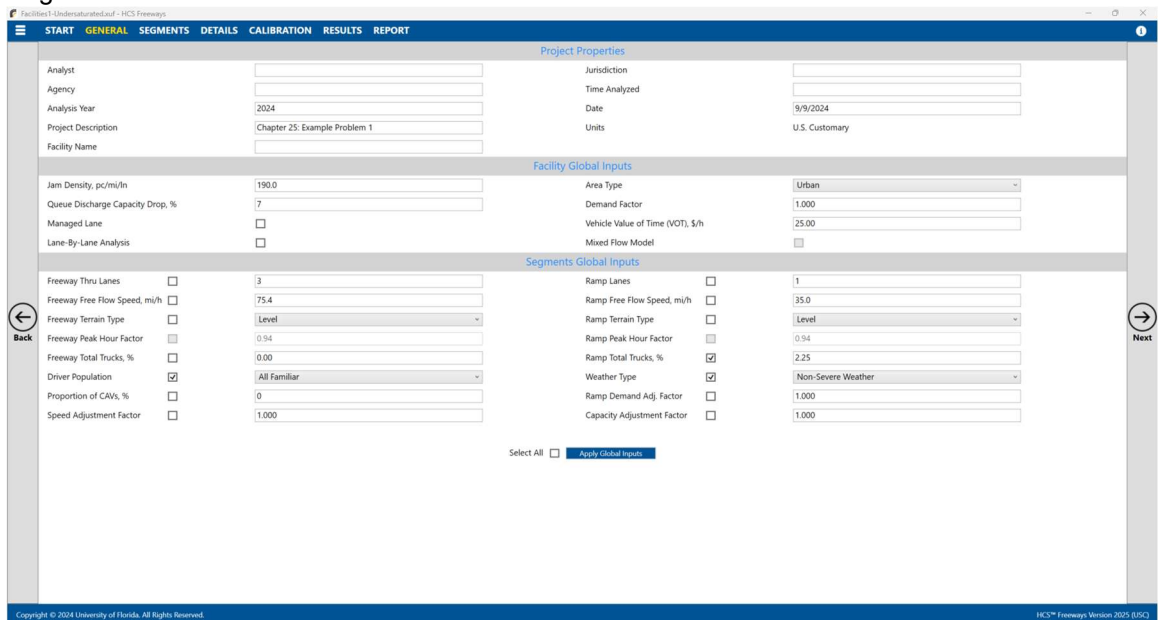


- f. Selecting “Example Folder...” from the Start screen; this can be found below in the red box. Opening the example folder will open the path of the HCS example files in File Explorer. The desired example file can be double-clicked or right-clicked and selecting ‘Open’, which will open the example file in the Freeways program.



2. Once an existing file is opened, you will be brought to the corresponding input page if in Page View or the input screen split with the report either on the right or the bottom of the screen if in Full View

a. Page View



b. Full View

The screenshot displays the 'HCS Freeway Facilities Report' software interface. The left pane shows configuration options for Project Properties, Facility Global Inputs, Segments Global Inputs, and Segments Input. The right pane displays a detailed report table.

**Project Properties:**

- Analyst: [ ]
- Agency: [ ]
- Analysis Year: 2024
- Project Description: Chapter 25: Example Problem 1
- Facility Name: [ ]
- Jurisdiction: [ ]
- Time Analyzed: [ ]
- Date: 9/9/2024
- Units: U.S. Customary

**Facility Global Inputs:**

- Jam Density, pc/mi/ln: 190.0
- Queue Discharge Capacity Drop, %: 7
- Managed Lane:
- Lane-By-Lane Analysis:
- Area Type: [ ]
- Demand Factor: 1,000
- Vehicle Value of Time (VOT), \$/h: 25.00
- Mixed Flow Model:

**Segments Global Inputs:**

- Freeway Thru Lanes:  3
- Freeway Free Flow Speed, mi/h:  75.4
- Freeway Terrain Type:  Level
- Freeway Peak Hour Factor:  0.94
- Freeway Total Trucks, %:  0.00
- Driver Population:  All Familiar
- Proportion of CAVs, %:  0
- Speed Adjustment Factor:  1,000
- Ramp Lanes:  1
- Ramp Free Flow Speed, mi/h:  35.0
- Ramp Terrain Type:  Level
- Ramp Peak Hour Factor:  0.94
- Ramp Total Trucks, %:  2.25
- Weather Type:  Non-Severe Weather
- Ramp Demand Adj. Factor:  1,000
- Capacity Adjustment Factor:  1,000

**Segments Input:**

Analysis Period: 1 | Start Time: 07:00

Type	Name	Length, ft	Lanes	Demand Volume, veh/h	Ramp Demand, veh/h	Segment Analysis Details
1	Basic	5280	3	4505	450	Details
2	Merge	1500	3	4505	450	Details
3	Basic	2280	3	4505	450	Details

**HCS Freeway Facilities Report Table:**

No.	Code	Analyzed	Name	Length, ft	Lanes
1	Basic	Basic	Basic	5280	3
2	Merge	Merge	Merge	1500	3
3	Basic	Basic	Basic	2280	3
4	Diverge	Diverge	Diverge	1500	3
5	Basic	Basic	Basic	5280	3
6	Weaving	Weaving	Weaving	2640	4
7	Basic	Basic	Basic	5280	3
8	Merge	Merge	Merge	1140	3
9	Overlap	Overlap	Overlap	360	3
10	Diverge	Diverge	Diverge	1140	3
11	Basic	Basic	Basic	5280	3

**Segment 1: Basic Table:**

AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	1.00	0.978	4066	6900	0.67	60.0	25.6	C
2	1.00	0.978	5066	6900	0.73	59.9	28.2	D
3	1.00	0.978	5343	6900	0.77	59.4	30.0	D
4	1.00	0.978	4790	6900	0.69	60.0	26.6	D
5	1.00	0.978	3870	6900	0.56	60.0	21.5	C

**Segment 2: Merge Table:**

AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	1.00	0.978	4066	6900	0.67	60.0	25.6	C
2	1.00	0.978	5066	6900	0.73	59.9	28.2	D
3	1.00	0.978	5343	6900	0.77	59.4	30.0	D
4	1.00	0.978	4790	6900	0.69	60.0	26.6	D
5	1.00	0.978	3870	6900	0.56	60.0	21.5	C

# Save a File

1. There are five options for saving an open file:

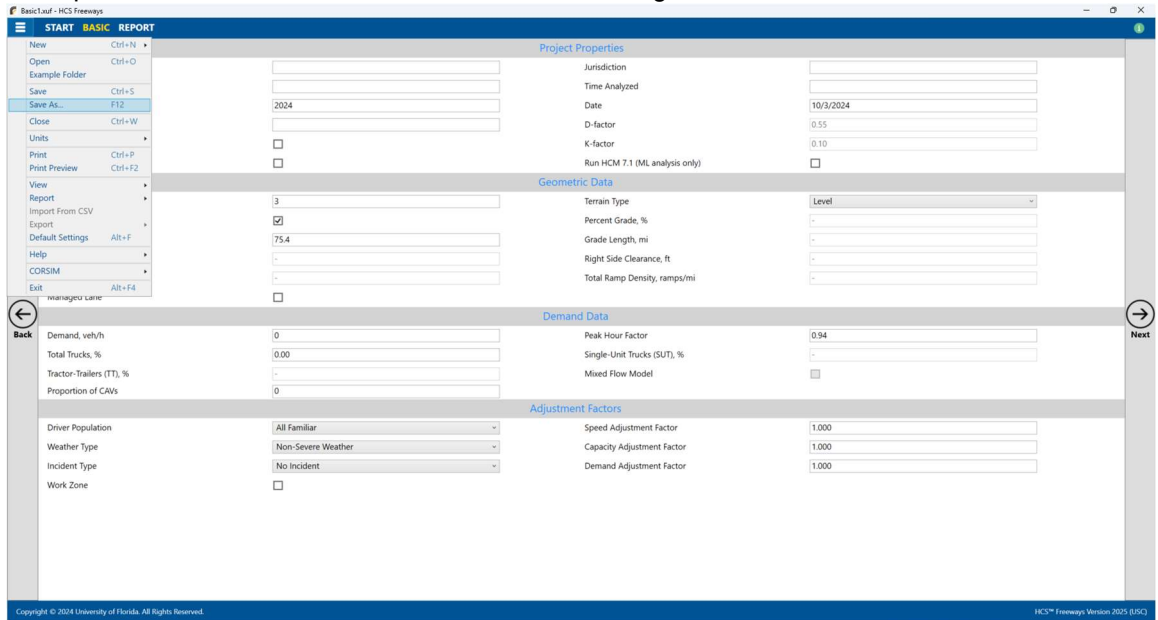
a. Selecting *File* > *Save* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting "Save"

The screenshot shows the 'HCS Freeway Facilities Report' software interface with the 'File' menu open. The menu options are:

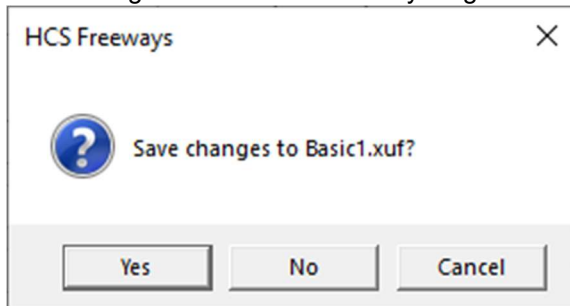
- New (Ctrl+N)
- Open (Ctrl+O)
- Example Folder
- Save (Ctrl+S)
- Save As... (F12)
- Close (Ctrl+W)
- Units
- Print (Ctrl+P)
- Print Preview (Ctrl+F2)
- View
- Report
- Report From CSV
- Export
- Default Settings (Alt+F)
- Help
- CORSIM
- Exit (Alt+F4)

The background shows the 'Project Properties' and 'Geometric Data' sections of the software interface.

- b. Selecting *File > Save As...* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting “Save As...”



- c. Using the keyboard shortcut “Ctrl+S” for Save  
 d. Using the keyboard shortcut “F12” for Save As  
 e. Exiting the program or closing the file without saving changes beforehand; this will prompt you to save changes to the file before anything is closed

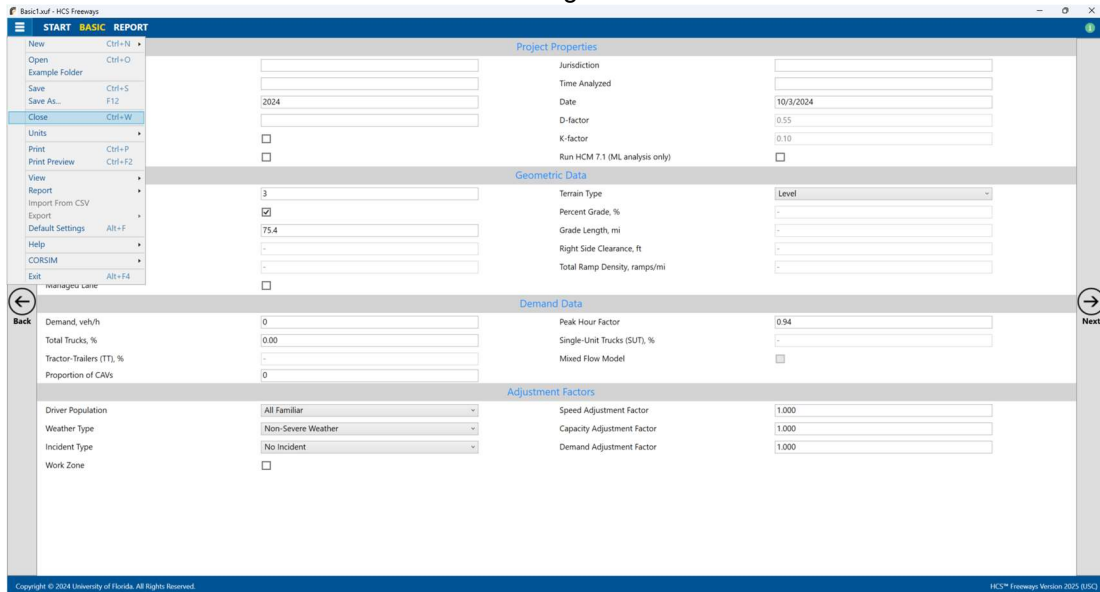


- i. Selecting “Yes” will save the file if it is an existing file. If the file has not been previously saved, the Save As dialog box will pop up allowing you to change the file name and save it.  
 ii. Selecting “No” will exit the program or close the file without saving the file  
 iii. Selecting “Cancel” will not save the file and prevent the file from closing

*Note: Using Save with an existing file will save a file without prompting you to specify a file name. Using Save with a new file will bring up the Save As dialog box for you to specify a file name for saving. Using Save As will always bring up the Save As dialog box for you to specify a file name for saving.*

## Close a File

1. There are three options for closing an open file:
  - a. Selecting *File > Close* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting “Close”



- b. Using the keyboard shortcut “Ctrl+W”
- c. Exiting the program itself; please see *How To: Exit the Program*

## Exit the Program

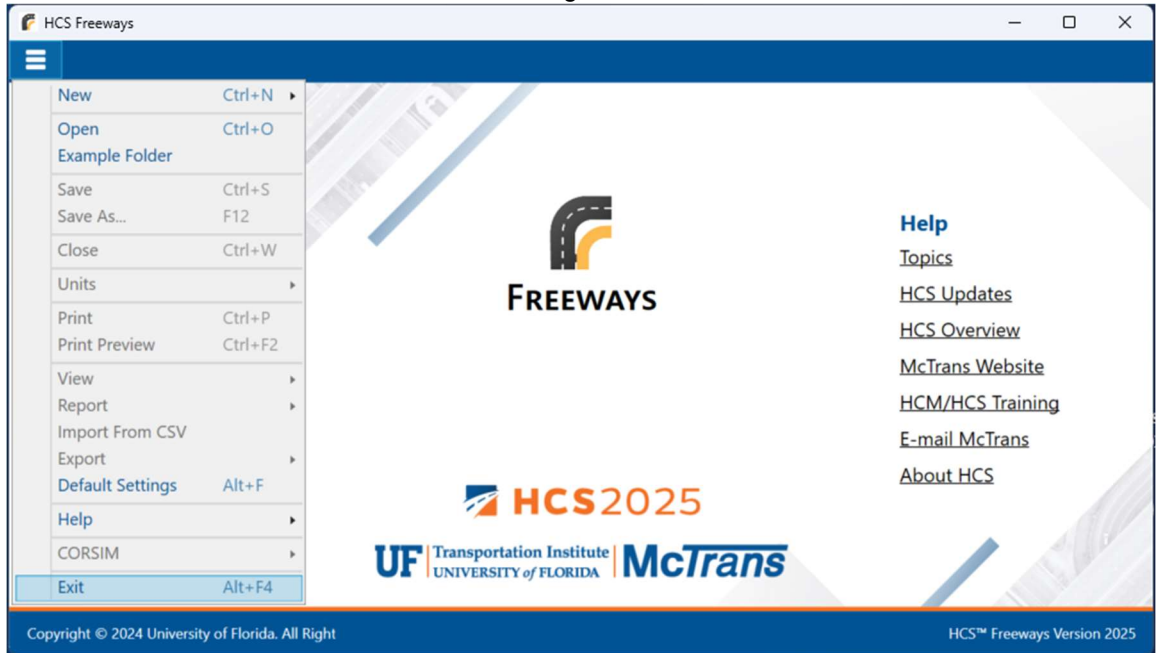
1. From the Start screen, there are three options for exiting the program:



*Note: The program can be exited even if a file is still open; you do not need to start from the Start screen.*



- a. Selecting *File > Exit* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting “Exit”



- b. Using the keyboard shortcut “Alt+F4”
- c. Selecting “X” in the top right-hand corner of the screen; this can be found below in the red box.





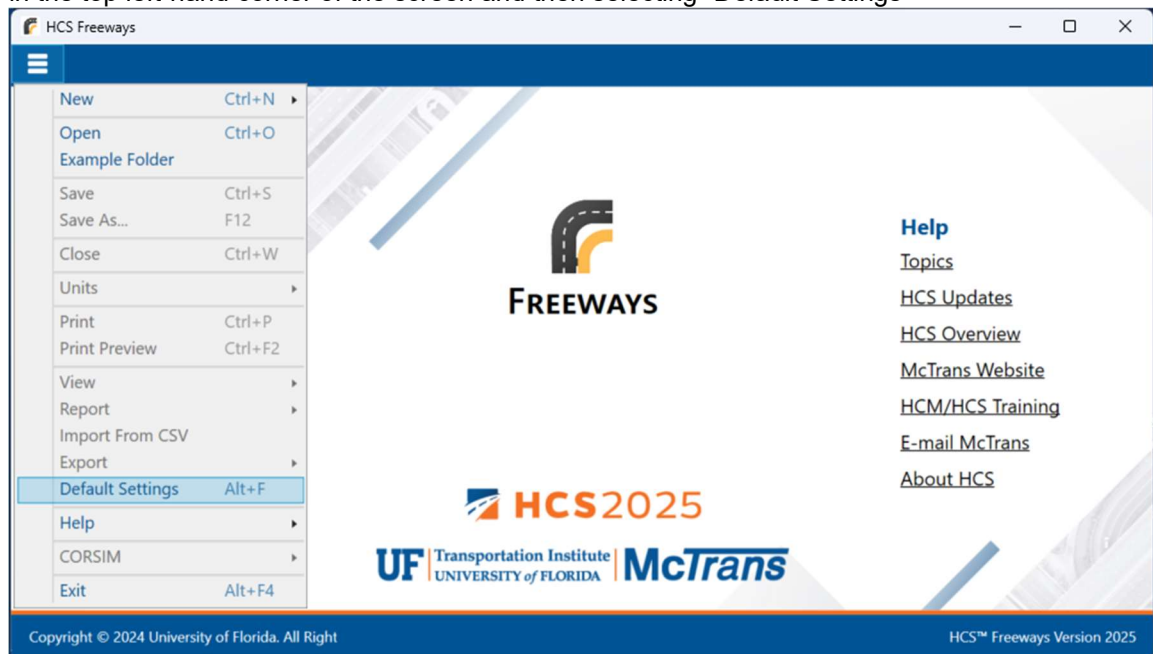
# Edit the Default Settings

1. From the Start screen, there are two options for editing the Default Settings:



*Note: The Default Settings can be changed even if an existing file is already open; you do not need to start from the Start screen.*

- a. Selecting *File > Default Settings* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting "Default Settings"



- b. Using the keyboard shortcut "Alt+F4"

2. Opening the Default Settings will cause a Default Settings window to pop up:

**Default Settings** [X]

Analyst

Agency

Jurisdiction

New File Default Units

USC  Metric

Export to CSV

Export Output

Descending Order (not allowed to be imported)

Export Oversaturated Results (if available)

Reports

Show Messages in Facility Formatted Report

Show Charts in Facility Formatted Report

Show Graphs in Facility Formatted Report

Safety Analysis

Show Safety Analysis Results in Reports

K-Factor:

D-Factor:

**OK** **Cancel**

3. Settings

- a. You can specify Analyst, Agency, and Jurisdiction by clicking in the corresponding text boxes and typing the desired text.
- b. Under 'Units', you are given the option of running the analysis in either *U.S. Customary (USC)* or *SI (Metric)* units.
- c. Under 'Export to CSV', three checkboxes are provided to indicate what to include when exporting to CSV.

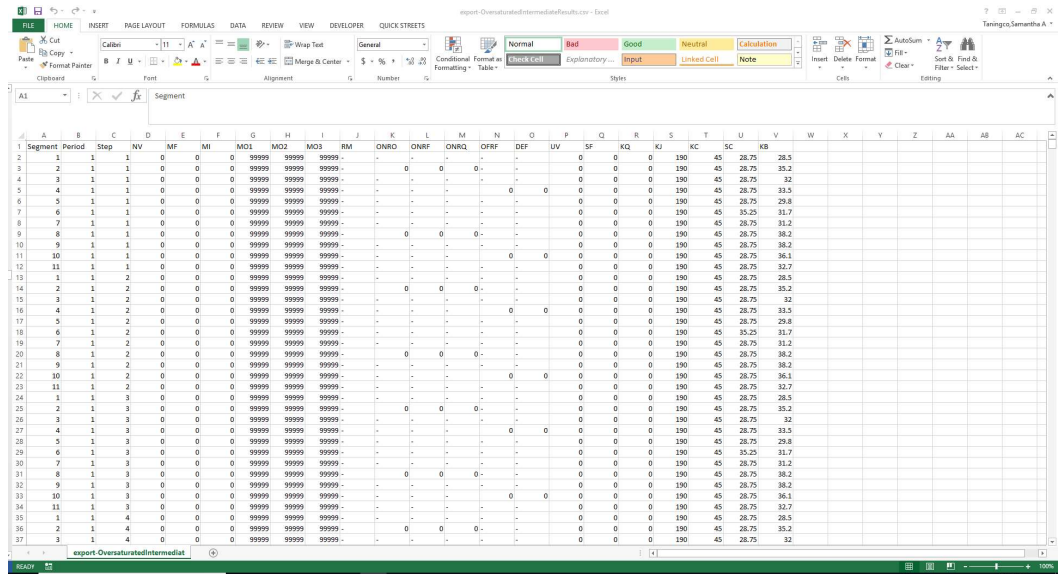
- i. Export Output: If this is checked, the output results will be exported along with the input.

Segment Number [GB01]	Seg-1	Seg-2	Seg-3	Seg-4	Seg-5	Seg-6	Seg-7	Seg-8	Seg-9	Seg-10	Seg-11
395 Volume (pc/h) [TBO1]	5113	5624	5624	5624	5317	5900	5511	6032	6033	6033	5726
396 TP2	5624	6236	6236	6236	5828	6645	6236	6848	6850	6850	6543
399 TP3	3930	6645	6645	6645	3927	6402	3710	6425	6425	6425	3991
400 TP4	5317	5726	5726	5726	5672	6178	5906	6417	6417	6417	5983
401 TP5	4296	4500	4500	4500	4259	4913	5027	5324	5324	5324	5049
402 Speed (mi/h) [TBO2]	59.8	58.2	58.6	58.9	58.5	48.7	59	52.6	52.6	52.6	58.3
404 TP2	58.6	52.1	55.8	55.5	57.9	45.4	55.8	50.5	50.5	50.5	53.9
405 TP3	57.4	51.1	53.1	53.4	57.4	24.1	28.5	31.6	31.6	31.6	57.1
406 TP4	59.5	53.1	58.3	55.8	57.7	20.6	26.3	31.7	31.7	31.7	57.2
407 TP5	60	54.4	59.7	58.2	60	50.4	59.9	53.6	53.6	53.6	59.9
408 Density (pc/mi/h) [TBO3]	28.5	35.2	32	35.3	28.8	31.7	31.2	38.2	38.2	38.2	32.7
409 TP1	32	39.9	37.3	37.5	33.6	36.6	37.3	45.2	45.2	45.2	40.5
411 TP3	34.4	43.3	41.7	40	34.4	66.4	66.7	41.5	41.5	41.5	35
412 TP4	29.8	35.9	32.7	34.2	33.9	77.4	65	41.4	41.4	41.4	34.9
413 TP5	23.9	27.6	25	26.7	23.7	24.6	27.9	33.1	33.1	33.1	28.1
414 LOS [TBO4]											
415 TP1	D	D	D	D	D	D	D	E	D	D	D
416 TP2	D	D	E	D	D	E	E	F	F	F	F
417 TP3	D	D	E	D	D	F	F	F	F	F	F
418 TP4	D	D	D	D	D	F	D	D	E	D	D
419 TP5	C	C	C	C	C	C	D	C	D	D	D
420 b/C [TBO5]											
421 TP1	0.74	0.82	0.82	0.82	0.77	0.7	0.8	0.87	0.87	0.87	0.83
422 TP2	0.82	0.9	0.9	0.9	0.84	0.78	0.9	0.99	0.99	0.99	0.85
423 TP3	0.86	0.96	0.96	0.96	0.92	0.85	0.99	1.1	1.1	1.1	1.02
424 TP4	0.77	0.83	0.83	0.83	0.79	0.68	0.79	0.86	0.86	0.86	0.82
425 TP5	0.62	0.65	0.65	0.65	0.61	0.52	0.62	0.67	0.67	0.67	0.64
426 Density (veh/mi/h) [TBO6]											
427 TP1	37.9	34.4	31.3	32.8	29.1	31	30.5	37.4	37.4	35.3	32
428 TP2	31.3	39	36.5	36.7	32.9	35.8	36.5	44.2	44.2	44.2	39.6
429 TP3	33.7	42.3	40.8	39.1	33.7	64.9	65.2	40.6	40.6	40.6	34.2
430 TP4	29.1	35.1	32	33.4	33.2	75.7	63.6	40.5	40.5	37.7	34.1

- ii. Descending Order (not allowed to be imported): If this is checked, segments will be exported in descending order instead of ascending order (i.e., an analysis with 11 segments will show the segment data starting from segment number 11 and ending with segment data for segment number 1). *Note: If the exported CSV file is later used for import, the Freeways program will not allow it to be imported. The CSV file must have data in ascending order for it to be imported.*

1	Version	7.8.3																		
2	Number of Segments [F1]	11	Descending Order																	
3	Number of Time Periods [F2]	5																		
4	Run Mixed Flow [F3]	No																		
5	Managed Lane [F4]	No																		
6	Jam Density [F5]	190																		
7	Queue Discharge Capacity [F6]	7																		
8	Density at Capacity [F7]	45																		
9	Area Type [F8]	Urban Area																		
10	Demand Factor [F9]	1																		
11	Start Time [F10]	7:00																		
12	Analyst [F11]																			
13	Jurisdiction [F12]																			
14	Agency [F13]																			
15	Time Period Analyzed [F14]																			
16	Analysis Year [F15]	2017																		
17	Date [F16]	4/17/2017																		
18	Segment Number [GB1]	Seg-11	Seg-10	Seg-9	Seg-8	Seg-7	Seg-6	Seg-5	Seg-4	Seg-3	Seg-2	Seg-1								
19	Segment Name [GB14]																			
20	Segment Type [GB2]	Basic	Diverge	Overlap	Merge	Basic	Weaving	Basic	Diverge	Basic	Merge	Basic								
21	Lanes [GB1]	3	3	3	3	3	4	3	3	3	3	3								
22	Measured FFS [GB4]	Measured	Measured	Measured	Measured	Measured	Measured	Measured	Measured	Measured	Measured	Measured								
23	FFS (mi/h) [GB5]	60	60	60	60	60	60	60	60	60	60	60								
24	Length [GB6]	5280	1140	300	1140	5280	2640	5280	1500	2280	1500	5280								
25	Terrain Type [GB7]	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level								
26	Grade [GB8]	-	-	-	-	-	-	-	-	-	-	-								
27	Grade Length [GB9]	-	-	-	-	-	-	-	-	-	-	-								
28	Right Side Clearance (ft) [GB10]	-	-	-	-	-	-	-	-	-	-	-								
29	Lane Width (ft) [GB11]	-	-	-	-	-	-	-	-	-	-	-								
30	Total Ramp Density (trucks/mi) [GB12]	-	-	-	-	-	-	-	-	-	-	-								
31	Managed Lane Type [GB13]	-	-	-	-	-	-	-	-	-	-	-								
32	Number of Managed Lanes [GB14]	-	-	-	-	-	-	-	-	-	-	-								
33	Managed Lane FFS (mi/h) [GB15]	-	-	-	-	-	-	-	-	-	-	-								
34	Managed Lane Terrain Type [GB16]	-	-	-	-	-	-	-	-	-	-	-								
35	Managed Lane Grade (%) [GB17]	-	-	-	-	-	-	-	-	-	-	-								
36	Managed Lane Grade Length (mi/h) [GB18]	-	-	-	-	-	-	-	-	-	-	-								
37	Ramp Lanes [GB19]	-	1	-	-	1	-	-	-	-	-	1								

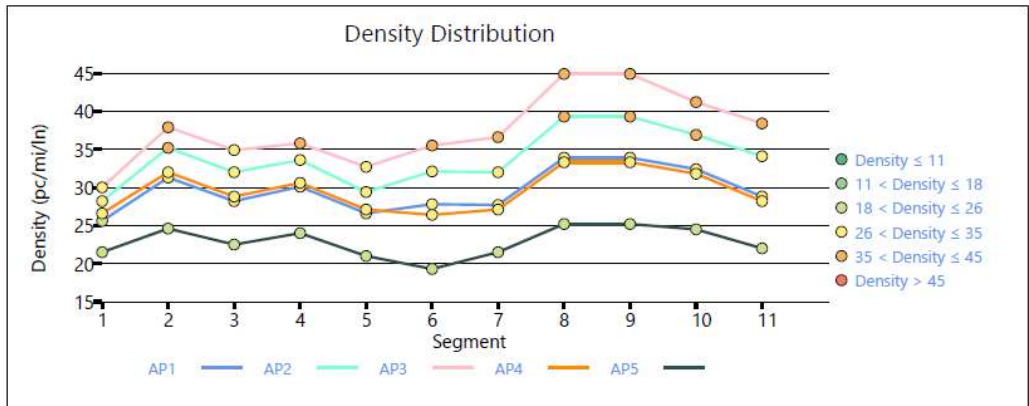
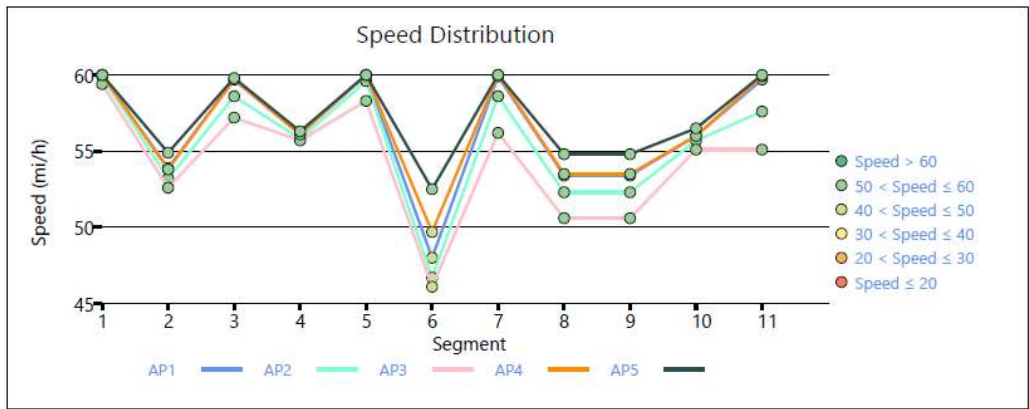
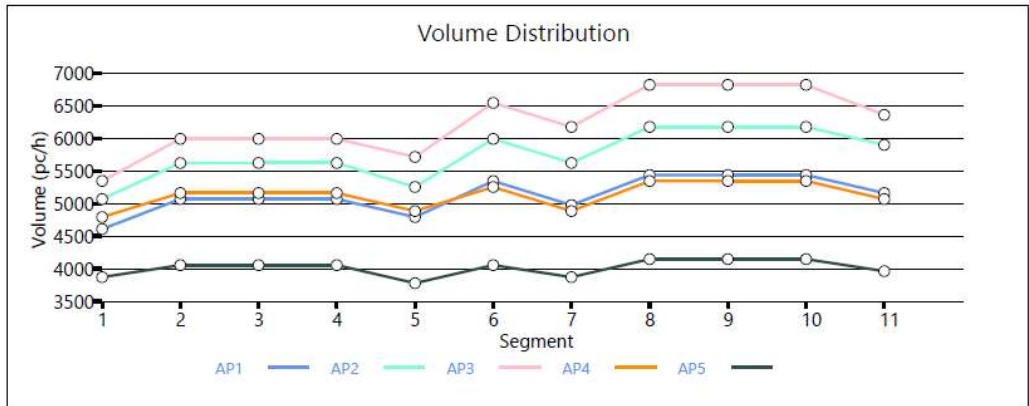
- iii. Export Oversaturated Results (if available): If this is checked, oversaturated results will be exported along with the input if the analysis uses the oversaturated procedure. The exported oversaturated results will be exported in a separate CSV file from the exported inputs CSV file. The default name for the exported oversaturated results file is 'export-OversaturatedIntermediateResults.csv'.



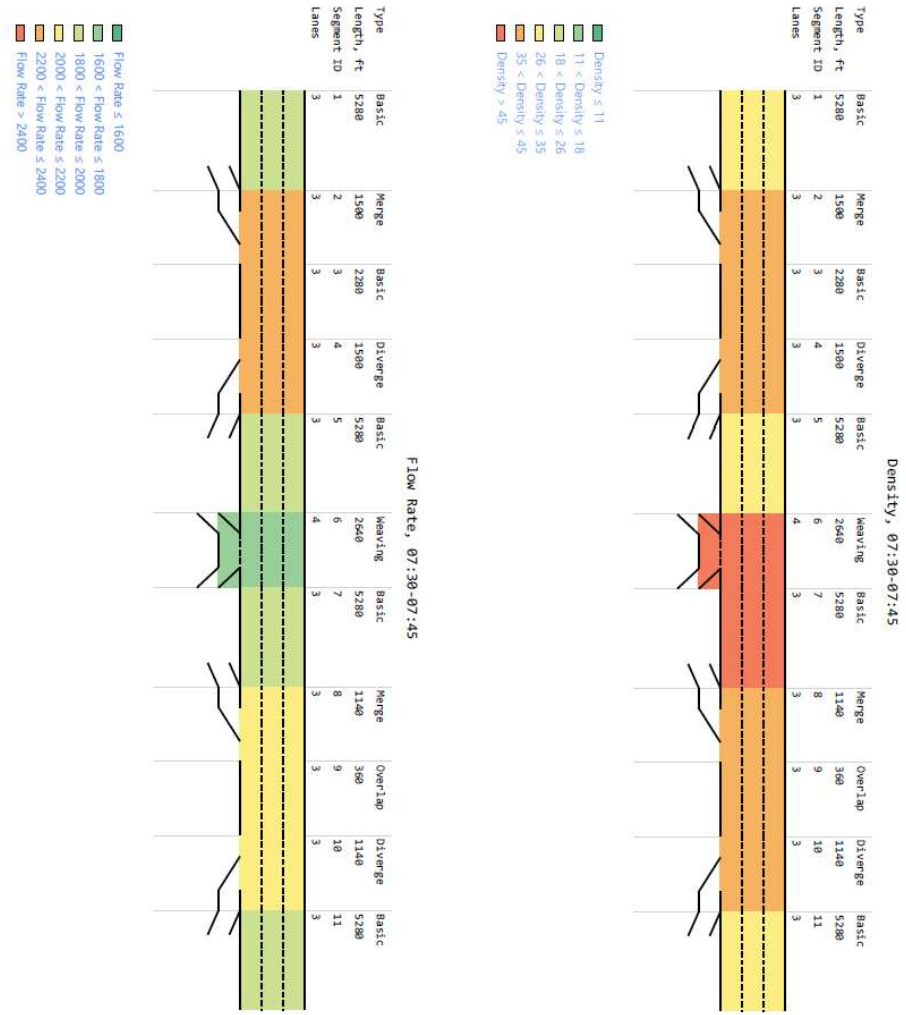
- d. Under 'Reports', three checkboxes are provided to indicate what to show in the formatted reports of facility analyses.
  - i. Messages: If this is checked, any warning or error messages displayed in the Information window will also be displayed on the facility formatted report.

Messages	
WARNING 1	Oversaturated conditions currently exist in boundary segment 11. Results may not be reliable. Consider expanding analysis in time and/or space to resolve this warning.

- ii. Charts: If this is checked, the Volume Distribution, Speed Distribution, and Density Distribution charts will be displayed on the facility formatted report.



- iii. Graphs: If this is checked, the facility heat map graphs for each analysis period for Flow Rate, Speed, Density, and LOS will be displayed on the facility formatted report.



- e. Under 'Safety Analysis', you are given the option of displaying safety analysis results in reports.
  - i. Show Safety Analysis Results in Reports: If this is checked, a section for safety analysis results will be displayed in the text report.

Highway Safety Software Output: Predicted Crashes and Safety Performance Function (SPF)

Number of Predicted Crashes, Npred	13.485	Crashes
Number of years	1	Year
SPF: Multiple and Single Vehicle (MV and SV) and Severity Level (Fatal and Injury - FI and Property Damage Only - PDO)		
N(SPF, MV, FI)	1.686	Crashes (base condition)
N(SPF, MV, PDO)	4.228	Crashes (base condition)
N(SPF, SV, FI)	2.245	Crashes (base condition)
N(SPF, SV, PDO)	5.000	Crashes (base condition)
Predicted Crashes(MV, FI)	1.686	Crashes
Predicted Crashes(MV, PDO)	4.228	Crashes
Predicted Crashes(SV, FI)	2.571	Crashes
Predicted Crashes(SV, PDO)	5.000	Crashes

- ii. K-Factor: The value indicated in this textbox will apply to the safety calculations if results are shown
- iii. D-Factor: The value indicated in this textbox will apply to the safety calculations if results are shown



4. Clicking “OK” will save the changes made and close the Default Settings window; clicking “Cancel” will close the Default Settings window without saving any changes
  - a. When a new file is created, the Analyst, Agency, and Jurisdiction fields will automatically be populated with the text specified in the Default Settings.
  - b. When starting a new file, the input and results will display according to the units specified in the Default Settings.
  - c. When exporting to CSV, whatever is checked in the Default Settings will be applied to the exported file.
  - d. When viewing the facility formatted report, whatever is checked in the Default Settings will be applied to the report.
  - e. When viewing the text report, safety results will be displayed or hidden depending on what is checked in the Default Settings.
    - i. If the desired selection indicates to show safety results, it is important to note that they will only update after saving the file.
      1. If a new file is created, the safety results section will at first be hidden.
      2. If inputs are changed in an existing file, it will be necessary to save the file first before the safety results will update.

## Change the View

1. When a file is open, there are three main options for the view of the program:
  - a. Page View: the inputs and results reports are separated into pages as seen below. You can navigate between pages using the “Back” and “Next” buttons or by clicking the page names found at the top of the screen. *Note: Page View is available for both single segment and facility analyses.*

The screenshot displays the 'BASIC REPORT' page in the HCS Freeways software. The interface is organized into four main sections, each with its own set of input fields and controls:

- Project Properties:** Includes fields for Analyst, Agency, Analysis Year (set to 2024), Project Description (Chapter 26: Example Problem 1), Design Analysis (checkbox), Service Volumes (checkbox), Jurisdiction, Time Analyzed, Date (9/9/2024), D-factor (0.55), K-factor (0.10), and Run HCM 7.1 (ML analysis only) (checkbox).
- Geometric Data:** Includes Number of Lanes (2), Measured FFS (checkbox), Base Free Flow Speed, mi/h (75.4), Length, ft (-), Lane Width, ft (11.0), Managed Lane (checkbox), Terrain Type (Level), Percent Grade, % (-), Grade Length, mi (-), Right Side Clearance, ft (2), and Total Ramp Density, ramps/mi (4.00).
- Demand Data:** Includes Demand, veh/h (2000), Total Trucks, % (5.00), Tractor-Trailers (TT), % (-), Proportion of CAVs (0), Peak Hour Factor (0.92), Single-Unit Trucks (SUT), % (-), and Mixed Flow Model (checkbox).
- Adjustment Factors:** Includes Driver Population (All Familiar), Weather Type (Non-Severe Weather), Incident Type (No Incident), Work Zone (checkbox), Speed Adjustment Factor (1.000), Capacity Adjustment Factor (1.000), and Demand Adjustment Factor (1.000).

Navigation is facilitated by 'Back' and 'Next' buttons on the left and right sides of the form, and a top navigation bar with 'START', 'BASIC', and 'REPORT' tabs.

- b. Full View with the report on the right of the screen: the screen is split with all inputs on the left side and the results reports on the right side. You can access all inputs and view all of the current report by using the corresponding scroll bars. There is also a screen splitter that can be moved to adjust the view of the input screen and results report.

The screenshot shows the HCS Basic Freeway Report software interface. The left pane contains input fields for Project Properties, Geometric Data, Demand Data, and Adjustment Factors. The right pane displays the HCS Basic Freeway Report, which includes sections for Project Information, Geometric Data, Adjustment Factors, Demand and Capacity, Speed and Density, and Highway Safety Manual - Predicted Crashes.

