2016

FREEVAL-WZ
Users Guide

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1 TABLE OF CONTENTS

1 INTRODUCTION

This document is intended to provide general guidance on the use of the FREEVAL-WZ planning level work zone analysis software. The software is based on the NCHRP 03-107 work zone methodology, which will be included in the HCM 6th edition. Detailed discussion on the procedure itself, along with engine documentation guidance for software developers is provided in the project's final report *(1)*. Since the software is developed as an extension of the FREEVAL-2015e computation engine of the Highway Capacity Manual, a number of references will be made to the underlying methodology. Throughout this document, we will refer to the HCM's 6th edition: A Guide for Multimodal Mobility Analysis, simply as "HCM".

This document assumes that the user is at least familiar with the basics of the Freeways Facilities methodology of the HCM. The core computational engine, FREEVAL (**FRE**eway **EVAL**uation) 2015e is a computerized tool designed to *faithfully implement* the operational analysis computations for undersaturated and oversaturated directional freeway facilities. FREEVAL-2015e is a faithful implementation of HCM Chapters 10 and 11, which incorporate all of the freeway segment procedures for basic freeway segments, weaving segments, and merge and diverge segments, respectively. For more information on FREEVAL-2015e, the reader is encouraged to consult the FREEVAL-2015e User Guide *(2)*.

1.1 OVERVIEW

FREEVAL-WZ is a work zone specific version of FREEVAL-2015e designed to provide a user friendly environment that implements a planning level approach for work zone analysis. The software strives to provide the ability to quickly test impacts of different work zone scenarios as well as quantify effects of congested periods over time and space. The planning level analysis provides many useful default values to ease date entry, as well as providing the option to enter either daily AADT values or hourly demand flows. The software has been developed as an extension of the FREEVAL-2015e computational engine, and as such allows access to the entire operational level analysis capabilities of the underlying FREEVAL core engine if the user decides to pursue that route.

Both the WZ toolbox and the core computational engine were built in the Java™ programming language. The environment allows the user to analyze a freeway facility of up to **500 HCM segments** (to be defined) and for up to **ninety-six 15-min analysis intervals (24 h)**. The engine can generally handle any facility that falls within these temporal and spatial constraints. However, it is highly recommended that the total facility length not exceed 9–12 miles in length to ensure consistency between demand variability over time and facility travel time. Further, the spatial and temporal boundaries for any analysis (i.e. first and last time intervals and first and last facility segments) should be uncongested and should allow all queues to form and clear within the specified time-space domain to assure that performance measures fully account for the predicted extent of congestion and delay. These aspects are discussed in detail in HCM Chapter 10. In conformance with the HCM, all analyses are carried out using US customary units.

The planning level approach implemented in the software includes the findings and work zone analysis methodology of NCHRP 03-107 *(3)*, as well as a number of North Carolina calibration defaults developed over the course of the project *(4)*.

1.2 JAVA™ REQUIREMENTS

Version 8 or newer of the Java™ SE Runtime Environment (JRE) is required to run FREEVAL-WZ. Any version of Java™ 8 will be sufficient, but it is generally preferable to have the most up-to-date version whenever possible. If you are not sure which version your computer is running, there are a number of ways to check if your installed version of Java™ is sufficient or up-to-date (see next sub section). The most recent version of Java can be acquired by going to the Java SE home page and selecting the JRE download (http://www.oracle.com/technetwork/java/javase/downloads/index.html).

As of the writing of this document, the most recent version of Java JRE 8 can be found at http://www.oracle.com/technetwork/java/javase/downloads/jre8-downloads-2133155.html.

1.2.1 CHECKING YOUR JAVA VERSION

1.2.1.1 WINDOWS USERS

In order to check the version of the JRE installed on your computer, open the Control Panel program and enter “java” in the search bar. This will allow you to open the Java Control Panel. Once in this screen, under the “General” tab, click the “About” button and a dialog displaying the version should appear (see Figure 1). If the search does not return any results, then it is likely that your computer does not have any version of the JRE installed. An alternative way of checking can be done by opening a Command Prompt window and entering the command “java –version”. If this command returns an error or the output does not say “java version 1.8.0_xx” (xx can be any number), then you will need to install or update the JRE.

1.2.1.2 MAC OS OR LINUX USERS

To check the installed version of java on a Mac OS or Linux computer, open an instance of “Terminal” using the Launchpad or by using the Spotlight search. Then enter the “java –version” command in the windows. If this command returns an error or the output does not say “java version 1.8.0_xx” (xx can be any number), then you will need to install or update the JRE.

Figure 1: Example “About Java” dialog showing the currently installed version.

1.3 INSTALLATION AND RUNNING

Once an up-to-date version of Java™ has been installed, FREEVAL-WZ can now be run on the computer. First, a copy of the FREEVAL_WZ.zip archive should be downloaded to the desired installation location. Next, **the contents of the archive must be extracted (Note: Some computers will extract the files automatically if the zip archive is double-clicked, but on many Windows machines the extraction must be done explicitly).**

To extract the contents of the folder, either right-click on the zip archive and select the "Extract" option, or if in the .zip archive folder, choose the Extract tab and select the "Extract All" option. In either case the user will be prompted with a few simple instructions about the desired location or the extracted file. Once the files have been extracted, FREEVAL-WZ is now ready to be run by double-clicking on the FREEVAL.jar executable.

1.4 DOCUMENT ORGANIZATION

Section 2 gives a brief description of the structure and organization of FREEVAL-WZ and details how to create a WZ project. The document then presents a step-by-step description of the process for creating a facility, designing a set of work zones, and conducting the comparison analysis. The 6 steps of the analysis are presented alongside a series of screen shots that develop an example based on Example Problem 1 of HCM Chapter 10. Section 3 presents a number of additional features of the software designed to help customize and extend the base analysis. These features can all be utilized at any point during the analysis of Section 2, but are left out of the initial description to maintain simplicity. Section 4 presents a case study on a stretch of I-40 east outside of Raleigh, NC in which the analysis is used to help determine an appropriate start time for an upcoming work zone. Finally, a number of appendices are included at the end of the document to provide further quick reference for the user.

2 CREATING AND ANALYZING A FACILITY IN FREEVAL-WZ

This section presents a detailed overview of the data input process necessary to create and analyze a FREEVAL-WZ project. This section presents a detailed overview of the data input process, through a series of steps and screenshots, necessary to create and analyze a FREEVAL-WZ project.