Analyst		Jurisdiction	
Agency		Time Analyzed	
Analysis Year	2024	Date	9/9/2024
Project Description	Chapter 26: Example Problem 1	D-factor	0.55
Design Analysis	<input type="checkbox"/>	K-factor	0.10
Service Volumes	<input type="checkbox"/>	Run HCM 7.1 (ML analysis only)	<input type="checkbox"/>

Number of Lanes	2	Terrain Type	Level
Measured FFS	<input type="checkbox"/>	Percent Grade, %	-
Base Free Flow Speed, mi/h	75.4	Grade Length, mi	-
Length, ft	-	Right Side Clearance, ft	2
Lane Width, ft	11.0	Total Ramp Density, ramps/mi	4.00
Managed Lane	<input type="checkbox"/>		

Demand, veh/h	2000	Peak Hour Factor	0.92
Total Trucks, %	5.00	Single-Unit Trucks (SUT), %	-
Tractor-Trailers (TT), %	-	Mixed Flow Model	<input type="checkbox"/>
Proportion of CAVs	0		

Driver Population	All Familiar	Speed Adjustment Factor	1.000
Weather Type	Non-Severe Weather	Capacity Adjustment Factor	1.000
Incident Type	No Incident	Demand Adjustment Factor	1.000
Work Zone	<input type="checkbox"/>		

Project Information			
Analyst		Date	9/9/2024
Agency		Analysis Year	2024
Jurisdiction		Time Analyzed	
Project Description	Chapter 26: Example Problem 1	Units	U.S. Customary
Geometric Data			
Number of Lanes (N), ln	2	Terrain Type	Level
Segment Length (L), ft	-	Percent Grade, %	-
Measured or Base Free-Flow Speed	Base	Grade Length, mi	-
Base Free-Flow Speed (BFFS), mi/h	75.4	Total Ramp Density (TRD), ramps/mi	4.00
Lane Width, ft	11.0	Free-Flow Speed (FFS), mi/h	60.8
Right-Side Lateral Clearance, ft	2		
Adjustment Factors			
Driver Population	All Familiar	Final Speed Adjustment Factor (SAF)	1.000
Weather Type	Non-Severe Weather	Demand Adjustment Factor (DAF)	1.000
Incident Type	No Incident	Final Capacity Adjustment Factor (CAF)	1.000
Proportion of CAVs in Traffic Stream	0	Capacity Adj. Factor for CAVs (CAFCAF)	1.000
Demand and Capacity			
Demand Volume (V), veh/h	2000	Heavy Vehicle Adjustment Factor (Hv)	0.952
Peak Hour Factor (PHF)	0.92	Flow Rate (v), pc/h/ln	1142
Total Trucks, %	5.00	Capacity (C), pc/h/ln	2308
Single-Unit Trucks (SUT), %	-	Initial Adjusted Capacity (IAC), pc/h/ln	2308
Tractor-Trailers (TT), %	-	Final Adjusted Capacity (FAC), pc/h/ln	2308
Passenger Car Equivalent (ET)	2.00	Volume-to-Capacity Ratio (v/c)	0.49
Speed and Density			
Lane Width Adjustment (LW)	1.9	Average Speed (S), mi/h	60.8
Right-Side Lateral Clearance Adj. (RLC)	2.4	Density (D), pc/mi/ln	18.8
Total Ramp Density Adjustment	10.3	Level of Service (LOS)	C
Adjusted Free-Flow Speed (FFS <sub>adj</sub> ), mi/h	60.8		
Highway Safety Manual - Predicted Crashes			
	Single-vehicle crashes	Multi-vehicle crashes	Total, crashes/year
Total and Injury - FI, crashes/year	2,336	0,031	3,369
Property Dmg Only - PDO, crashes/year	2,492	1,506	3,998

- c. Full View with the report on the bottom of the screen: the screen is split with all inputs on the top of the screen and the results reports on the bottom of the screen. You can access all inputs and view all of the current report by using the corresponding scroll bars. There is also a screen splitter that can be moved to adjust the view of the input screen and results report. *Note: Full View with the report on the bottom is only available for single segment analyses.*

The screenshot shows the HCS Basic Freeway Report software interface. The top section contains input fields for Project Properties, Geometric Data, Demand Data, and Adjustment Factors. The bottom section displays the HCS Basic Freeway Report, which includes sections for Project Information, Geometric Data, Adjustment Factors, Demand and Capacity, Speed and Density, and Highway Safety Manual - Predicted Crashes.

Analyst		Jurisdiction	
Agency		Time Analyzed	
Analysis Year	2024	Date	9/9/2024
Project Description	Chapter 26: Example Problem 1	D-factor	0.55
Design Analysis	<input type="checkbox"/>	K-factor	0.10
Service Volumes	<input type="checkbox"/>	Run HCM 7.1 (ML analysis only)	<input type="checkbox"/>

Number of Lanes	2	Terrain Type	Level
Measured FFS	<input type="checkbox"/>	Percent Grade, %	-
Base Free Flow Speed, mi/h	75.4	Grade Length, mi	-

Demand, veh/h	2000	Peak Hour Factor	0.92
Total Trucks, %	5.00	Single-Unit Trucks (SUT), %	-
Tractor-Trailers (TT), %	-	Mixed Flow Model	<input type="checkbox"/>
Proportion of CAVs	0		

Driver Population	All Familiar	Speed Adjustment Factor	1.000
Weather Type	Non-Severe Weather	Capacity Adjustment Factor	1.000
Incident Type	No Incident	Demand Adjustment Factor	1.000
Work Zone	<input type="checkbox"/>		

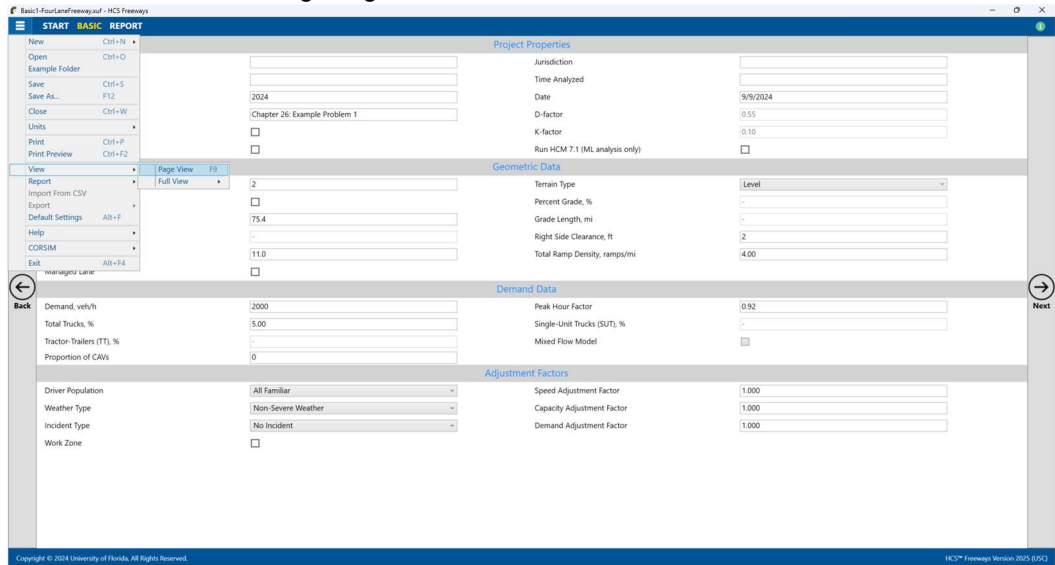
Project Information			
Analyst		Date	9/9/2024
Agency		Analysis Year	2024
Jurisdiction		Time Analyzed	
Project Description	Chapter 26: Example Problem 1	Units	U.S. Customary
Geometric Data			
Number of Lanes (N), ln	2	Terrain Type	Level
Segment Length (L), ft	-	Percent Grade, %	-
Measured or Base Free-Flow Speed	Base	Grade Length, mi	-
Base Free-Flow Speed (BFFS), mi/h	75.4	Total Ramp Density (TRD), ramps/mi	4.00
Lane Width, ft	11.0	Free-Flow Speed (FFS), mi/h	60.8
Right-Side Lateral Clearance, ft	2		
Adjustment Factors			
Driver Population	All Familiar	Final Speed Adjustment Factor (SAF)	1.000
Weather Type	Non-Severe Weather	Demand Adjustment Factor (DAF)	1.000
Incident Type	No Incident	Final Capacity Adjustment Factor (CAF)	1.000
Proportion of CAVs in Traffic Stream	0	Capacity Adj. Factor for CAVs (CAFCAF)	1.000
Demand and Capacity			
Demand Volume (V), veh/h	2000	Heavy Vehicle Adjustment Factor (Hv)	0.952
Peak Hour Factor (PHF)	0.92	Flow Rate (v), pc/h/ln	1142
Total Trucks, %	5.00	Capacity (C), pc/h/ln	2308
Single-Unit Trucks (SUT), %	-	Initial Adjusted Capacity (IAC), pc/h/ln	2308
Tractor-Trailers (TT), %	-	Final Adjusted Capacity (FAC), pc/h/ln	2308
Passenger Car Equivalent (ET)	2.00	Volume-to-Capacity Ratio (v/c)	0.49
Speed and Density			
Lane Width Adjustment (LW)	1.9	Average Speed (S), mi/h	60.8
Right-Side Lateral Clearance Adj. (RLC)	2.4	Density (D), pc/mi/ln	18.8
Total Ramp Density Adjustment	10.3	Level of Service (LOS)	C
Adjusted Free-Flow Speed (FFS <sub>adj</sub> ), mi/h	60.8		
Highway Safety Manual - Predicted Crashes			
	Single-vehicle crashes	Multi-vehicle crashes	Total, crashes/year
Total and Injury - FI, crashes/year	2,336	0,031	3,369
Property Dmg Only - PDO, crashes/year	2,492	1,506	3,998



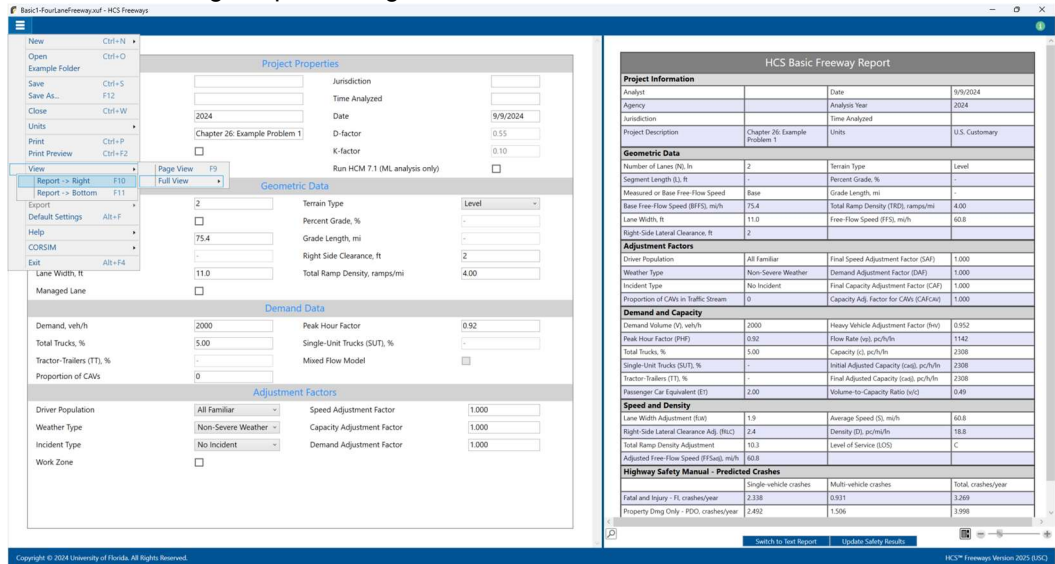
2. Views can be changed by using the main menu items or the keyboard shortcuts.

a. Main Menu Items

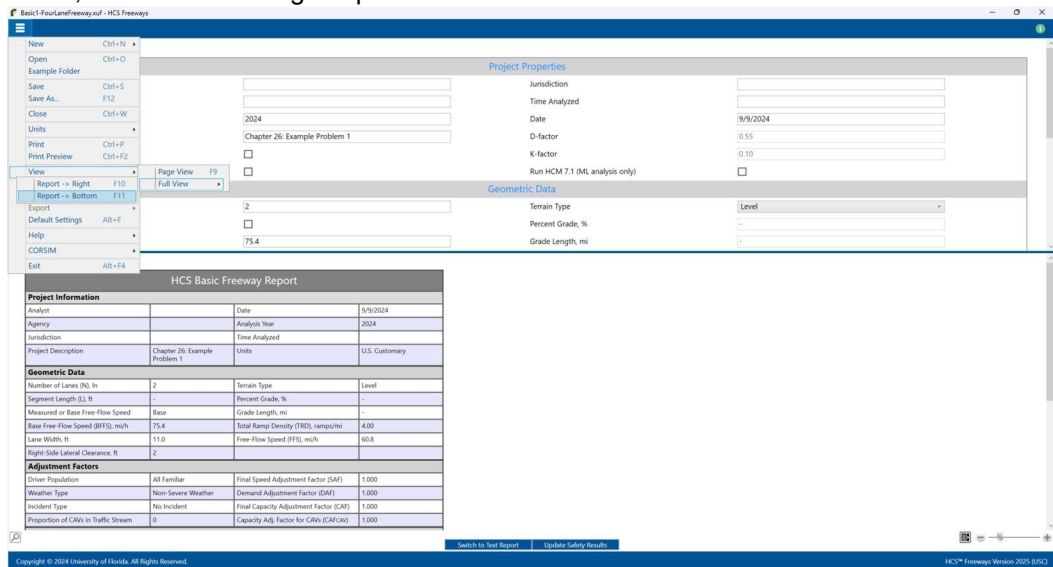
- i. To switch to Page View, select *File > View > Page View* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen, hovering over “View”, and then selecting “Page View”



- ii. To switch to Full View with the report on the right of the screen, select *File > View > Full View > Report -> Right* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen, hovering over “View”, hovering over “Full View”, and then selecting “Report -> Right”.



- iii. To switch to Full View with the report on the bottom of the screen, select *File > View > Full View > Report -> Bottom* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen, hovering over “View”, hovering over “Full View”, and then selecting “Report -> Bottom”.



*Note: This is only available for single segment analyses; it is not available for facility analyses.*

#### b. Keyboard Shortcuts

- i. Page View: keyboard shortcut is “F9”
  - ii. Full View with report on the right of the screen: keyboard shortcut is “F10”
  - iii. Full View with report on the bottom of the screen: keyboard shortcut is “F11”
- Note: This is only applicable for single segment analyses; it does not apply to facility analyses.*

## Model a Lane Addition

1. A lane addition is a location along a roadway where the number of continuous through lanes increases by one or more. To model a lane addition, a facility analysis needs to be created with a merge segment and either an upstream segment or downstream segment. Please note that due to the lane addition, the coded merge segment will be analyzed as a basic segment with the same number of mainline lanes coded in the merge.
2. The following are different ways to create a lane addition:
  - a. When there is an upstream segment followed by a merge segment, the number of freeway lanes for the merge segment should be set to at least 1 more lane than the number of freeway lanes for the upstream segment.

Segment Data

Segment: 2> Analysis Period: 07:00-07:15  
 Coded Type: Merge Analyzed Type: Basic

Segment

- None
- Flow
- Speed
- Density
- TTI
- LOS

Type	Basic	Merge	Basic
Length, ft	5200	1500	5200
Segment ID	1	2	3
Lanes	3	4	4

Fast Slow

Geometric Data

Number of Lanes	4	Ramp Lanes	1
Free Flow Speed, mi/h	75.4	Ramp Free Flow Speed, mi/h	35.0
Freeway Length, ft	1500	Ramp Side	Right
Freeway Terrain Type	Level	Ramp Terrain Type	Level
Freeway Grade, %	-	Ramp Grade, %	-
Freeway Grade Length, mi	-	Ramp Grade Length, mi	-
Measured FFS	<input checked="" type="checkbox"/>	C-D Roadway	<input type="checkbox"/>
Right Side Clearance, ft	-	Length of First Accel. Lane (LA), ft	800
Lane Width, ft	-	Length of Second Accel. Lane (LA2), ft	-
Total Ramp Density, ramps/mi	-		
Managed Lane	<input type="checkbox"/>		

Information

INFORMATION 1: When the merge segment (segment 2) has 1 or more lanes more than upstream segment, then the merge segment is analyzed as a basic segment with 4 lanes due to the lane addition(s).

- b. When there is a merge segment followed by a downstream segment, the following needs to be true:
- The number of freeway lanes for the downstream segment should be set to equal or greater than the sum of mainline and ramp lanes at the subject merge AND
  - The acceleration lane length should equal the segment length for the merge segment. In the case of a two-lane on-ramp, the sum of the first acceleration lane ( $L_{A1}$ ) and second acceleration lane ( $L_{A2}$ ) must be equal to the segment length of the merge.

Segment Data

Segment: 2> Analysis Period: 07:00-07:15  
 Coded Type: Merge Analyzed Type: Basic

Segment

- None
- Flow
- Speed
- Density
- TTI
- LOS

Type	Basic	Merge	Basic
Length, ft	5200	1500	5200
Segment ID	1	2	3
Lanes	3	4	4

Fast Slow

Geometric Data

Number of Lanes	3	Ramp Lanes	1
Free Flow Speed, mi/h	75.4	Ramp Free Flow Speed, mi/h	35.0
Freeway Length, ft	1500	Ramp Side	Right
Freeway Terrain Type	Level	Ramp Terrain Type	Level
Freeway Grade, %	-	Ramp Grade, %	-
Freeway Grade Length, mi	-	Ramp Grade Length, mi	-
Measured FFS	<input checked="" type="checkbox"/>	C-D Roadway	<input type="checkbox"/>
Right Side Clearance, ft	-	Length of First Accel. Lane (LA), ft	1500
Lane Width, ft	-	Length of Second Accel. Lane (LA2), ft	-
Total Ramp Density, ramps/mi	-		
Managed Lane	<input type="checkbox"/>		

Information

INFORMATION 1: When the segment following a merge segment (segment 2) has 1 or more lanes more than the number of lanes in the merge segment, then the merge segment is analyzed as a basic segment with 3 lanes due to the lane addition(s)

# Model a Lane Drop

1. A lane drop is a location along a roadway where the number of through lanes is reduced by one or more. To model a lane drop, a facility analysis needs to be created with a diverge segment and a downstream segment. Please note that due to the lane drop, the coded diverge segment will be analyzed as a basic segment with the same number of mainline lanes coded in the diverge.
2. The following are different ways to create a lane drop:
  - a. When there is a diverge segment followed by a downstream segment, the following needs to be true:
    - i. The number of freeway lanes for the downstream segment should be set to at least 1 less lane than the subject diverge AND
    - ii. The deceleration lane length is equal to the segment length of the diverge. In the case of a two-lane off-ramp, the sum of the first deceleration lane ( $L_{D1}$ ) and second deceleration lane ( $L_{D2}$ ) must be equal to the segment length of the diverge.

Segment Data

Segment	2>	Analysis Period	07:00-07:15
Coded Type	Diverge	Analyzed Type	Basic

Segment

None

Flow

Speed

Density


TTI

LOS

▶ ||

Fast      Slow

Type	Basic	Diverge	Basic
Length, ft	5280	5280	5280
Segment ID	1	2	3
Lanes	4	2	2



Geometric Data

<table style="width: 100%; border-collapse: collapse;"> <tr><td>Number of Lanes</td><td>4</td></tr> <tr><td>Free Flow Speed, mi/h</td><td>75.4</td></tr> <tr><td>Freeway Length, ft</td><td>1500</td></tr> <tr><td>Freeway Terrain Type</td><td>Level</td></tr> <tr><td>Freeway Grade, %</td><td>.</td></tr> <tr><td>Freeway Grade Length, mi</td><td>.</td></tr> <tr><td>Measured FFS</td><td><input checked="" type="checkbox"/></td></tr> <tr><td>Right Side Clearance, ft</td><td>.</td></tr> <tr><td>Lane Width, ft</td><td>.</td></tr> <tr><td>Total Ramp Density, ramps/mi</td><td>.</td></tr> <tr><td>Managed Lane</td><td><input type="checkbox"/></td></tr> </table>	Number of Lanes	4	Free Flow Speed, mi/h	75.4	Freeway Length, ft	1500	Freeway Terrain Type	Level	Freeway Grade, %	.	Freeway Grade Length, mi	.	Measured FFS	<input checked="" type="checkbox"/>	Right Side Clearance, ft	.	Lane Width, ft	.	Total Ramp Density, ramps/mi	.	Managed Lane	<input type="checkbox"/>	<table style="width: 100%; border-collapse: collapse;"> <tr><td>Ramp Lanes</td><td>1</td></tr> <tr><td>Ramp Free Flow Speed, mi/h</td><td>35.0</td></tr> <tr><td>Ramp Side</td><td>Right</td></tr> <tr><td>Ramp Terrain Type</td><td>Level</td></tr> <tr><td>Ramp Grade, %</td><td>.</td></tr> <tr><td>Ramp Grade Length, mi</td><td>.</td></tr> <tr><td>C-D Roadway</td><td><input type="checkbox"/></td></tr> <tr><td>Length of First Decel. Lane (LD), ft</td><td>1500</td></tr> <tr><td>Length of Second Decel. Lane (LD2), ft</td><td>.</td></tr> </table>	Ramp Lanes	1	Ramp Free Flow Speed, mi/h	35.0	Ramp Side	Right	Ramp Terrain Type	Level	Ramp Grade, %	.	Ramp Grade Length, mi	.	C-D Roadway	<input type="checkbox"/>	Length of First Decel. Lane (LD), ft	1500	Length of Second Decel. Lane (LD2), ft	.
Number of Lanes	4																																								
Free Flow Speed, mi/h	75.4																																								
Freeway Length, ft	1500																																								
Freeway Terrain Type	Level																																								
Freeway Grade, %	.																																								
Freeway Grade Length, mi	.																																								
Measured FFS	<input checked="" type="checkbox"/>																																								
Right Side Clearance, ft	.																																								
Lane Width, ft	.																																								
Total Ramp Density, ramps/mi	.																																								
Managed Lane	<input type="checkbox"/>																																								
Ramp Lanes	1																																								
Ramp Free Flow Speed, mi/h	35.0																																								
Ramp Side	Right																																								
Ramp Terrain Type	Level																																								
Ramp Grade, %	.																																								
Ramp Grade Length, mi	.																																								
C-D Roadway	<input type="checkbox"/>																																								
Length of First Decel. Lane (LD), ft	1500																																								
Length of Second Decel. Lane (LD2), ft	.																																								

Freeways User Guide

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Segment Data

Segment: 2> Analysis Period: 07:00-07:15  
 Coded Type: Diverge Analyzed Type: Basic

Segment

None  
 Flow  
 Speed  
 Density  
 TTI  
 LOS

Type	Basic	Diverge	Basic
Length, ft	5200	5200	5200
Segment ID	1	2	3
Lanes	4	4	4

Fast Slow

Geometric Data

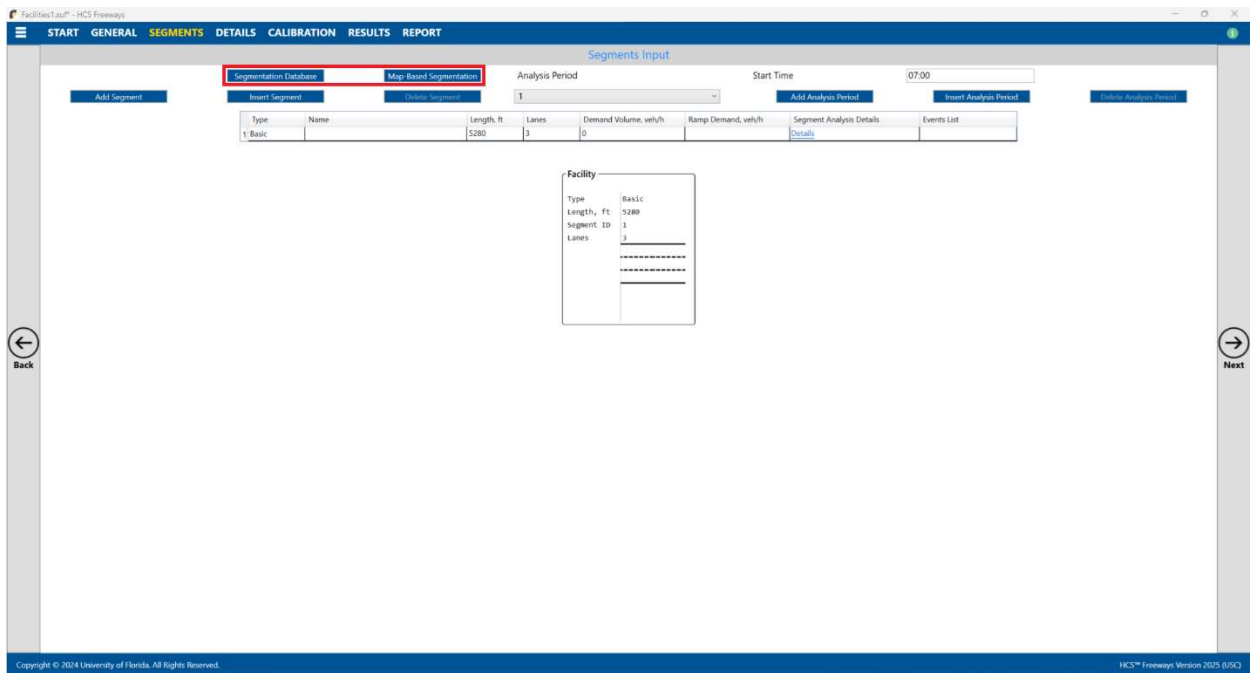
Number of Lanes	4	Ramp Lanes	2
Free Flow Speed, mi/h	75.4	Ramp Free Flow Speed, mi/h	35.0
Freeway Length, ft	1500	Ramp Side	Right
Freeway Terrain Type	Level	Ramp Terrain Type	Level
Freeway Grade, %	-	Ramp Grade, %	-
Freeway Grade Length, mi	-	Ramp Grade Length, mi	-
Measured FFS	<input checked="" type="checkbox"/>	C-D Roadway	<input type="checkbox"/>
Right Side Clearance, ft	-	Length of First Decel. Lane (LD1), ft	1000
Lane Width, ft	-	Length of Second Decel. Lane (LD2), ft	500
Total Ramp Density, ramps/mi	-	Major Diverge	<input type="checkbox"/>
Managed Lane	<input type="checkbox"/>		

Information

INFORMATION 1: When the segment following a diverge segment (segment 2) has 1 or more lanes less than the number of lanes in the diverge segment, then the diverge segment is analyzed as a basic segment with 4 lanes due to the lane drop(s).

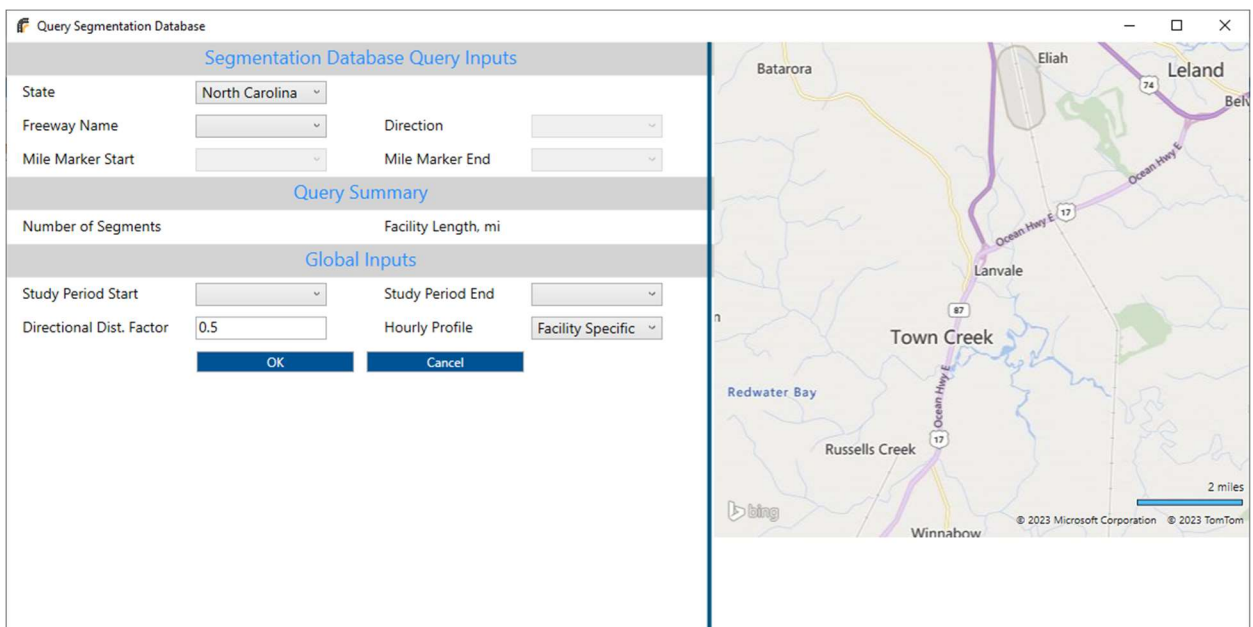
## Model a Freeway Facility by Segmentation

1. Segmentation allows the user to quickly model a freeway facility by providing the locations of ramp gore points, while HCS applies the HCM guidance to determine segment lengths in between the ramps.
2. There are two options for Segmentation: *Segmentation Database* and *Map-Based Segmentation*
3. To access either of these options, a freeway facility analysis must be done. On the Segments page, two buttons can be found at the top of the page. They are 'Segmentation Database' and 'Map-Based Segmentation'.



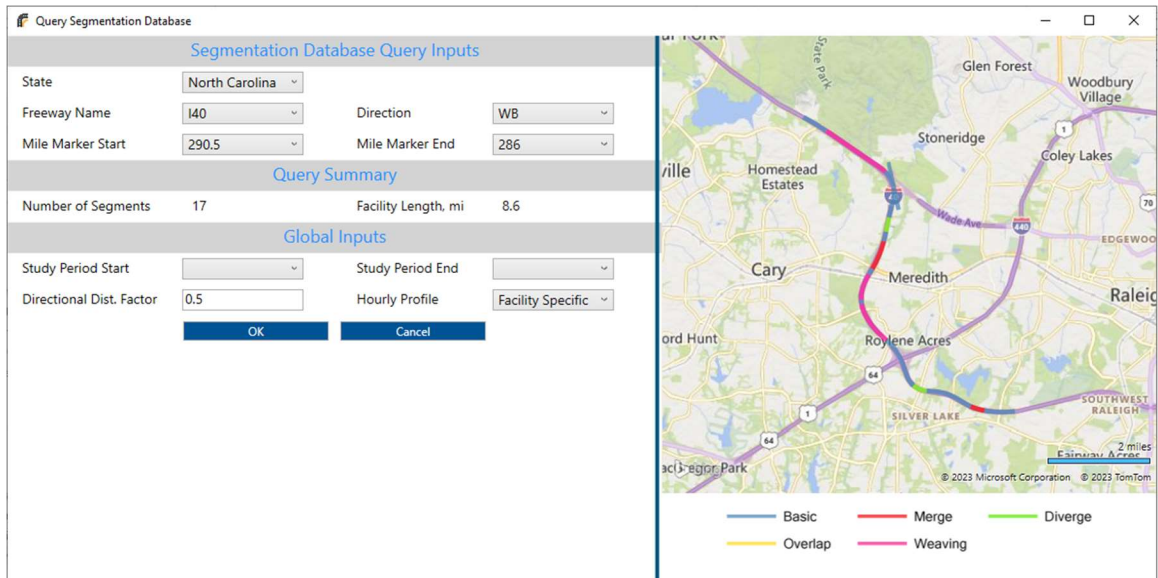
- a. Clicking 'Segmentation Database' will cause the Query Segmentation Database window to pop up.
- b. Clicking 'Map-Based Segmentation' will cause the 'Segmentation' window to pop up.

#### 4. Segmentation Database:

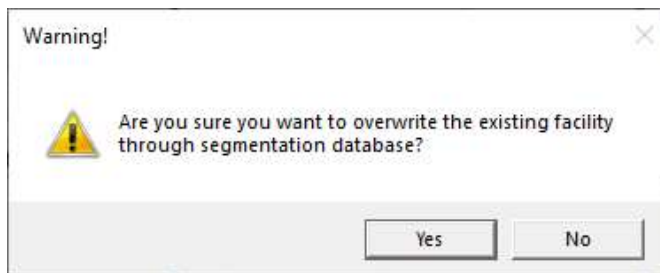


The segmentation database contains pre-coded facilities within *HCS Freeways*, providing quick access to both geometry and demand data. This tool helps users save time during the design process.

- a. This will allow selection of a freeway from a database, which can automatically generate segments for a freeway facility for analysis.
- b. The following needs to be specified: Database Date, State, Freeway Name, Direction, Mile Marker Start, and Mile Marker End. Once these inputs are specified, the selected freeway will appear on the map.



- c. After defining the facility, the user needs to specify the global inputs for the facility to complete the query.
  - i. **Study Period Start and Study Period End:** Specifies the time range during which the facility will be evaluated.
  - ii. **Directional Distribution Factor:** This factor represents the distribution of traffic in each direction of the facility. It ranges from 0.0 (no traffic in the defined direction) to 1.0 (all traffic in the defined direction).
  - iii. **Hourly Profile:** There are four hourly traffic distribution options – Facility Specific (weekdays), Default Distribution-AM Peak, Default Distribution-PM Peak, and Default Distribution-Unimodal.
- d. Once all inputs are specified, the freeway facility can be created for analysis.
- e. Clicking 'OK' will prompt the user asking to overwrite the existing facility through the segmentation database.

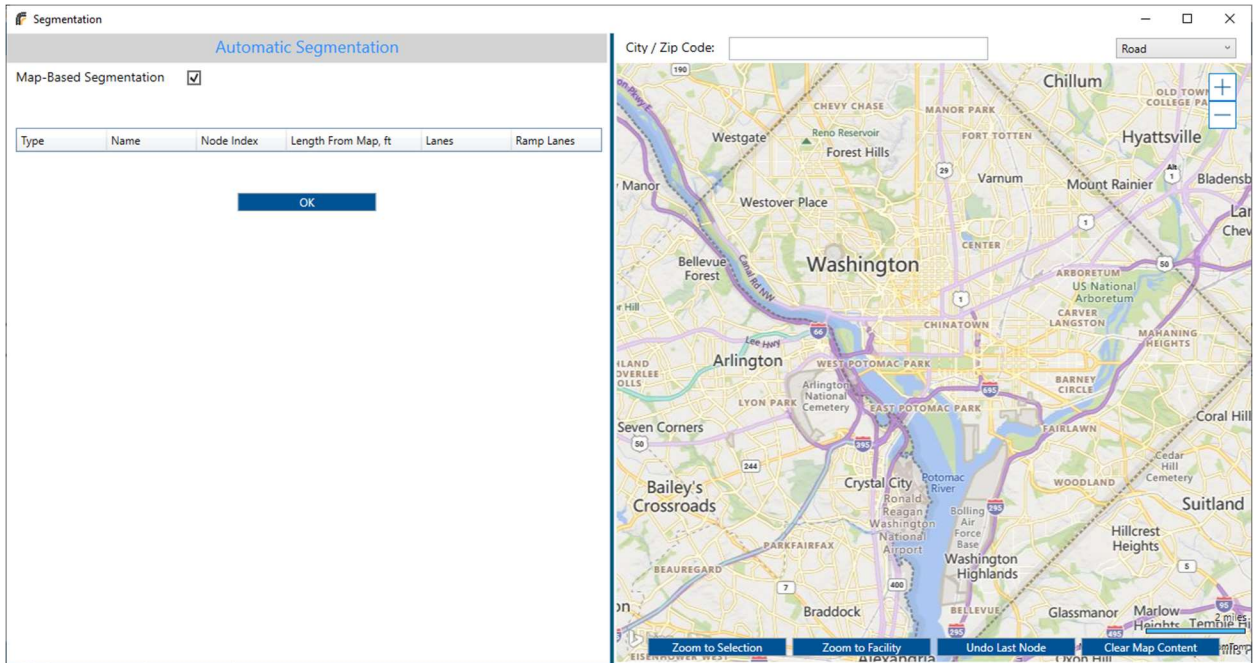


- i. Clicking 'Yes' will bring the user back to the Segments page in Freeways and any freeway facility model previously developed will be overwritten based on the query and information found in the database.
  - ii. Clicking 'No' will bring the user back to the Query Segmentation Database window to make any necessary changes.
- f. Clicking 'Cancel' will cause the inputs entered in the window to be ignored and will bring the user back to the Segments page in Freeways.

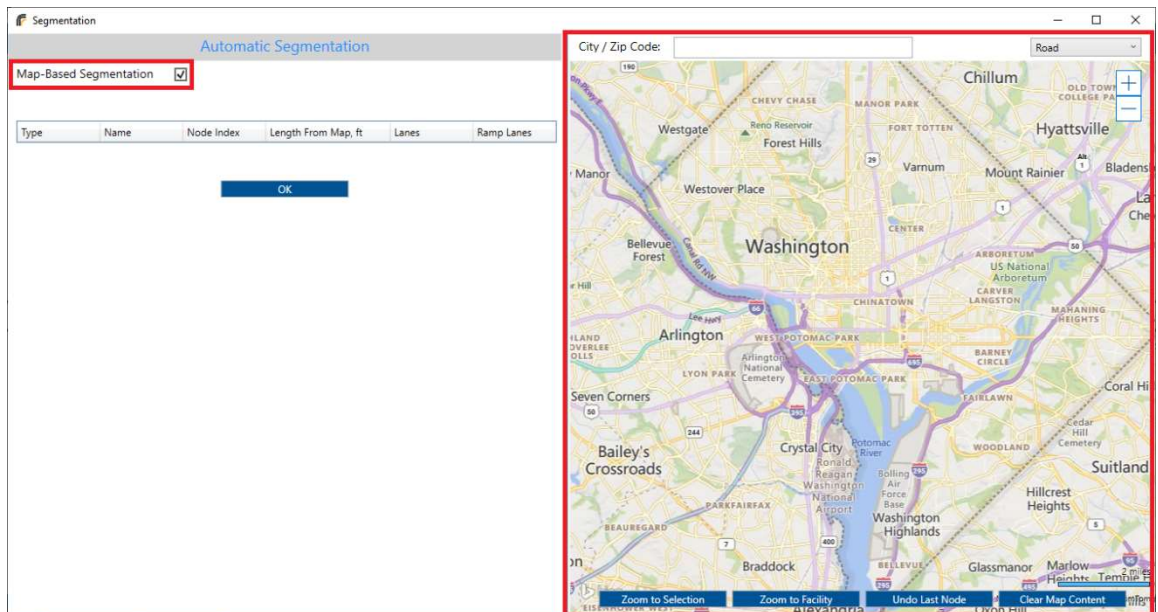


- g. Once a freeway facility is created for analysis, users can make any necessary adjustments to inputs. For example, users can navigate to the Calibration page, where various parameters of the freeway facility can be adjusted. This includes parameters such as defining work zones by modifying the capacity adjustment factors for each segment.
- h. The McTrans Center can integrate additional freeways into the platform. For more information, please contact [mctrans@ce.ufl.edu](mailto:mctrans@ce.ufl.edu).

5. Map-Based Segmentation:

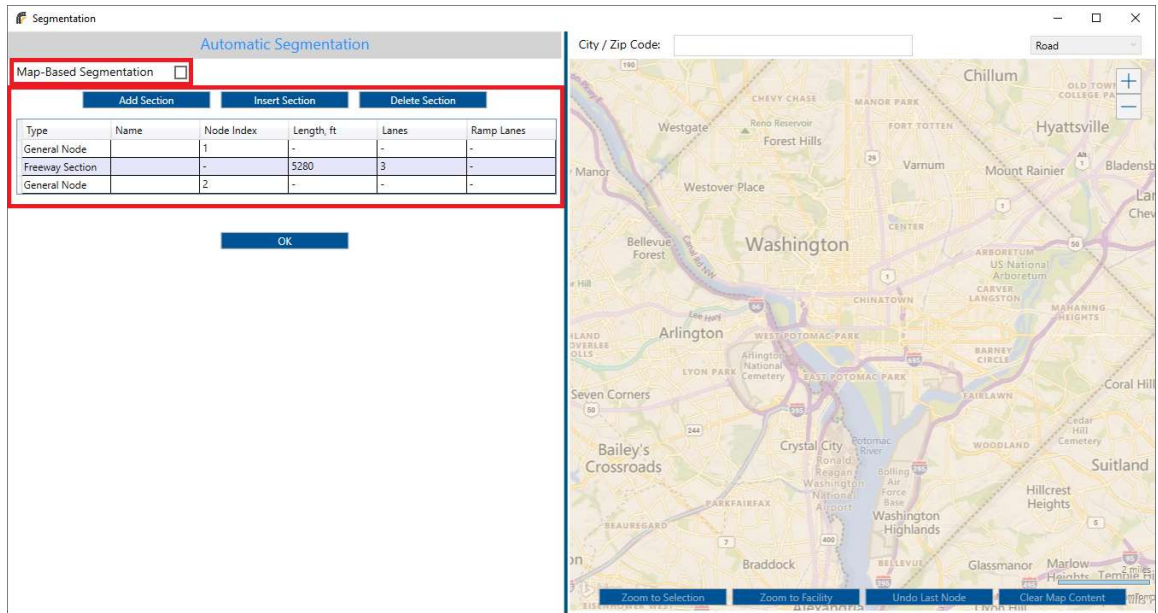


- a. This gives the option to create sections through a map or through a data grid alone.
- b. Checking the 'Map-Based Segmentation' checkbox will enable the map and disable buttons for adding, inserting, and deleting sections within the data grid provided.





- c. Unchecking the 'Map-Based Segmentation' checkbox will disable the map and enable buttons for adding, inserting, and deleting sections within the data grid provided.



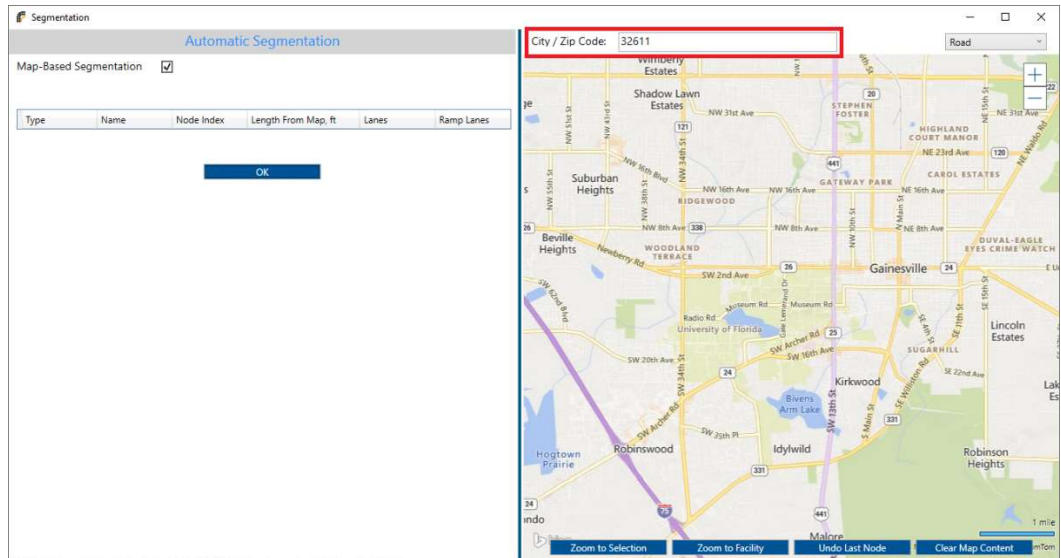
- d. Note: If changes were made in one mode and then the user decides to switch modes, a prompt will appear asking for confirmation to exit the current mode.



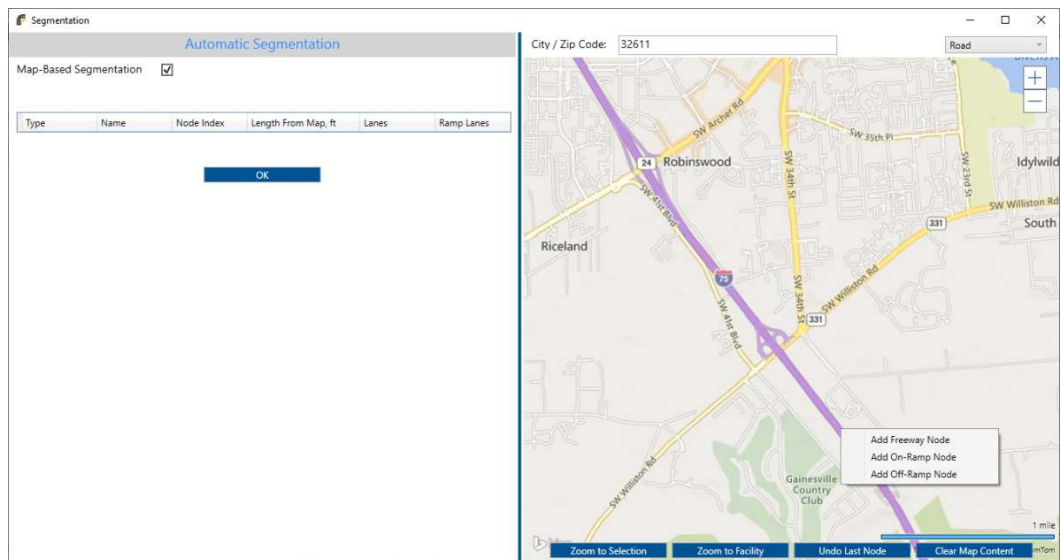
- i. Clicking 'Yes' will switch modes and cause any changes made to be discarded. The user will need to start segmentation from scratch.
- ii. Clicking 'No' will exit the prompt without making any changes in the Map-Based Segmentation window.

e. When the map is enabled:

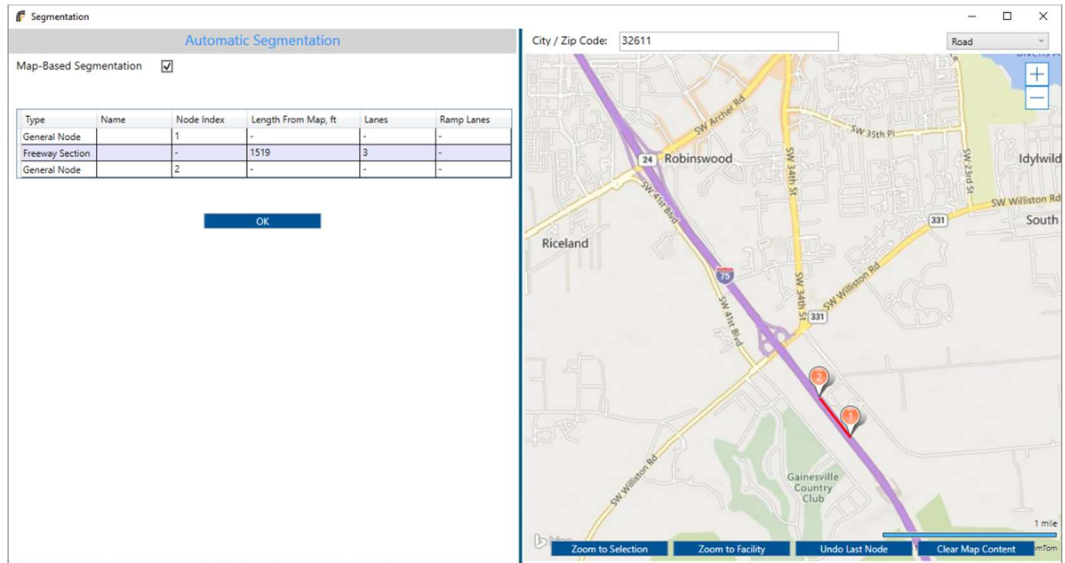
- i. Specific locations can be searched using the 'City / Zip Code' textbox. When a city or zip code is entered, the map will adjust to find that location. The user may also zoom in/out or drag the map to find a location.



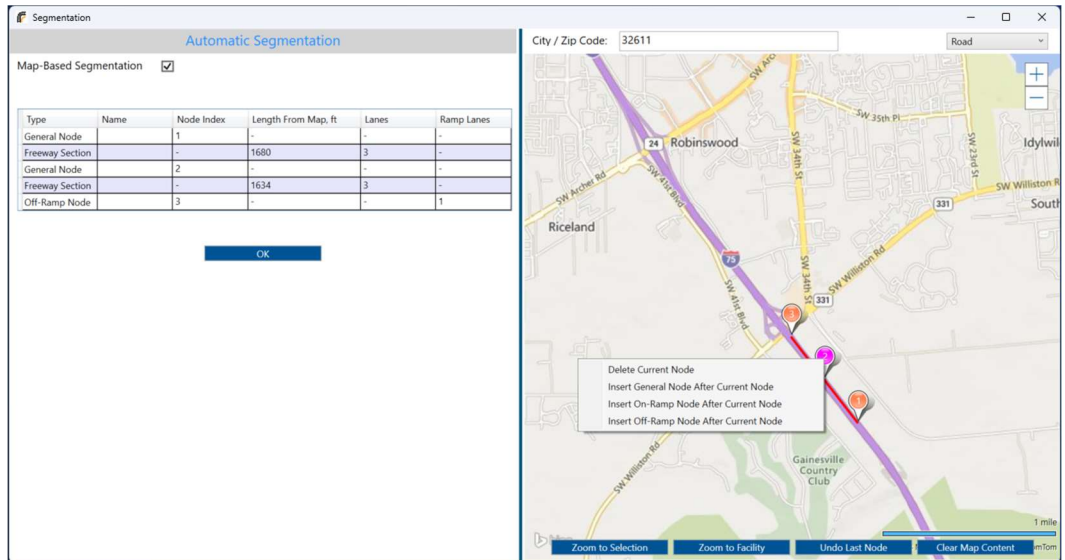
- ii. When ready to add a node, the user can right-click on the map which will bring up a menu with the following: Add Freeway Node, Add On-Ramp Node, and Add Off-Ramp Node.



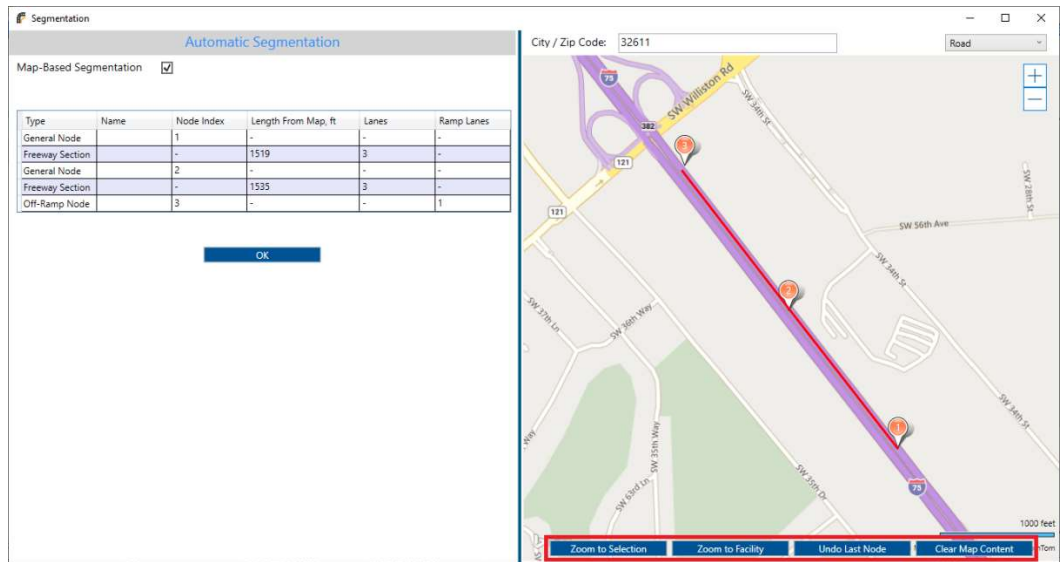
- iii. Adding a node will place a pin on the map with a number. As more nodes are added, the pins will be connected by lines representing sections of the roadway.



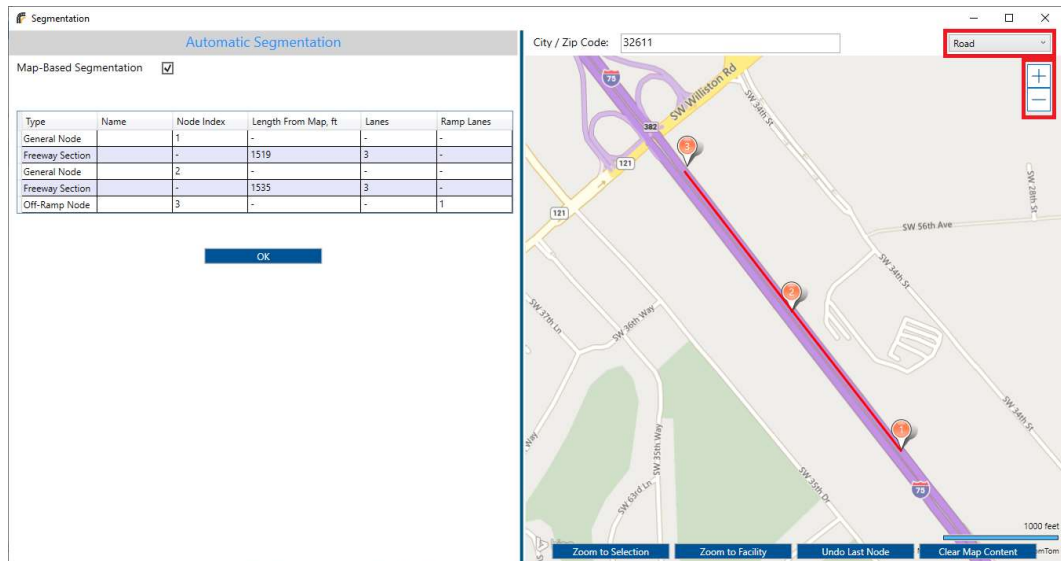
- iv. If there is already a node on the map, the user can right-click that node which will bring up a menu with the following: Delete Current Node, Insert General Node After Current Node, Insert On-Ramp Node After Current Node, and Insert Off-Ramp Node After Current Node.



- v. Buttons are provided at the bottom of map to make editing the facility easier. They include the following: Zoom to Selection, Zoom to Facility, Undo Last Node, and Clear Map Content.

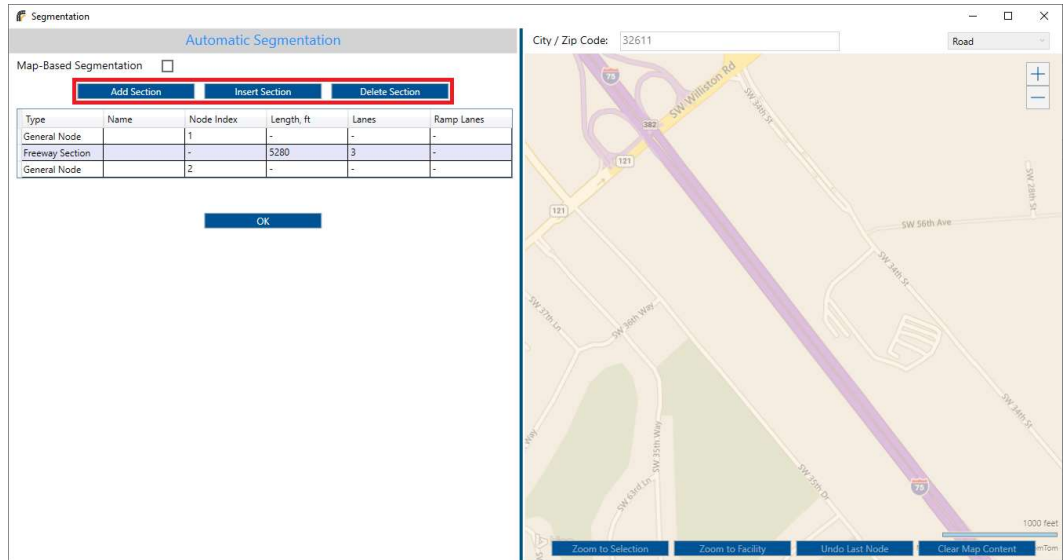


1. Zoom to Selection: zooms in to the selected nodes/sections on the map; the user will need to highlight rows within the table to use this feature
  2. Zoom to Facility: zooms in/out to show the entire facility on the map
  3. Undo Last Node: removes the last node added to the map
  4. Clear Map Content: removes everything that was added to the map
- vi. At the top right corner of the map, there are '+' and '-' buttons that allow zooming in and out, respectively. Above that is a drop-down menu that allows changing of the map view. Options include the following: *Road* and *Aerial With Labels*.

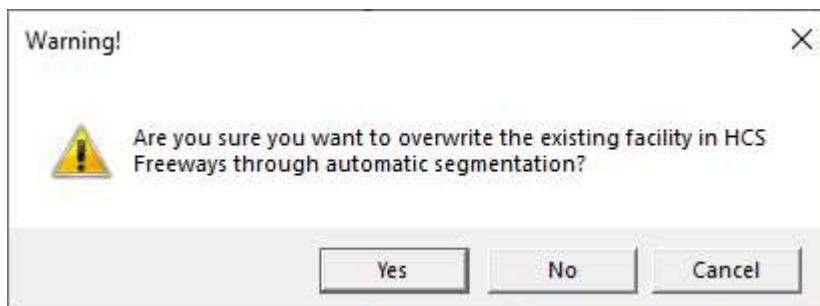


f. When the map is disabled:

- i. The map and all corresponding map buttons will be grayed out and cannot be used. The data grid will start off with General Node, Freeway Section, and General Node. The facility must also start and end with a General Node.
- ii. To edit the facility, there will be three buttons above the data grid: Add Section, Insert Section, and Delete Section.



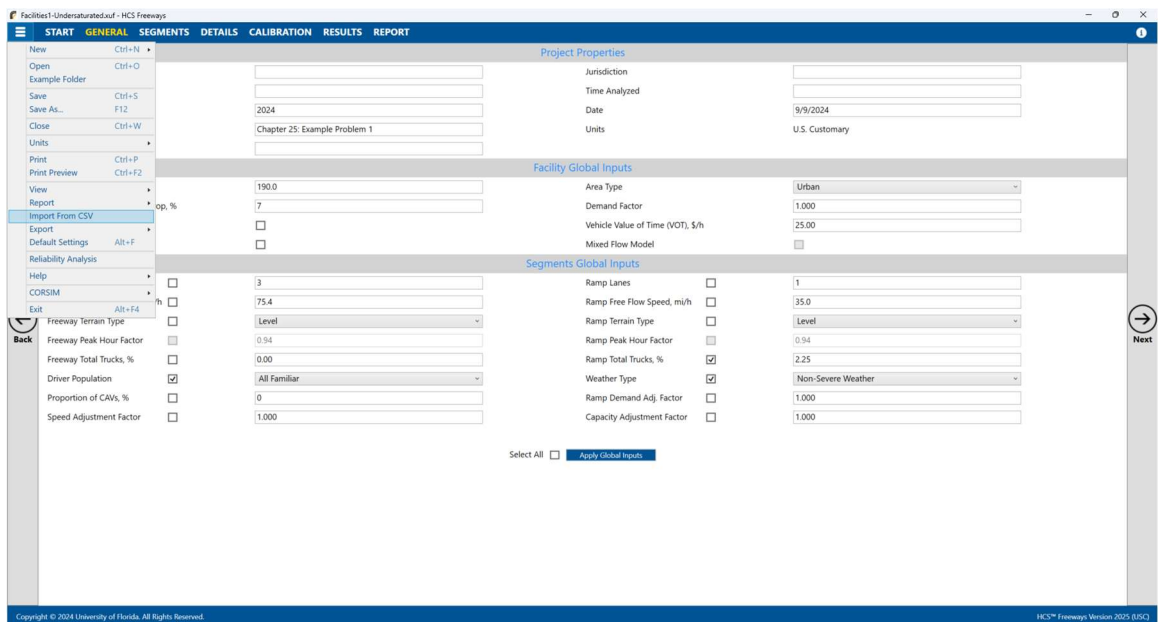
1. Adding a section will add an On-Ramp Node and a Freeway Section.
  2. Inserting a node will insert a General Node and Freeway Section before the row selected in the data grid.
  3. Deleting a section will delete whichever row(s) are selected in the data grid.
- g. Once all inputs are specified, the freeway facility can be created for analysis.
- h. Clicking 'OK' after finalizing sections will prompt the user asking to overwrite the existing facility through automatic segmentation.



- i. Clicking 'Yes' will bring the user back to the Segments page in Freeways and any freeway facility model previously developed will be overwritten based on the information specified in the map or data grid.
- ii. Clicking 'No' will bring the user back to the Segmentation window to may any necessary changes.

# Import

1. When there is a facility analysis open, there is only one option for import: Import from CSV
  - a. A CSV file (\*.csv) with all the necessary labels and identifiers in brackets is required for importing.
  - b. Before importing, the facility analysis open in *HCS Freeways* must have the same number of segments and number of analysis periods as the CSV file to be imported. If it does not, the CSV file cannot be imported, and Freeways will give an error. Please see *Freeway Facilities: Import/Export Facility* for more detailed information.
  - c. The imported CSV file also cannot be in descending order. Please see *How To: Edit the Default Settings* for more detailed information.
  - d. To import data from a CSV file, select *File > Import From CSV* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting “Import from CSV”.

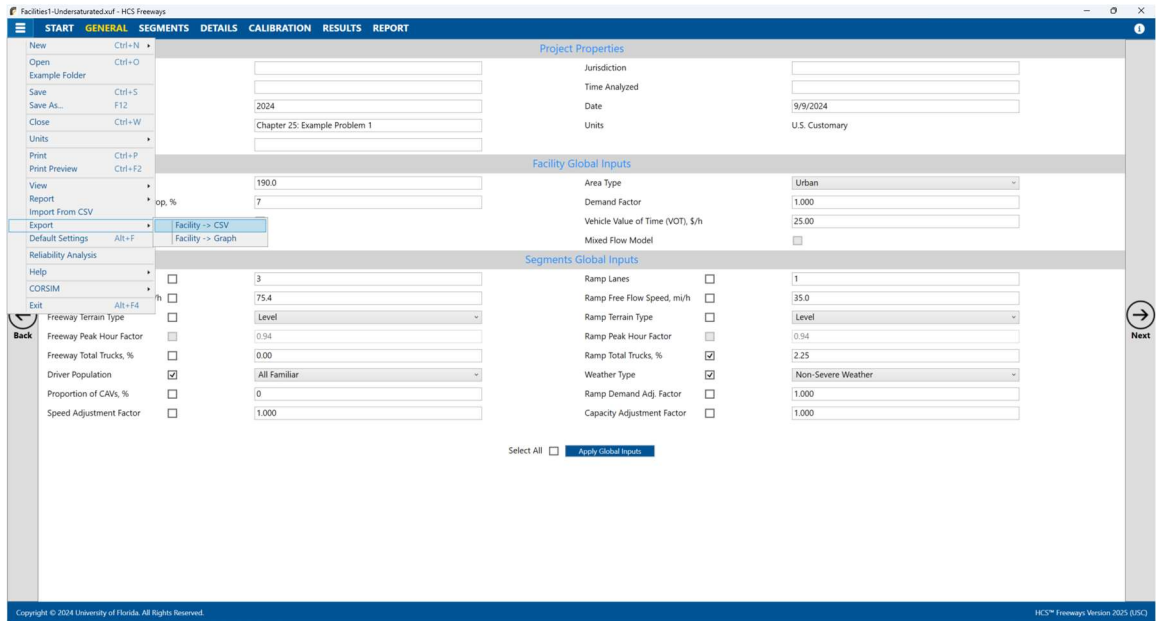


- e. Note: The import function is only applicable for facility analyses; they do not apply to single segment analyses. The *File > Import From CSV* menu item will only be enabled for facility analyses; it will be disabled for single segment analyses.

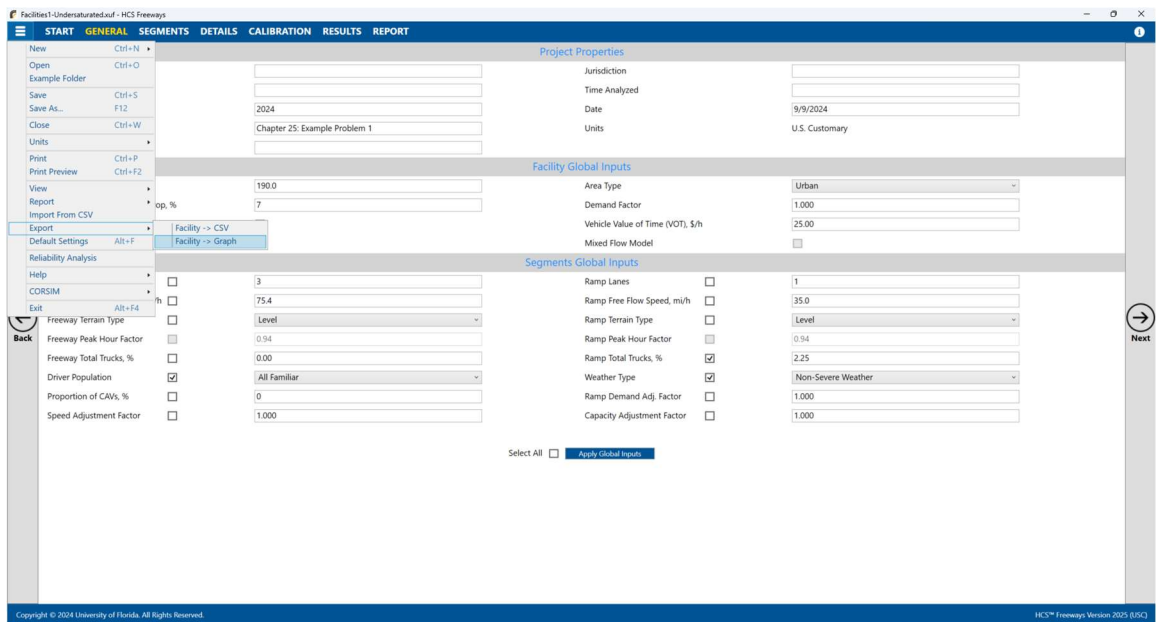


# Export

1. When there is a facility analysis open, there are two options for export: Facility to CSV and Facility to Graph
  - a. To export facility data to a CSV file, select *File > Export > Facility -> CSV* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen, hovering over “Export”, and then selecting “Facility -> CSV”.



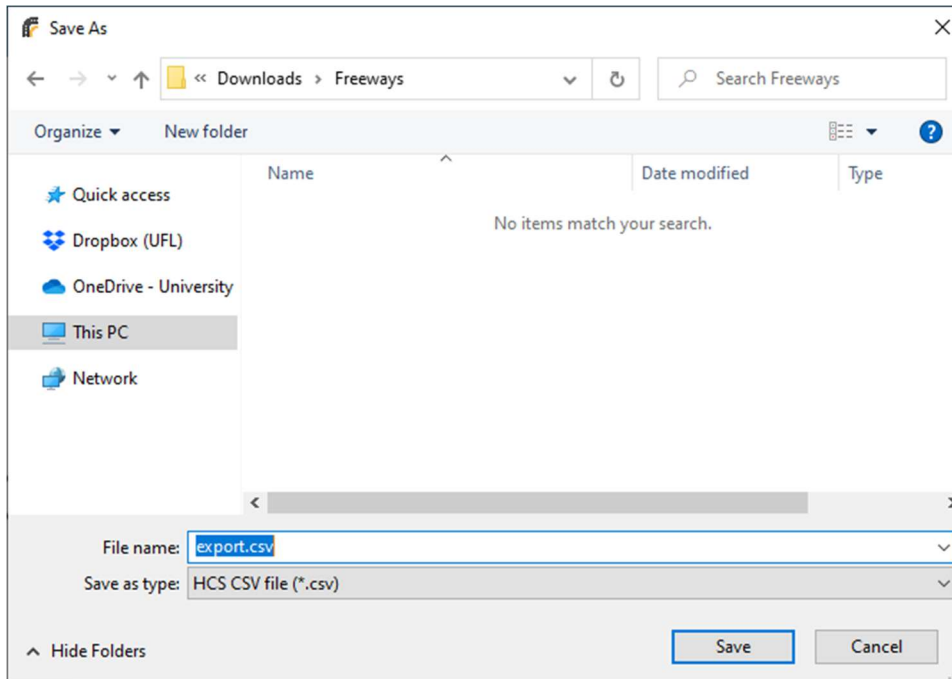
- b. To export the facility graph to an image file (\*.png), select *File > Export > Facility -> Graph* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen, hovering over “Export”, and then selecting “Facility -> Graph”.



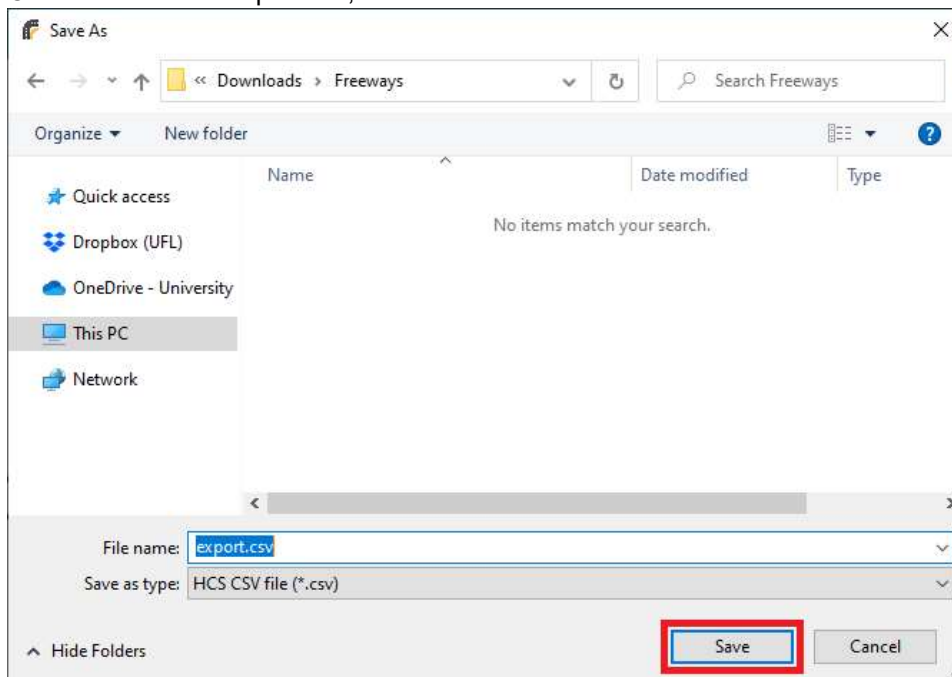
- c. Note: The export functions are only applicable for facility analyses; they do not apply to single segment analyses. The *File > Export > Facility -> CSV* and *File > Export > Facility -> Graph* menu items will only be enabled for facility analyses; it will be disabled for single segment analyses.

## 2. Export Facility to CSV

- a. When a facility is exported to a CSV file, a Save As dialog box will pop up allowing you to specify a name for saving the HCS CSV file (\*.csv). *Note: The default CSV file name is export.csv but can be overwritten.*

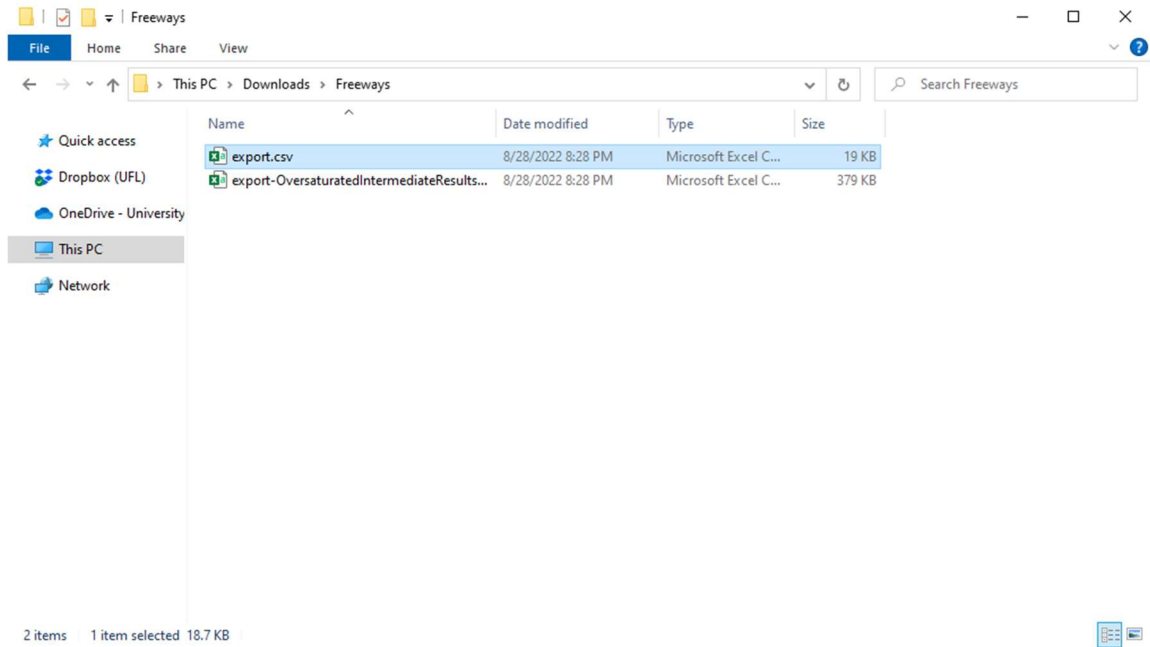


- b. Once a file name is specified, click the Save button.

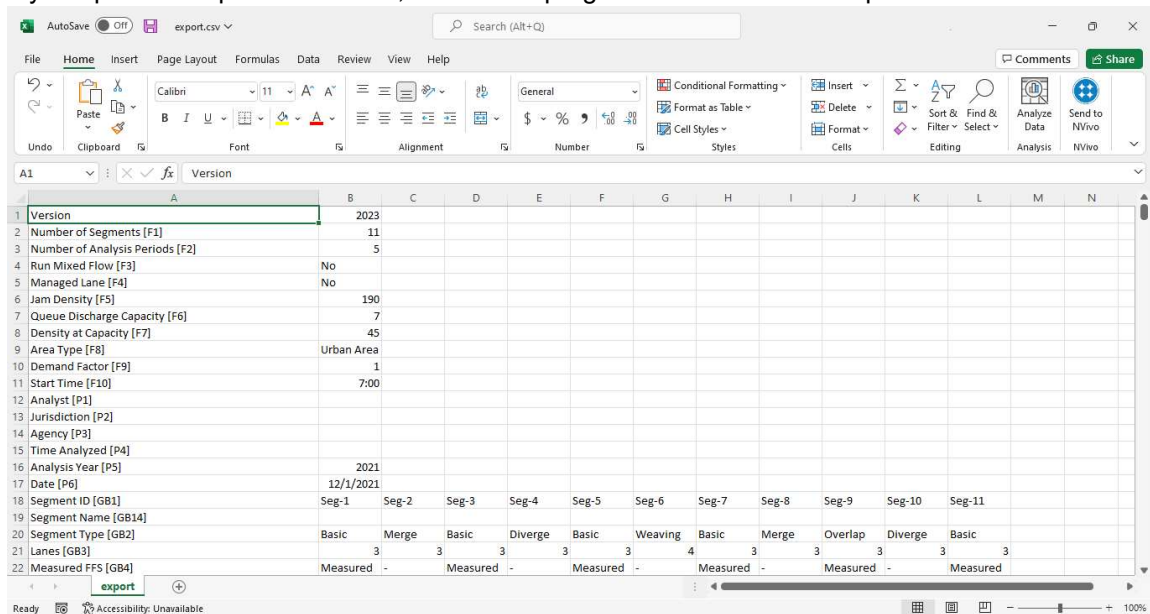




- c. The CSV file of the facility data will be saved in the folder you specified when saving.



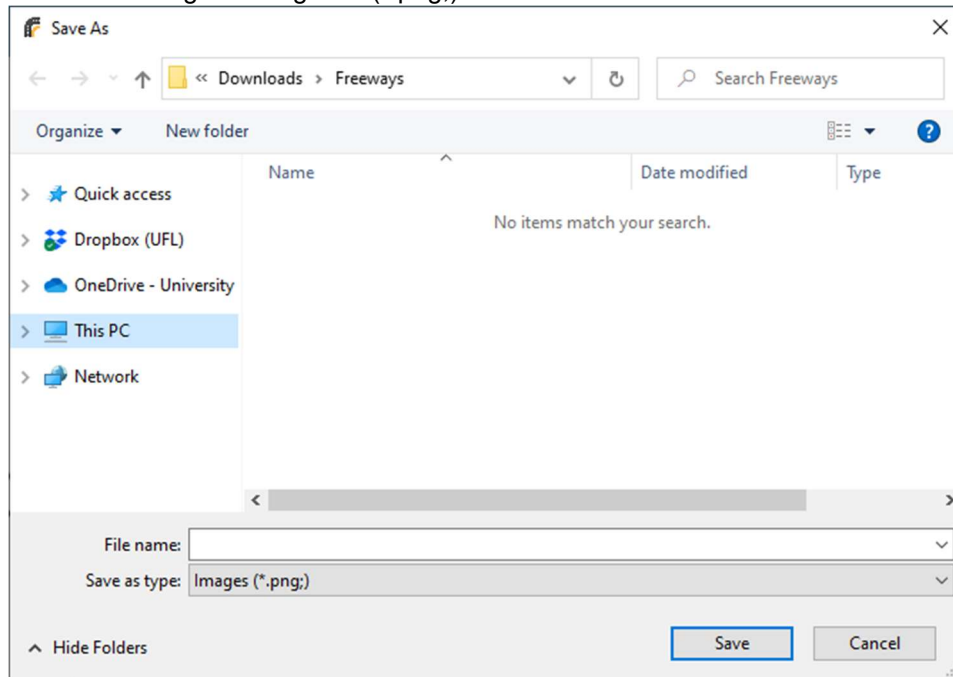
- d. If you open the exported CSV file, the default program for CSV files will open.



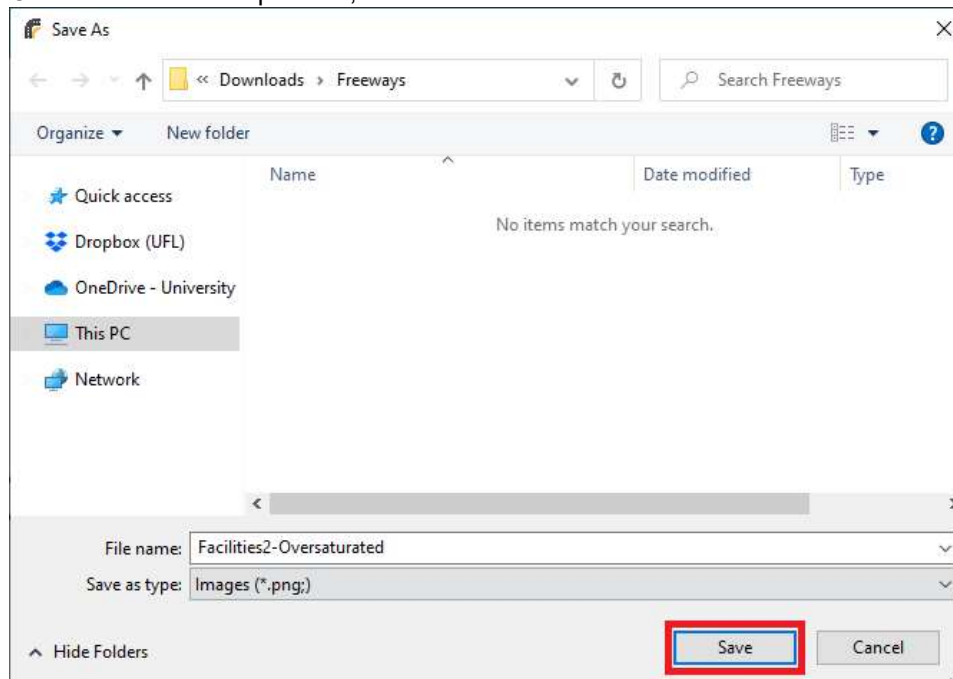
- e. All data from the Freeways facility file (\*.xuf) will be displayed in the CSV file. The first value of each line consists of the input label along with identifiers in brackets. Please see *Freeway Facilities: Import/Export Facility* for more detailed information.
- f. The data in the CSV file and how it is displayed is also dependent on the settings specified in the Defaults Settings. Please see *How To: Edit the Default Settings* for more detailed information.