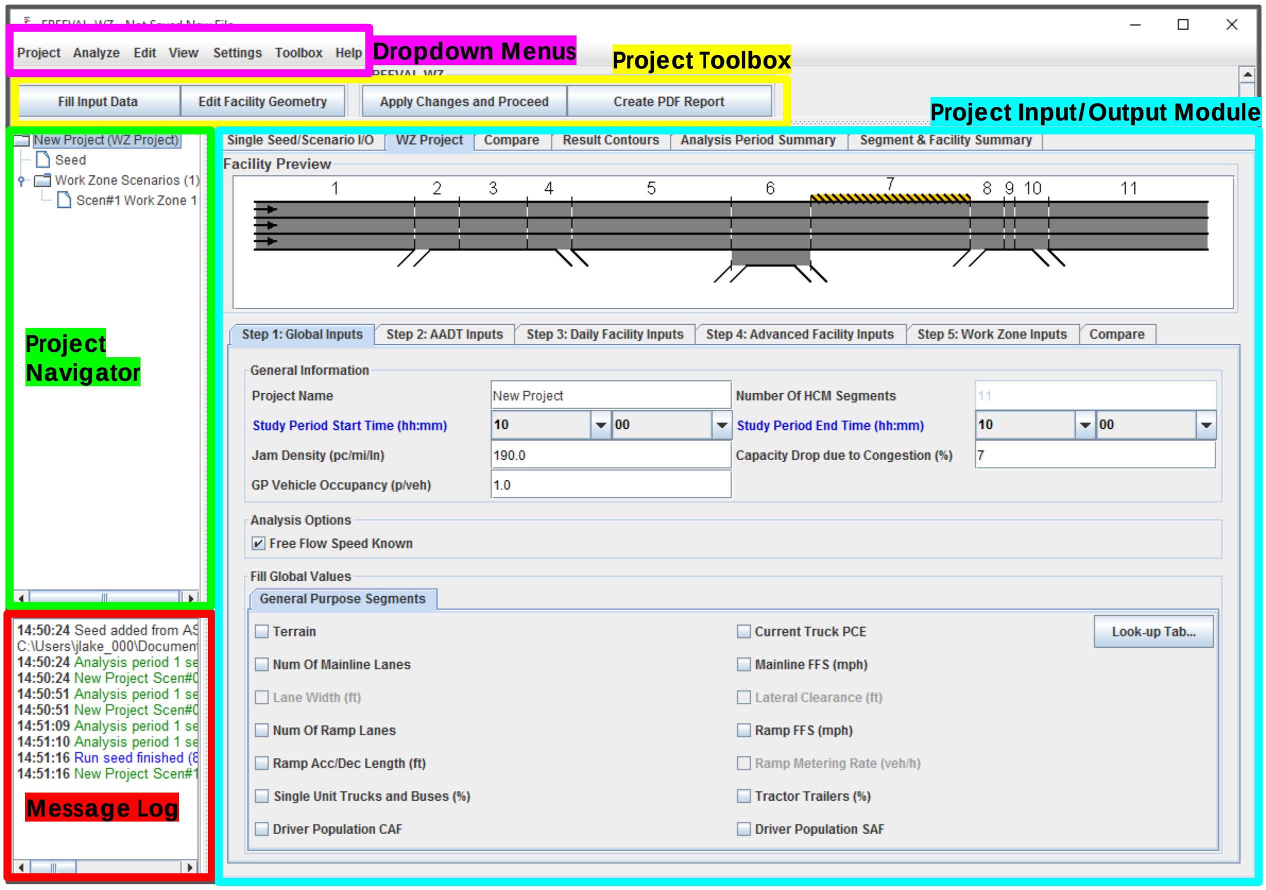


Figure 2: Layout of FREEVAL-WZ

The general layout of the main window of the program is very similar to FREEVAL-2015e and is shown in Figure 2. A bar of option dropdown menus is shown at the top, and the Project Toolbox is found just below it. The left pane is divided into two sections. The top section holds the *Project Navigator*, where projects are displayed in a collapsible/expandable tree format. As a note, for the majority of the FREEVAL-WZ Project creation and analysis process, the analyst will not need to use the project navigator. Its use is mostly confined to aiding in conducting additional operational-level analysis using some of FREEVAL-2015e's core analysis features. The bottom presents a *message log* for the program, where a log of the actions by the user is recorded, and some errors may be displayed if they occur. The largest central area of the window is the *WZ Project input/output module*, which consists of a set of tabs corresponding to the six input and analysis steps discussed in the following sections.

Those users familiar with core computational engine will notice that the *WZ Project* tab falls within the set of analysis tabs of FREEVAL-2015e. For the majority of the WZ analysis, these will be disabled and unused. However, once the WZ analysis is completed, these features will be enabled to allow the user to conduct a more in-depth operational level analysis.

2.1 CREATING A FREEVAL-WZ PROJECT FILE

Before conducting the analysis, the user must first create a FREEVAL WZ project. Alternatively, if the user has already created a WZ project, he or she may open that file and pick up the analysis from where it was left off. For instructive purposes, this document will proceed as if this is the user's first interaction with the program and will assume a brand new project is being created.

To create a new project, the user should select the *New WZ Project* option from the "Project" dropdown menu at the top of the program window (see Figure 2). At this point, the user will be prompted with two options: start from a new facility, or import data from an existing facility (e.g. ASCII or .seed facility file NOT an existing WZ Project). If the user chooses to start from a new facility, he or she will be prompted for a name for the project (see Figure 3), and upon clicking the "Create" button, the process will move directly to Step 1 (see Section 2.2).

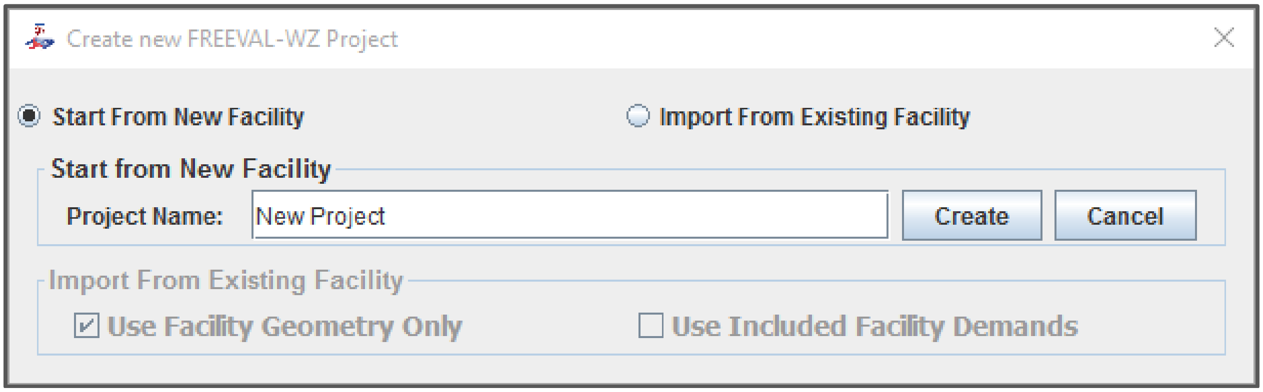


Figure 3: Options for creating a new FREEVAL-WZ Project

Selecting the "Import From Existing Facility" option allows the user to use a previously created facility as a template for the new WZ Project. The new project dialog will prompt the user to specify the file location, which must have either been saved in the ASCII (.txt) or SEED (.seed) file format. This primarily allows analysts to make use of facilities created in the FREEVAL-2015e core engine, or even those created in a previous Java version of FREEVAL (via the ASCII file format). However, facilities of either file format can be saved at any point during the creation of a facility in FREEVAL-WZ by using the "Export Base Facility" option in the *Project* dropdown menu.

After the location of the facility file has been specified, the user is given two options to choose how much data is imported from the template facility. The user can choose either to extract just the geometry of the facility or to import both the geometry and any pre-existing demands of the facility. If just the geometry of the facility is used, the process will skip directly to Step 2 to allow the AADT inputs and distribution to be specified (see Section 2.3). If both the geometry and demands of the facility are used, the process will skip directly to Step 4 as both the facility and ramp AADT inputs are no longer needed (see Section 2.5).

2.2 STEP 1: GLOBAL INPUTS

After selecting the *New WZ Project* menu option and specifying a project name, the process will proceed to the Global Inputs step. The "Step 1: Global Inputs" tab for new facility is shown in Figure 4. Here, the user selects the study period to be analyzed and specifies the number of segments in the facility. The user can revise these at a later time in the analysis if necessary (see Section 3.3). Other settings include whether the facility free-flow speed is known or should be calculated, whether ramp metering is used, the type of terrain, and the jam density of the facility (used for oversaturated calculations). For a full explanation of all of the Global Input parameters, please refer to the HCM and the FREEVAL-2015e User Guide. After completing all global settings, the user should select "Apply Changes and Proceed" option in the program toolbar and FREEVAL-WZ will then generate the facility. Depending on the computer used, there may be a slight delay in this process.

Notice that in Figure 4 the facility preview graphic is blank during the initial process of specifying the global inputs. This is because the facility has not yet been created, and the graphic will be updated as soon as it is. Note that the facility graphics does not fully represent number of lanes on the on-ramps and off-ramps and they will be always shown on the right side of the mainline.