### 3. Export Facility to Graph

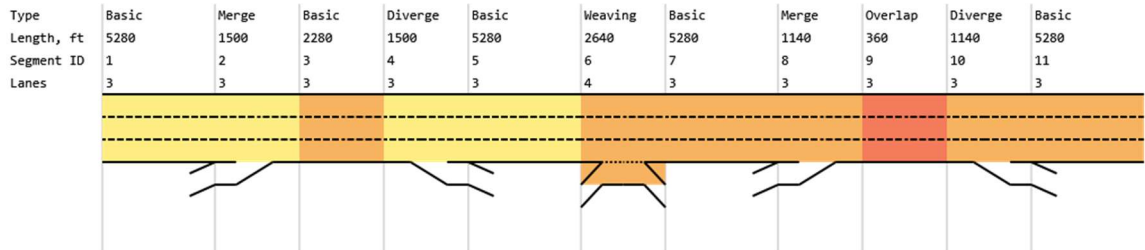
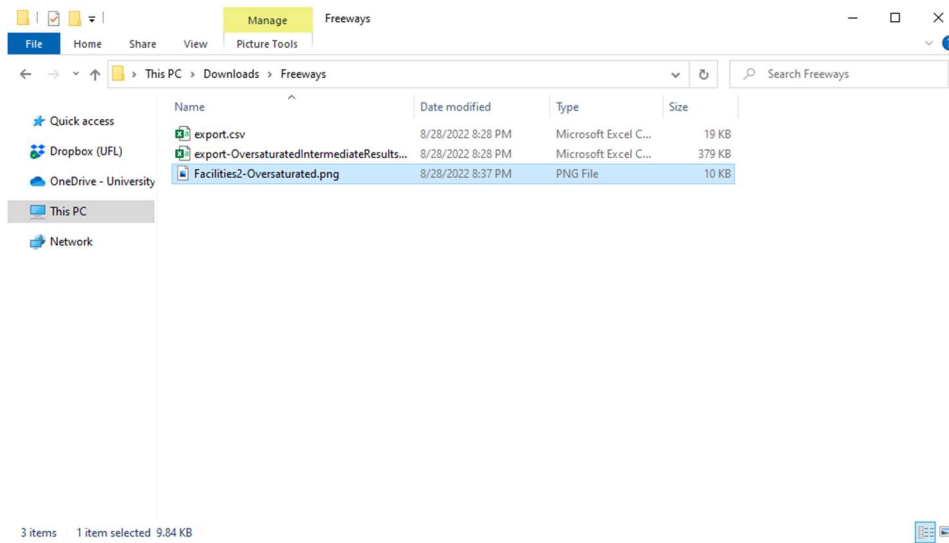
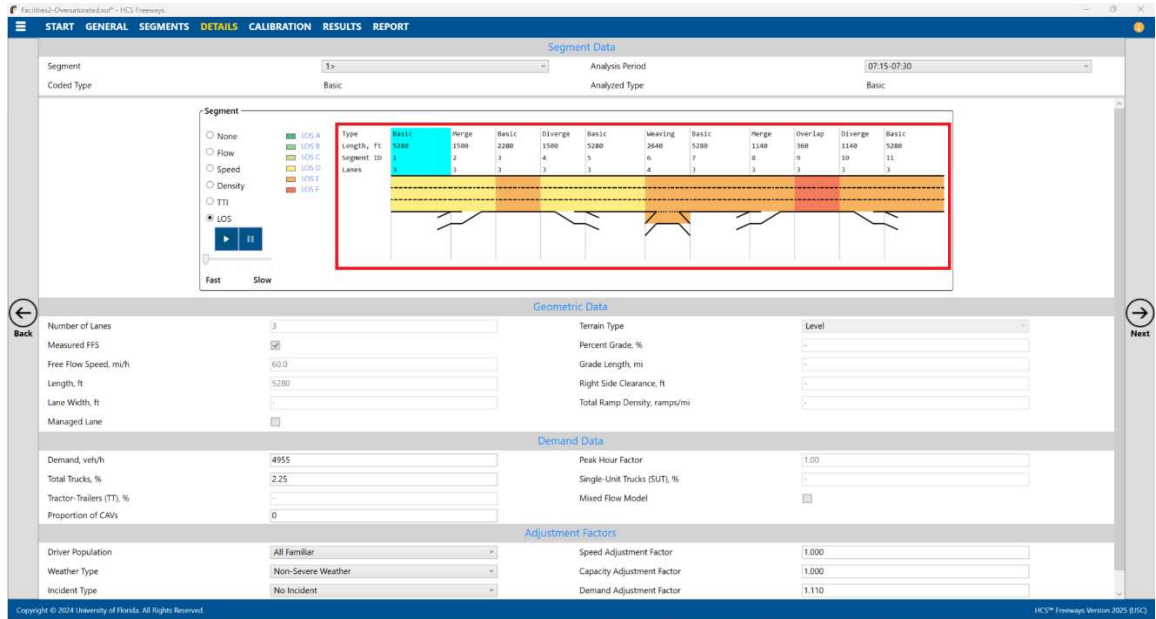
- a. When a facility is exported to a graph, a Save As dialog box will pop up allowing you to specify a name for saving the image file (\*.png;).



- b. Once a file name is specified, click the Save button.

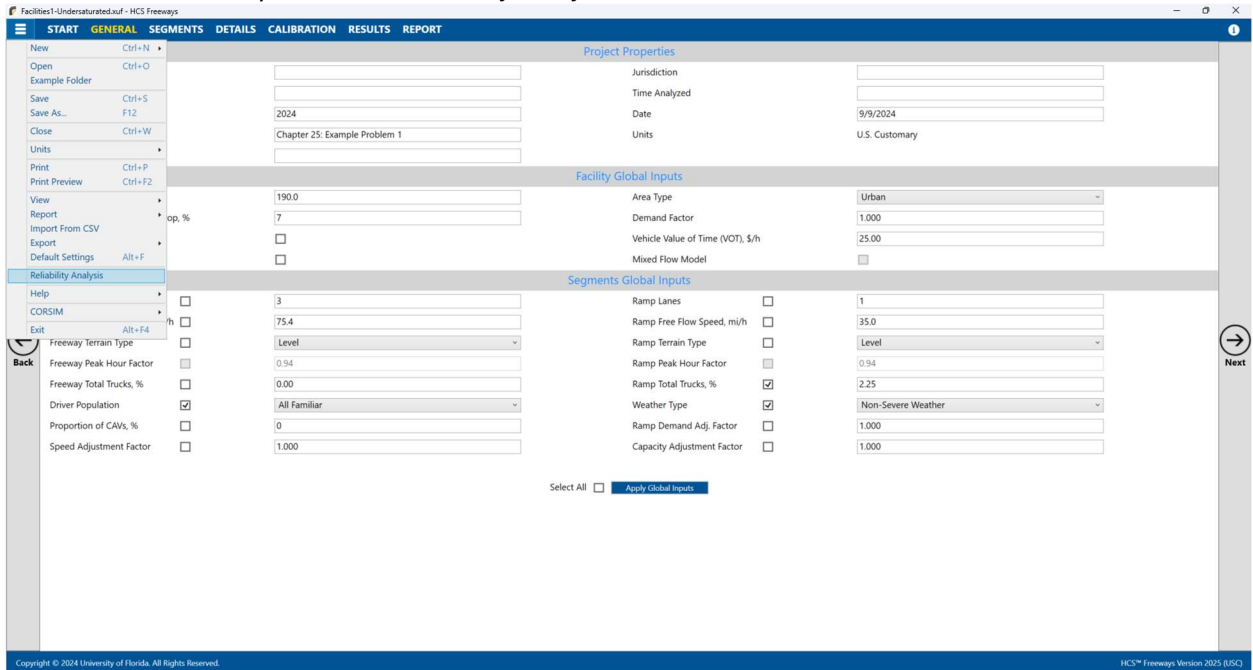


- c. The image of the facility displayed on the Details or Results page will be saved in the folder you specified when saving.

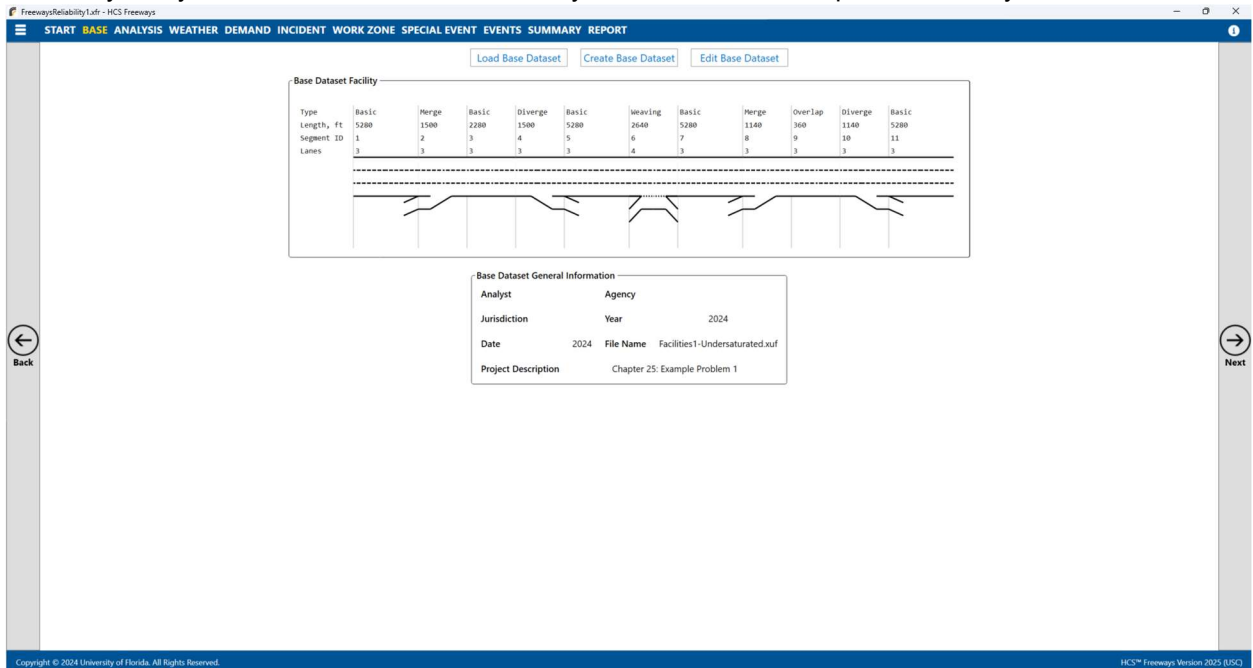


# Run a Reliability Analysis

- To run a reliability analysis, select *File > Reliability Analysis* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting “Reliability Analysis”.  
*Note: A file must be open to run a reliability analysis.*



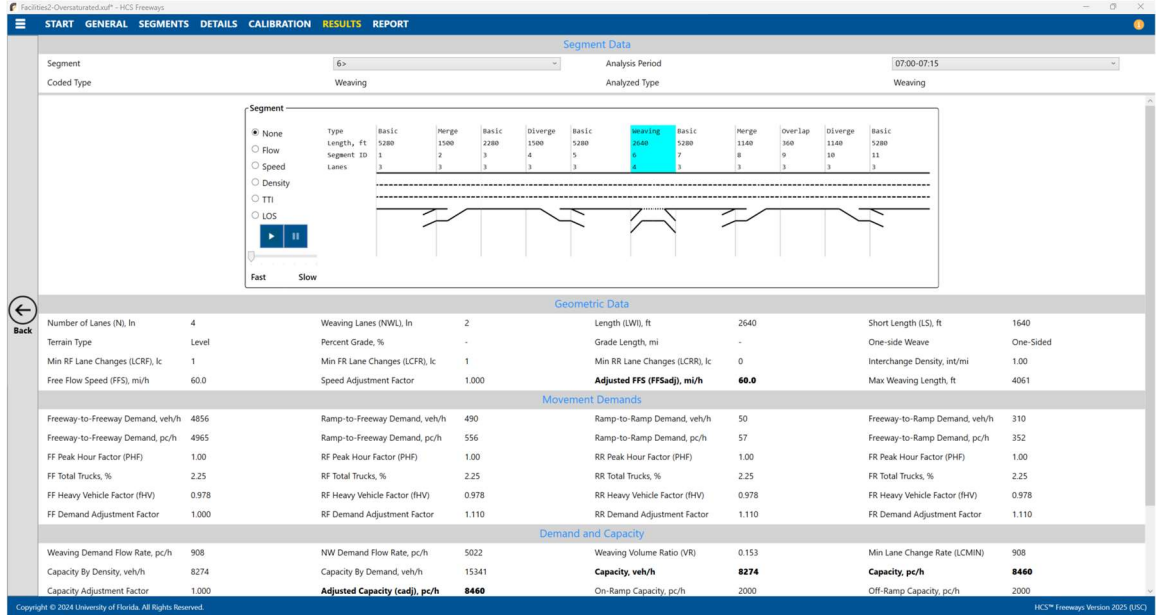
- Running a Reliability analysis from within *HCS Freeways* will bring you to the Base page for a Freeways Reliability analysis with the Base Dataset already loaded with the file open in Freeways.



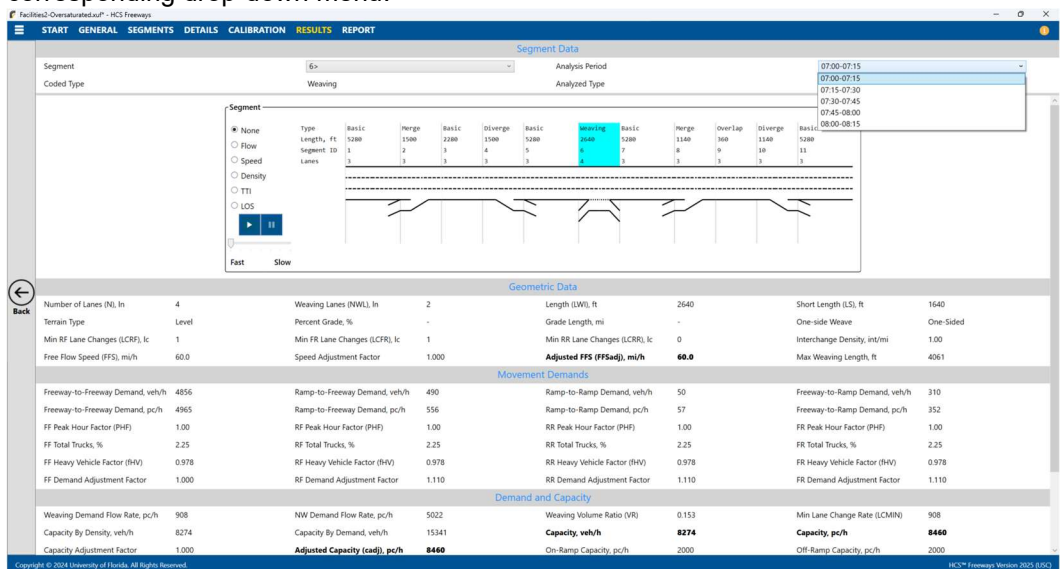
- All other inputs will need to be specified for running the reliability analysis. Please see the *Freeways Reliability User Guide* for more detailed information.

# View Results of the Analysis

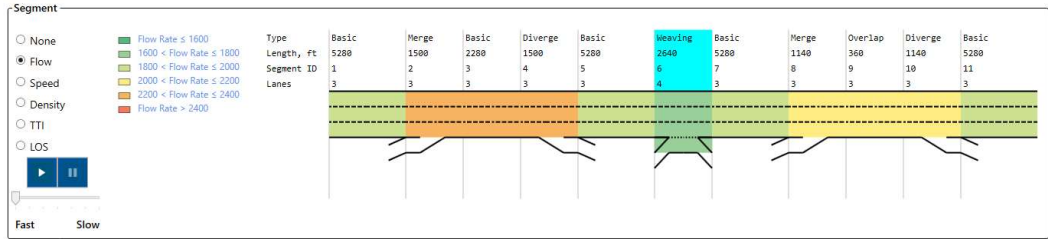
1. After editing all the necessary inputs, results of the analysis can be found in the form of pages for facility analyses, and in the form of reports for both single segment and facility analyses. Reports can be found on the Report page if using Page View or on the results portion of the split screen if using Full View.
2. There are two options for pages: Results and Report
  - a. The Results page is only available for facility analyses. On the Results page, Segment Data, Geometric Data, Demand and Capacity, and Speed and Density sections are provided for each individual segment. Additional sections may be available depending on the segment type or other special cases within the analysis.



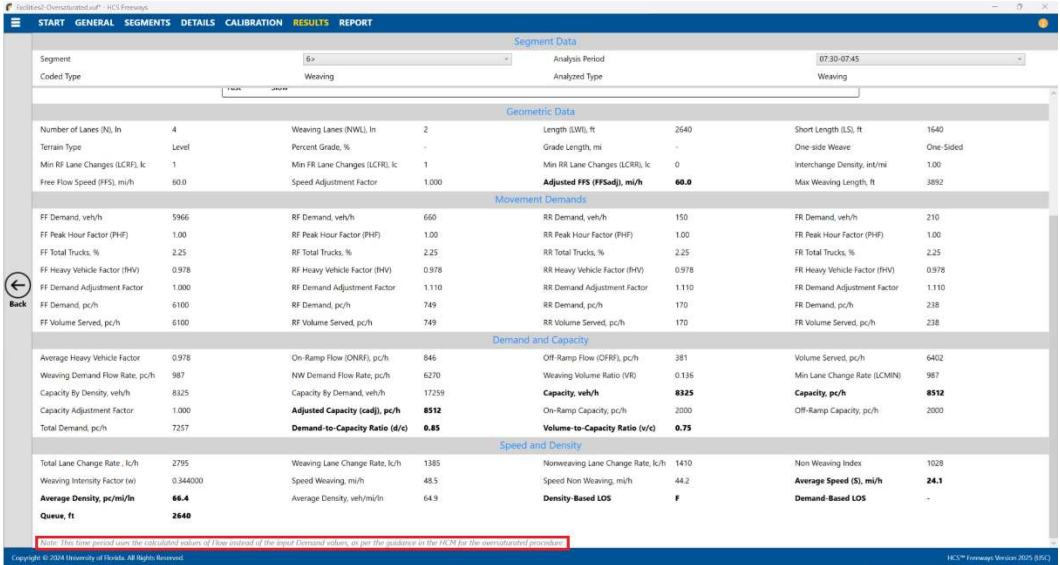
- i. Under the Segment Data, you can specify which segment within the facility to display by selecting the segment number in the drop-down menu or selecting the specific segment in the Segment graph. The analysis period can also be specified by selecting it in the corresponding drop-down menu.



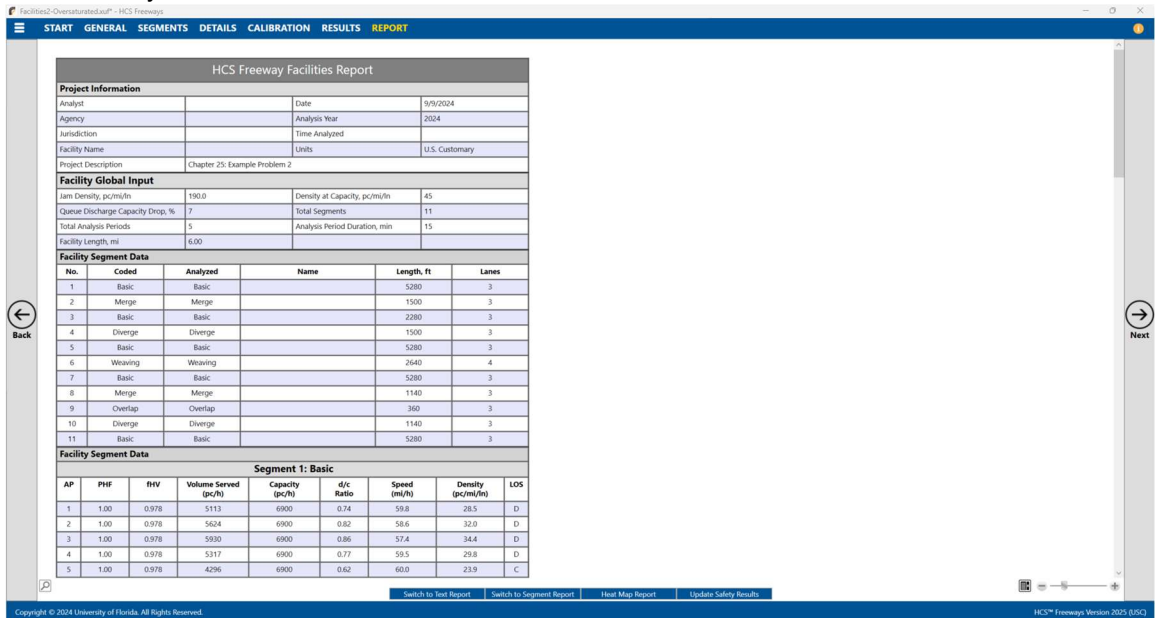
- ii. The Segment graph also gives options to display the facility for the current analysis period by color coding the facility graph based on a selected performance measure.



- iii. If the oversaturated procedure is being used, a note will be displayed at the bottom of the Results page.



- b. The Report page can display a single segment formatted report, single segment text report, facility formatted report, facility text report, or heat map report. Reports available are dependent on the current analysis.

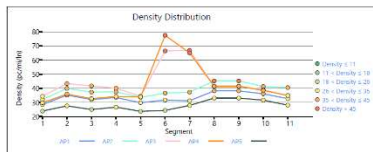
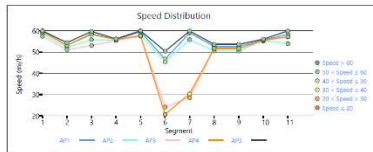
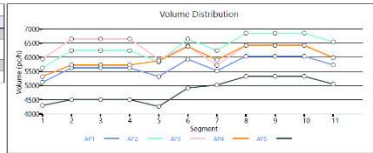




### 3. There are three options for reports: Formatted, Text, and Heat Map

#### a. Formatted reports show the most important results in a presentable format

HCS Freeway Facilities Report											
<b>Project Information</b>											
Analysis	Date	8/31/2022									
Agency	Analysis Year	2022									
Intersection	Time Analyzed										
Facility Name	Link	I-15, Cummins									
Project Description		Chapter 20 Example Problem 2									
<b>Facility Global Input</b>											
Jam Density, pc/mi/ft	1900	Density at Capacity, pc/mi/ft		45.0							
Capacity (Default) Capacity Util., %	7	Total Delay, min		15							
Total Analysis Period	5	Analysis Period Duration, min		15							
Facility Length, mi	6.00										
<b>Facility Segment Data</b>											
No.	Control	Analysis	Name	Length, ft	Lanes						
1	Basic	Basic	5280	3							
2	Merge	Merge	1500	3							
3	Basic	Basic	2280	3							
4	Diverge	Diverge	1500	3							
5	Basic	Basic	5280	3							
6	Weaving	Weaving	2540	4							
7	Basic	Basic	5780	3							
8	Merge	Merge	1140	3							
9	Overlap	Overlap	300	3							
10	Diverge	Diverge	1140	3							
11	Basic	Basic	5280	3							
<b>Facility Segment Data</b>											
Segment 1: Basic											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	0.978	5111	6000	5.74	55.8	28.1	D			
2	1.00	0.978	5624	6000	5.82	56.6	32.0	D			
3	1.00	0.978	5990	6000	5.86	57.4	34.4	D			
4	1.00	0.978	5817	6000	5.77	56.3	29.8	D			
5	1.00	0.978	4766	6000	5.60	60.0	31.8	C			
Segment 2: Merge											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	0.978	5231	6000	5.80	57.0	29.7	D			
2	1.00	0.978	6286	6000	6.00	55.0	37.0	F			
3	1.00	0.978	3710	6000	5.00	60.0	28.5	B			
4	1.00	0.978	3906	6000	5.00	60.0	29.0	B			
5	1.00	0.978	5817	6000	5.80	56.6	29.8	D			
Segment 3: Basic											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
2	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
3	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
4	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
5	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
Segment 4: Diverge											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
2	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
3	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
4	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
5	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
Segment 5: Basic											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
2	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
3	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
4	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
5	1.00	1.00	6319	6319	6.00	55.0	35.0	D			
Segment 6: Weaving											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	0.978	5830	6000	5.75	60.7	31.7	D			
2	1.00	0.978	6645	6000	6.00	57.8	36.8	F			
3	1.00	0.978	6603	6000	6.00	58.1	36.8	F			
4	1.00	0.978	6378	6000	5.80	56.6	32.4	F			
5	1.00	0.978	4911	6000	5.52	60.4	34.4	C			
Segment 7: Basic											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	0.978	5830	6000	5.75	60.7	31.7	D			
2	1.00	0.978	6645	6000	6.00	57.8	36.8	F			
3	1.00	0.978	6603	6000	6.00	58.1	36.8	F			
4	1.00	0.978	6378	6000	5.80	56.6	32.4	F			
5	1.00	0.978	4911	6000	5.52	60.4	34.4	C			
Segment 8: Merge											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	0.978	5231	6000	5.80	57.0	29.7	D			
2	1.00	0.978	6286	6000	6.00	55.0	37.0	F			
3	1.00	0.978	3710	6000	5.00	60.0	28.5	B			
4	1.00	0.978	3906	6000	5.00	60.0	29.0	B			
5	1.00	0.978	5817	6000	5.80	56.6	29.8	D			
Segment 9: Overlap											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	0.978	6031	6000	5.87	52.6	35.0	F			
2	1.00	0.978	6000	6000	6.00	55.0	35.0	F			
3	1.00	0.978	6425	6000	6.00	55.0	35.0	F			
4	1.00	0.978	6447	6000	6.00	55.0	35.0	F			
5	1.00	0.978	3124	6000	5.87	52.6	35.0	D			
Segment 10: Diverge											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	0.978	6031	6000	5.87	52.6	35.0	F			
2	1.00	0.978	6000	6000	6.00	55.0	35.0	F			
3	1.00	0.978	6425	6000	6.00	55.0	35.0	F			
4	1.00	0.978	6447	6000	6.00	55.0	35.0	F			
5	1.00	0.978	3124	6000	5.87	52.6	35.0	D			
Facility Overall Results											
AP	PHF	RHV	Volume Served (pc/h)	Capacity (pc/h)	4/c Ratio	Speed (mi/h)	Density (pc/mi/ft)	LOS			
1	1.00	0.978	5830	6000	5.75	60.7	31.7	D			
2	1.00	0.978	6645	6000	6.00	57.8	36.8	F			
3	1.00	0.978	6603	6000	6.00	58.1	36.8	F			
4	1.00	0.978	6378	6000	5.80	56.6	32.4	F			
5	1.00	0.978	4911	6000	5.52	60.4	34.4	C			
6	1.00	0.978	5830	6000	5.75	60.7	31.7	D			
7	1.00	0.978	6645	6000	6.00	57.8	36.8	F			
8	1.00	0.978	6603	6000	6.00	58.1	36.8	F			
9	1.00	0.978	6378	6000	5.80	56.6	32.4	F			
10	1.00	0.978	4911	6000	5.52	60.4	34.4	C			
11	1.00	0.978	5830	6000	5.75	60.7	31.7	D			
Total VMT, veh-mi			41619			Total VMT, veh-h			14612		
Value of Time (VOT), \$/h			2030			Total Delay Cost, \$			335814		
<b>Messages</b>											
WARNING 1: Unanalyzed conditions currently exist on boundary segment 11. Results may not be reliable. Consider analyzing segments 11 (up and/or down) before the analysis.											
<b>Comments</b>											



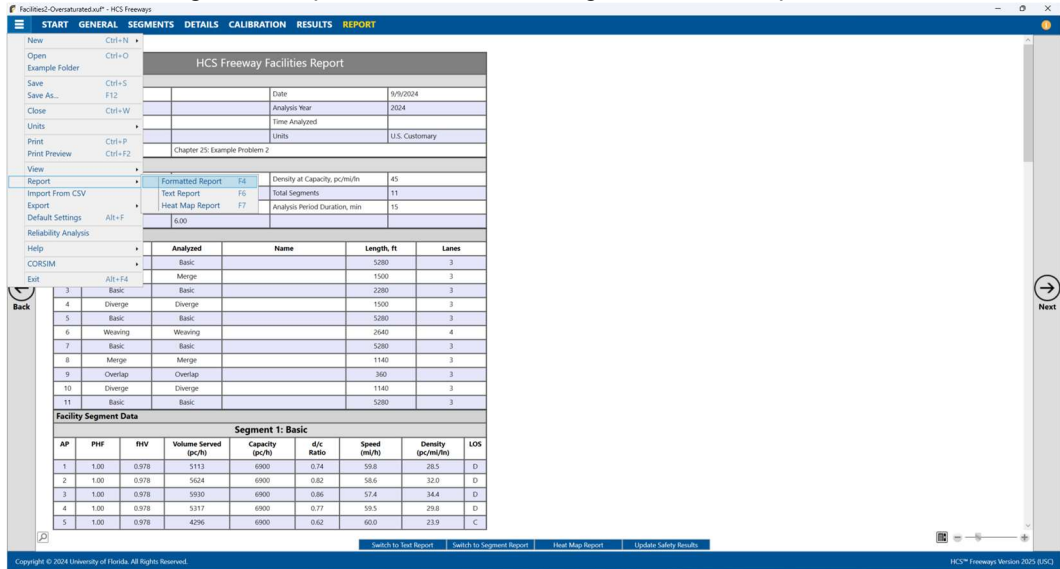




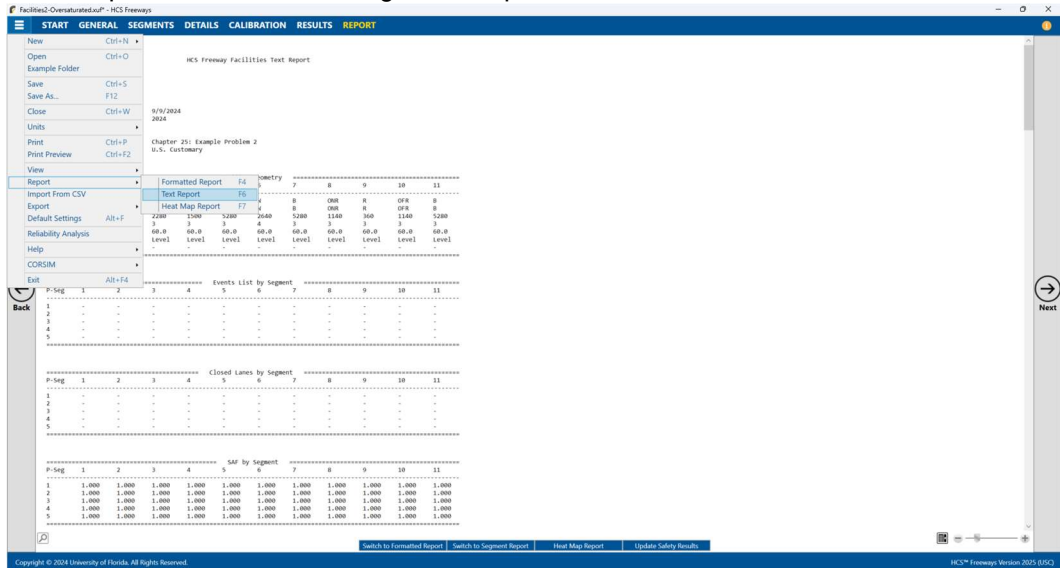
4. The type of report displayed can be changed by using the main menu items, keyboard shortcuts, or toggle buttons found under the report

a. Main Menu Items

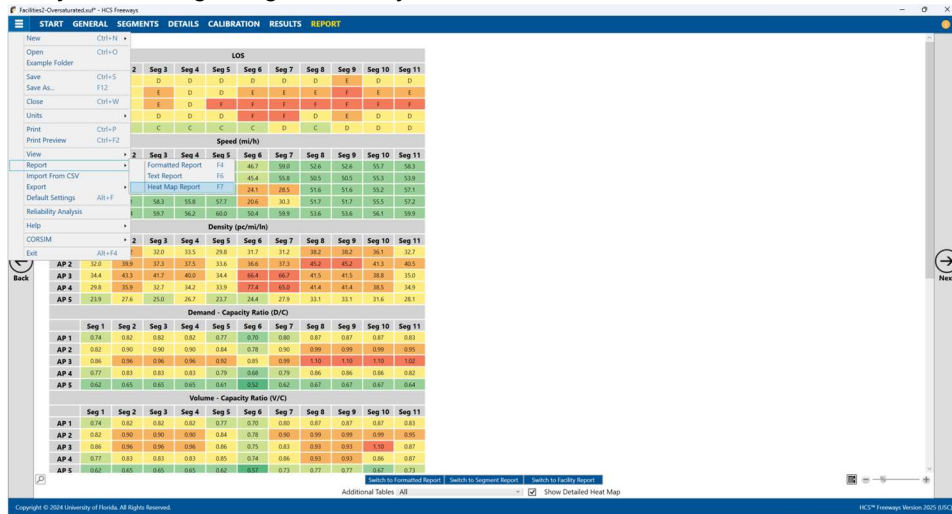
i. To switch to the Formatted Report, select *File > Report > Formatted Report* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen, hovering over “Report”, and then selecting “Formatted Report”.



ii. To switch to the Text Report, select *File > Report > Text Report* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen, hovering over “Report”, and then selecting “Text Report”.



- iii. To switch to the Heat Map Report, select *File > Report > Heat Map Report* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen, hovering over “Report”, and then selecting “Heat Map Report”. *Note: Heat Map Report is only available for facility analyses. The menu item is removed when the current analysis is a single segment analysis.*

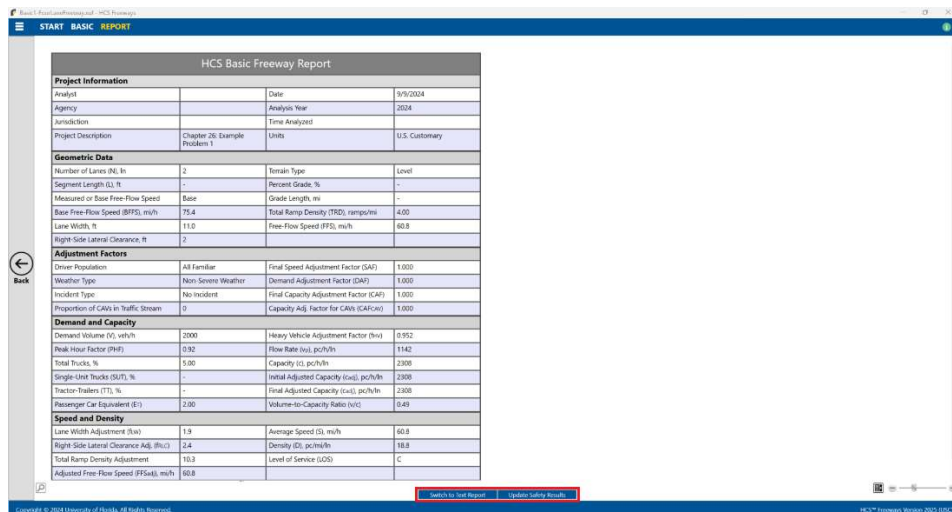


b. Keyboard Shortcuts

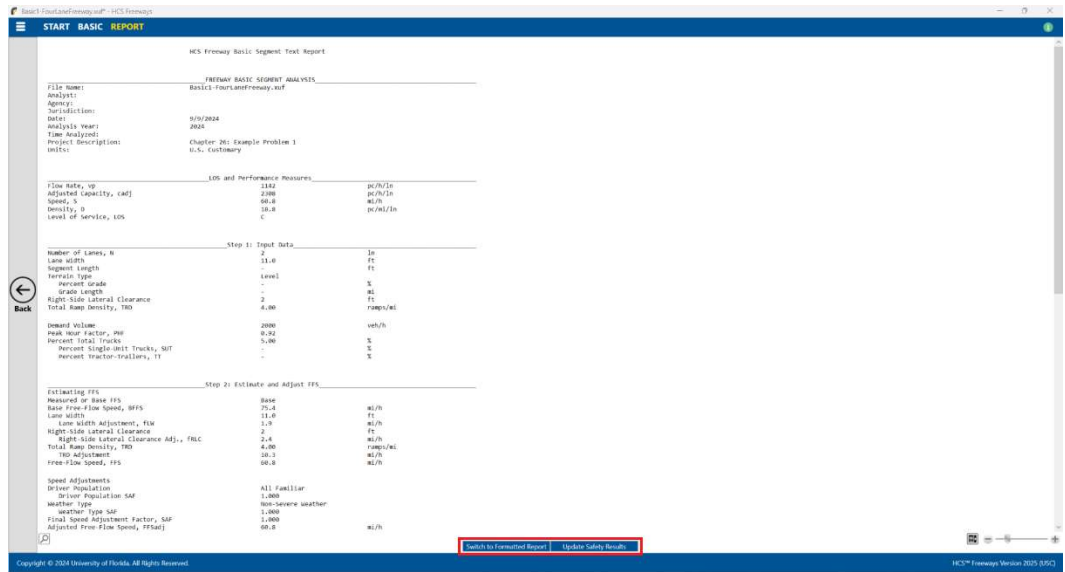
- i. Formatted Report: keyboard shortcut is “F4”
- ii. Text Report: keyboard shortcut is “F6”
- iii. Heat Map Report: keyboard shortcut is “F7”; *Note: Heat Map Report is only available for facility analyses. The keyboard shortcut does not work when the current analysis is a single segment analysis.*

c. Report Toggle Buttons

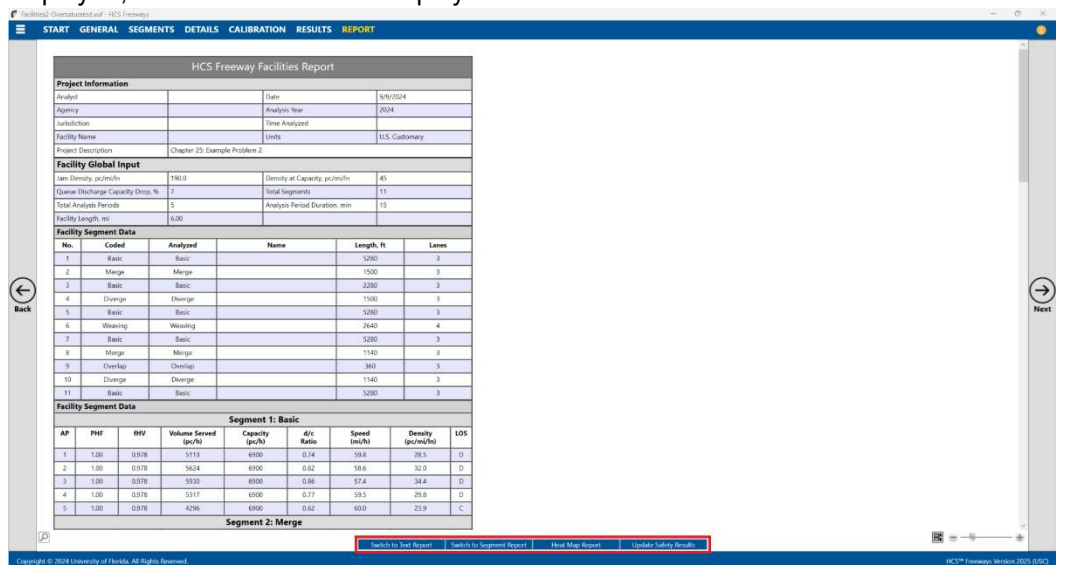
- i. Whether viewing the report in Page View or Full View, a toggle button(s) will be available at the bottom of the screen underneath the report.
- ii. If a single segment analysis is the current analysis and the formatted report is currently being displayed, a toggle button will be displayed and will say “Switch to Text Report” which will allow you to display the text report if clicked. If safety results are set in the *Default Settings* to show on the reports, an additional “Update Safety Results” button will be available to update the safety results on the report when changes are made to any inputs.



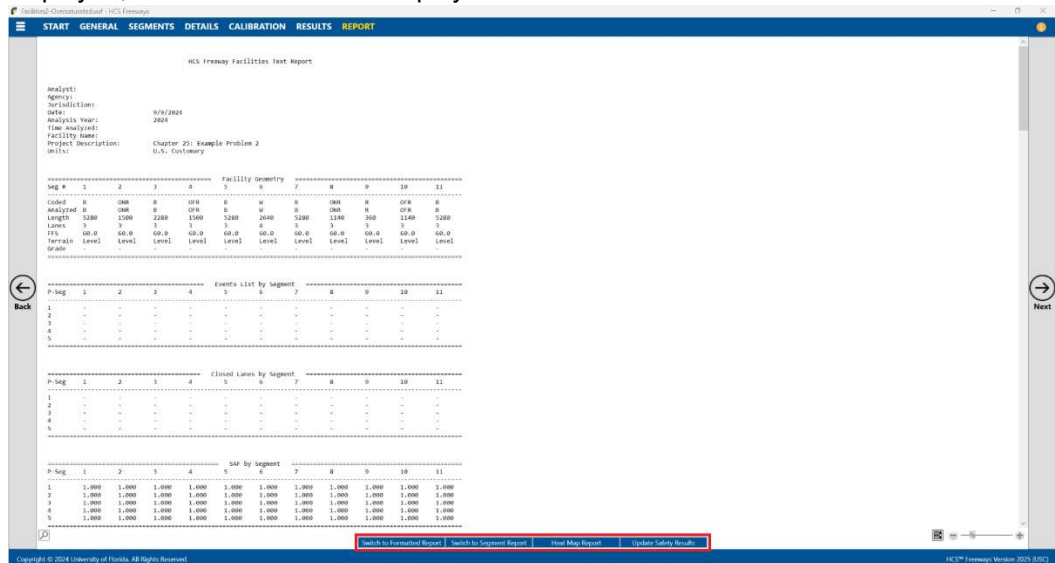
- iii. If a single segment analysis is the current analysis and the text report is currently being displayed, a toggle button will be displayed and will say “Switch to Formatted Report” which will allow you to display the formatted report if clicked. If safety results are set in the *Default Settings* to show on the reports, an additional “Update Safety Results” button will be available to update the safety results on the report when changes are made to any inputs.



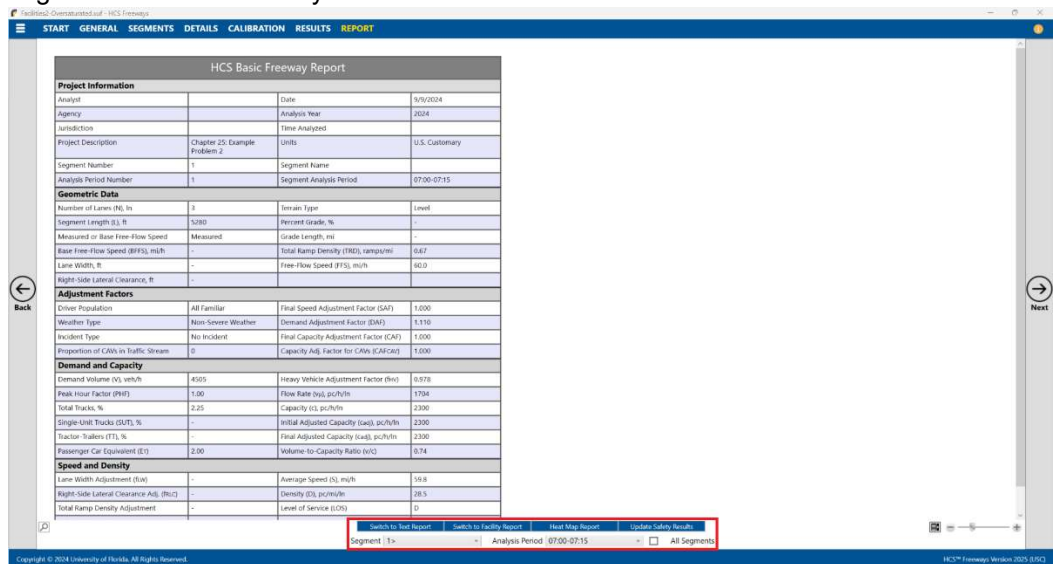
- iv. If a facility analysis is the current analysis and the facility formatted report is currently being displayed, a few buttons will be displayed.



1. One button will say “Switch to Text Report” which will allow you to display the facility text report if clicked.
  2. The second button will say “Switch to Segment Report” which will allow you to display the single segment formatted report if clicked. It will also bring up two drop down menus; one for Segment and one for Analysis Period. This will allow you to display the report for specific segments within the facility and for specific analysis periods.
  3. The third button will say “Heat Map Report” which will allow you to display the facility heat map report if clicked. This will add a drop-down menu for Additional Tables which will allow you to add more heat map tables for different performance measures to display. A ‘Show Detailed Heat Map’ checkbox will also be available to specify if a detailed heat map is desired. When checked, values will be shown in each individual cell. When unchecked, a legend will be provided and each of the heat map tables will only show colored cells without values inside.
  4. If safety results are set in the *Default Settings* to show on the reports, an additional “Update Safety Results” button will be available to update the safety results on the report when changes are made to any inputs.
- v. If a facility analysis is the current analysis and the facility text report is currently being displayed, a few buttons will be displayed.



1. One button will say “Switch to Formatted Report” which will allow you to display the facility formatted report if clicked.
  2. The second button will say “Switch to Segment Report” which will allow you to display the single segment text report if clicked. It will also bring up two drop down menus; one for Segment and one for Analysis Period. This will allow you to display the report for specific segments within the facility and for specific analysis periods.
  3. The third button will say “Heat Map Report” which will allow you to display the facility heat map report if clicked. This will add a drop-down menu for Additional Tables which will allow you to add more heat map tables for different performance measures to display. A ‘Show Detailed Heat Map’ checkbox will also be available to specify if a detailed heat map is desired. When checked, values will be shown in each individual cell. When unchecked, a legend will be provided and each of the heat map tables will only show colored cells without values inside.
  4. If safety results are set in the *Default Settings* to show on the reports, an additional “Update Safety Results” button will be available to update the safety results on the report when changes are made to any inputs.
- vi. If a facility analysis is the current analysis and the segment formatted report is currently being displayed, a few buttons along with two drop down menus and an ‘All Segments’ checkbox will be displayed. The two drop down menus allow you to specify the specific segment within the facility and specific analysis period to display in the current report. The ‘All Segments’ checkbox allows you to display the individual segment reports for all segments within the facility.





1. One button will say “Switch to Formatted Report” which will allow you to display the segment formatted report if clicked. This will also add an ‘All Segments’ checkbox for you to display individual segment reports for all segments within the facility.
  2. The second button will say “Switch to Facility Report” which will allow you to display the facility text report if clicked. This will also remove the two drop down menus.
  3. The third button will say “Heat Map Report” which will allow you to display the facility heat map report if clicked. This will remove the two drop down menus and checkboxes; however, it will add another drop-down menu for Additional Tables which will allow you to add more heat map tables for different performance measures to the display. A ‘Show Detailed Heat Map’ checkbox will also be available to specify if a detailed heat map is desired. When checked, values will be shown in each individual cell. When unchecked, a legend will be provided and each of the heat map tables will only show colored cells without values inside.
  4. If safety results are set in the *Default Settings* to show on the reports, an additional “Update Safety Results” button will be available to update the safety results on the report when changes are made to any inputs.
- viii. If a facility analysis is the current analysis and the heat map report is currently being displayed, a few buttons along with one drop down menu and a ‘Show Detailed Heat Map’ checkbox will be displayed. The drop-down menu allows you to change/add more heat map tables for different performance measures to the display. The ‘Show Detailed Heat Map’ checkbox will allow you to change how values are shown on the heat map. Checking ‘Show Detailed Heat Map’ will display the actual values of the performance measure results in each cell. Unchecking ‘Show Detailed Heat Map’ will remove the values of the performance measure results from each cell. Instead, a legend will be provided at the top of the heat map to indicate the range of values for each color of each performance measure.

The screenshot displays the HCM3 Freeway software interface in the 'REPORT' tab. The report is organized into several sections, each with a table of data across 11 segments (Seg 1 to Seg 11). The sections are:

- LOS**: A table with 5 rows (AP 1 to AP 5) and 11 columns (Seg 1 to Seg 11). Values are mostly 'D' or 'F'.
- Speed (mi/h)**: A table with 5 rows (AP 1 to AP 5) and 11 columns (Seg 1 to Seg 11). Values range from approximately 34.4 to 60.8.
- Density (pc/mi/ln)**: A table with 5 rows (AP 1 to AP 5) and 11 columns (Seg 1 to Seg 11). Values range from approximately 29.8 to 34.4.
- Demand - Capacity Ratio (D/C)**: A table with 5 rows (AP 1 to AP 5) and 11 columns (Seg 1 to Seg 11). Values range from approximately 0.74 to 0.96.
- Volume - Capacity Ratio (V/C)**: A table with 5 rows (AP 1 to AP 5) and 11 columns (Seg 1 to Seg 11). Values range from approximately 0.74 to 0.96.

At the bottom of the interface, there is a control bar with the following elements:

- Buttons: "Switch to Formatted Report", "Switch to Facility Report", "Switch to Segment Report", "Update Safety Results".
- A dropdown menu for "Additional Tables" currently set to "All".
- A checkbox for "Show Detailed Heat Map" which is currently checked.



1. One button will say “Switch to Formatted Report” which will allow you to display the formatted report if clicked.
2. The second button will say “Switch to Segment Report” or “Switch to Facility Report” depending on which report was displayed last before switching to the heat map report. Clicking “Switch to Segment Report” will allow you to display the single segment formatted report. Clicking “Switch to Facility Report” will allow you to display the facility formatted report.
3. The third button will say “Switch to Segment Report” or “Switch to Facility Report” depending on what is shown for the second button. Clicking “Switch to Segment Report” will allow you to display the single segment formatted report. Clicking “Switch to Facility Report” will allow you to display the facility formatted report.
4. If safety results are set in the *Default Settings* to show on the reports, an additional “Update Safety Results” button will be available to update the safety results on the report when changes are made to any inputs.
5. The magnification of the report currently being displayed can be changed using the zoom slider found at the bottom right-hand corner of the screen.

**Project Information**

Analyst		Date	9/5/2024
Agency		Analysis Year	2024
Jurisdiction		Time Analyzed	
Facility Name		Units	U.S. Customary
Project Description	Chapter 25: Example Problem 2		

**Facility Global Input**

Jam Density, pc/mi/ln	190.0	Density at Capacity, pc/mi/ln	45
Queue Discharge Capacity Drop, %	7	Total Segments	11
Total Analysis Periods	5	Analysis Period Duration, min	15
Facility Length, mi	6.00		

**Facility Segment Data**

No.	Coded	Analyzed	Name	Length, ft	Lanes
1	Basic	Basic		5280	3
2	Merge	Merge		1500	3
3	Basic	Basic		2280	3
4	Diverge	Diverge		1500	3
5	Basic	Basic		5280	3
6	Weaving	Weaving		2640	4
7	Basic	Basic		5280	3
8	Merge	Merge		1140	3
9	Overlap	Overlap		360	3
10	Diverge	Diverge		1140	3
11	Basic	Basic		5280	3

**Facility Segment Data**

**Segment 1: Basic**

AP	PHF	H/V	Volume Served (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	1.00	0.978	5113	6500	0.74	59.8	28.5	D
2	1.00	0.978	5624	6500	0.82	58.6	32.8	D
3	1.00	0.978	5930	6500	0.86	57.4	34.4	D
4	1.00	0.978	5317	6500	0.77	59.5	29.8	D
5	1.00	0.978	4296	6500	0.62	60.0	23.8	C

**Segment 2: Merge**

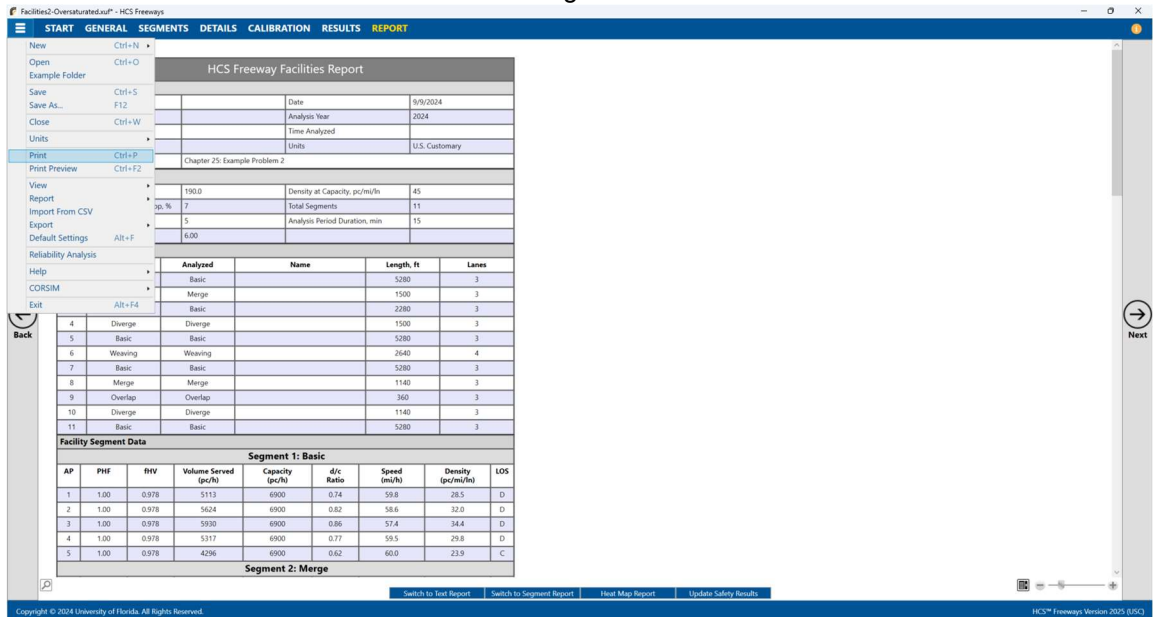
- a. To zoom in, drag the slider to the right; to zoom out, drag the slider to the left
- b. Clicking the plus (+) button will zoom in; clicking the minus (-) button will zoom out
- c. Holding down “ctrl” on the keyboard and scrolling up on the mouse wheel will zoom in; holding “ctrl” on the keyboard and scrolling down on the mouse wheel will zoom out



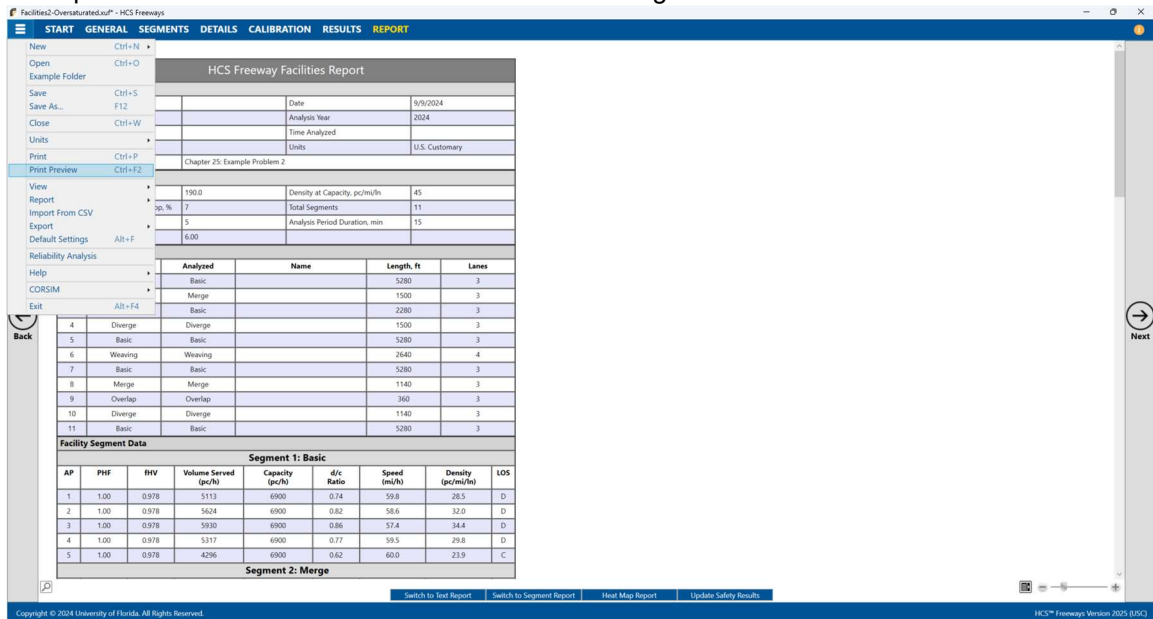
# Print a Report

1. There are four options for printing a report:

a. Selecting *File > Print* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting “Print”



b. Selecting *File > Print Preview* from the main menu; this can be found by selecting the three lines in the top left-hand corner of the screen and then selecting “Print Preview”

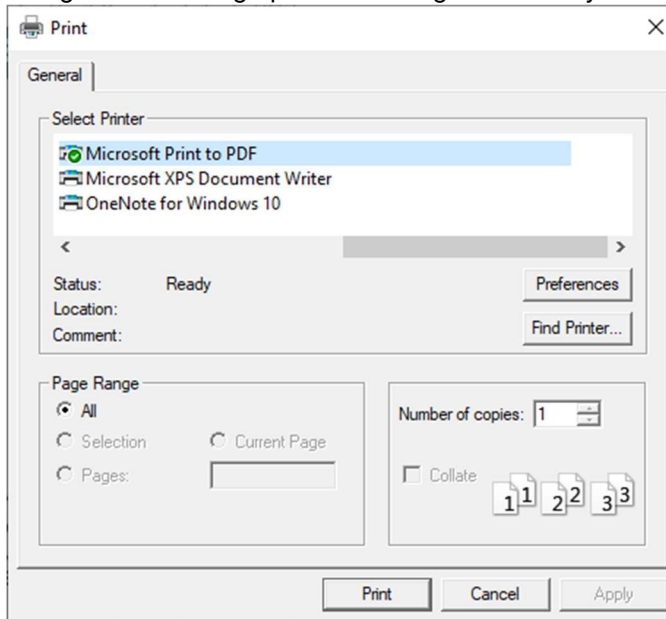


c. Using keyboard shortcut “Ctrl+P” for Print

d. Using keyboard shortcut “Ctrl+F2” for Print Preview

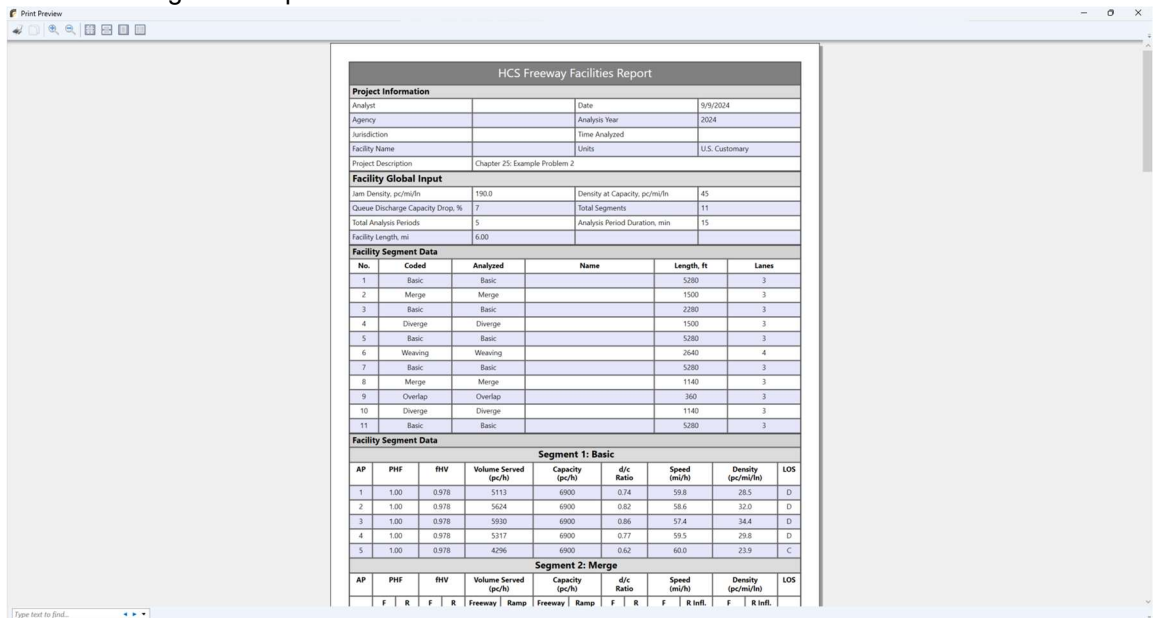
## 2. Print

- a. Using Print will bring up a Print dialog box where you can select which printer to print to



## 3. Print Preview

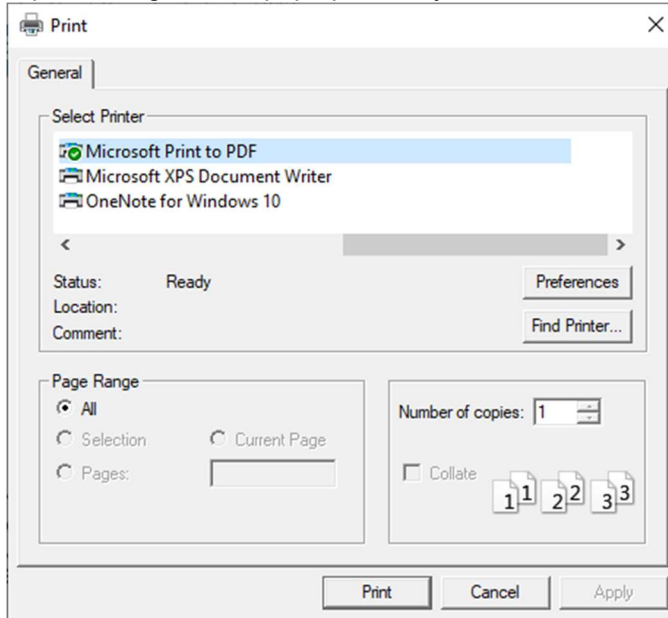
- a. Using Print Preview will bring up a window where you can view how the report will look on paper before sending it to the printer



- b. The print icon in the toolbar found in the top left-hand corner can then be selected



c. A print dialog box will pop up where you can select which printer to print to



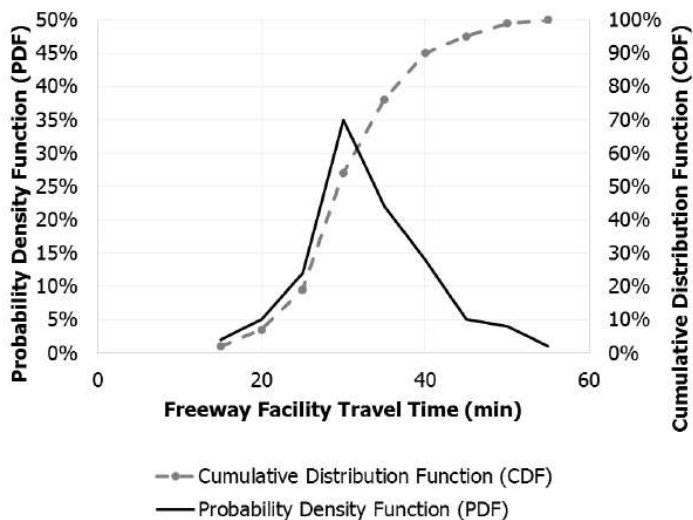
# Glossary of Terms

## 50<sup>th</sup> Percentile Travel Time Index

50<sup>th</sup> Percentile Travel Time Index ( $TTI_{50}$ ) describes the median of the TTI distribution. This can be a useful measure and is less influenced by outliers than the mean.

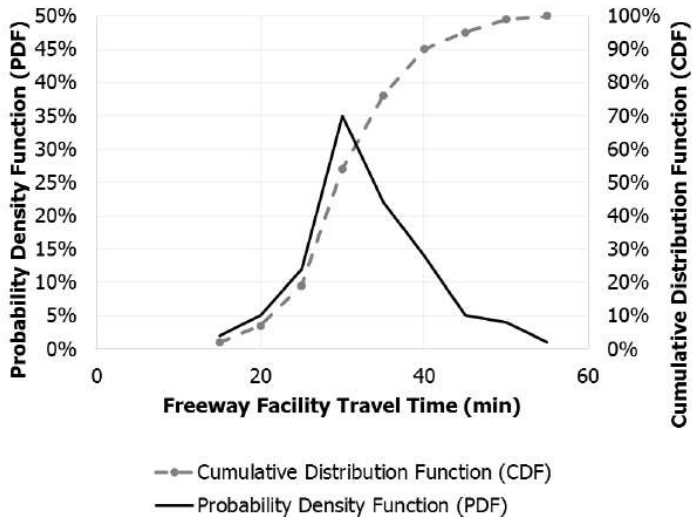
## 80<sup>th</sup> Percentile Travel Time Index

The 80<sup>th</sup> Percentile Travel Time Index ( $TTI_{80}$ ) has been found to be more sensitive to operational changes than the  $TTI_{95}$ , which makes it useful for strategy comparison and prioritization purposes. In the exhibit found below, the 80<sup>th</sup> percentile travel time is approximately 36 minutes, thus the 80<sup>th</sup> percentile TTI is  $36/15 = 2.4$ .



## 95<sup>th</sup> Percentile Travel Time Index

The 95<sup>th</sup> Percentile Travel Time Index ( $TTI_{95}$ ) is also referred to as the planning time index (PTI) and is a useful measure for estimating the added time travelers must budget to ensure an on-time arrival with “failure” limited to one trip per month. In the exhibit found below, the 95<sup>th</sup> percentile travel time is 45 min, compared to a free-flow travel time of 15 min; thus,  $TTI_{95} = 3.0$ . The planning time is the difference between the 95<sup>th</sup> percentile and free-flow travel times, or 30 min.

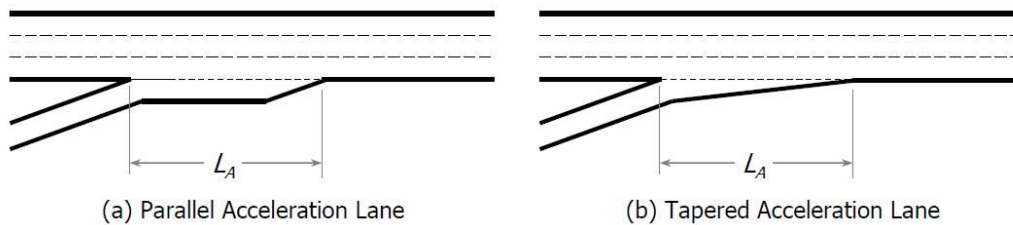


## AADT

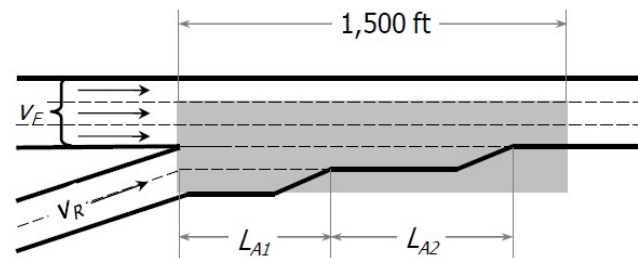
The Annual Average Daily Traffic in one direction.

## Acceleration Lane Length

This value defines the length for on-ramp acceleration lanes. The typical length of acceleration lanes for ramps should be obtained from the design standards used by the highway operation agency. It is measured from the intersection of the edge of the travel way for the freeway and the ramp (the first point) and the downstream merge point of the freeway and ramp edges of the travel way (the second point). The default value is 800 feet (or 243.8 meters in metric).



The exhibit below illustrates the geometry of a typical two-lane ramp-freeway junction. It is characterized by two separate acceleration lanes, each successively forcing merging maneuvers to the left.



For two-lane ramps, the effective acceleration length must be calculated by the user based on the lengths of the two lanes. In all equations using the length of the acceleration lane  $L_A$ , this value is replaced by the effective length of both acceleration lanes  $L_{Aeff}$ . The formula for calculating effective acceleration length is:

$$L_{Aeff} = 2 * L_{A1} + L_{A2}$$

where

$L_{Aeff}$  = Effective acceleration length,

$L_{A1}$  = Length of the shorter acceleration lane, and

$L_{A2}$  = Difference in length between the longer acceleration lane and the shorter acceleration lane

In merge and diverge areas, the capacity of the two outer lanes is reduced by 100 and 200 veh/h/ln, respectively. When the user sets the acceleration lanes to 1500 feet (or 457.2 meters in metric), only the outer lane of the merge experiences a capacity reduction, as opposed to normally both of the outer two lanes.

## ACR

The facility AADT divided by its two-way hourly capacity; this value is used in the computation of *CR*, which is the crash rate per 100 million VMT (or 161 million VkmT in metric).

See also *Highway Economic Requirements System (HERS)*.

## Add Analysis Period

Clicking on the button 'Add Analysis Period' will add a new analysis period after the last analysis period along with the default values for each of the segment types. The user can add an unlimited number of analysis periods and can manually change the inputs to the desired values.

## Add Section

Clicking on the button 'Add Section' will add rows of inputs with default Section Types of 'Freeway Section' and 'On-Ramp' along with the corresponding default values. The user can add an unlimited number of sections and can manually change the inputs to the desired values.

## Add Segment

Clicking on the button 'Add Segment' will add a row of inputs with the Segment Type of 'Basic' along with the default values for the Basic segment type. The user can add an unlimited number of segments and can manually change the inputs to the desired values.

## Adjacent Ramp

If a ramp exists upstream or downstream of the analysis ramp and is close enough to affect the ramp-freeway merge or diverge operations, then an adjacent ramp exists. An adjacent ramp can be either upstream or downstream of the analysis ramp. The adjacent ramp must be defined as either a Merge or Diverge.

## Agency

This field is provided to document the agency or company associated with this analysis or project.

## Analysis Direction

The direction of the freeway being studied (e.g., Northbound)

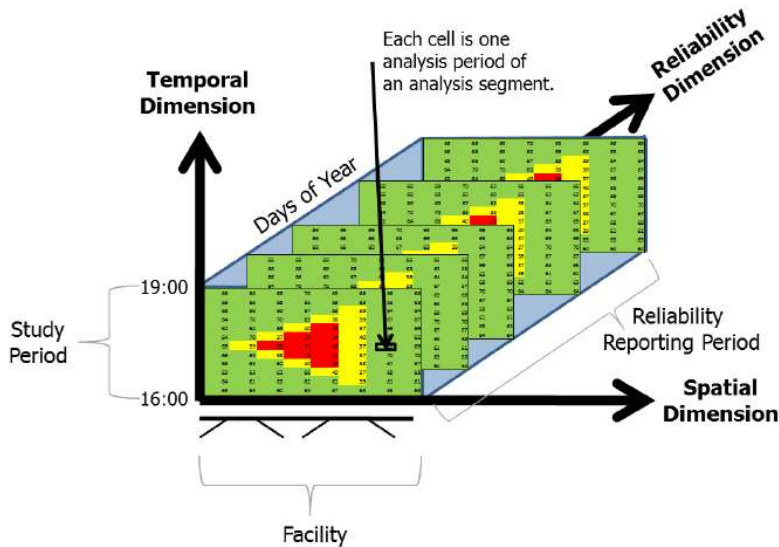
## Analysis Period

*Freeways Analysis*

The time frame for which the traffic demand on the freeway is being studied; a single analysis period (for example, the peak 15 min of the peak hour) during which a capacity analysis is performed on a system element.

## Reliability Analysis

The time interval evaluated by a single application of an HCM methodology (15 min for the freeway facility core methodology). In the exhibit found below, there are 12 such analysis period for the facility, represented by the rows in the rectangles. Each cell in a rectangle represents a single analysis period for a single analysis segment.

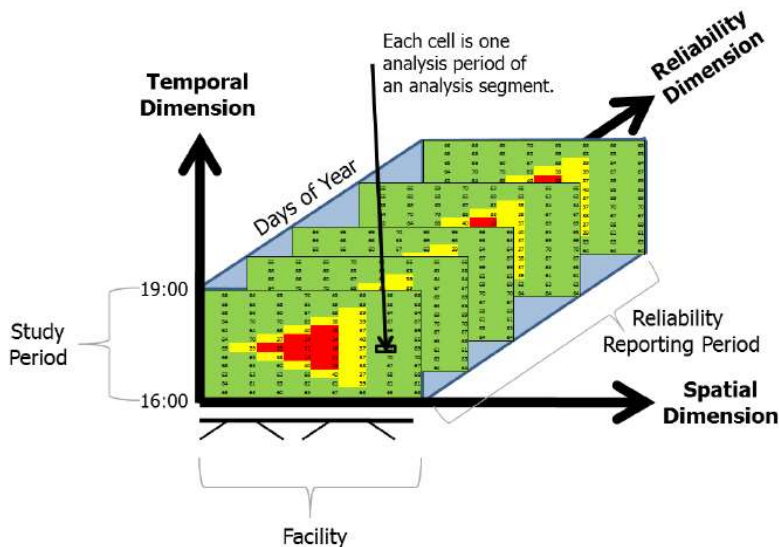


## Analysis Period Start Time

This is the time specified, in HH:MM, for the beginning of the analysis period.

## Analysis Segment

An HCM freeway segment (e.g., basic, merge, diverge, weaving) as described in Chapters 12 through 14. Each column in the exhibit found below represents an analysis segment.



## Analysis Year

This field is provided to document the year for which the analysis is being performed

## Analyst

This field is provided to document the name of the analyst.

## Analyzed Type

In Freeway Facilities, Analyzed Type is the Segment Type analyzed regardless of what was coded by the user. For example, if there is a Merge segment coded with a lane addition, the coded Merge segment will be analyzed as a Basic segment.

## Apply Global Inputs

Clicking on the button 'Apply Global Inputs' will apply any input that is checked under the 'Segments Global Inputs' section to the entire facility.

## Area Type

There are two area types: urban areas and rural areas. Urban areas are typified by high development densities or concentrations of population. Rural areas are areas with widely scattered development and low housing and employment densities. Generally, the entire length of the facility needs to be assigned the same area type.

LOS criteria for an urban and rural freeway facility are shown in the exhibit below:

<b>Freeway Facility Density (pc/mi/ln)</b>		
<b>LOS</b>	<b>Urban</b>	<b>Rural</b>
A	≤11	≤6
B	>11–18	>6–14
C	>18–26	>14–22
D	>26–35	>22–29
E	>35–45	>29–39
F	>45 or any component segment $v_d/c$ ratio > 1.00	>39 or any component segment $v_d/c$ ratio > 1.00

Urban LOS thresholds are the same density-based criteria used for basic freeway segments. Studies on LOS perception by rural travelers indicate the presence of lower density thresholds when compared with their urban freeway counterparts. The average LOS applies to a specific analysis period, usually 15 min.

LOS criteria for an urban and rural freeway facility in metric units are shown below:

<b>Freeway Facility Density (pc/km/ln)</b>		
<b>LOS</b>	<b>Urban</b>	<b>Rural</b>
A	≤7	≤4
B	>7-11	>4-9
C	>11-16	>9-14
D	>16-22	>14-18
E	>22-28	>18-24
F	>28 or any component segment $v_d/c$ ratio > 1.00	>24 or any component segment $v_d/c$ ratio > 1.00



## Average Speed

For Basic Freeway and Freeway Weaving Segments, Average Speed is the mean speed of the traffic stream under base conditions, in miles per hour. For the Basic segment procedure, the following equations are used to determine average speed:

$$S = FFS_{adj} \quad v_p \leq BP$$
$$S = FFS_{adj} - \frac{\left( FFS_{adj} - \frac{c_{adj}}{D_c} \right) (v_p - BP)^a}{(c_{adj} - BP)^a} \quad BP < v_p \leq c$$

where

- $S$  = Space mean speed of the traffic stream (mi/h),
- $FFS_{adj}$  = Adjusted free-flow speed (mi/h),
- $c_{adj}$  = Adjusted segment capacity (pc/h/ln),
- $D_c$  = Density at capacity (pc/mi/ln),
- $v_p$  = Demand flow rate under equivalent base conditions (pc/h/ln),
- $BP$  = Breakpoint (pc/h/ln), and
- $a$  = Exponent calibration parameter (decimal).

For metric units, Average Speed is measured in kilometers per hour.

## Barrier Type

There are two barrier types: concrete and hard barrier separation; and cone, plastic drum, or other soft barrier separation.

The barrier type indicator variable,  $f_B$ , can largely be interpreted as being synonymous with the distinction of short-term versus long-term work zones, with longer-term work zones more likely to be configured using concrete barriers. In research, the barrier type was found to be more-clearly defined and more-readily applied than the distinction of short-term and long-term work zone effects. For long-term work zones, there may be a learning effect for drivers that increases capacities over time, but no conclusive evidence for this effect was found in the research.

## Base Free-Flow Speed

The methodology covers basic freeway segments with a FFS in the range of 55 to 75 mi/h (or 88.5 to 120.7 km/h in metric). The predictive algorithm for free flow speed therefore starts with a value greater than 75 mi/h (or 120.7 km/h in metric), specifically a default base FFS of 75.4 mi/h (121.3 km/h in metric), which resulted in the most accurate predictions in the underlying research. The adjusted free-flow speed is determined by subtracting each speed adjustment from the base free-flow speed.

## Base Dataset

In a reliability analysis, the base dataset provides all the required input data for the freeway facilities core methodology described in HCM Chapter 10. Some data are specific to the freeway facility being studied. These include, at a minimum, all segment geometries (both general purpose and managed lanes, if applicable), free-flow speed, lane patterns, and segment type, along with base demands that are typically, but not necessarily, reflective of average (AADT) conditions. In addition, the base dataset contains the required input data to execute HCM Chapter 11's reliability methodology. These data include a demand multiplier matrix, weather, work zones, and incident events as described later in this section. The majority of the reliability-specific input data can be defaulted when they are not available locally, but the analyst is encouraged to supply facility-specific data whenever feasible.

The user has the option to load a base dataset or create a base dataset. Clicking on 'Load Base Dataset' will open a dialog box to allow the user to select a Freeways Facility (\*.xuf) file for the user to open and load into the Freeways Reliability program. Once loaded, a facility graphic of the base dataset will be displayed on the page, along with general information. Clicking on 'Create Base Dataset' will open the HCS Freeways program to allow the user to create a new base dataset for use in the Freeways Reliability program.

## Base Dataset Date

This specifies the date of the base dataset. A base scenario is always required and is used to describe base conditions (particularly demand and factors influencing capacity and free-flow speed). The base scenario is intended to represent average demand conditions (e.g., annual average daily traffic, AADT), or the demand measured on a specific day. HCM Chapter 11's methods factor these demands on the basis of user-supplied or defaulted demand patterns to generate demands representative of all other analysis periods during the reliability reporting period.

## Base Scenario (Seed File)

A set of parameters representing the facility's calibrated operating conditions during one study period. All other scenarios are developed by adjusting the base scenario's inputs to reflect the effects of varying demand, weather, incidents, work zones, or a combination of these that occur in other study periods. When the methodology is executed using a computational engine, the base scenario's parameters become inputs to the seed file used by the engine.

## Basic Freeway Segment

A length of freeway facility whose undersaturated operations are unaffected by weaving, diverging, or merging. Basic Freeway Segments are denoted as "B".

## Capacity

The maximum sustainable hourly flow rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given analysis period under prevailing roadway, environmental, traffic, and control conditions.

## Capacity Adjustment Factor (CAF)

Factor used to allow the user to adjust the capacity for reduced-capacity situations or to match field measurements. The capacity in any cell of the time-space domain can be reduced to represent incident situations such as construction and maintenance activities, adverse weather, traffic accidents, and vehicle breakdowns.

## CAVs

Connected and automated vehicles, or CAVs, integrate two separate types of technology, communications and automation. The combination of these technologies is required to achieve roadway capacity increases, as described below:

- *Connected vehicles* transmit data about their status to their surroundings (e.g., roadside infrastructure, other road users). They also receive information about their surroundings (e.g., traffic conditions, weather conditions, presence of potential conflicting vehicles, traffic signal timing) that motorists can use to adjust their driving behavior in response to conditions present at a given time and location. This exchange of information offers potential safety, fuel economy, and environmental benefits. However, because a human is still driving the vehicle, car-following and other behavior that influences freeway capacity is not expected to fundamentally change.
- *Automated vehicles* take over all or a portion of the driving task. Depending on the level of automation, a human may still need to take over under certain conditions. In the absence of connectivity, the information available to automated vehicles is limited to that which can be gathered by on-board sensors, which is typically constrained by a sensor's line of sight and the rate at which the sensor takes measurements (e.g.,

10 time per second). As a result, for both safety and passenger comfort reasons, current adaptive cruise control systems offer minimum time gaps that are similar to, or longer than, the gaps used by human drivers, and thus may decrease roadway capacity when in widespread use.

- *Connected and automated vehicles* communicate with each other and with roadside infrastructure. The connectivity element provides automated driving systems with more complete information about a vehicle's surroundings and enables cooperative vehicle maneuvers that improve roadway operations. The vehicles' enhanced detection capabilities, as well as redundancy in detection, enable an automated driving system to operate more efficiently and more safely than with only an on-board system.

## Cell Background Color

In the Calibration Tool, a drop-down selection is provided to establish a heat map by associating a chosen performance measure with background colors of the cells in the calibration table. Choices include the following: Per-Lane Demand; Speed; Density; Density-Based LOS; Demand-Based LOS; Demand - Capacity Ratio (D/C); Volume - Capacity Ratio (V/C); and Queue, %. Editing the cell values in the table can show the effect it has on the chosen performance measure. Please note that colors used for density are based on thresholds for segment density, which are different from facility urban and rural density.