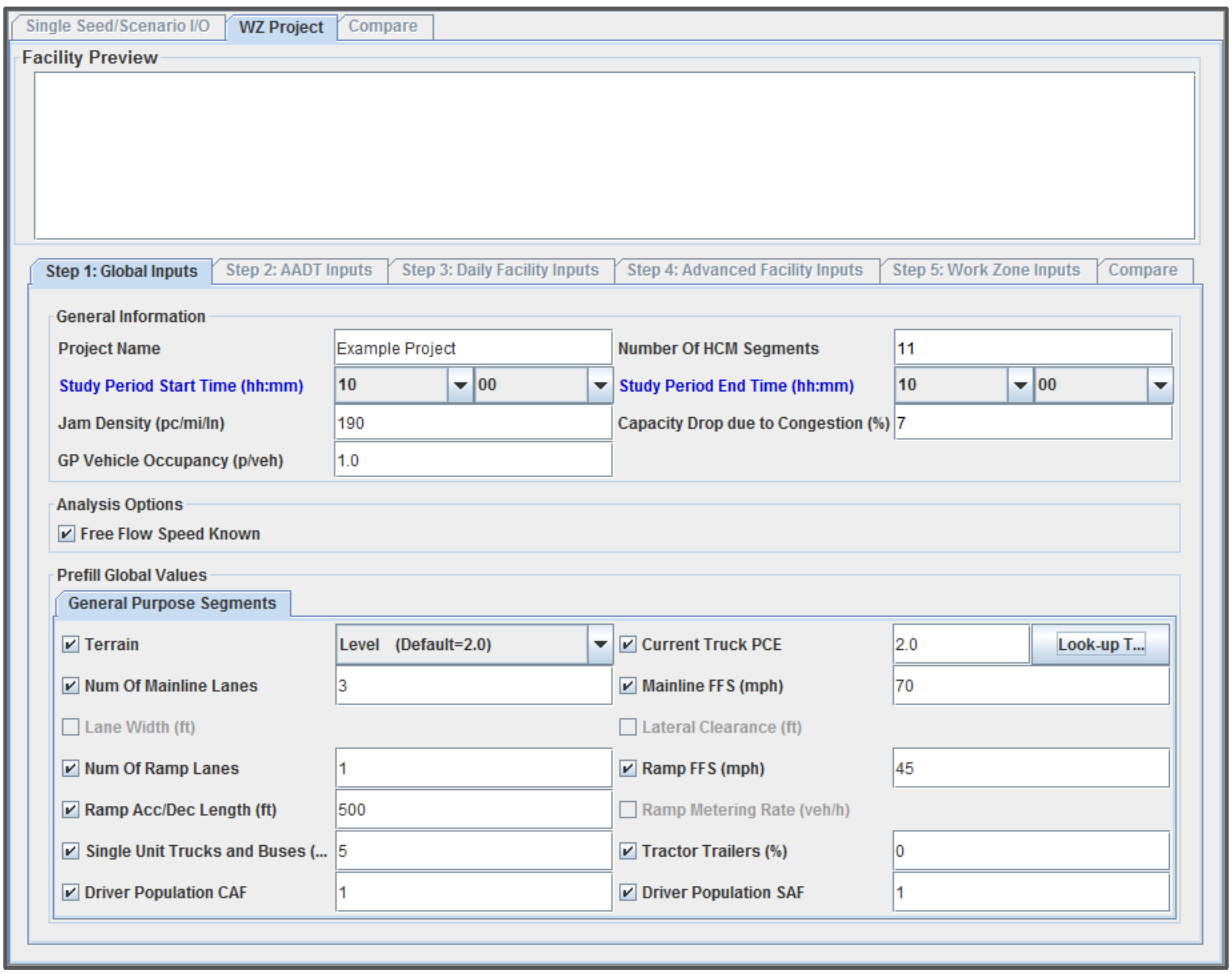


Figure 4: Global Input dialog for FREEVAL-2015e.

If at any point during the analysis the user returns to the global inputs step, many of the check boxes and data entry fields will be hidden. To change a global parameter that has already been set, the user must first check the parameter and then enter the value when the data entry field becomes visible. This is done as a safety measures such to ensure the analyst does alter any values by accident.

2.2.1 CHOOSING THE STUDY PERIOD

For any FREEVAL-WZ analysis it is very important that the analyst chooses appropriate start and end times for the study period. **Poorly chosen study period start and end times can result in inaccurate analysis and widely varying performance measures.** This occurs because the underlying HCM methodology for the work zone simulation analysis relies on flow information that is passed between consecutive analysis periods in order to correctly model the behavior and growth of queues. Hence if a study period start time is chosen while a queue would normally exist on the facility, the methodology has no information about congestion build up from previous periods and thus cannot accurately predict the queue size and behavior. For a more detailed explanation and an example, the user can refer to Section 2.2.2.

In general**, the start and end times of the study period should be chosen such that any congestion and queues occurring in the analysis are fully contained in the study period**. Failure to do so will result in inconsistent and inaccurate simulation**.** Both the first and last 15 minute analysis period should be uncongested, and the queue should not extend outside of the facility during the study period. **For a 24-hour analysis, it is preferable that the start and end time fall at the point of lowest congestion during the day.** For many cases, this will likely fall sometime in the early morning between 0:00am (midnight) and 6:00am. However, there may be cases in which the work zone being analyzed is active for less than 24 hours, and the active periods span this entire time period. For example, this could take the form of a work zone scenario active from 10pm to 7am. This makes choosing a start/end time between the hours of midnight and 6am impossible. When this occurs, the user should use their best judgment to pick the lowest point of congestion that does not interfere with the time periods in which the work zone scenario is active. Figure 5 shows an example of using the AADT distribution graphic (discussed in section 2.3) to identify low points of congestion, and Figure 6 shows two facility contour plots that confirm that a low point of congestion has been identified.

If during a work zone analysis the software detects an issue related to the selection of study period start and end times, the user will be notified of the potential issue. Further, the software will recommend that contour plots be included with any PDF report (see section 2.8) that is generated for the analysis.

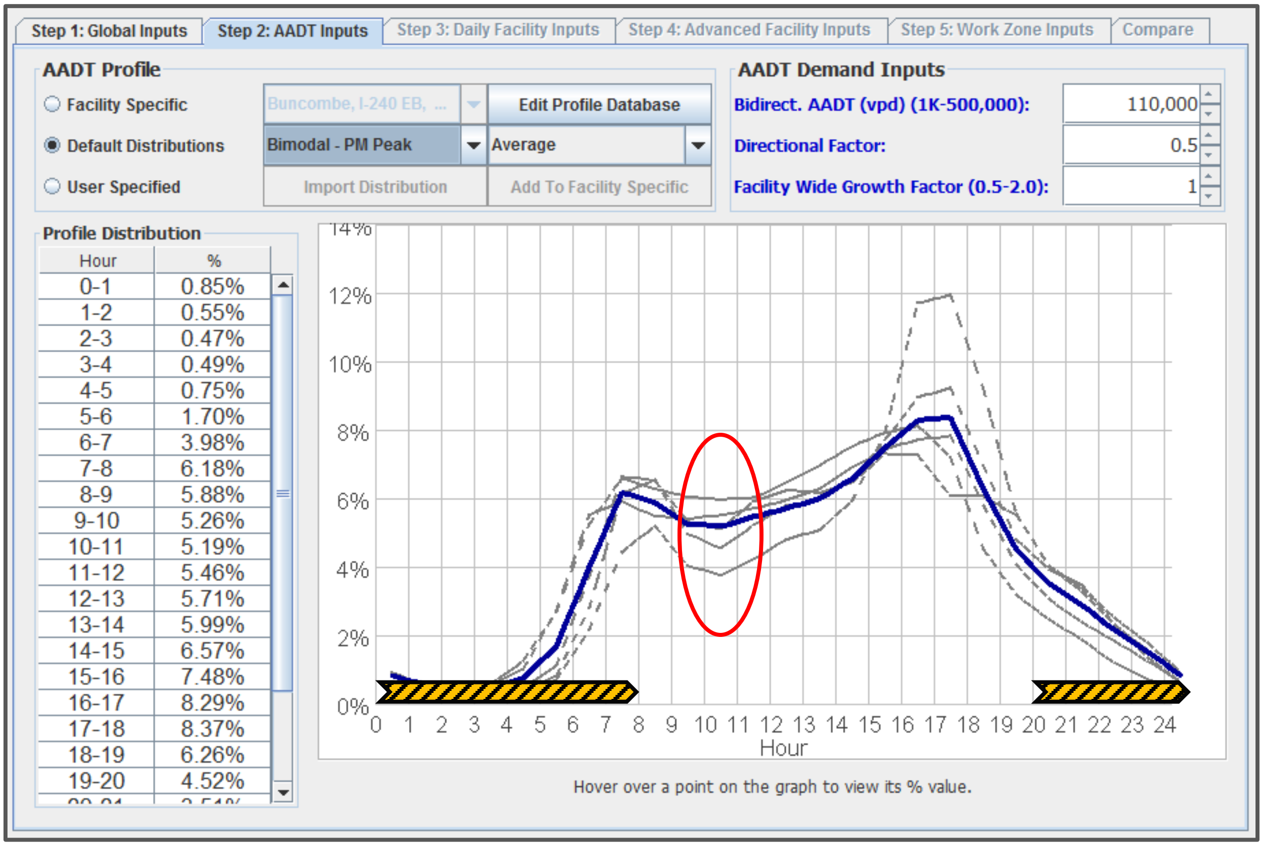


Figure 5: Using the AADT distribution profile to identify potential low points of congestion on a facility with a work zone occurring between 10pm and 7am.