## Cell Values

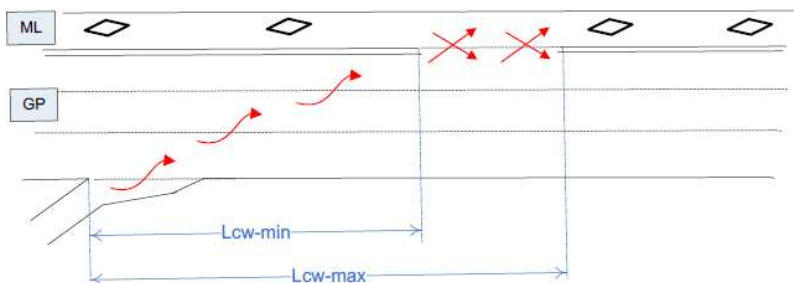
In the Calibration Tool, a drop-down selection is provided to establish which values are shown in the cells of the calibration table. Choices include the following: Mainline Demand (veh/h), Entry Demand (veh/h), Exit Demand (veh/h), Ramp-to-Ramp Demand (veh/h), Mainline Free Flow Speed, Capacity Adjustment Factor, and Speed Adjustment Factor. The values can be edited within the table to adjust for calibration. Adjusting values in the table will also automatically update the same values on the Details page.

## Coded Type

In Freeway Facilities, Coded Type is the Segment Type coded by the user.

## Cross Weave Demand

The exhibit below illustrates a managed lane with three general purpose (GP) freeway lanes:



Where an on-ramp is in close proximity to the managed lane (ML) Access segment, the cross-weave demand is the on-ramp vehicles crossing all of the GP freeway lanes in the distance  $L_{cw-min}$  to reach the managed lane. This cross-weave demand can cause a reduction in the capacity of the GP lanes, which must be considered. While not shown, the same effect exists when an off-ramp is in close proximity to the ML Access segment, with the distance  $L_{cw-min}$  measured from the end of the access segment to off-ramp junction point.

For a *Merge* segment within a facility, the cross weave demand is a portion of the *Merge Demand* that crosses the GP lanes to enter the ML. The remaining *Merge Demand* adds to the *GP (Freeway) Demand*.

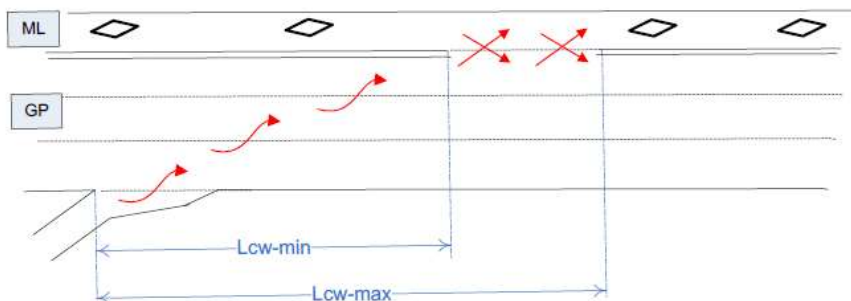
For a *Diverge* segment within a facility, the cross weave demand is the demand leaving the ML and entering the Freeway/GP lanes. The *Diverge Demand* is then the Demand exiting the Freeway using the off-ramp.

For Weaving within the ML Access segment, the cross weave demand is the demand crossing between the ML and adjacent GP lane.

## Cross Weaving Effect

Cross Weaving Effect applies to *Merge* or *Diverge* segments in a facility when a managed lane is present. When *Cross Weaving Effect* is checked, a 'Cross-Weaving Effects' section will enable with *Cross Weave Demand* and *Minimum Cross Weave Length* fields available.

Where managed lanes have defined intermittent access segments, two types of weaving movements may be created. The exhibit below illustrates the two weaving situations that may be created.



The exhibit illustrates a managed lane with three general purpose (GP) freeway lanes. Where an on-ramp is in close proximity to the managed lane (ML) Access segment, on-ramp vehicles destined for the managed lane must cross all of the general purpose freeway lanes in the distance  $L_{cw-min}$ . The cross-weave demand can cause a reduction in the capacity of the general purpose lanes which must be considered. While not shown, the same effect exists when an off-ramp is in close proximity to the ML Access segment, with the distance  $L_{cw-min}$  measured from the end of the access segment to off-ramp junction point.

See *Cross Weaving Managed Lane* for the second type of cross weaving.

### Cross-Weaving Between Ramps and the ML Access Segment

The impact of cross-weaving movements on general purpose lane capacity is handled using a CAF, as shown in the equation below:

$$CAF = 1 - CRF$$

$$CRF = -0.0897 + 0.0252 \ln(CW) - 0.00001453L_{cw-min} + 0.002967N_{GP}$$

where

$CRF$  = capacity reduction factor (decimal),

$CAF$  = capacity adjustment factor (decimal),

$CW$  = cross-weave demand flow rate (pc/h),

$L_{cw-min}$  = cross-weave length (ft), and

$N_{GP}$  = number of general purpose lanes (ln).

The capacity of the general purpose lanes is then computed as:

$$c_{GPA} = c_{GP} \times CAF$$

where

$c_{GPA}$  = adjusted capacity of the general purpose lanes (veh/h), and

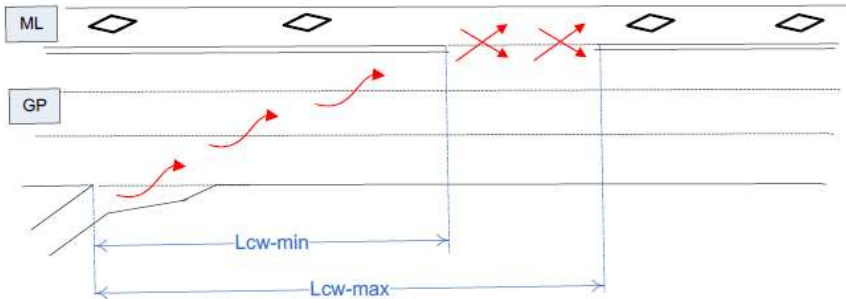
$c_{GP}$  = unadjusted capacity of the general purpose lanes, estimated using basic freeway procedures in Chapter 12 (veh/h).

For metric units, the cross-weave length is measured in meters; it is converted from meters to feet and then CRF is computed using the above equation.

## Cross Weaving Managed Lane

Cross Weaving Managed Lane applies to a *Weaving* single segment. When *Cross Weaving Managed Lane* is checked, a 'Cross Weaving' section will enable with *GP Segment Type*, *Minimum Cross Weaving Length*, *FFS of Managed Lane*, *Cross-Weave Demand*, *Ramp Terrain Type*, *Ramp Total Trucks*, and *Ramp Peak Hour Factor* fields available.

Where managed lanes have defined intermittent access segments, two types of weaving movements may be created. The exhibit below illustrates the two weaving situations that may be created.



See *Cross Weaving Effect* for the first type of weaving situation.

The second type of weaving occurs within the ML Access segment, as vehicles entering and exiting from the managed lane cross each other within the distance  $L_{cw-max} - L_{cw-min}$ .  $L_{cw-min}$  is defined as distance between the on-ramp gore area and the beginning of the managed lane access segment, while  $L_{cw-max}$  is the distance from the gore to the end of the access segment.

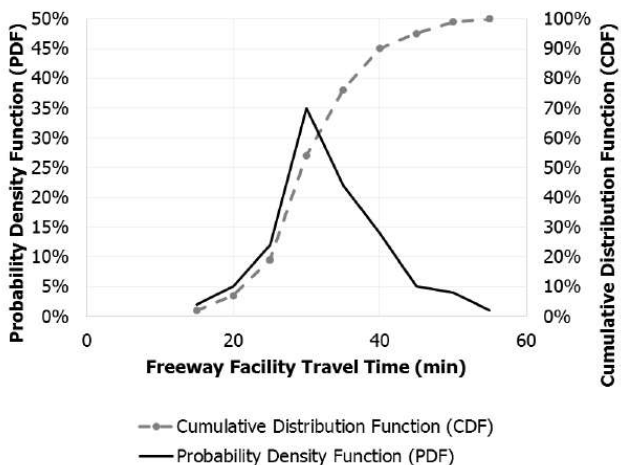
### Weaving Within the ML Access Segment

Weaving within the ML Access segment is treated using the procedures of chapter 13. The access segment is treated as a left-side, ramp-weave segment with a length of  $L_{cw-max} - L_{cw-min}$ .

It is assumed that the interaction and weave turbulence effect applies to the entire ML Access segment, including all general purpose lanes. Consequently, the methodology is identical to the evaluation of a weaving segment on the left side of a freeway.

## Cumulative Density Function (CDF)

The CDF gives the number of percent of all observations *at or below* a specified travel time bin. The exhibit found below illustrates two types of distributions, with the PDF shown by the solid line and the CDF by the dashed line. The facility travel times shown on the x-axis represent the midpoints of the various travel bins. See also *Probability Density Function (PDF)*.



## Current Analysis Period

A drop-down menu is provided for Current Analysis Period to allow the user to switch between detailed input data for the different analysis periods coded in a dataset.

## Current Segment

A drop-down menu is provided for Current Segment to allow the user to switch between detailed input data for the different segments coded in a dataset.

## Database Date

This field is provided to document the date when the analysis is performed.

## Date

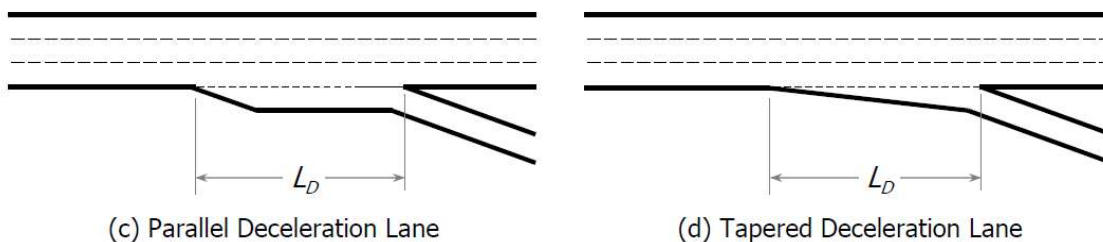
This field is provided to document the date when the analysis is performed.

## Daylight or Night

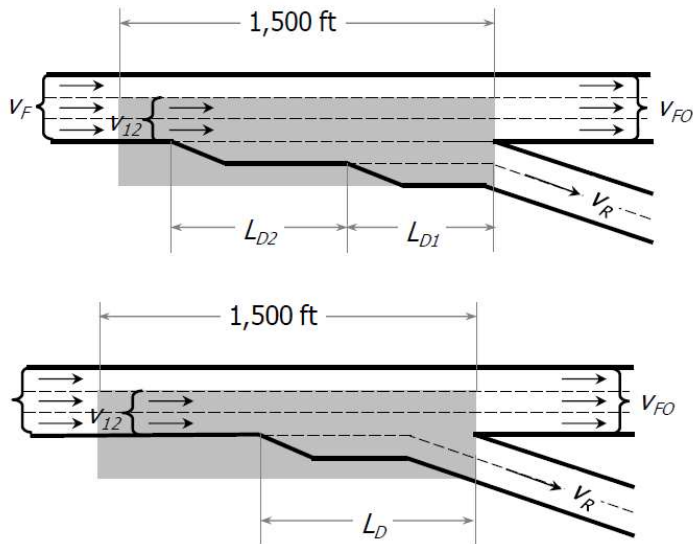
This is used to determine whether daytime or nighttime operations are considered for work zone events. The choice determines the indicator variable  $f_{DN}$ : 0 for daylight, and 1 for night.

## Deceleration Lane Length

This value defines the length for off-ramp deceleration lanes. The typical length of deceleration lanes for ramps should be obtained from the design standards used by the highway operation agency. It is measured from the departing point between the edge of the travel way for the freeway and outer edge of the ramp (the first point) and the downstream intersection point of the freeway and inner ramp edge of the travel way (the second point). The default value is 400 feet (or 121.9 meters in metric).



Two common types of diverge geometries are in use with two-lane off-ramps, as shown in the exhibit below. In the first, two successive deceleration lanes are introduced. In the second, a single deceleration lane is used. The left-hand ramp lane splits from Lane 1 of the freeway at the gore area, without a deceleration lane.



Where a single deceleration lane is used, there is no modification to the length of the deceleration lane  $L_D$ ; where two deceleration lanes exist, the length is replaced by the effective length  $L_{Deff}$  in all equations.

For two-lane ramps in the Freeways module, the effective deceleration length must be calculated by the user based on the lengths of the two lanes. Where two deceleration lanes exist, the length of the deceleration lane  $L_D$  is replaced by the effective length  $L_{Deff}$  in all equations. The formula for calculating effective deceleration length is:

$$L_{Deff} = 2 * L_{D1} + L_{D2}$$

where

$L_{Deff}$  = Effective deceleration length,

$L_{D1}$  = Length of the shorter deceleration lane, and

$L_{D2}$  = Difference in length between the longer deceleration lane and the shorter deceleration lane

In merge and diverge areas, the capacity of the two outer lanes is reduced by 100 and 200 veh/h/ln, respectively. When the user sets the deceleration lanes to 1500 feet (or 457.2 meters in metric), only the outer lane of the diverge experiences a capacity reduction, as opposed to normally both of the outer two lanes.

## Delete Analysis Period

Clicking on the button 'Delete Analysis Period' will delete the analysis period currently selected.

## Delete Section

After the user selects a section(s) to delete, clicking on the button 'Delete Section' will delete the row(s) of inputs from all analysis periods corresponding to the selected section(s).

## Delete Segment

After the user selects a segment(s) to delete, clicking on the button 'Delete Segment' will delete the row(s) of inputs from all analysis periods corresponding to the selected segment(s).

## Demand

The number of vehicles or other roadway users desiring to use a given system element during a specific analysis period, typically 1 h or 15 min.

Demand flow rates must be specified for the entering freeway mainline flow and for each merge and diverge segment. For Merge and Diverge analyses, the demand for adjacent ramps must also be specified if one exists

For weaving segments, demand flow rates must be identified by component movement: freeway to freeway, ramp to freeway, freeway to ramp, and ramp to ramp. Where this level of detail is not available, the following procedure may be used to estimate the component flows. It is not recommended, however, as weaving segment performance is sensitive to the split of demand flows.

- *Ramp-weave segments:* Assume that the ramp-to-ramp flow is 0. The ramp-to-freeway flow is then equal to the on-ramp flow; the freeway-to-ramp flow is then equal to the off-ramp flow.
- *Major weave segments:* On-ramp flow is apportioned to the two exit legs (freeway and ramp) in the same proportion as the total flow on the exit legs (freeway and ramp).

## Demand Adjustment Factor (DAF)

Factor used to allow the user to adjust the demand for the purpose of calibration, or to reflect the impacts of weather, incidents, and work zones.

## Demand Ratios

The exhibits found below present default demand ratios by day of week and month of year for urban and rural freeway facilities. The ratios were derived from a national freeway dataset developed by SHRP 2 Project L03. All ratios reflect demand relative to a Monday in January. Where possible, analysts should obtain local or regional estimates of demand variability to account for facility-specific and seasonal trends on the subject facility.

Default Urban Freeway Demand Ratios (ADT/Mondays in January):

Month	Day of Week						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
January	1.00	1.00	1.02	1.05	1.17	1.01	0.89
February	1.03	1.03	1.05	1.08	1.21	1.04	0.92
March	1.12	1.12	1.14	1.18	1.31	1.13	0.99
April	1.19	1.19	1.21	1.25	1.39	1.20	1.05
May	1.18	1.18	1.21	1.24	1.39	1.20	1.05
June	1.24	1.24	1.27	1.31	1.46	1.26	1.10
July	1.38	1.38	1.41	1.45	1.62	1.39	1.22
August	1.26	1.26	1.28	1.32	1.47	1.27	1.12
September	1.29	1.29	1.32	1.36	1.52	1.31	1.15
October	1.21	1.21	1.24	1.27	1.42	1.22	1.07
November	1.21	1.21	1.24	1.27	1.42	1.22	1.07
December	1.19	1.19	1.21	1.25	1.40	1.20	1.06

Source: Derived from data presented by Cambridge Systematics et al. (2).

Note: Ratios represent demand relative to a Monday in January.



Default Rural Freeway Demand Ratios (ADT/Mondays in January):

Month	Day of Week						
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
January	1.00	0.96	0.98	1.03	1.22	1.11	1.06
February	1.11	1.06	1.09	1.14	1.35	1.23	1.18
March	1.24	1.19	1.21	1.28	1.51	1.37	1.32
April	1.33	1.27	1.30	1.37	1.62	1.47	1.41
May	1.46	1.39	1.42	1.50	1.78	1.61	1.55
June	1.48	1.42	1.45	1.53	1.81	1.63	1.57
July	1.66	1.59	1.63	1.72	2.03	1.84	1.77
August	1.52	1.46	1.49	1.57	1.86	1.68	1.62
September	1.46	1.39	1.42	1.50	1.78	1.61	1.55
October	1.33	1.28	1.31	1.38	1.63	1.47	1.42
November	1.30	1.25	1.28	1.35	1.59	1.44	1.39
December	1.17	1.12	1.14	1.20	1.43	1.29	1.24

Source: Derived from data presented by Cambridge Systematics et al. (2).

Note: Ratios represent demand relative to a Monday in January.

These default demand ratios are displayed in the first table of the Demand page depending on the Freeway Area Type selected. The second table of the Demand page displays the demand ratios relative to the base dataset. The values in the first table can be edited by the user, if necessary, and the corresponding values in the second table will change based on the edited values.

## Density

The number of vehicles occupying a given length of a lane or roadway at a particular instant. It is expressed as passenger cars per mile per lane (pc/mi/ln) or vehicles per mile per lane (veh/mi/ln). It is the performance measure that determines Level of Service. Density is computed as flow rate (pc/h/ln) divided by speed (mi/h).

For metric units, it is expressed as passenger cars per kilometer per lane (pc/km/ln) or vehicles per kilometer per lane (veh/km/ln) and is computed as flow rate (pc/h/ln) divided by speed (km/h).

## Density at Capacity

The value of density when the component segments or facility is considered at capacity. The density at capacity is 45 pc/mi/ln (or 28 pc/km/ln in metric), which must be converted to veh/mi/ln (or veh/km/ln in metric) by using the heavy-vehicle adjustment factor  $f_{hv}$  described in Chapter 12, Basic Freeway and Multilane Highway Segments.

Thus, when a facility-level analysis is performed, LOS F for a component segment will be identified in two complementary ways:

- When  $v_d/c$  is greater than 1.00 for one or more critical segments, or
- When the segment density is greater than 45 pc/mi/ln (or 28 pc/km/ln in metric) for basic freeway segments or 43 pc/mi/ln (or 27 pc/km/ln in metric) for weaving segments.

## Design Analysis

Select the 'Design Analysis' checkbox to add a table to the report listing the results for the current freeway segment with different number of lanes. This can help guide the design of freeways with certain design standards.

## D-factor

$D$  is the proportion of traffic moving in the peak direction of travel on a given roadway during the peak hour. It is used, along with AADT (annual average daily traffic) and the  $K$ -factor (proportion of AADT occurring during the peak

hour), in the following equation to determine the demand volume ( $V$ ) or directional peak-hour demand volume ( $DDHV$ ) in a planning and preliminary engineering analysis:

$$V = DDHV = AADT \times K \times D$$

Directional distributions vary, but a typical value for both urban and rural freeways is 0.55. As with all default values, locally or regionally calibrated values are preferred and yield more accurate results. Both the  $K$ -factor and the  $D$ -factor have a significant impact on the estimated hourly demand volume.

## Direction

In the Query Segmentation Database, this refers to the forward direction of the selected Freeway.

## Directional Distribution Factor

The Directional Distribution Factor, or D-factor is the proportion of traffic moving in the peak direction of travel on a given roadway during the peak hour.

## Distance to Adjacent Ramp

The distance from the analysis ramp to the adjacent ramp

## Diverge Segment

A freeway segment in which a single traffic stream divides to form two or more separate traffic streams. Also *freeway diverge segment*. Off-ramps refer to freeway diverge segments. An off-ramp is a ramp that accommodates diverging maneuvers. Off-ramps are denoted as "OFR".

## Driver Population

Driver population describes the level of driver familiarity in the traffic stream and is used in adjustments for speed and capacity. The base traffic stream characteristics for basic freeway segments are representative of traffic streams composed primarily of commuters or drivers who are familiar with the facility.

The driver population adjustment factor  $f_p$  had previously been used in the HCM to reflect the effects of unfamiliar drivers in the traffic stream and was applied as an increase in demand volume. With the addition of a unified speed flow equation in Chapter 12 of the HCM and the ability to adjust both the base FFS and capacity in all freeway segment chapters (12-14) to account for incidents and weather events, the driver population factor is no longer used. Instead, FFS and capacity adjustment factors  $SAF_{pop}$  and  $CAF_{pop}$  are applied in combination with other applicable SAFs and CAFs.

Analyst judgment is still required when applying recommended adjustments. However, should there be expectations of significant presence of unfamiliar drivers, the values shown in the exhibit below can serve as a guide for the analysis.

Level of Driver Familiarity	$CAF_{pop}$	$SAF_{pop}$
All familiar drivers, regular commuters	1.000	1.000
Mostly familiar drivers	0.968	0.975
Balanced mix of familiar and unfamiliar drivers	0.939	0.950
Mostly unfamiliar drivers	0.898	0.913
All or overwhelmingly unfamiliar drivers	0.852	0.863

## Equilibrium Separation Distance

Where an upstream or downstream adjacent off-ramp exists on a six-lane freeway, a determination as to whether the ramp is close enough to the subject merge area to influence the area's operation is necessary. The

determination is made by finding the equilibrium separation distance  $L_{EQ}$ . If the actual distance is larger than or equal to  $L_{EQ}$ , then Equation 14-3 should be used. If the actual distance is shorter than  $L_{EQ}$ , then Equation 14-4 or Equation 14-5 should be used as appropriate. The equilibrium distance is obtained by finding the distance at which Equation 14-3 would yield the same value of  $P_{FM}$  as Equation 14-4 or Equation 14-5 as appropriate. This results in the following:

For adjacent upstream off-ramps, use Equation 14-6:

$$L_{EQ} = 0.214(v_F + v_R) + 0.444L_A + 52.32S_{FR} - 2403$$

For adjacent downstream off-ramps, used Equation 14-7:

$$L_{EQ} = \frac{v_D}{0.1096 + 0.000107L_A}$$

Where an upstream on-ramp or downstream off-ramp on a six-lane freeway exists, a determination as to whether the ramp is close enough to the subject off-ramp to affect its operation is necessary. As was the case for on-ramps, this is done by finding the equilibrium distance  $L_{EQ}$ . This distance is determined when Equation 14-9 yields the same value of  $P_{FD}$  as Equation 14-10 (for adjacent upstream on-ramps) or Equation 14-11 (adjacent downstream off-ramps). When the actual distance between the ramps is greater than or equal to  $L_{EQ}$ , Equation 14-9 is used. When the actual distance between ramps is less than  $L_{EQ}$ , Equation 14-10 or Equation 14-11 is used as appropriate.

For adjacent upstream on-ramps, use Equation 14-12:

$$L_{EQ} = \frac{v_U}{0.071 + 0.000023v_F - 0.000076v_R}$$

For adjacent downstream off-ramps, use Equation 14-13:

$$L_{EQ} = \frac{v_D}{1.15 + 0.000032v_F - 0.000369v_R}$$

## Export Buttons

Export buttons are provided on the Events page and Summary page in a reliability analysis.

On the Events page, Export to CSV is provided under each tab for the user to export the table results into a CSV file. For example, if the user wants to export the Incident data, a dialog box will appear after clicking 'Export to CSV' under the Incident tab. The user can specify a name for the CSV file or keep the default name. After saving the file, all incident events from all pages will be saved in CSV format.

On the Summary page, three export buttons are provided. These include: Export Summary Results to CSV, Export to XUF, and Export Facility to CSV. 'Export Summary Results to CSV' is similar to the export buttons on the Events page. Clicking this button will allow the user to save the summary results displayed in the table to be saved in CSV format. 'Export to XUF' will allow the user to save all the scenarios generated in the Freeways XUF format. Clicking this button will open a dialog box allowing the user to browse folders or create a folder which will save a folder with all the scenarios generated. The folder holding all the scenarios will be titled the same as the Freeways Reliability XFR file and all the scenarios will be titled Scenario#, with # being the corresponding scenario number. 'Export Facility to CSV' will export the inputs of each scenario into corresponding CSV files.

## Facility Evaluation

In the facility evaluation step in a reliability analysis, each scenario is analyzed using the freeway facilities core methodology. The performance measures of interest to the evaluation—in particular, facility travel time—are calculated for each analysis period in each scenario and stored. At the end of this process, a travel time distribution is formed from the travel time results stored for each scenario.

## Facility Name

This field is provided to document a name for the facility.

## Failure or On-Time Measures

The percentage of analysis time periods with space mean speeds above (on time) or below (failure) one or more target values (e.g., 35, 45, and 50 mi/h; or 56, 72, and 80 km/h in metric). These measures address how often trips succeed or fail in achieving a desired travel time or speed.

## Flow Rate

The equivalent hourly rate at which vehicles or other roadway users pass over a given point or section of a lane or roadway during a given time interval of less than 1 h, usually 15 min

## Free-Flow Speed

1. The average speed of vehicles on a given segment, measured under low-volume conditions, when drivers are free to drive at their desired speed and are not constrained by the presence of other vehicles or downstream traffic control devices.
2. The theoretical speed when both density and flow rate are zero.

The adjusted free-flow speed is determined by the HCM equation found below.

$$FFS = BFFS - f_{LW} - f_{RLC} - 3.22 \times TRD^{0.84}$$

where

- $FFS$  = free-flow speed of the basic freeway segment (mi/h),
- $BFFS$  = base FFS for the basic freeway segment (mi/h),
- $f_{LW}$  = adjustment for lane width (mi/h),
- $f_{RLC}$  = adjustment for right-side lateral clearance (mi/h), and
- $TRD$  = total ramp density (ramps/mi).

If a field measured free-flow speed is entered for the mainline, no subsequent adjustments are made, and the adjusted free-flow speed will simply be the field-measured free-flow speed.

Ramp free-flow speed, or SFR, is the FFS of the ramp at the junction point and is measured in mi/h. The ramp FFS entered is the measured speed and is not adjusted.

For metric units, Free-Flow Speed, along with all the corresponding adjustments, are measured in kilometers per hour.

## Freeway Facility

An extended length of freeway composed of continuously connected basic freeway, weaving, merge, and diverge segments.

## Freeway Name

This selection refers to the name of the Freeway found in the database.

## GP Segment Type

The General Purpose (GP) Segment Type establishes if there is an Upstream On-Ramp or a Downstream Off-Ramp that interacts with the ML Access Segment.

## Grade Length

The length of the segment, in miles (or kilometers in metric), to represent the percent grade

## Growth Factor

The traffic growth factor is provided to dynamically scale the traffic volume to represent future conditions. Values less than 1 will reduce the demand and values more than 1 will increase the demand.

## Heavy Vehicle Adjustment Factor

$f_{HV}$  denotes the adjustment factor for presence of heavy vehicles in the traffic stream. All heavy vehicles are classified as single-unit trucks (SUTs) or tractor-trailers (TTs).

The heavy-vehicle adjustment factor is computed as follows:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)}$$

where

- $f_{HV}$  = heavy-vehicle adjustment factor (decimal),
- $P_T$  = proportion of SUT and TTs in traffic stream (decimal), and
- $E_T$  = passenger-car equivalent of one heavy-vehicle in the traffic stream (PCEs).

## Highway Economic Requirements System (HERS)

When the crash rate is not available locally, the Highway Economic Requirements System (HERS) model can be used to estimate it. The crash or incident rate is estimated per 100 million VMT (or per 161 million VkmT in metric). The HERS models uses the following equation to estimate crash rate:

$$CR = (154.0 - 1.203 \times ACR + 0.258 \times ACR^2 - 0.00000524 \times ACR^5) \times e^{0.0082 \times (12 - LW)}$$

where  $CR$  is the crash rate per 100 million VMT (or per 161 million VkmT in metric),  $ACR$  is the facility AADT divided by its two-way hourly capacity, and  $LW$  is the lane width in feet (or meters in metric).

## Hourly Profile

This references the K-factor, which is the proportion of AADT that occurs during the peak hour. Instead of inputting a specific K-factor, an hourly profile is used. Choices for Hourly Profile include the following: Default Distribution-AM Peak, Default Distribution-PM Peak, and Default Distribution-Unimodal.

## Import from XUF File

Clicking this will allow the user to choose a file to override the default event creation.

## Incident Distribution and Duration

The duration of each incident severity type is assumed to follow a lognormal distribution. The default parameters for the incident duration distribution was developed through research. The defaults for freeway incident severity distribution and duration parameters, in minutes, are provided below:

Parameter	Incident Severity Type				
	Shoulder Closed	1 Lane Closed	2 Lanes Closed	3 Lanes Closed	4+ Lanes Closed
Distribution %	75.4%	19.6%	3.1%	1.9%	0%
Duration (Mean)	34	34.6	53.6	67.9	67.9
Duration (Std Dev)	15.1	13.8	13.9	21.9	21.9
Duration (Min)	8.7	16	30.5	36	36
Duration (Max)	58	58.2	66.9	93.3	93.3

Source: Zegeer et al. (1).

## Incident Frequency Data

Radio button choices are provided for specifying the type of Incident Frequency Data. These choices include: Local Incident Frequency, Local Crash Frequency, and Calculated Crash Frequency.

Selecting Local Incident Frequency will provide a table with defaults for Incident Frequency (per 100 million VMT in USC or per 161 million VkmT in metric) that vary by month. The values are editable for the user to calibrate for local conditions.

Selecting Local Crash Frequency will provide a table with defaults for Crash Frequency (per 100 million VMT in USC or per 161 million VkmT in metric) that vary by month. The values are editable for the user to calibrate for local conditions. In addition to this table, a field is provided for the user to specify the Incident-to-Crash Ratio (ICR).

Selecting Calculated Crash Frequency will cause the Highway Economic Requirements System (HERS) model to be used to calculate crash rate. Fields for ICR, ACR, and Lane Width will also be provided for the user to specify.

## Incident Type

The following exhibit shows the default CAFs associated with each incident severity:

Directional Lanes	No Incident	Shoulder Closed	1 Lane Closed	2 Lanes Closed	3 Lanes Closed	4 Lanes Closed
2	1.00	0.81	0.70	N/A	N/A	N/A
3	1.00	0.83	0.74	0.51	N/A	N/A
4	1.00	0.85	0.77	0.50	0.52	N/A
5	1.00	0.87	0.81	0.67	0.50	0.50
6	1.00	0.89	0.85	<u>0.75</u>	0.52	0.52
7	1.00	0.91	0.88	0.80	0.63	0.63
8	1.00	0.93	0.89	0.84	0.66	0.66

Source: Zegeer et al. (1).

Notes: N/A: not applicable, the number of lanes closed equals or exceeds the number of directional lanes. The methodology does not permit all directional lanes of a facility to be closed.

The values shown in the exhibit reflect the *remaining relative capacity per open lane*. For example, a two-lane closure incident on a six-lane directional facility (underscored) results in a loss of two full-lane capacities, in addition to maintaining only 75% of the remaining four open lanes' capacities. The result is that only three lanes worth (50%) of the facility's original six-lane capacity is maintained. No information is currently available on the effect of incidents on free-flow speed, so this effect is not accounted for at this time.

## Incident-to-Crash Ratio (ICR)

ICR is the local incident-to-crash ratio. In the absence of other data, a national default value for ICR is 4.9.

## Insert Analysis Period

Clicking on the button 'Insert Analysis Period' will add a new analysis period in the position of the selected analysis period. For example, if analysis period 3 is currently selected, inserting an analysis period will create a new analysis period 3. The previous analysis period 3 will become analysis period 4 and so on. The user can insert an unlimited number of analysis periods.

## Insert Section

Clicking on the button 'Insert Section' will add a row of inputs with the Section Type of 'Freeway Section' along with the default values for the Freeway Section type above the selected section. The user can insert an unlimited number of sections and can manually change the inputs to the desired values.

## Insert Segment

Clicking on the button 'Insert Segment' will add a row of inputs with the Segment Type of 'Basic' along with the default values for the Basic segment type above the selected segment. The user can insert an unlimited number of segments and can manually change the inputs to the desired values.

## Interchange Density

The average number of interchanges per mile, measured over 3 miles upstream and 3 miles downstream from the midpoint of the weaving segment.

For metric units, it is the average number of interchanges per kilometer, measured over 4.8 kilometers upstream and 4.8 kilometers downstream from the midpoint of the weaving segment.

## Items per page

A drop-down menu is provided for the user to specify the scenarios or events to be displayed per page.

## Jam Density

The maximum density that can be achieved on a segment. It occurs when speed is zero (i.e., when there is no movement of persons or vehicles).

## Jurisdiction

This field is provided to document any jurisdiction convention or project related information.

## K-factor

$K$  is the proportion of AADT (annual average daily traffic) that occurs during the peak hour. It is used, along with AADT and the  $D$ -factor (the proportion of peak-hour volume traveling in the peak direction), in the following equation to determine the demand volume ( $V$ ) or directional peak-hour demand volume ( $DDHV$ ) in a planning and preliminary engineering analysis:

$$V = DDHV = AADT \times K \times D$$

On urban freeways, the typical range of  $K$ -factors is from 0.08 to 0.10. On rural freeways, values typically range between 0.09 and 0.13. As with all default values, locally or regionally calibrated values are preferred and yield more accurate results. Both the  $K$ -factor and the  $D$ -factor have a significant impact on the estimated hourly demand volume.

## Lane Addition

A location along a roadway where the number of continuous through lanes increases by one or more.

On-ramps do not always include merge elements. In some cases, there are lane additions at on-ramps. Lane additions are defined as merge segments with acceleration lane lengths exceeding 1,500 ft (or 457.2 m in metric).

Analysis of single-lane additions is relatively straightforward. The freeway segment downstream of the on-ramp is simply considered to be a basic freeway segment with an additional lane. The procedures in Chapter 12, Basic Freeway and Multilane Highway Segments, should be applied in this case.

See also *Lane Drop*.

## Lane Closure Type

Lane Closure Type expresses how many lanes are closed in the work zone.



The lane closure configuration in a work zone is expressed as the ratio of the number of original lanes to the number of lanes present in the work zone. For instance, a 3-to-1 lane closure configuration means that three lanes are normally available, but that two lanes were closed during construction and only one lane was open. Research shows that this ratio is effective in showing the influences of different lane configurations on speed or capacity.

## Lane Drop

A location along a roadway where the number of through lanes is reduced by one or more.

Off-ramps do not always include diverge elements. In some cases, there are lane drops at off-ramps. Lane drops are defined as diverge segments with deceleration lane lengths exceeding 1,500 ft (or 457.2 m in metric).

Analysis of single-lane drops is relatively straightforward. The freeway segment upstream of the off-ramp is simply considered to be a basic freeway segment with an additional lane. The procedures in Chapter 12, Basic Freeway and Multilane Highway Segments, should be applied in this case.

See also *Lane Addition*.

## Lane Width

The lateral distance between stripes for a given lane; measured in feet (or meters in metric)

## Lane Width Adjustment

This is an adjustment to Base Free-Flow Speed based on the average lane width. The base condition for lane width is 12 ft or greater. When the average lane width across all lanes is less than 12 ft, the FFS is negatively affected. Adjustments to reflect the effect of narrower average lane width are shown below:

Average Lane Width (ft)	Reduction in FFS, $f_{LW}$ (mi/h)
≥12	0.0
≥11–12	1.9
≥10–11	6.6

For metric units, Average Lane Width is measured in meters, and the corresponding Lane Width Adjustment is measured in kilometers per hour.

## Lane-by-Lane Analysis

A facility analysis must be open to apply a lane-by-lane analysis. A 'Lane-by-Lane Analysis' checkbox is provided under the *Facility Global Inputs* section on the General page. Checking it will apply the lane-by-lane analysis methodology from HCM chapter 38 to the file. When it is applied, new sections on the Details page will become available.

## Lateral Clearance Adjustment

This is an adjustment to Base Free-Flow Speed based on the Right-Side Lateral Clearance. The base condition for right-side lateral clearance is 6 ft (or 1.8 m in metric) or greater. The lateral clearance is measured from the right edge of the travel lane to the nearest lateral obstruction. Care must be taken to identify a "lateral obstruction." Some obstructions may be continuous, such as retaining walls, concrete barriers, guardrails, or barrier curbs. Others may be periodic, such as light supports or bridge abutments. In some cases, drivers may be accustomed to certain types of obstructions, often making their influence on traffic negligible.



Adjustments to the base FFS due to the existence of obstructions closer than 6 ft to the right travel lane edge are shown below:

Right-Side Lateral Clearance (ft)	Lanes in One Direction			
	2	3	4	≥5
≥6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	3.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

Median clearances of 2 ft (or 0.6 m in metric) or more generally have little impact on traffic. No adjustments are available to reflect the presence of left-side lateral obstructions closer than 2 ft (or 0.6 m in metric) to the left travel lane edge. Such situations are, however, quite rare on modern freeways, except in constrained work zones.

The impact of a right-side lateral clearance restriction depends on both the distance to the obstruction and the number of lanes in one direction on the basic freeway segment. A lateral clearance restriction causes vehicles in the right lane to move somewhat to the left. This movement, in turn, affects vehicles in the next lane. As the number of lanes increases, the overall effect on freeway operations decreases.

## Lateral Distance

The distance, in feet (or meters in metric), from the edge of travel lane adjacent to the work zone to the barrier, barricades, or cones.

## Level of Service (LOS)

A quantitative stratification of a performance measure or measures that represent quality of service, measured on an A-F scale, with LOS A representing the best operating conditions from the traveler’s perspective and LOS F the worst.

*Units: USC*

LOS criteria for urban and rural freeway facilities are shown below. Urban LOS thresholds are the same density-based criteria used for basic freeway segments. Studies on LOS perception by rural travelers indicate the presence of lower density thresholds when compared with their urban freeway counterparts. The average LOS applies to a specific analysis period, usually 15 min.

LOS	Freeway Facility Density (pc/mi/ln)	
	Urban	Rural
A	≤11	≤6
B	>11–18	>6–14
C	>18–26	>14–22
D	>26–35	>22–29
E	>35–45	>29–39
F	>45 or any component segment $v_d/c$ ratio > 1.00	>39 or any component segment $v_d/c$ ratio > 1.00

User of a LOS descriptor for the overall freeway facility must be done with care. It is critical that the LOS for individual segments composing the facility also be reported. Because the overall LOS is an average, it may mask serious problems in individual segments of the facility.

For urban freeway facilities, LOS A through E are defined using the same densities that apply to basic freeway segments. Rural freeway facilities have lower density thresholds. This difference is a results of rural motorists' higher LOS expectations. The analyst is cautioned that a rural facility analysis may produce LOS F without any of its segment experiencing breakdown ( $v_d/c > 1$ ). As a result, LOS F for a facility represents a case in which any component segment of the freeway has a  $v_d/c$  ratio that exceeds 1.00, or the average density of the study facility exceeds 45 pc/mi/ln (for urban freeways) or 39 pc/mi/ln (for rural freeways).

The following provides LOS criteria for basic freeway segments:

LOS	Density (pc/mi/ln)
A	≤11
B	>11–18
C	>18–26
D	>26–35
E	>35–45
F	Demand exceeds capacity OR density >45

The following provides LOS criteria for weaving segments on freeways, collector-distributor (C-D) roads, and multilane highways:

LOS	Density (pc/mi/ln)	
	Freeway Weaving Segments	Weaving Segments on Multilane Highways or C-D Roads
A	0–10	0–12
B	>10–20	>12–24
C	>20–28	>24–32
D	>28–35	>32–36
E	>35–43	>36–40
F	>43, or demand exceeds capacity	>40, or demand exceeds capacity

The following provides LOS criteria for freeway merge and diverge segments. These criteria apply to all ramp-freeway junctions and may also be applied to major merge and diverges; high-speed, uncontrolled merge or diverge ramps on multilane highway sections; and merge and diverges on freeway C-D roadways. LOS is not defined for ramp roadways, while the LOS of a ramp-street junction is defined in Chapter 23, Ramp Terminals and Alternative Intersections.

LOS	Density (pc/mi/ln)
A	≤10
B	>10–20
C	>20–28
D	>28–35
E	>35
F	Demand exceeds capacity

Units: Metric

Density is measured in passenger cars per kilometer per lane. LOS criteria for urban and rural freeway facilities are shown below. Urban LOS thresholds are the same density-based criteria used for basic freeway segments. Studies on LOS perception by rural travelers indicate the presence of lower density thresholds when compared with their urban freeway counterparts. The average LOS applies to a specific analysis period, usually 15 min.

**Density (pc/km/ln)**

<b>LOS</b>	<b>Urban</b>	<b>Rural</b>
A	≤7	≤4
B	>7-11	>4-9
C	>11-16	>9-14
D	>16-22	>14-18
E	>22-28	>18-24
F	>28 or any component segment $v_d/c$ ratio > 1.00	>24 or any component segment $v_d/c$ ratio > 1.00

User of a LOS descriptor for the overall freeway facility must be done with care. It is critical that the LOS for individual segments composing the facility also be reported. Because the overall LOS is an average, it may mask serious problems in individual segments of the facility.

For urban freeway facilities, LOS A through E are defined using the same densities that apply to basic freeway segments. Rural freeway facilities have lower density thresholds. This difference is a results of rural motorists' higher LOS expectations. The analyst is cautioned that a rural facility analysis may produce LOS F without any of its segment experiencing breakdown ( $v_d/c > 1$ ). As a result, LOS F for a facility represents a case in which any component segment of the freeway has a  $v_d/c$  ratio that exceeds 1.00, or the average density of the study facility exceeds 28 pc/km/ln (for urban freeways) or 24 pc/km/ln (for rural freeways).

The following provides LOS criteria for basic freeway segments:

<b>LOS</b>	<b>Density (pc/km/ln)</b>
A	≤7
B	>7-11
C	>11-16
D	>16-22
E	>22-28
F	Demand exceeds capacity OR density > 28

The following provides LOS criteria for weaving segments on freeways, collector-distributor (C-D) roads, and multilane highways:

**Density (pc/km/ln)**

<b>LOS</b>	<b>Freeway Weaving Segments</b>	<b>Weaving Segments on Multilane Highway or C-D Roads</b>
A	0-6	0-7
B	>6-12	>7-15
C	>12-17	>15-20
D	>17-22	>20-22
E	>22-27	>22-25
F	>27, or demand exceeds capacity	>25, or demand exceeds capacity

The following provides LOS criteria for freeway merge and diverge segments. These criteria apply to all ramp-freeway junctions and may also be applied to major merge and diverges; high-speed, uncontrolled merge or diverge ramps on multilane highway sections; and merge and diverges on freeway C-D roadways. LOS is not defined for ramp roadways, while the LOS of a ramp-street junction is defined in Chapter 23, Ramp Terminals and Alternative Intersections.

<b>LOS</b>	<b>Density (pc/km/ln)</b>
A	≤6
B	>6-12
C	>12-17
D	>17-22
E	>22
F	Demand exceeds capacity

## Level Terrain

Any combination of grades and horizontal or vertical alignment that permits heavy vehicles to maintain the same speed as passenger cars, typically containing short grades of no more than 2%.

## Level of Travel Time Reliability (LOTTR)

Level of travel time reliability, or LOTTR, is the measure of the 80<sup>th</sup> percentile travel time index (TTI<sub>80</sub>) divided by the 50<sup>th</sup> percentile travel time index (TTI<sub>50</sub>):

$$\text{LOTTR} = \text{TTI}_{80} / \text{TTI}_{50}$$

## Local Crash Frequency

Fields are provided for Crash Frequency (per 100 million VMT in USC or per 161 million VkmT in metric) if the analyst is aware of recurring crash occurrences that vary by month. If, for example, crashes are more likely in winter months (despite potentially lower demands), the analyst should adjust the crash rate defaults and calibrate for local conditions.

## Local Incident Frequency

Fields are provided for Incident Frequency (per 100 million VMT in USC or per 161 million VkmT in metric) if the analyst is aware of recurring incident occurrences that vary by month. If, for example, incidents are more likely in winter months (despite potentially lower demands), the analyst should adjust the incident rate defaults and calibrate for local conditions.

## Location

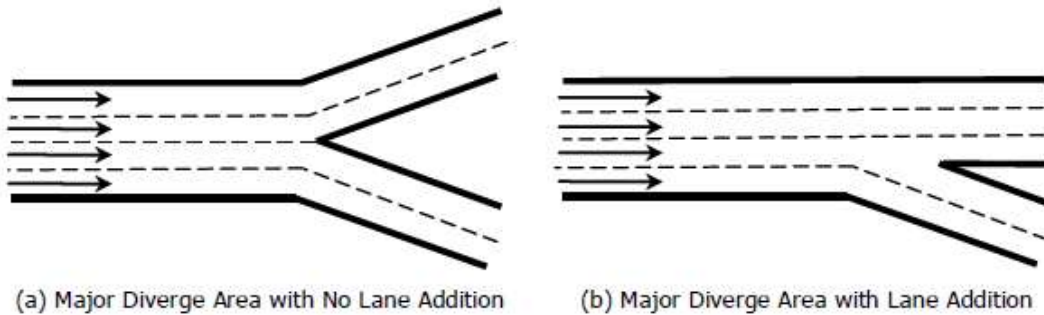
Rainfall, snow, temperature, and visibility weather data were collected for several different cities. Defaults are provided by month for each of the cities listed in the drop-down menu on the Weather page. If a city is not listed and the analyst has local data available, the fields in the table can be edited and the Current Location will become 'Custom'.

## Major Diverge

In a single segment diverge analysis, a Major Diverge checkbox will appear when the number of Ramp Lanes is 2. The checkbox will be hidden when the number of Ramp Lanes is 1. When Major Diverge is checked, the text and formatted report results will change to reflect a major diverge analysis.

A major diverge area is one in which two primary roadways, each having multiple lanes, diverge from a single freeway segment. Such junctions occur when a freeway splits to become two separate freeways or when a major multilane high-speed ramp diverges from the freeway. Major diverges are different from one- and two-lane off-ramps in that each of the diverging roadways is generally at or near freeway design standards and no clear ramp or deceleration lane is involved in the diverge.

The two common geometries for major diverge areas are illustrated in the exhibit below. In the first case, the number of lanes leaving the diverge area is the same as the number entering it. In the second, the number of lanes leaving the diverge area is one more than the number entering it.



The principal analysis of a major diverge area involves checking the capacity of entering and departing roadways, all of which are generally built to mainline standards. A failure results when any of the demand flow rates exceeds the capacity of the segment.

For major diverge areas, a model exists for computing the average density across all approaching freeway lanes within 1,500 ft of the diverge, as given in the following equation:

$$D_{MD} = 0.0175 \left( \frac{V_F}{N} \right)$$

where

- $D_{MD}$  = density in the major diverge influence area (which includes all approaching freeway lanes) (pc/mi/ln)
- $V_F$  = demand flow rate immediately upstream of the major diverge influence area (pc/h), and
- $N$  = number of lanes approaching the major diverge (ln).

The result can be compared with the criteria of HCM Exhibit 14-3 to determine a LOS for the major diverge influence area. Note that the density and LOS estimates are only valid for stable cases (i.e., not in cases in which LOS F exists because of a capacity deficiency on the approaching or departing legs of the diverge).

For metric units, the calculated density in pc/mi/ln is converted to pc/km/ln.

## Managed Lane

A limited number of lanes set aside within a freeway cross section where multiple operational strategies are utilized and actively adjusted as needed for the purpose of achieving predefined performance objectives. Examples include priced lanes and special-use lanes such as high-occupancy vehicle (HOV), high-occupancy toll (HOT), express, bus-only, or truck-only lanes.

The vehicle composition, driver type, free-flow speed, capacity, and driver behavior characteristics of managed lane traffic streams are quite different from those of general purpose lanes. In addition, interaction occurs between the two traffic streams, especially when there is no physical barrier separation between the managed and general purpose lanes.

## Managed Lane Segment Type

Four types of managed lane (ML) freeway segments are defined in HCM Chapters 12 through 14: ML merge and diverge segments, ML weaving segments, ML access segments, and ML basic freeway segments.

The analysis procedures for general purpose lanes with adjacent managed lanes build on the core methodology's segment classification. In addition, the lane group concept is introduced to allow analysts to assign separate attributes to managed and general purpose lanes, while retaining a degree of interaction between the two facilities. The adjacent lane groups (one general purpose and one managed) are required to have the same segment length.

*HCS Freeways* allows selection of five different types of managed lanes: ML Basic, ML Merge, ML Diverge, ML Weave, and ML Access.

## Managed Lane Separation Type

Five types of basic managed lane segments are identified, based on the number of managed lanes and the type of separation from the general purpose lanes. The speed-flow characteristics of each basic managed lane segment type are different. The five segment types include:

1. *Continuous Access*. Skip-stripe or solid single line-separated, single lane.
2. *Buffer 1*. Buffer-separated, single lane.
3. *Buffer 2*. Buffer-separated, multiple lanes.
4. *Barrier 1*. Barrier-separated, single lane.
5. *Barrier 2*. Barrier-separated, multiple lanes.

## Map-Based Segmentation

Clicking on the 'Map-Based Segmentation' button will bring up the Segmentation window, where the user can choose to create sections through a map or through a data grid alone. Checking the 'Map-Based Segmentation' checkbox will enable the map and disable buttons for adding, inserting, and deleting sections within the data grid. Unchecking the 'Map-Based Segmentation' checkbox will disable the map and enable buttons for adding, inserting, and deleting sections within the data grid. Clicking 'OK' after finalizing sections will bring the user back to the Segments page in Freeways and will automatically generate the appropriate segments for the facility.

When the map is enabled:

Specific locations can be searched using the 'City / Zip Code' textbox. When a city or zip code is, the map will adjust to find that location. The user may also zoom in/out or drag the map to find a location. When ready to add a node, the user can right-click on the map which will bring up a menu with the following: Add Freeway Node, Add On-Ramp Node, and Add Off-Ramp Node. Adding a node will place a pin on the map with a number. As more nodes are added, the pins will be connected by lines representing sections of the roadway. If there is already a node on the map, the user can right-click that node which will bring up a menu with the following: Delete Current Node or Insert Node After Current Node.

At the bottom of the map, there are also buttons provided to make editing the facility easier. They include the following: Zoom to Selection, Zoom to Facility, Undo Last Node, and Clear Map Content. For 'Zoom to Selection', the user will need to highlight rows within the data grid. Once selected, clicking on 'Zoom to Selection' will zoom in to the selected nodes/sections on the map. Clicking on 'Zoom to Facility' will zoom in/out to show the entire facility on the map. Clicking on 'Undo Last Node' will remove the last node added to the map. Clicking on 'Clear Map Content' will remove everything that was added to the map.

At the top right corner of the map, there are '+' and '-' buttons that allow zooming in and out, respectively. Above that is a drop-down menu that allows changing of the map view. Options include the following: Road and Aerial With Labels.

When the map is disabled:

The map and all corresponding map buttons will be grayed out and cannot be used. The table will start off with General Node, Freeway Section, and General Node. The facility must also start and end with a General Node. To edit the facility, there will be three buttons above the data grid: Add Section, Insert Section, and Delete Section. Adding a section will add an On-Ramp Node and a Freeway Section. Inserting a node will insert a General Node and Freeway Section before the row selected in the data grid. Deleting a section will delete whichever row(s) are selected in the data grid.

## Maximum Weaving Length

Strictly defined, maximum length is the length at which weaving turbulence no longer has an impact on operations within the segment, or alternatively, on the capacity of the weaving segment. This methodology uses the second definition (based on the equivalence of capacity). The maximum length of a weaving segment (in feet) is computed from Equation 12-4:

$$L_{MAX} = [5,728(1 + VR)^{1.6}] - [1,566N_{WL}]$$

where

- $L_{MAX}$  = maximum weaving segment length (using the short length definition)
- $VR$  = volume ratio
- $N_{WL}$  = number of lanes from which weaving maneuvers may be made with either one or no lane changes

The value of  $L_{MAX}$  is used to determine whether continued analysis of the configuration as a weaving segment is justified:

- If  $L_S < L_{MAX}$ , continue to Step 5 (Determine Weaving Segment Capacity); or
- If  $L_S \geq L_{MAX}$ , analyze the merge and diverge junctions as separate segments by using the methodology in Chapter 13.

For metric units, the maximum weaving length is measured in meters; it is computed using the above equation and then converted from feet to meters.

## Mean Travel Time Index ( $TTI_{mean}$ )

$TTI_{mean}$  describes the mean of the TTI distribution. This can be a useful measure and more influenced by outliers than the median.

## Measured Free-Flow Speed

The measured free-flow speed is the FFS measured in the field and provided by the user. If the FFS is measured directly, no adjustments are applied to the measured value.

## Merge Segment

A freeway segment in which two or more traffic streams combine to form a single traffic stream. Also *freeway merge segment*. On-ramps refer to freeway merge segments. An on-ramp is a ramp that accommodates merging maneuvers. On-ramps are denoted as “ONR”.

## Mile Marker End

This indicates the mile marker number where the selected freeway ends.

## Mile Marker Start

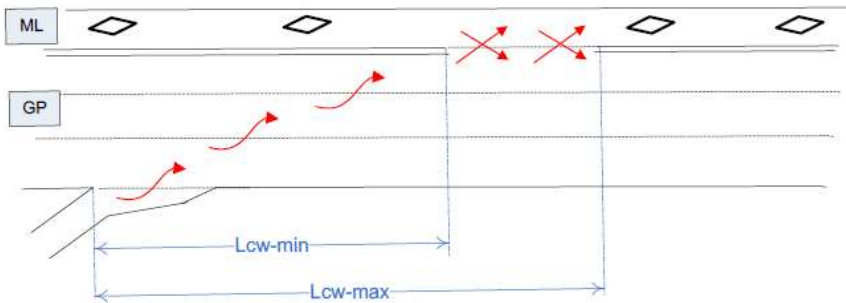
This indicates the mile marker number where the selected freeway starts.

## Minimum Cross Weaving Length

$L_{cw-min}$  is the minimum cross weaving length. Where an on-ramp is present,  $L_{cw-min}$  is defined as the distance between the on-ramp gore area and the beginning of the managed lane access segment. Where an off-ramp is present,  $L_{cw-min}$  is the distance measured from the end of the access segment to off-ramp junction point.

For weaving within the ML Access segment, vehicles entering and exiting from the managed lane cross each other within the distance  $L_{cw-max} - L_{cw-min}$ .  $L_{cw-min}$  is defined as distance between the on-ramp gore area and the beginning of the managed lane access segment, while  $L_{cw-max}$  is the distance from the gore to the end of the access segment.

These distances are illustrated in the exhibit below:



## Minimum Freeway-to-Ramp Lane Changes

Minimum number of lane changes that a freeway-to-ramp weaving vehicle must make to complete the freeway-to-ramp movement successfully. This is only applicable for one-sided weaving segments. This is denoted as  $LC_{FR}$ .

## Minimum Lane Change Rate

The minimum rate of lane changing that must exist for all weaving vehicles to complete their weaving maneuvers successfully, in lane changes per hour (lc/h).

$$LC_{MIN} = (LC_{RF} \times v_{RF}) + (LC_{FR} \times v_{FR})$$

where

- $LC_{MIN}$  = minimum rate of lane changing that must exist for all weaving vehicles to complete their weaving maneuvers successfully (lc/h)
- $LC_{RF}$  = minimum number of lane changes that must be made by a single weaving vehicle moving from the on-ramp to the freeway (lc/h)
- $v_{RF}$  = ramp-to-freeway demand flow rate in the weaving segment (pc/h)
- $LC_{FR}$  = minimum number of lane changes that must be made by a single weaving vehicle moving from the freeway to the off-ramp (lc/h)
- $v_{FR}$  = freeway-to-ramp demand flow rate in the weaving segment (pc/h)

## Minimum Ramp-to-Freeway Lane Changes

Minimum number of lane changes that a ramp-to-freeway weaving vehicle must make to complete the ramp-to-freeway movement successfully. This is only applicable for one-sided weaving segments. This is denoted as  $LC_{RF}$ .

## Minimum Ramp-to-Ramp Lane Changes

Minimum number of lane changes that must be made by one ramp-to-ramp vehicle to execute the desired maneuver successfully. This is only applicable for two-sided weaving segments. This is denoted as  $LC_{RR}$ .

## Misery Index

A measure comparing the average of the worst 5% of travel times to the free-flow travel time.



## Mixed-Flow Model

The mixed-flow model is one of two distinct methodologies offered to assess the effect of heavy vehicles on capacity and LOS on freeways in the HCM. The model directly assesses the capacity, speed, and density of traffic streams that include a significant percentage of heavy vehicles operating on a single or composite grade. When using the mixed-flow models, no PCEs are needed, as the passenger car, SUT, and TT volumes are used directly in the estimation of mixed-flow speed and density.

For most freeway analyses, PCE tables are sufficient and provide a reasonable approximation of the truck effects. However, if truck percentages are high, grades are significant, or both, the mixed-flow model is expected to give a more accurate result. If estimates of the actual mixed-flow speeds and densities are desired, the mixed-flow model in Volume 4 of the HCM should be employed. If the basic freeway segment is analyzed as part of a freeway facility using the methodology in Chapter 10 of the HCM, a PCE approximation is typically appropriate and recommended.

For a Basic single segment, a Mixed Flow Model checkbox is provided. This checkbox is enabled only when the Terrain Type is coded as Specific Grade.

For a freeway facility, a Mixed Flow Model checkbox is provided on the General page. This checkbox is enabled only when the facility has Basic segments coded. If any other segment type is added to the facility, the checkbox will be disabled, and the mixed flow model will not be applied. If 'Mixed Flow Model' is checked, the mixed-flow model for composite grades will be applied. The procedure builds on the single-grade methodology described in the HCM Chapter 26, Freeway and Highway Segments: Supplemental, and uses the same basic set of equations. The procedure computes LOS, capacity, speed, and density for each segment and for the composite grade as a whole. Many of the equations in this section are identical to those presented in Chapter 26, although they have different equation numbers. The major difference with composite grades is that the analyst must compute the spot travel rates or spot speeds at the start and end of each segment on the composite grade as an input to the analysis of the next grade segment.

## Navigation Buttons

On the Events page and Summary page in a reliability analysis, there are four buttons that can be found at the bottom of the table being displayed. These buttons include: << First, < Previous, Next >, and Last >>. When there are several scenarios or events in an analysis that are displayed in multiple pages, the user can use the buttons to navigate between pages. The '<< First' button will display the first page, the '< Previous' button will display one page back, the 'Next >' will display one page forward, and the 'Last >>' button will display the last page. If all scenarios or events can be displayed on one page, then all four buttons will be disabled.

## Non-Work Zone Speed Limit

The non-work zone speed limit is the speed limit, in miles per hour (or kilometers per hour in metric), in non-work zone conditions.

To determine the work zone impacts on free-flow speed, the analyst must specify the ratio of non-work zone speed limit to work zone speed limit, the work zone regulatory speed limit, lane closure type, barrier type, day or night work, and the number of ramps within 3 mi of the center of the work zone.

The speed ratio, or  $f_{sr}$ , is the ratio of non-work zone speed limit (before the work zone was established) to work zone speed limit.

## Number of Lanes on Freeway

This specifies the number of lanes on the freeway in the analysis direction. If there is a weaving segment, the number of auxiliary lanes is also included. When there is a managed lane, the number of lanes is the number of general purpose lanes. See also *Lane Addition* and *Lane Drop*.

## Number of Lanes on Ramp

This specifies the number of lanes on the ramp roadway (on- or off-ramp). There can be 1 or 2 lanes.

## Number of Managed Lanes

This specifies the number of lanes on the freeway that are set aside for specific use in a managed lane.

## Number of Maneuver Lanes

Number of lanes from which weaving maneuvers may be made with either one or no lane changes; denoted as  $N_{WL}$ .

For one-sided weaving segments, the value of  $N_{WL}$  is either 2 or 3. The determination is made by a review of the geometric design and the configuration of the segment.

For two-sided weaving segments, the value of  $N_{WL}$  is always 0 by definition.

## Number of Replications

This number ensures a sufficient sample size for scenario generation in a reliability analysis.

For a one-year RRP, the methodology is typically applied with four replications for each of five weekdays (Monday through Friday) and 12 months in the year, for a total of 240 scenarios. This approach roughly corresponds to 250 work days in a typical calendar year. A reliability analysis that includes weekend effects would result in an increased number of scenarios.

For RRP that are significantly shorter than one year, the analyst should increase the number of replications to ensure a sufficient sample size for scenario generation. The exhibit below provides guidance on the recommended number of replications in such cases.

RRP Duration (months)	Number of Days Considered	Recommended Number of Replications	Resulting Number of Scenarios
1	5 (all weekdays)	48	240
2	5	24	240
4	5	12	240
6	5	8	240
9	5	6	270
12*	5	4*	240*
12	2 (weekend only)	10	240
12	7 (all days)**	3	252

Notes: RRP = reliability reporting period.

\*Default value.

\*\*Not desirable; separating weekday and weekend reliability analysis is preferred.

## Number of Weaving Lanes

Number of lanes from which weaving maneuvers may be made with either one or no lane changes. The determination is made by a review of the geometric design and the configuration of the segment.

For one-sided weaving segments, the number of weaving lanes considers ramp-to-freeway and freeway-to-ramp, denoted by  $NW_{RF}$  and  $NW_{FR}$ , respectively.

For two-sided weaving segments, the number of weaving lanes considers ramp-to-ramp, denoted by  $NW_{RR}$ .

$NW_{RF}$  = number of on-ramp lanes from which a weaving maneuver to the freeway may be completed with one lane change or no lane changes

$NW_{FR}$  = number of freeway lanes entering the segment from which a weaving maneuver to the off-ramp may be completed with one lane change or no lane changes

$NW_{RR}$  = number of freeway lanes from which a ramp-to-ramp weaving maneuver may be completed with one lane change or no lane changes

## Oversaturated Flow

Traffic flow where (a) the arrival flow rate exceeds the capacity of a point or segment, (b) a queue created from a prior breakdown of a facility has not yet dissipated, or (c) traffic flow is affected by downstream conditions

## Passenger Car Equivalent (PCE)

The use of passenger-car-equivalent (PCE) factors is one of two distinct methodologies offered to assess the effect of heavy vehicles on capacity and LOS on freeways in the HCM. Traditional PCE factors allow the analyst to convert a mixed stream of cars and trucks to a single uniform PCE stream for purpose of analysis. Passenger Cars include all sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers. Heavy vehicles include single-unit trucks and tractor-trailers.

For most freeway analyses, PCE tables are sufficient and provide a reasonable approximation of the truck effects. However, if truck percentages are high, grades are significant, or both, the mixed-flow model is expected to give a more accurate result. If estimates of the actual mixed-flow speeds and densities are desired, the mixed-flow model in Volume 4 of the HCM should be employed. If the basic freeway segment is analyzed as part of a freeway facility using the methodology in Chapter 10 of the HCM, a PCE approximation is typically appropriate and recommended.

## Peak Hour Factor (PHF)

The hourly volume during the analysis hour divided by the peak 15-min flow rate within the analysis hour; a measure of traffic demand fluctuation within the analysis hour.

## Peak Hour Speed

The speed expected on the freeway during the peak hour in miles per hour (or kilometers per hour in metric).

## Percent Drop in Capacity

Percent Drop in Capacity ( $\alpha_{wz}$ ) refers to the percentage drop in pre-breakdown capacity at the work zone due to queuing conditions. Research shows an average queue discharge drop of 7% in non-work zone conditions, and an average value of 13.4% in freeway work zones. The underlying research measured pre-breakdown capacities, as well as queue discharge rates, to estimate the magnitude of  $\alpha_{wz}$ . When there is little local information available on  $\alpha_{wz}$ , these values can be used as defaults.

## Percent Grade

The longitudinal slope of a roadway; provided by the user as a percentage

## Percentile Travel Time Index (TTI<sub>pp</sub>)

Represents the  $pp$  percentile TTI in the travel time distribution. For example,  $TTI_{85}$  means that this observation is exceeded only 15% of the time in the travel time distribution. Common TTI percentiles are  $TTI_{50}$  (the median TTI) and  $TTI_{95}$  (the 95<sup>th</sup> percentile TTI). When  $pp$  is omitted, the value often represents the *mean* TTI for the distribution, which in HCM chapter 11 is referred to as  $TTI_{mean}$ .

## Performance Summary

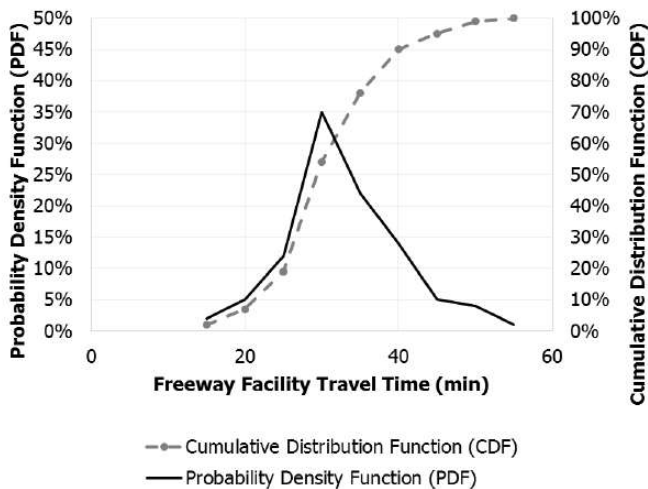
In the final step, travel time reliability is described for the entire RRP. The travel time distribution is used to quantify a range of variability and reliability metrics.

## Planning Time Index (PTI)

See 95<sup>th</sup> Percentile Travel Time Index ( $TTI_{95}$ ).

## Probability Density Function (PDF)

The PDF gives the number or percent of all observations within a specified travel time (or TTI) bin. The exhibit found below illustrates two types of distributions, with the PDF shown by the solid line and the CDF by the dashed line. The facility travel times shown on the x-axis represent the midpoints of the various travel bins. See also *Cumulative Distribution Function (CDF)*.



## Project Description

This field is provided for the user to document the analysis with any information for identification purposes.

## Proportion of CAVs

This is the proportion of CAVs in the traffic stream. CAV is a connected autonomous vehicle, defined here as a vehicle with an operating cooperative adaptive cruise control system. The range of proportion of CAVs in the traffic stream is from 0 to 100.

The proportion of CAVs is used in determining a Capacity Adjustment Factor where CAVs are present in the traffic stream ( $CAF_{CAV}$ ).

## Proportion of Flow Outside 4<sup>th</sup> Lane

The input for proportion of flow outside 4th lane is available when the number of freeway lanes is greater than 5. There is no calibrated procedure for adapting the methodology of HCM chapter 14 to freeways with more than five lanes in one direction. However, the approach of Equation 14-27 is conceptually adaptable to such situations. A local calibration of the amount of traffic using Lanes 5+ would be needed. The remaining flow could then be modeled as if it were taking place on a four-lane (one direction) segment.

## Queue Discharge Capacity Drop

A fraction of capacity drop in queue discharge conditions due to congestion on the facility. If the number of vehicles stored on a segment is greater than zero, this indicates that a queue is present on the facility upstream of the node in question. The presence of a queue and congestion further indicates that the node capacity is in queue discharge mode, which means that the queue discharge capacity is reduced relative to the pre-breakdown capacity by a factor  $\alpha$ . In order to account for this queue discharge effect, the equation below is applied to any active bottleneck along the facility if the number of unserved vehicles stored on the segment is greater than 0.001.

$$SC(i,t,p) = (1-\alpha) \times SC(i,t,p)$$

where

$SC(i,t,p)$  = segment capacity: maximum number of vehicles that can pass through segment  $i$  in time step  $t$  in time interval  $p$  based strictly on traffic and geometric properties

$\alpha$  = fraction of capacity drop in queue discharge conditions due to congestion on the facility

## Ramp Access Density

In a network analysis, ramp access density is the total number of ramps 0.5 mi (or 0.8 km in metric) upstream and 0.5 mi (or 0.8 km in metric) downstream of the segment.

## Ramp Metering

Roadway metering is the storing of surges in demand at various points in the transportation network. Freeway on-ramp metering is an example of roadway metering. A checkbox is provided to indicate whether ramp metering exists for a merge or weaving segment when a systems analysis is applied.

## Ramp Metering Rate

When ramp metering is active, the metering rate, in veh/h, is required and is stored in the existing variable  $RM(i,t,p)$ , as defined in HCM Chapter 25. The maximum output flow rate  $ONRO(i,t,p)$  that can enter the merge point takes into consideration the ramp metering rate as one of its possible constraints and is properly adjusted if the ramp metering becomes the restricting factor to the on-ramp discharge.

$ONRO(i,t,p)$  is the maximum output flow rate that can enter the merge point from on-ramp  $i$  during time step  $t$  in time interval  $p$ ; it is constrained by Lane 1 (shoulder lane) flow on segment  $i$  and the segment  $i$  capacity or by a queue spillback filling the mainline segment from a bottleneck further downstream, whichever governs.

## Ramp Overlap Segment

Whenever a series of ramps on a freeway is analyzed, the 1,500-ft (or 457.2-m for metric) ramp influence areas could overlap. In such cases, the operation in the overlapping region is determined by the ramp influence area having the highest density. Ramp Overlap Segments are denoted as "R".

## Random Number Seed

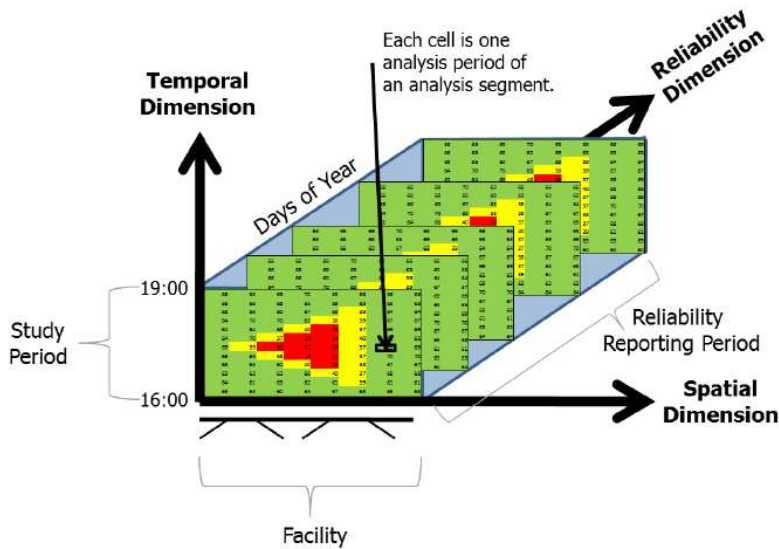
A random number seed is used with the Monte Carlo methods in the reliability methodology. A seed is used so that the sequence of random events can be reproduced. Unique seed numbers are separately established for weather events and incidents. For a given set of two seed numbers, a unique combination of demand levels, weather events, incidents, and work zones is estimated for each analysis period in the reliability reporting period.

## Reliability Rating

The percentage of vehicle miles traveled (or vehicle kilometers traveled in metric) on the freeway facility that experiences a TTI less than 1.33. This threshold approximates the points beyond which travel times become much more variable (unreliable).

## Reliability Reporting Period (RRP)

The specific set of days over which travel time reliability is computed; for example, all non-holiday weekdays in a year. The RRP represents the third dimension that extends the freeway facility core methodology and is illustrated in the exhibit found below by the series of rectangles (scenarios).



The Start Date indicates the beginning date of the RRP, the End Date indicates the final date of the RRP, and the days checked off indicate which days of the week are considered within the timeframe of the RRP.

The RRP can be as long as one calendar year, although shorter periods are also possible. A one-year RRP is most typical, as it encompasses all day-to-day, and month-to-month variability in demand, as well as all weather and incident effects. However, shorter RRPs can be used to focus on reliability during specific analysis periods. The minimum recommended RRP is one month to capture sufficient variability in demand and other factors.

## Reset to Default Ratios

The 'Reset to Default Ratios' button is provided to undo changes to cells within the Default Freeways Demand Ratios table made by the user. If this button is clicked, all cells within the table will revert back to the default values.

## Right Side Clearance

The right-side clearance is the distance from the rightmost travel lane to fixed obstructions on a freeway; measured in feet (or meters in metric).

## Roadway Type

Roadway types include Multilane Highways or Collector-Distributor (C-D) Roadways and Freeways. For Weavings segments, the LOS criteria changes based on the roadway type. For Merge and Diverge segments, the FFS range is somewhat lower (45-60 mi/h) and can be estimated by using the methodology in Chapter 12 if no field measurements are available. The capacity checks and the maximum desirable flow rates of the ramp influence areas also change based on the roadway type.

## Rolling Terrain

Any combination of grades and horizontal or vertical alignment that causes heavy vehicles to reduce their speed substantially below that of passenger cars but that does not cause heavy vehicles to operate at crawl speeds for any significant length of time or at frequent intervals.

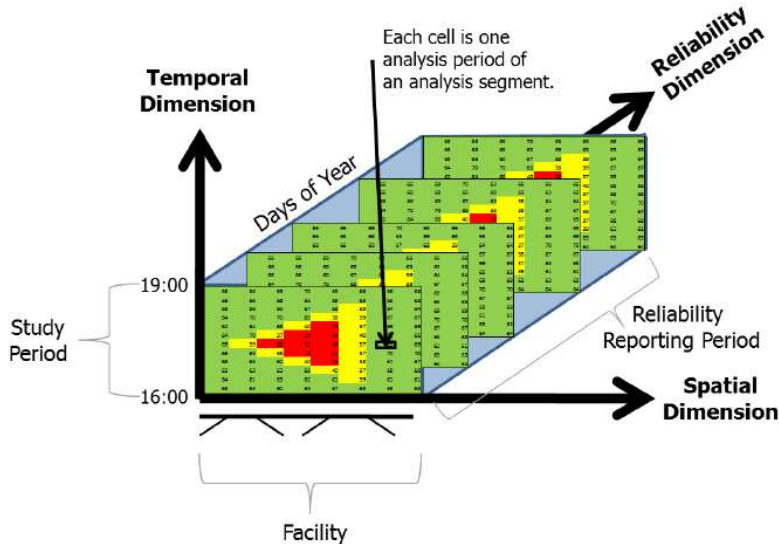
## Run HCM 7.1

A 'Run HCM 7.1' checkbox is provided in single segment analyses to indicate whether or not to use the new HCM methodology for merge, diverge, and weaving. This checkbox is not available for facility analyses. In a single segment analysis, the Highway Capacity Manual 7th Edition (HCM7) methodologies will be used if the checkbox is unchecked. If the checkbox is checked, the update to the Highway Capacity Manual 7th Edition (HCM 7.1, based

on NCHRP 07-26 research) methodologies will be used. This applies to merge, diverge, weaving, ML merge, ML diverge, and ML weaving analyses. There were no changes to the Basic methodology. However, the checkbox is available in the analysis for managed lane analyses (e.g., Basic segment analysis with a ML weave).

## Scenario

A single instance of a study period for the facility, having a unique combination of traffic demands, capacities, geometries, and free-flow speeds represented in its analysis periods. Each rectangle in the exhibit found below represents a unique scenario, or in other words one day of the year.



## Scenario Generation

The process of enumerating the various combinations of factors including demand, weather, incidents, and scheduled work zones, and calculating their probability of occurrence is termed *freeway scenario generation*.

The scenario generator develops a set of scenarios reflecting conditions that the freeway facility may experience during the reliability reporting period. Each scenario represents a single study period (typically several hours long) that is fully characterized in terms of demand and capacity variations in time and space. The data supplied to the scenario generator are expressed as multiplicative factors (CAFs, SAFs, and demand adjustment factors [DAFs]) or additive factors (number of lanes) that are applied to the base free-flow speed, demand, capacity, and number of lanes.

The scenario generation process includes the following steps:

- Adjusting the base demand to reflect day-of-week and month-of-year variation associated with a given scenario;
- Generating inclement weather events on the basis of their local probability of occurrence in a given time of year and adjusting capacities and free-flow speeds to reflect the effects of the weather events;
- Generating various types of incidents on the basis of their probability of occurrence and adjusting capacities to reflect their effects; and
- Incorporating analyst-supplied information about when and where work zones and special events occur, along with any corresponding changes to the base demand or geometry.

The results from these steps are used to develop one scenario for each study period in the reliability reporting period.

The Scenario Generation Settings allow the user to indicate whether or not to include Demand, Weather, Incident, and/or Work Zone in scenario generation.

## Scenario ID

Scenarios generated from the reliability analysis are numbered in a natural order (1, 2, 3, etc.). The scenario IDs are numbered starting with the earliest demand combination (i.e., Jan-Mon comes before Jan-Tue).

## Scenario ID for Special Event

This is provided for the user to enter the appropriate scenario for the special event to be added.

## Scenario Name

This is provided for the user to enter a name that describes the corresponding special event.

## Section Length

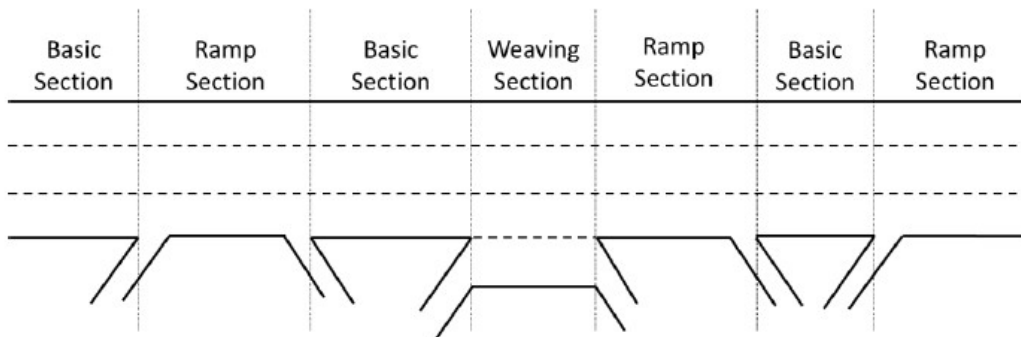
Sections are typically divided by ramp gore points and ramp sections can be longer than the 1500 ft (or 457.2 m in metric) limited by the operations method. For cases where a ramp section length exceeds 2 mi (or 3.2 km in metric), it is recommended to divide the section into multiple sections to avoid having the lower ramp section apply for a very long distance.

## Section Name

This field is provided for each section to identify the section or specify the start point and end point of the section under analysis.

## Section Type

Freeways planning procedure segments the facility into sections. These sections can be basic (no ramps), weaving (on- and off-ramp with auxiliary lane(s)), or ramp (on, off, or both).



## Segment ID

The segments of a facility are numbered in a natural order (1, 2, 3, etc.). The segment ID number refers to the number of the segment found in the Base Dataset Facility graphic in a reliability analysis.

## Segment Length

Distance in feet (or meters in metric) of each segment.

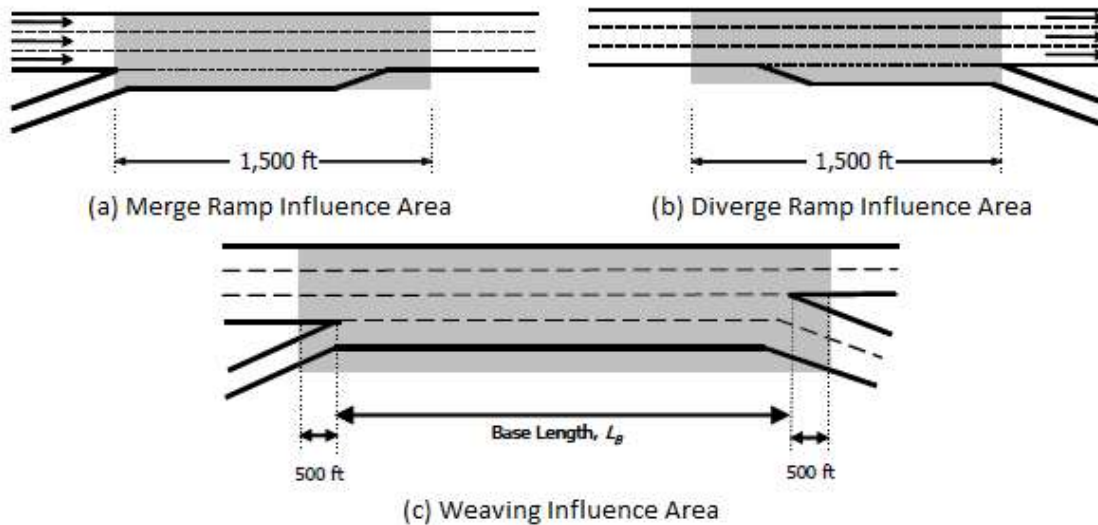
Default Segment Lengths

- Basic: 5280 ft (or 1609.3 m in metric)
- Merge: 1500 ft (or 457.2 m in metric)



- Diverge: 1500 ft (or 457.2 m in metric)
- Weaving: 3000 ft (or 914.4 m in metric)
- Overlap: 500 ft (or 152.4 m in metric)

The exhibit below illustrates the influence areas of Merge, Diverge, and Weaving segments without managed lanes. A weaving segment is usually defined as the distance between the on-ramp and off-ramp gore points. However, its influence area extends 500 ft (or 152.4 m in metric) upstream and downstream of the gore-to-gore length.