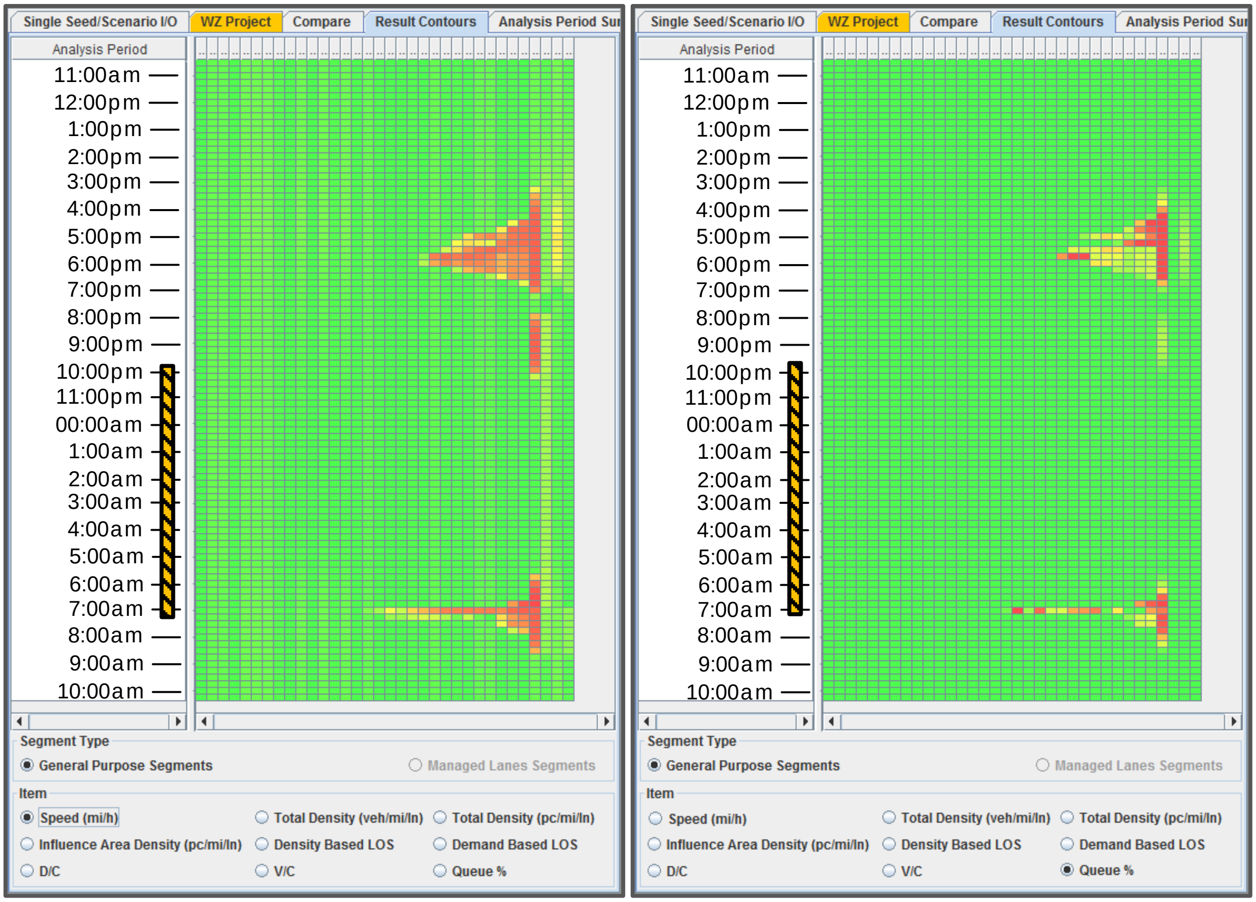


Figure 6: Contour plots for speed and queue % showing that the areas of congestion are fully contained within the 24 hour study period which runs from 10:30am – 10:30am.

2.2.2 EXAMPLE OF EFFECTS OF STUDY PERIOD BOUNDS

As mentioned in section 2.2.1, poor choices for study period start and end times can alter the summary performance measures and costs of a work zone analysis. This section will demonstrate how this can happen with a brief example. Consider a work zone analysis with a 24 hour study period, where the work zone scenario only causes congestion during the PM peak hours (4 – 6pm). It is likely in this case that the analyst will choose to use the default 24 hour study period start and end time of midnight (0:00am). The contour and summary of outputs for this analysis is shown in Figure 7. However, if the analyst were to instead choose a study period that starts and ends during the middle of the PM peak hour congestion, say choosing a start and end time of 5pm (17:00pm) the results of the analysis will be different. During the first 15 minute analysis period from 17:00-17:15, the underlying HCM methodology has no knowledge of any queue that has built up during the previous hour, and thus the congestion and queueing dynamics are not captured correctly. This can be clearly seen in Figure 8 where the first period is congested since the analysis picks up in the middle a congested time period. Further, the last period of the study period is also congested, which additionally implies that the analysis is not capturing the full impacts of the congestion at the end of the study period. Comparing the summary tables, it can be seen that overall they are drastically different, with the calculated cost being much lower when the study period is chosen incorrectly.

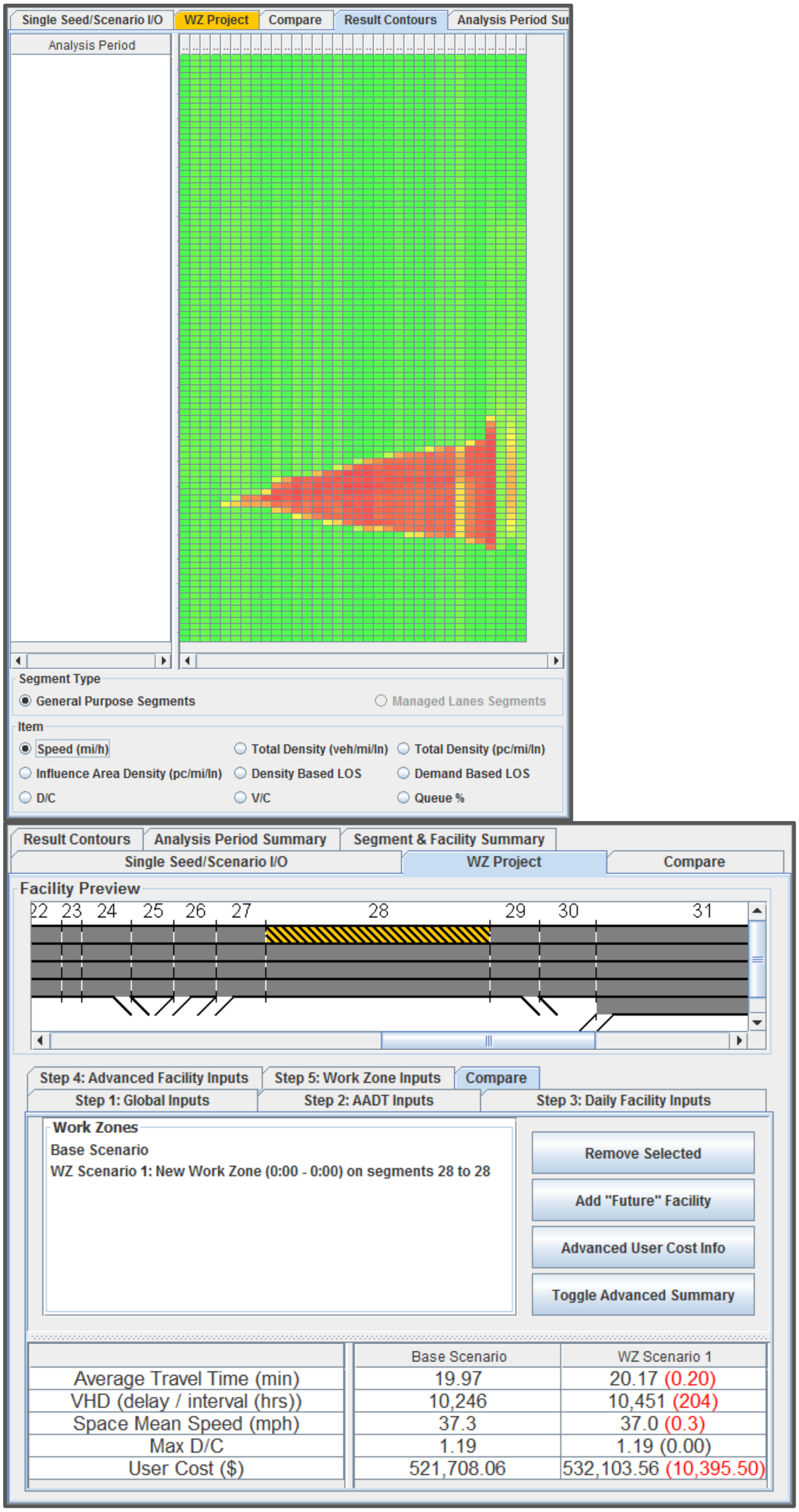


Figure 7: Analysis with a study period from midnight to midnight which completely contains the congestion dynamics.