## Segment LOS

Segment Level of Service is based on density. See *Level of Service (LOS)* for Basic Freeway Segment thresholds and Freeway Facility thresholds.

Units: USC

The following table shows the criteria for Freeway Merge and Diverge Segments:

LOS	Density (pc/mi/ln)	Comments
A	≤10	Unrestricted operations
B	>10–20	Merging and diverging maneuvers noticeable to drivers
C	>20–28	Influence area speeds begin to decline
D	>28–35	Influence area turbulence becomes intrusive
E	>35	Turbulence felt by virtually all drivers
F	Demand exceeds capacity	Ramp and freeway queues form

The following table shows the criteria for Weaving Segments:

LOS	Density (pc/mi/ln)	
	Freeway Weaving Segments	Weaving Segments on Multilane Highways or C-D Roadways
A	0–10	0–12
B	>10–20	>12–24
C	>20–28	>24–32
D	>28–35	>32–36
E	>35	>36
F	Demand exceeds capacity	

### Units: Metric

The following shows the criteria for Freeway Merge and Diverge Segments:

LOS	Density (pc/km/ln)	Comments
A	≤6	Unrestricted operations
B	>6-12	Merging and diverging maneuvers noticeable to drivers
C	>12-17	Influence area speeds begin to decline
D	>17-22	Influence area turbulence becomes intrusive
E	>22	Turbulence felt by virtually all drivers
F	Demand exceeds capacity	Ramp and freeway queues form

The following shows the criteria for Weaving Segments:

LOS	Density (pc/km/ln)	
	Freeway Weaving Segments	Weaving Segments on Multilane Highway or C-D Roads
A	0-6	0-7
B	>6-12	>7-15
C	>12-17	>15-20
D	>17-22	>20-22
E	>22	>22
F	Demand exceeds capacity	

## Segment Name

This field is provided for each segment to identify the segment or specify the start point and end point of the segment under analysis

## Segment Type

There are 5 possible segment types: basic segment, weaving segment, merge segment, diverge segment, and overlapping ramp segment. See also *Basic Freeway Segment*, *Weaving Segment*, *Merge Segment*, *Diverge Segment*, and *Ramp Overlap Segment*.

## Segmentation

Segmentation usually requires significant analyst time to ensure that the segment types and the computational procedures for those segments have been correctly entered. HCM Chapter 10 Section 2 provides guidelines on segmenting facilities.

## Segmentation Database

Clicking the 'Segmentation Database' button will cause the Query Segmentation Database window to pop up. This will allow selection of a freeway from a database, which can automatically generate segments for a freeway facility within the HCS Freeways module for analysis.

The user will need to specify the following: Database Date, State, Freeway Name, Direction, Mile Marker Start, Mile Marker End. Once these inputs are specified, the selected freeway will appear on the map. Study Period Start, Study Period End, Directional Distribution Factor, and Hourly Profile will also need to be specified to complete the query.

Once all inputs are specified, the freeway facility can be created for analysis. If the user selects 'OK' the user will be brought back to the Segments page in Freeways and the freeway facility will automatically be created based on the query and information found in the database. If the user selects 'Cancel', the inputs entered in the window will be ignored and the user will be brought back to the Segments page in Freeways.

## Segmentation Section Length

Freeway Section length is measured from gore to gore of the ramps. If there are two freeway sections adjacent to each other, then the length is measured to the breakpoint of the two sections. Extremely short sections may cause problems with the automatic segmentation.

## Segmentation Section Type

To complete automatic segmentation, insert a list of each freeway section and each ramp. Ramps need a freeway section between them, and multiple freeway sections can be put together.

## Select All

A 'Select All' checkbox is provided under the 'Segment Global Inputs' section of a Freeway Facility analysis to easily select and apply all inputs provided under that section to the entire facility.

## Semi-Standard Deviation

A one-sided standard deviation, with the reference point being free-flow travel time (or TTI=1) instead of the mean. It reflects the mean variability from free-flow conditions.

## Service Volumes

A checkbox is provided for the user to indicate whether or not to include service volumes tables in the reports. Included in the table are Target LOS, Max Service Flow Rate, Service Flow Rate, Service Volume, One Direction Daily Service Volume, and Bi-Directional Daily Service Volume.

## Side of Junction

The location of the ramp(s) relative to the freeway. There are two types: *right-sided* and *left-sided*.

## Single-Unit Trucks (SUT)

Single-Unit Trucks are defined as one of two categories of heavy vehicles. Buses and RVs are treated as SUTs in the HCM. SUTs include the following:

- Other Two-Axle, Four-Tire Single-Unit Vehicles: Two-axle, four-tire vehicles, other than passenger cars. Generally pickup trucks, sports utility vehicles, and vans.
- Buses: All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. Excludes modified buses no longer capable of mass passenger transport.
- Two-Axle, Six-Tire, Single-Unit Trucks: All vehicles on a single frame with two axles and dual rear wheels. Includes some trucks, camping and recreational vehicles, and motor homes.
- Three-Axle Single-Unit Trucks: All vehicles on a single frame with three axles. Includes some trucks, camping and recreational vehicles, and motor homes.
- Four or More Axle Single-Unit Trucks. All trucks on a single frame with four or more axles.

## Special Event Buttons

On the Special Event page in a reliability analysis, the user can add and delete special events to be included in the reliability analysis. The "Add Special Event" button allows the user to add a special event for the preselected scenario. The "Delete Special Event" button allows the user to delete one or multiple special events at a time. The user must select the special event(s) to be deleted before clicking the button.

## Special Events

Special events are short-term events, such as major sporting events, concerts, and festivals that produce intense traffic demands on a facility for limited periods. Special traffic control procedures may need to be implemented to accommodate the traffic demands. The analyst should identify whether any events that occur in or near the study area warrant special treatment. If so, a schedule for the event (dates, starting times, typical duration) should be obtained. Some types of events also have varying intensities that will require separate treatment (e.g., a sold-out baseball game compared with a lower-attendance midweek game). Recurring events may have developed special traffic control procedures; if so, these plans should be consulted to identify any changes required from base conditions. Each combination of special event venue and event intensity to be included in the analysis will need to be specified.

## Specific Grade

A single grade of a roadway segment or extended roadway segment expressed as a percentage.

## Speed

A rate of motion expressed as distance per unit of time; measured in miles per hour (or kilometers per hour in metric)

## Speed Adjustment Factor (SAF)

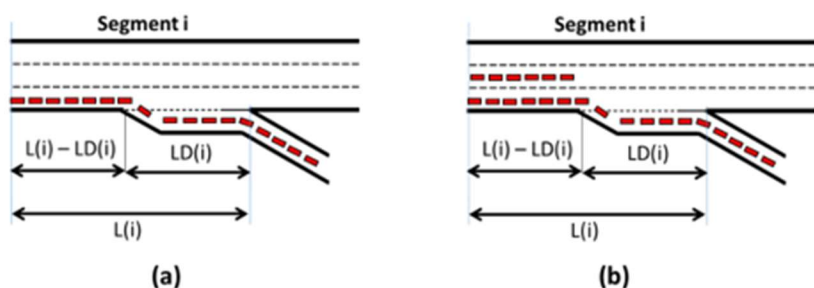
Factor used to allow the user to adjust speed based on a combination of different sources, including weather and work zone effects. The SAF may also be used to calibrate the estimated FFS for local conditions or other effects that contribute to a reduction in FFS. For example, poor pavement conditions or sun glare may result in drivers reducing their speeds even under low-volume conditions.

## Spillback Predicted Queue Length

Queue Length is the distance between the upstream and downstream ends of the queue. The predicted queue length is the estimation of the spillback queue length, measured in vehicles.

## Spillback Queue Storage Length

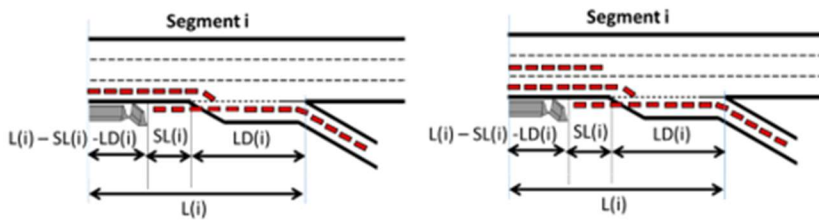
The maximum storage length for off-ramp queues on segment  $i$  is computed as a function of the segment length  $L(i)$ , the deceleration lane length  $LD(i)$ , and the number of queued lanes  $NQ(i)$ .



**Exhibit 38-A14**  
Maximum Off-Ramp Queue Storage Length at Diverge Segments with Occurrence of (a) Regime 3 Queue Spillback And (b) Regime 4 Queue Spillback, when no Shoulder is Available

## Spillback Shoulder Queue Storage Length

When a shoulder is present, but its storage length is not sufficient to accommodate the unserved vehicles, this is a special case of queue spillback. In the exhibit below, the first case occurs when there is blockage of one mainline lane in addition to the shoulder. The second case occurs when there is blockage of two mainline lanes in addition to the shoulder.



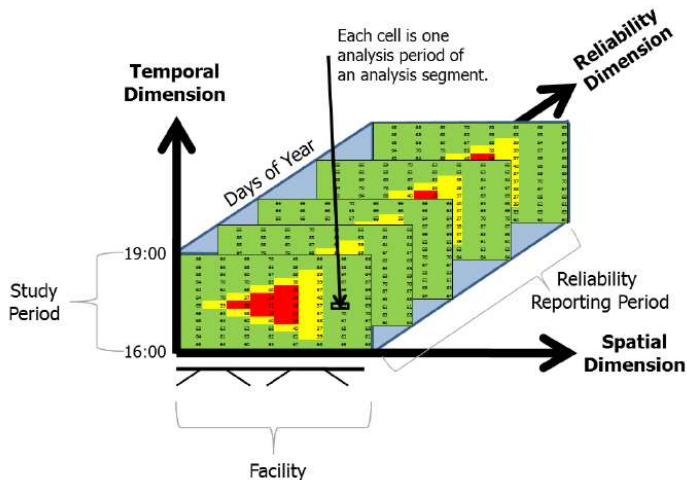
**Exhibit 38-A15**  
 Maximum Off-Ramp Queue Storage Length at Diverge Segments with Occurrence of (A) Regime 3a Queue Spillback and (B) Regime 4a Queue Spillback, when Shoulder is Available

## State

This indicates the state in which to create a query. The state selected will determine which Freeway are available for selection.

## Study Period

The time interval within a day for which facility performance is evaluated. It consists of one or more consecutive analysis periods, represented by the rows in the rectangles in the exhibit found below. In this example, the study period is 3 h long, running from 4 p.m. to 7 p.m. (i.e., 16:00 to 19:00 hours). The start time is 4 p.m. or 16:00 hours. The end time is 7 p.m. or 19:00 hours.



## Study Period End

This indicates when the study period of the query ends. Choices are every 15 minutes based on a 24-hr clock starting with 00:00.

## Study Period Start

This indicates when the study period of the query starts. Choices are every 15 minutes based on a 24-hr clock starting with 00:00.

## SUT Kinematic End Spot Rate

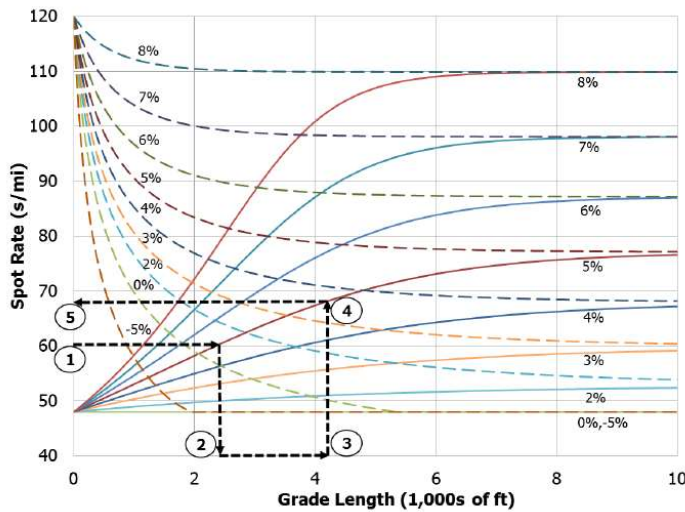
Truck spot rates are needed for the mixed-flow model for composite grades. Step 4 of the model computes the SUT and TT space-based travel time rates for each of the segments and the spot rates at the end of each segment. The first substep involves analyzing the kinematic behavior of the trucks on the grade. The final spot rates are needed, as well as a determination of whether the trucks accelerated or decelerated on the grade.

The graph below can be used for these purposes and are based on kinematic relationships given elsewhere. Alternative models of propulsive and resistive forces, such as more complex ones that account for gear shifting,

can produce longer travel times. Such considerations can be incorporated into the mixed-flow model by adjusting the parameter values that affect the tractive effort to account for the additional losses. The travel time rates presented here are based on a model that assumes constant peak-engine power. Other models account for the power losses that occur for the time intervals prior to an after gear shifting when the engine speed is outside the range that produces peak power.

The graph below shows the trends in SUT spot rates for various grades starting from travel rates of 48 s/mi (75 mi/h) and 120 s/mi (30 mi/h). Clearly, trucks decelerate as upgrades become steeper. For milder grades, trucks can often accelerate.

SUT Spot Rates versus Distance with Initial Speeds of 75 and 30 mi/h:



Notes: Curves in this graph assume a weight-to-horsepower ratio of 100. Solid curves are for an initial speed of 75 mi/h (48 s/mi) and dashed curves are for an initial speed of 30 mi/h (120 s/mi).

For metric units, spot rates are converted from USC units to seconds per kilometer.

## Target LOS

Target LOS is used in a planning and preliminary engineering analysis. This is the Level of Service (LOS) the analyst wishes to achieve based on other parameters, such as Number of Lanes and FFS.

See also *Level of Service (LOS)*.

## Terrain Type

An extended length of highway containing a number of upgrades or downgrades where no single grade is long enough or steep enough to have a significant impact on the operation of the overall segment. There are three types of terrain: Level, Rolling, and Specific Grade.

See also *Level Terrain, Rolling Terrain, and Specific Grade*.

## Time Analyzed

This field is provided to document the time frame of the analysis as morning peak, afternoon peak, existing conditions, future projections, etc.

## Total Ramp Density

The average number of on-ramp, off-ramp, major merge, and major diverge junctions per mile (or kilometer in metric). It applies to a 6-mi (or 9.7-km in metric) segment of freeway facility, 3 mi (or 4.8 km in metric) upstream and 3 mi (or 4.8 km in metric) downstream of the midpoint of the study segment.

For segment analyses, ramp density is computed for a 6-mi (or 9.7-km in metric) section centered on the segment's midpoint; however, for facility analyses, ramp density is calculated across the entire facility (i.e., total number of ramps divided by total facility length).

## Total Ramp Density Adjustment

This is an adjustment to Base Free-Flow Speed based on the Total Ramp Density. This adjustment is equal to  $3.22 \times \text{TRD}^{0.84}$ , where TRD = Total Ramp Density.

## Total Trucks

The percentage of trucks in the traffic stream. Trucks are heavy vehicles engaged primarily in the transport of goods and materials or in the delivery of services other than public transportation. All heavy vehicles are classified as single-unit trucks (SUTs) or tractor-trailers (TTs).

## Tractor-Trailers (TT)

Tractor-Trailers are defined as one of two categories of heavy vehicles. TTs include the following:

- Four or Fewer Axle Single-Trailer Trucks: All vehicles with four or fewer axles consisting of two units, one of which is a tractor or straight truck power unit.
- Five-Axle Single-Trailer Trucks: All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.
- Six or More Axle Single-Trailer Trucks: All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.
- Five or Fewer Axle Multi-Trailer Trucks: All vehicles with five or fewer axles consisting of three or more units, one of which is a tractor or straight truck power unit.
- Six-Axle Multi-Trailer Trucks: All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.
- Seven or More Axle Multi-Trailer Trucks: All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit. Includes triple-trailer combinations.

## Traffic Demand

The methodology accounts for demand variability by adjusting the traffic demands for the analysis periods included in the various scenarios. This is done through the use of a *demand multiplier*, which is the ratio of the daily (weekday-month combination) facility demand to the average daily traffic (or to any combination of day of week and month of year). A second adjustment is needed to factor the demand measured on the specific day-month combination *in the base scenario* to any other day-month combination in the year. Traffic demand variation for different hours of the day is already accounted for in the base scenario obtained from the HCM Chapter 10 core facility analysis.

For example, if the *base scenario* demand data were gathered on a Monday in January that has a demand multiplier of 0.85, and a demand scenario is being tested on a Friday in June that has a demand multiplier of 1.10, then the base scenario demands should be factored by a ratio of  $1.10/0.85 = 1.29$  to create the demand profile for that Friday-in-June scenario. When considering all days of the week, there could be up to 84 demand combinations; for weekday-only analyses, there could be up to 60 demand combinations.

## Traffic Incidents

Incidents are generated on the basis of their expected frequency of occurrence per study period (analysis hours in a day), in a given month on the facility. The analyst may opt to use default expected incident frequencies, may supply a facility-specific incident or crash rate, or may supply a 12-month table of facility specific expected frequencies of any incident type. The incident frequency represents the average number of all incidents experienced on the facility during the study period, and is allowed to vary in each month.



The method makes the following assumptions about a given incident:

- The incident start time is assigned stochastically to any analysis period, which is done automatically by the computational engine;
- The incident duration is assigned stochastically, on the basis of the severity-defined incident duration distribution;
- The incident location is assigned stochastically, weighted by the individual segment vehicle miles traveled (VMT) or vehicle kilometers traveled (VkmT); and
- The incident severity is assigned stochastically, on the basis of the distribution of incident severity.

Default adjustment factors for incidents are provided in Section 5 of HCM Chapter 11.

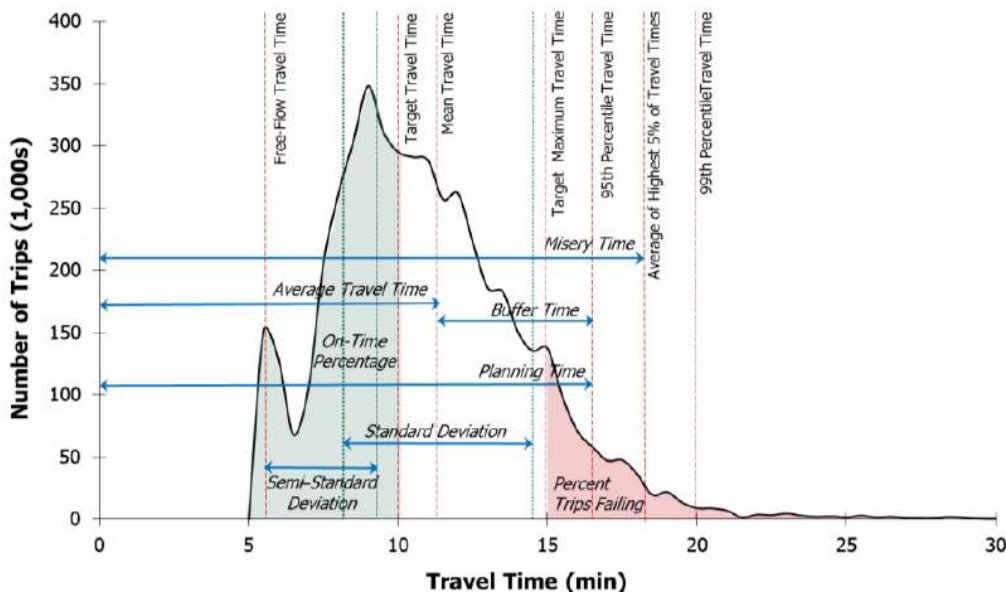
## Travel Time

The time required for a vehicle to travel the full length of the freeway facility from mainline entry point to mainline exit point without leaving the facility or stopping for reasons unrelated to traffic conditions

## Travel Time Distribution

The distribution of average facility travel times by analysis period across the reliability reporting period. Each 15-min analysis period within each scenario contributes one data point to the travel time distribution. It is *not* the distribution of individual vehicle travel times (or TTIs).

The travel time distribution and some of its key performance measures are illustrated in the exhibit found below.



## Travel Time Index (TTI)

The ratio of the actual travel time to the free-flow travel time. By definition, TTI is always  $\geq 1.0$ . The TTI has an identical distribution to travel time, except that its values are indexed to the free-flow travel time.

## TT Kinematic End Spot Rate

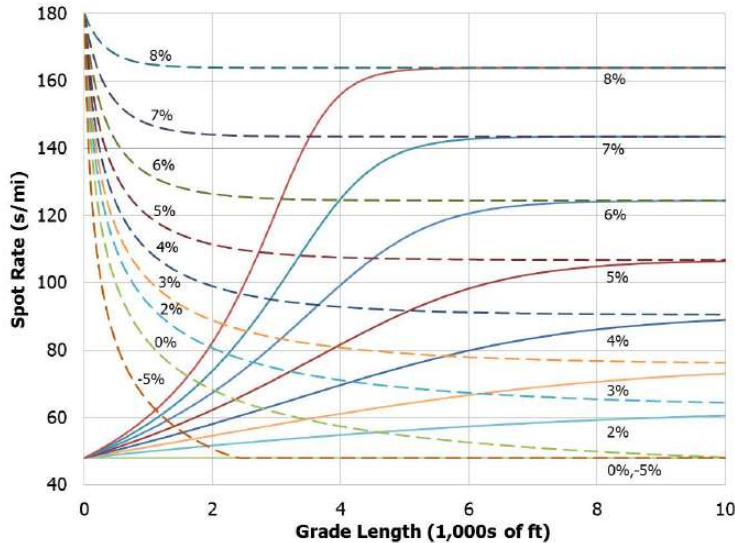
Truck spot rates are needed for the mixed-flow model for composite grades. Step 4 of the model computes the SUT and TT space-based travel time rates for each of the segments and the spot rates at the end of each segment. The first substep involves analyzing the kinematic behavior of the trucks on the grade. The final spot rates are needed, as well as a determination of whether the trucks accelerated or decelerated on the grade.



The graph below can be used for these purposes and are based on kinematic relationships given elsewhere. Alternative models of propulsive and resistive forces, such as more complex ones that account for gear shifting, can produce longer travel times. Such considerations can be incorporated into the mixed-flow model by adjusting the parameter values that affect the tractive effort to account for the additional losses. The travel time rates presented here are based on a model that assumes constant peak-engine power. Other models account for the power losses that occur for the time intervals prior to an after gear shifting when the engine speed is outside the range that produces peak power.

The graph below shows the same trends for a TT. Clearly, trucks decelerate as upgrades become steeper. For milder grades, trucks can often accelerate.

TT Spot Rates versus Distance with Initial Speeds of 75 and 20 mi/h:



Notes: Curves in this graph assume a weight-to-horsepower ratio of 100. Solid curves are for an initial speed of 75 mi/h (48 s/mi) and dashed curves are for an initial speed of 20 mi/h (180 s/mi).

For metric units, spot rates are converted from USC units to seconds per kilometer.

## Undersaturated Flow

Traffic flow where (a) the arrival flow rate is lower than the capacity of a point or segment, (b) no residual queue remains from a prior breakdown of the facility, and (c) traffic flow is unaffected by downstream conditions

## Vehicle Hours of Delay (VHD)

VHD is the vehicle hours of delay during time period  $t$ . The facility VHD is the sum of each segment  $i$ , which is calculated using the equation below:

$$VHD = \sum_i \left[ \left( \left( V_i \times \frac{L_i}{S_i} \right) - \left( V_i \times \frac{L_i}{FFS} \right) \right) \times T \right]$$

where

- VHD = Vehicle Hours of Delay (hours/time period)
- $V_i$  = Segment Volume Served (veh/h)
- $L_i$  = Segment Length (mi)
- $S_i$  = Segment Average Speed (mi/h)
- FFS = Free-Flow Speed (mi/h)
- $T$  = Length of time period (h)

Please note that VHD is computed for every 15 minutes, but expressed with hour units, regardless of whether a single-period or multi-period analysis is performed.

For metric units, Segment Length is measured in km, while Segment Average Speed and Free-Flow Speed are measured in km/h.

Please also note that the VHD in Freeways does not include the ramp delay or unserved vehicles from ramps.

## Vehicle Hours of Travel (VHT)

VHT is the vehicle hours of travel during time period  $t$ . The facility VHT is the sum of each segment  $i$ , which is calculated using the equation below:

$$VHT = \sum_i \left[ \left( V_i \times \frac{L_i}{S_i} \right) \times T \right]$$

where

- $VHT$  = Vehicle Hours of Travel (hours/time period)
- $V_i$  = Segment Volume Served (veh/h)
- $L_i$  = Segment Length (mi)
- $S_i$  = Segment Average Speed (mi/h)
- $T$  = Length of Time Period (h)

Please note that VHT is computed for every 15 minutes, but expressed with hour units, regardless of whether a single-period or multi-period analysis is performed.

For metric units, Segment Length is measured in km, while Segment Average Speed is measured in km/h.

## Vehicle Miles Traveled (VMT)

VMT is the vehicle miles traveled during time period  $t$ . The facility VMT is the sum of each segment  $i$ , which is calculated using the equation below:

$$VMT = \sum_i [V_i \times L_i \times T]$$

where

- $VMT$  = Vehicle Miles Traveled (veh-miles/time period)
- $V_i$  = Segment Volume Served (veh/h)
- $L_i$  = Segment Length (mi)
- $T$  = Length of Time Period (h)

Please note that VMT is computed for every 15 minutes, but expressed with hour units, regardless of whether a single-period or multi-period analysis is performed.

For metric units, Vehicle Miles Traveled (VMT) is converted to vehicle-kilometers per time period and is then denoted as VkmT, which stands for Vehicle Kilometers Traveled.

## Vehicle Value of Time (VOT)

This references travel-time savings and the willingness to pay for savings with regards to vehicle hours of delay. It is measured in dollars per hour (\$/h) and is multiplied by Vehicle Hours of Delay (VHD) to determine the Total Delay Cost.

## Volume

The total number of vehicles or other roadway users that pass over a given point or section of a lane or roadway during a given time interval, often 1 hour.

## Volume Ratio (VR)

The ratio of weaving demand flow rate in the weaving segment to total demand flow rate in the weaving segment.

## Volume-to-Capacity (v/c) Ratio

The ratio of flow rate to capacity for a system element

## Weather Event Duration

The duration associated with each weather event is the length of time of the weather event in minutes. The default duration for each weather event is the same for each location. If a duration is changed, the weather location originally selected will change to 'Custom'. To revert back to the default values, the user can set the location again.

## Weather Event Probability

The probability of a weather event happening is displayed for each month based on the location and the study period start time and end time. The default probabilities are based on the Metropolitan Weather Database for Freeway Reliability Analysis in Volume 4 of the HCM. If any of the probability defaults are changed, the weather location originally selected will change to 'Custom'. To revert back to the default values, the user can set the location again.

## Weather Events

Weather events are generated on the basis of their probability of occurrence during a given month. The scenario generation process accounts for ten categories of severe weather events that have been shown to reduce capacity by at least 4%, along with a *non-severe weather* category that encompasses all other weather conditions and that generates no capacity, demand, or speed adjustments. Default capacity and speed adjustment factors for weather events are provided in Section 5 of HCM Chapter 11.

To capture the actual occurrences of various weather events, the analyst may use default weather data from any of 101 U.S. metropolitan areas, based on 2001-2010 weather records. These values are documented in HCM Chapter 25, Freeway Facilities: Supplemental.

Alternatively, the analyst may supply a 12-month by 11-weather-event matrix (132 total values) of local probabilities of each weather event, along with the average duration for each event (10 values). As mentioned earlier, different weather events are assigned stochastically to the various scenarios in a manner that will match their monthly occurrence based on the site's meteorological data.

## Weather Type

There are different types of weather conditions. The HCM categorizes weather into 11 different types. These include: Medium rain, Heavy rain, Light snow, Light-medium snow, Medium-heavy snow, Severe cold, Low visibility, Very low visibility, Minimal visibility, and Non-severe weather.

The tables below provide default CAFs and SAFs by weather type and facility free-flow speed. Note that the changes in CAFs and SAFs for decreasing visibility shown in the exhibit may be counterintuitive, since they are based on a single site.

The SAF is applied to the base free-flow speed, and CAF is applied to the base capacity, both of which are calculated in the respective methodological chapters for the various freeway segment types. Both may also have been adjusted in the process of calibrating the core facility in Chapter 10 of the HCM. The adjustment factors below should be applied in addition to any prior CAF and SAF calibration.

Default CAFs by Weather Type:

Weather Type	Weather Event Definition	Capacity Adjustment Factors				
		55 mi/h	60 mi/h	65 mi/h	70 mi/h	75 mi/h
Medium rain	> 0.10-0.25 in/h	0.94	0.93	0.92	0.91	0.90
Heavy rain	> 0.25 in/h	0.89	0.88	0.86	0.84	0.82
Light snow	>0.00 – 0.05 in/h	0.97	0.96	0.96	0.95	0.95
Light-medium snow	>0.05 – 0.10 in/h	0.95	0.94	0.92	0.90	0.88
Medium-heavy snow	>0.10 – 0.50 in/h	0.93	0.91	0.90	0.88	0.87
Heavy snow	>0.50 in/h	0.80	0.78	0.76	0.74	0.72
Severe cold	<-4°F	0.93	0.92	0.92	0.91	0.90
Low visibility	0.50 – 0.99 mi	0.90	0.90	0.90	0.90	0.90
Very low visibility	0.25 – 0.49 mi	0.88	0.88	0.88	0.88	0.88
Minimal visibility	< 0.25 mi	0.90	0.90	0.90	0.90	0.90
Non-severe weather	All conditions not listed above	1.00	1.00	1.00	1.00	1.00

Source: Zegeer et al. (1).

Note: Speeds given in column heads are free-flow speeds.

Default SAFs by Weather Type:

Weather Type	Weather Event Definition	Speed Adjustment Factors				
		55 mi/h	60 mi/h	65 mi/h	70 mi/h	75 mi/h
Medium rain	> 0.10-0.25 in/h	0.96	0.95	0.94	0.93	0.93
Heavy rain	> 0.25 in/h	0.94	0.93	0.93	0.92	0.91
Light snow	>0.00 – 0.05 in/h	0.94	0.92	0.89	0.87	0.84
Light-medium snow	>0.05 – 0.10 in/h	0.92	0.90	0.88	0.86	0.83
Medium-heavy snow	>0.10 – 0.50 in/h	0.90	0.88	0.86	0.84	0.82
Heavy snow	>0.50 in/h	0.88	0.86	0.85	0.83	0.81
Severe cold	<-4°F	0.95	0.95	0.94	0.93	0.92
Low visibility	0.50 – 0.99 mi	0.96	0.95	0.94	0.94	0.93
Very low visibility	0.25 – 0.49 mi	0.95	0.94	0.93	0.92	0.91
Minimal visibility	< 0.25 mi	0.95	0.94	0.93	0.92	0.91
Non-severe weather	All conditions not listed above	1.00	1.00	1.00	1.00	1.00

Source: Zegeer et al. (1).

Note: Speeds given in column heads are free-flow speeds.

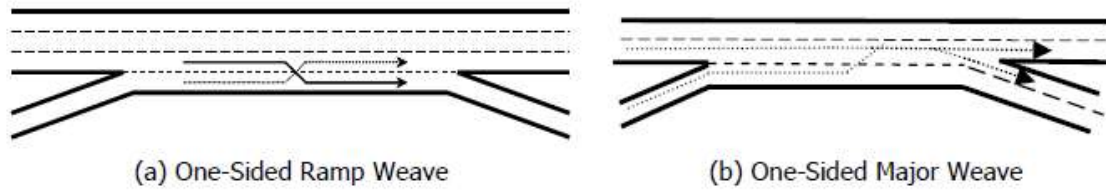
## Weaving Configuration

Configuration of a weaving segment refers to the way that entry and exit lanes are linked. The configuration determines how many lane changes a weaving driver must make to complete the weaving maneuver successfully.

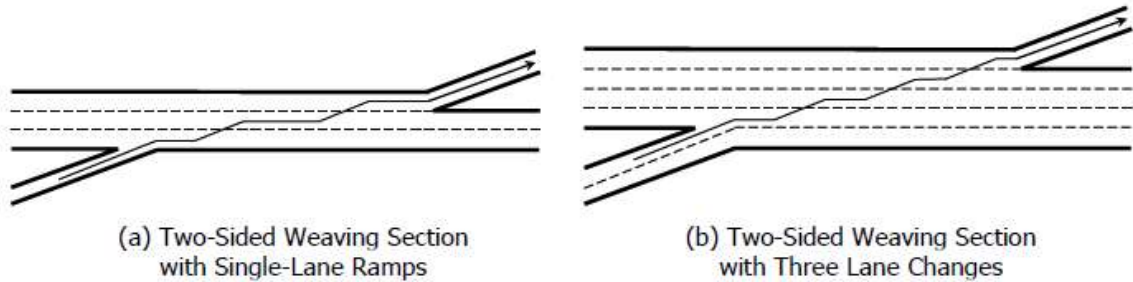
### HCM7

In the Highway Capacity Manual 7<sup>th</sup> Edition (HCM7) methodology, there are two types of weaving configurations: *one-sided* and *two-sided*.

- A *one-sided weaving segment* is one in which no weaving maneuvers require more than two lane changes to be completed successfully. The following illustrates two examples of one-sided weaving segments:



- A *two-sided weaving segment* is one in which at least one weaving maneuver requires three or more lane changes to be completed successfully or in which a single-lane on-ramp is closely followed by a single-lane off-ramp on the opposite side of the freeway. The following illustrates two examples of two-sided weaving segments:



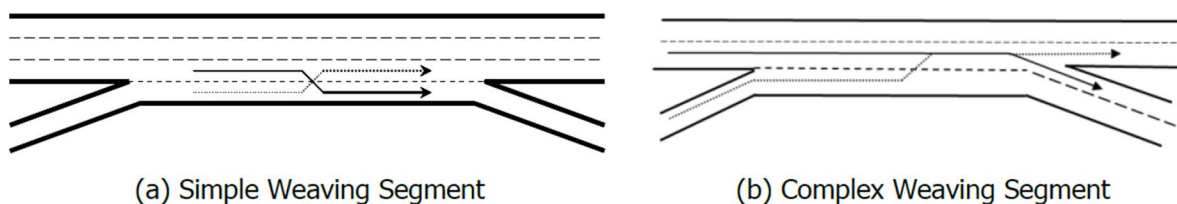
### HCM 7.1

In the update to the Highway Capacity Manual 7th Edition (HCM 7.1), methodology, there are three types of weaving configurations: *one-sided simple*, *one-sided complex*, and *two-sided*.

One- and two-sided weaving segments are defined as follows:

- A *one-sided weaving segment* is one in which the on-ramp and off-ramp are located on the same side of the freeway.
- A *two-sided weaving segment* is one in which an on-ramp is closely followed by an off-ramp on the opposite side of the freeway.

The exhibit below illustrates the difference between a *simple weaving segment* and a *complex weaving segment*.



(a) shows an example of a typical ramp-weaving segment, which is formed by a one-lane on-ramp closely followed by a one-lane off-ramp, connected by a continuous freeway auxiliary lane. The unique feature of the simple configuration is that all weaving drivers must execute a lane change across the lane line separating the freeway auxiliary lane from the right lane of the freeway mainline.

(b) shows a typical *complex weaving segment*, which is formed when three or more entry or exit legs have multiple lanes. A complex weaving segment is distinguished from a major merge or diverge segment in the sense that the latter segments do not feature an auxiliary lane movement between an on-ramp and a downstream off-ramp. A complex weave can arise because of a system interchange and connection with another freeway or because of an interchange with an arterial street with multiple lanes on the on-ramp, the off-ramp, or both.

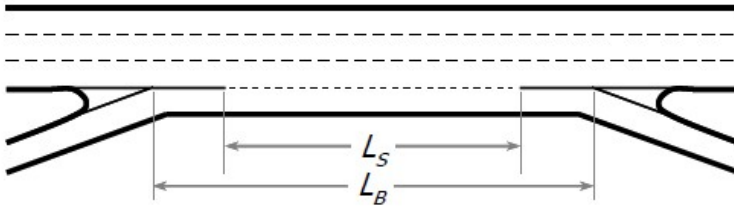
The values of Minimum Ramp-to-Freeway Lane Changes ( $LC_{RF}$ ) and Minimum Freeway-to-Ramp Lane Changes ( $LC_{FR}$ ) can be used to describe the type of complex weaving segment. For example, a segment would be called a "Complex 0-1" weaving segment for a configuration where  $LC_{RF} = 0$  and  $LC_{FR} = 1$ . Similarly, a segment would be called a "Complex 0-2" weaving segment for a configuration where  $LC_{RF} = 0$  and  $LC_{FR} = 2$ .

## Weaving Length

The distance between the merge and diverge that form the weaving segment. There are two measures of weaving segment length: *short length* and *base length*.

- $L_S$  = short length, the distance in feet (or meters in metric) between the end points of any barrier markings (solid white lines) that prohibit or discourage lane changing
- $L_B$  = base length, the distance in feet (or meters in metric) between points in the respective gore areas where the left edge of the ramp-traveled way and the right edge of the freeway-traveled way meet

The following illustrates the two measures of weaving segment:



## Weaving Segment

Freeway segments in which two or more traffic streams traveling in the same general direction cross paths along a significant length of freeway without the aid of traffic control devices (except for guide signs). Also *freeway weaving segment*. Weaving Segments are denoted as "W".

## Weaving Width

The width of a weaving segment is measured as the number of continuous lanes within the segment, that is, the number of continuous lanes between the entry and exit gore areas. Acceleration or deceleration lanes that extend partially into the weaving segment are not included in this count.

## Work Zone

A segment of highway in which maintenance or construction operations reduce the number of lanes available to traffic or affect the operational characteristics of traffic flowing through the segment.

In a Freeways analysis, checking this checkbox indicates there is a work zone present. A set of work zone inputs will appear when this box is checked.

In a Reliability analysis, this portion of the analysis pertains exclusively to scheduled, significant work zone events. Minor patching and repair activities are not treated as work zones, but these important activities can be treated as incident events in the procedure and may be added to the incident tally. As such, a work zone constitutes any activity that results in scheduled closures of the shoulder or one or more travel lanes. Typically, a work zone lasts multiple days or weeks. In some cases, it involves multiple stages, each with different shoulder- and lane-closure parameters.

The details of scheduled work-zone activities must be entered by the analyst and cannot be defaulted. A work-zone log should be entered in which the following information is input for each work-zone activity that is planned during the RRP:

- Calendar days of the start and end dates of the work-zone activity;
- Facility segment(s) and analysis periods impacted by the work-zone activity;
- Portions of the facility cross-section impacted by closures (i.e., shoulder, one-lane, or multiple-lane closures);
- Type of barrier used to separate traffic from the work activity (i.e., concrete or other hard barrier, or cones, drums, or other soft barrier);

- Regulatory speed limit in effect during the work zone activity; and
- Lateral separation between traffic and the work zone.

The methodology can accommodate multiple work-zone activities, each with its own sets of inputs. CAFs and SAFs for work zones have been developed by national research and are described in Section 4 of HCM Chapter 10, Freeway Facilities Core Methodology.

## Work Zone Buttons

On the Work Zone page, the user can add, insert, or delete work zone events to be included in the reliability analysis. The 'Work Zone Event +' button allows the user to add work zone events. An unlimited number of work zone events can be added. The 'Insert Work Zone Event' button allows the user to insert a work zone event in between existing work zone events. The user must select a work zone event to insert a new work zone event before it. The 'Work Zone Event -' button allows the user to delete one or multiple work zone events at a time. The user must select the work zone event(s) to be deleted before clicking the button.

## Work Zone Duration Analysis Period

This number specifies how many analysis periods the work zone event lasts.

## Work Zone End Date

This is the date the work zone event finishes.

## Work Zone Free-Flow Speed

The work zone free-flow speed is the free-flow speed, in miles per hour (or kilometers per hour in metric), of the work zone. When the Work Zone Speed Limit is less than 55 mi/h (or 89 km/h in metric), the input for Work Zone FFS will appear and the value entered will be used directly in the computation without checking the speed limit.

## Work Zone Speed Limit

The work zone speed limit, or  $SL_{wz}$ , is the speed limit, in miles per hour (or kilometers per hour in metric), of the work zone. Higher work zone speed limits and higher speed ratios result in higher work zone FFS.

## Work Zone Start Date

This is the date the work zone event begins.

## Work Zone Start Period

This is the beginning analysis period for the work zone event.



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