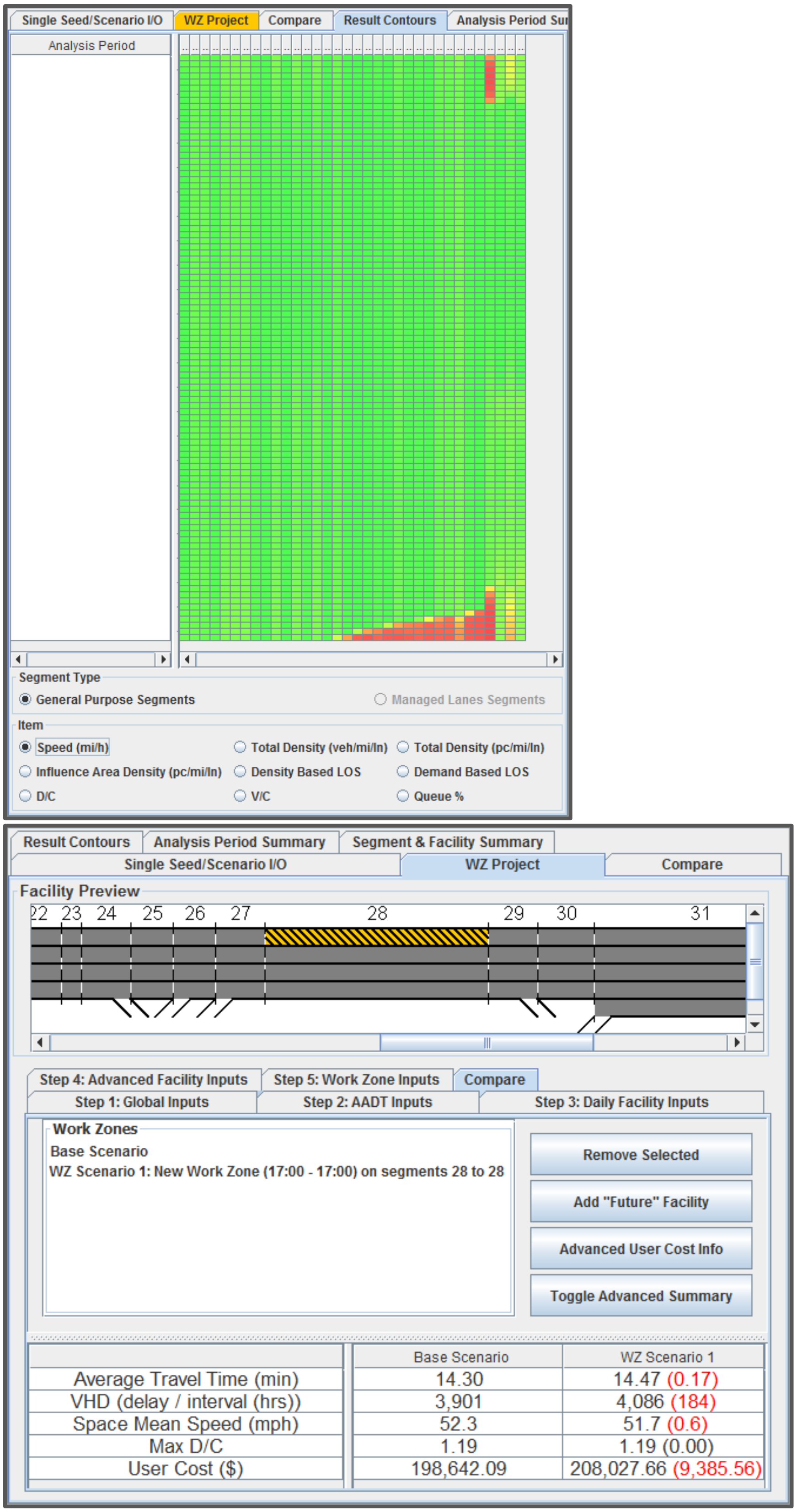


Figure 8: Analysis with a study period from 17:00 to 17:00 which fails to properly contain the congestion dynamics.

2.3 STEP 2: SPECIFYING AADT INPUTS

In the second step of the analysis the user specifies the AADT inputs for the facility. The user is responsible for specifying a 24-hour distribution for AADT, as well as providing the bidirectional AADT, directional factor, and facility wide growth factor.

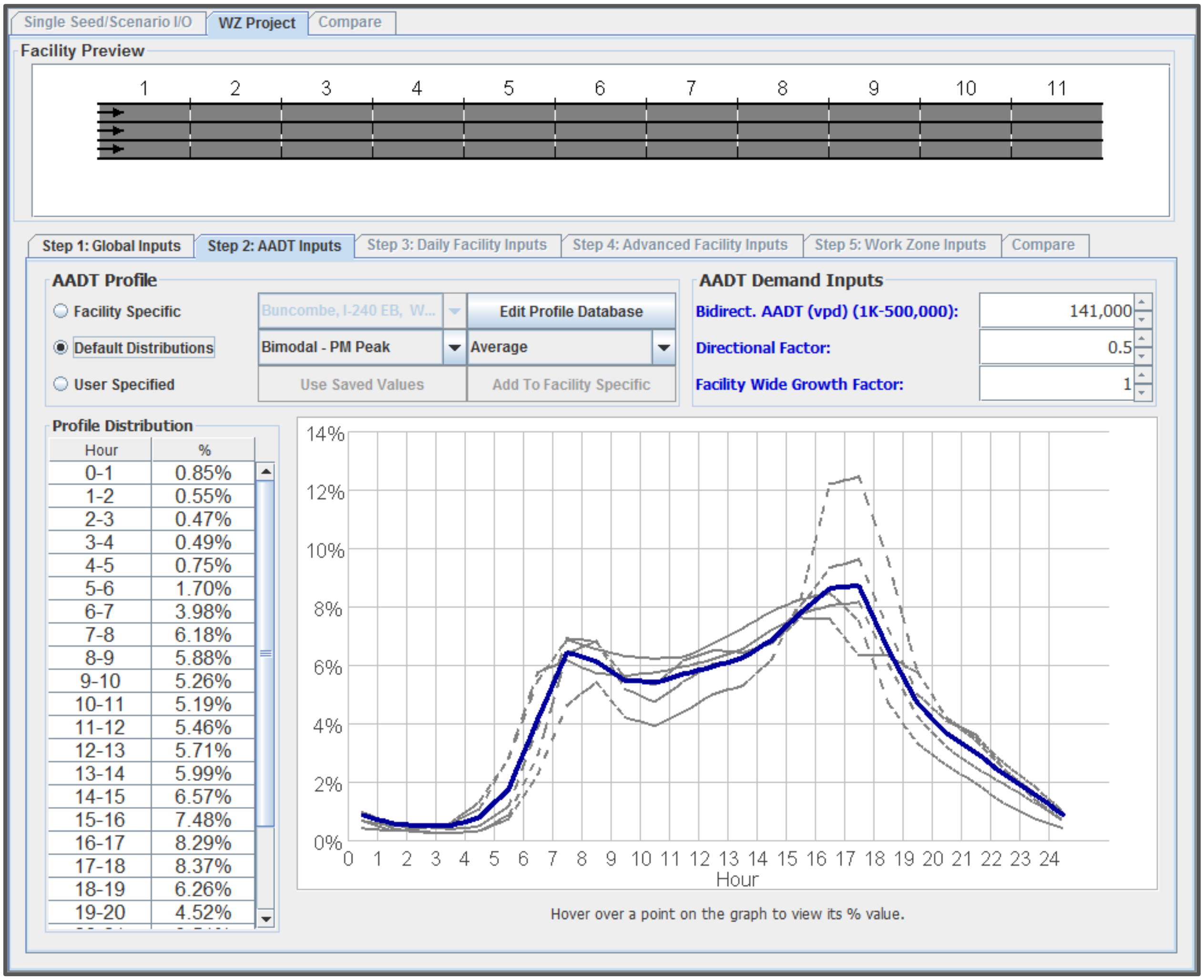


Figure 9: AADT Inputs

2.3.1 AADT DISTRIBUTION

The AADT distribution provides a set of percentages that describe how the bidirectional AADT is dispersed over the course of the day. The distribution requires the entry of twenty-four percentages that each correspond an hour of the day. For example, the percentage of AADT that is on the facility from 12am to 1am is specified in the "0-1" hour bin, and the percentage on the facility from 5pm to 6pm is specified in the "17-18" hour bin. The user can choose to specify the AADT distribution in one of three ways: use a facility specific distribution, use a "default" distribution, or specify a custom distribution.

The first option allows the user to select a distribution from a set of facility specific defaults based on data collection done in the associated NCDOT project *(1)*. Each of these distributions represents the observed behavior at the corresponding facility. The user can choose from a list of 52 facilities in North Carolina, with each labeled by county, route number, direction (e.g. eastbound), and a brief description. More detailed information about the facilities can be found in the report and all available facilities are listed in Appendix A: List of Facility Specific AADT Distributions (Section 7).

It is possible to create a new facility specific distribution (discussed below), and the set of distributions can be viewed using the “Edit Profile Database” button. Note however, that the included 52 distributions cannot be edited or deleted, only those that have been added to the database. In order to adjust an existing facility specific distribution, the user should first select the distribution, then choose “User Specified,” which will maintain the values currently selected, adjust them as needed, and finally add the new distribution to the database using the process described in the final paragraph of this section.

The second option provides a set of “default” AADT distributions. These represent the three “shapes” of distributions that were most commonly observed. The three shapes are *Bimodal-AM Peak, Bimodal-PM Peak*, and *Unimodal.* The two *bimodal* distributions essentially represent behavior observed on commuter roads during weekdays. These distributions have two peaks, one occurring in the morning hours, and one occurring in the afternoon rush hours. The two types are differentiated by which time has the higher peak. For *Bimodal-AM Peak*, the bulk of the traffic is concentrated in the morning rush, while for *Bimodal-PM Peak*, the bulk of the traffic is concentrated in the afternoon rush. For example, the AADT distribution graph in Figure 9 shows a *Bimodal-PM Peak* distribution. The *Unimodal* distribution represents an AADT distribution shape with only one peak. This typically represents traffic on rural roads or traffic on weekends. Figure 10 shows an example of a *Unimodal* distribution. For more information on how these default distributions were developed, the user can refer to the associated NCDOT project report *(1)*.

Within each of the “default” distribution shapes, the user must also specify a subtype that indicates the severity of the distribution. Each of the three shapes has 6 subtypes: minimum, 25th percentile, average, 75th percentile, maximum, and median. Each of these corresponds to the respective skew of the shape based on the distributions that were observed in the data collection process discussed in the associated NCDOT project report *(1)*. The AADT distribution line graph displays each of these subtypes with a dotted grey line, with the currently selected shape drawn in a bolded blue line.

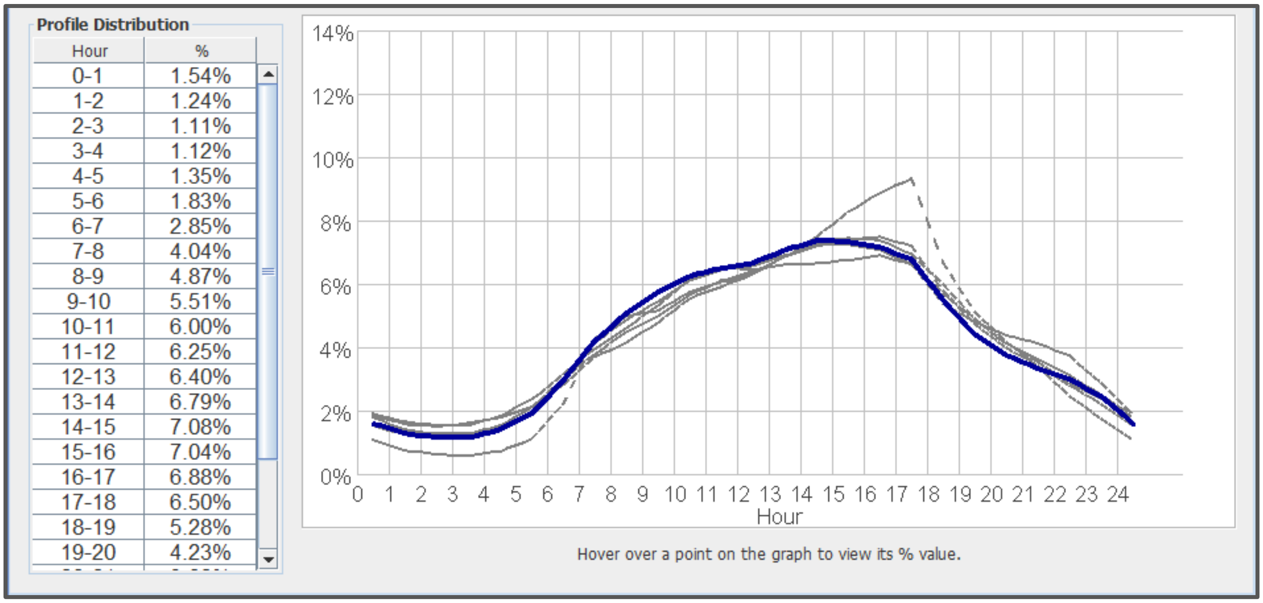


Figure 10: Unimodal AADT Distribution Shape.

The final option for selecting an AADT distribution allows the user to input a custom distribution. This can be used in the event that the analyst has data pertaining to the specific location being modeled. The only requirement is that the distribution must sum to 100%. Further, once a custom distribution has been created, it can be saved to the list of facility specific distributions by clicking the "Add to Facility Specific" button as seen in Figure 11. When adding a distribution to the facility specific database, the user is asked to provide a facility name or description, the facility route number, the route direction, and the county where the facility is located. The "Use Saved Values" button can be used to import a facility created by another user, which can then be saved to the set of facility specific using the process discussed previously.

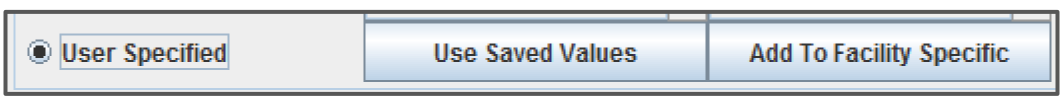


Figure 11: Options for saving a sum

2.3.2 AADT DEMAND INPUTS

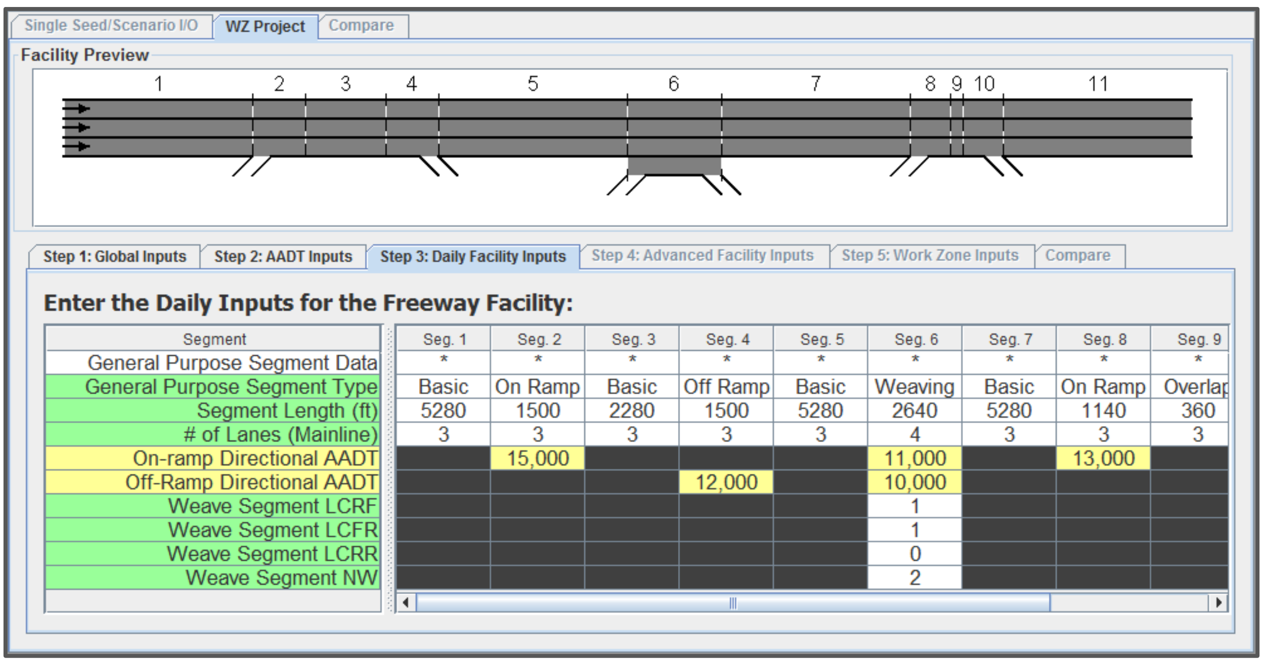
Apart from specifying the AADT distribution, the user is responsible for providing three additional values. First and most importantly, the user must specify the bidirectional AADT. As this value is represents the traffic flowing in both directions of the facility, it will need to be divided by the "bidirectional factor," which is the next value that must be specified by the user. A value of "0.5" evenly splits the AADT at 50% for each direction, while a value of "0.6" indicates a skewed allocation with 60% of the AADT being allowed for the direction of the current analysis. Lastly, the user can specify a "Facility Wide Growth Factor." The purpose of this value is to allow for easy sensitivity analysis to be conducted, and by specifying a value such as "1.2," the user can indicate that he or she wishes to analyze the facility when it has experienced a 20% growth in demand.

Once these inputs have been specified and an AADT distribution has been selected, the user can use the "Apply Changes and Proceed" button to move to the next step of the analysis.

2.4 STEP 3: DAILY FACILITY INPUTS

The third step of the process requires the user to enter all inputs values for the facility that can be viewed as daily inputs. These include a few essential segment inputs such as segment type (Basic, Off-Ramp, On-Ramp, and Weave), segment, length, and number of lanes. Further, the user must specify **directional AADT** values for all on-ramps, off-ramps and weave segments, as well as a few additional inputs for each weave segment. More information on these inputs can be found in the HCM chapters 10 and 11, as well as in the FREEVAL-2015e user guide. Figure 12 shows the input table for the *Daily Facility Inputs* tab, which has been populated with the inputs for the example facility.

The values for ramp AADT's are assumed to follow the same distribution of the entire facility that was specified in the previous step (see Section 2.3.1). However, if the user knows that one or more ramp demands of the particular facility they are modeling do not follow this AADT distribution, the opportunity to rectify this and further calibrate the facility is given in the following (optional) step (see Section 2.5).



Segment	Seg. 1	Seg. 2	Seg. 3	Seg. 4	Seg. 5	Seg. 6	Seg. 7	Seg. 8	Seg. 9
General Purpose Segment Data	*	*	*	*	*	*	*	*	*
General Purpose Segment Type	Basic	On Ramp	Basic	Off Ramp	Basic	Weaving	Basic	On Ramp	Overlap
Segment Length (ft)	5280	1500	2280	1500	5280	2640	5280	1140	360
# of Lanes (Mainline)	3	3	3	3	3	4	3	3	3
On-ramp Directional AADT		15,000				11,000		13,000	
Off-Ramp Directional AADT				12,000		10,000			
Weave Segment LCRF						1			
Weave Segment LCFR						1			
Weave Segment LCRR						0			
Weave Segment NW						2			

Figure 12: Panel and data entry table for Step 3: Daily Facility Inputs.

2.5 STEP 4 ADVANCED FACILITY INPUTS (OPTIONAL)

The fourth step of the process allows the user to configure the full slate of facility inputs just as it would be done for a core HCM analysis. **This step is entirely optional for planning level work zone analysis**, and should only be undertaken by someone familiar with the HCM methodology in the event that a facility requires further calibration. This process is covered in detail in the FREEVAL-2015e user guide, and as such, this section will only contain a brief overview.

2.5.1 CONFIGURING AND CALIBRATING A FACILITY IN THE SEGMENT I/O TABLE

With the completion of the previous three steps, all facility inputs have been determined and populated throughout the seed facility file. Most inputs regarding individual segment geometry and volumes appear in the individual time-period segment input table. The AADT inputs from Steps 2 and 3 have been automatically converted to demand values for each analysis period using the specified distribution, and can be viewed in the mainline, on-ramp, and off-ramp demand cells.

There are two options for viewing inputs in the table which are controlled by selecting either "Summary" or "Full" in the top left of the panel (see Figure 13). The "Summary" option presents a small subset of key inputs, while "Full" will display the entire slate of HCM inputs. In the input table, a green row name indicates that the input parameter is time-independent (e.g. segment type and segment length), and a yellow row name indicates that the parameter can vary for each analysis period (e.g. mainline and ramp demands). If a parameter is not applicable to a given segment, then the table cell will not be editable and will have a dark gray background. The rows of the segment input table are generally grouped by the segment type for which they are applicable. Parameters pertaining to all segment types are found at the top of the table, followed by basic segment parameters, on-ramp segment parameters, off-ramp segment parameters, and finally weave segment parameters (see Figure 14).

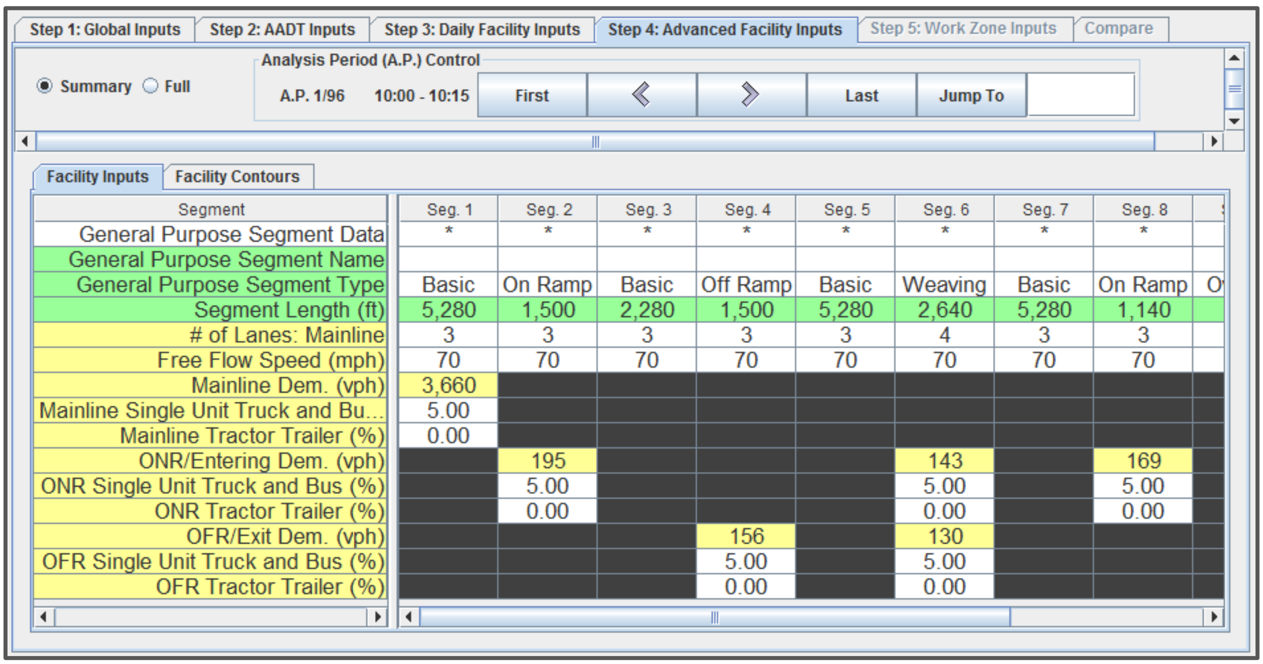


Figure 13: Panel for Step 4: Advanced Facility Inputs showing the segment input table and analysis period controls.

After entering input for one time period, the Analysis Period (AP) control buttons found at the top of the panel can be used to move to the next time interval. The control panel allows the user to move forward or backward in steps of one period (arrow buttons), to move directly to the first or last period, or to "jump" to a specific period. The "active time period" is the period for which inputs are currently displayed, and for which level of service (LOS) outputs give the facility preview graphic its color coding (Green=LOS A, Red=LOS F). The active time period is given immediately to the left of the AP control buttons, specifying both its index in the numerical order of periods and the 15 minute interval to which it corresponds.

Some inputs will always need to be entered for all time intervals, but if any parameters are constant for some or all time periods (or segments), it is recommended to use the “Fill Data” tool, which is available via the toolbar at the top of the program window. This is a powerful tool that can greatly simplify data entry by allowing redundant values to be entered in one step. For a full discussion of this tool, the user should refer to the FREEVAL-2015e user guide.

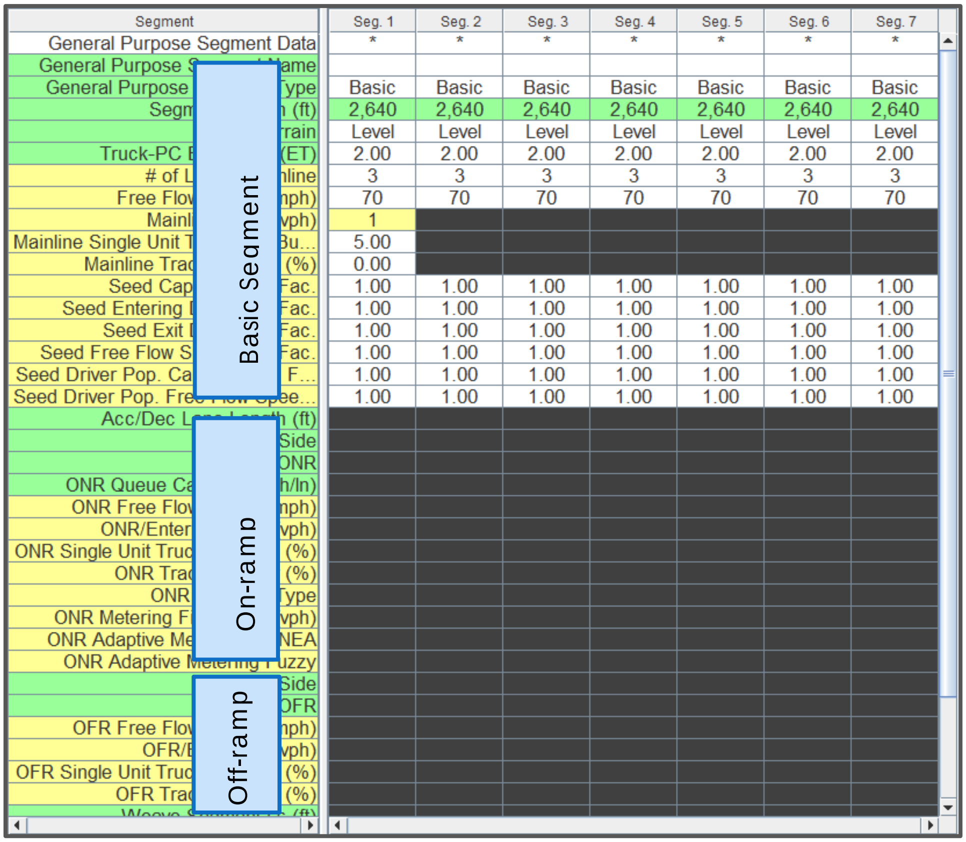


Figure 14: Expanded advanced set of inputs available in the segment input table.

2.5.2 VERIFYING BASE FACILITY PERFORAMANCE

Before moving on to specifying work zone inputs, it is important for the user to first verify the performance of the base facility. As the underlying FREEVAL-2015e engine continuously computes outputs and facility performance measures as inputs are entered, there is no need to ask the program to perform an analysis run for a seed facility. A set of outputs and performance measures can be viewed at any point during this step, though results from a facility with incomplete inputs may be misleading. The outputs for a given base facility can be found in two different places in the advanced facility inputs panel.

First, the facility preview graphic provides a simple set of Level of Service (LOS) outputs. In the graphic each segment is colored according to its LOS for the active time period. The colors range from green (LOS A) to red (LOS F). Scrolling through the study period with the analysis period controls can give a brief look at how congestion evolves over time on the facility.

The second way to view output is through a set of contour plots, which can be accessed by selecting the “Facility Contours” tab directly above the segment input table. These contours show how a number of performance measures vary by segment and time interval. The available performance measures include volume-to-capacity ratio (v/c), demand-to-capacity ratio (d/c), segment speed, segment density, influence area density, and queue percentage. To change the available performance measures, use the toggle buttons at the bottom of the panel. An example contour table is shown in Figure 15.

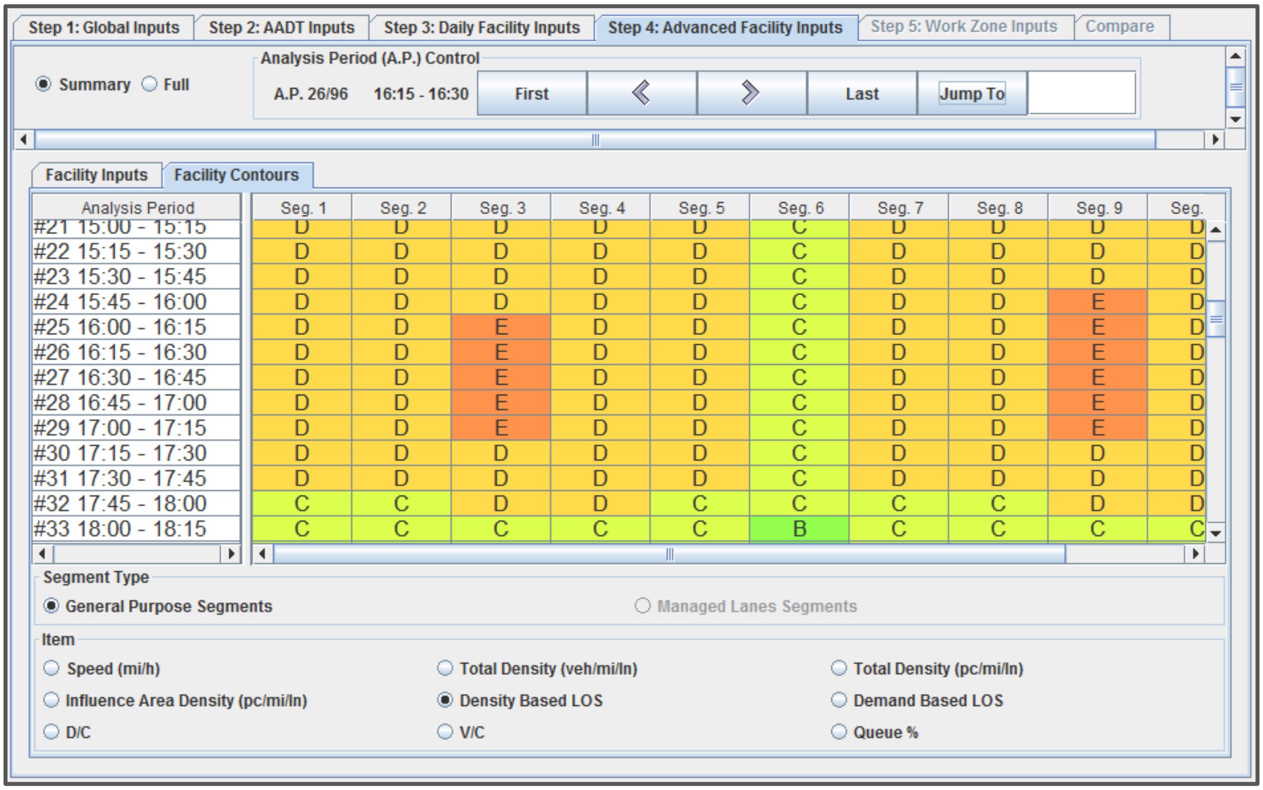


Figure 15: Example of a density based LOS contour plot.

For facilities with a large number of segments or when analyzing facilities over long study periods, the contour tables can become too large to view effectively on most screens. To help alleviate this issue, a zoom function has been included in the engine. To zoom out (make rows and columns smaller), the user should hold the “Ctrl” key and scroll up using their mouse’s scroll wheel. To zoom back in, the user simply needs to hold the “Ctrl” key and scroll down using the mouse’s scroll wheel. Alternatively, the user can zoom in or out by pressing “alt-shift-plus” (+) or “alt-shift-minus” (-). However, if this method is used, the user must first click on a cell inside the table to enable this functionality. All tables in the summary contour tab can further be copied and pasted into a post-processing tool like Microsoft Excel.

2.6 STEP 5: WORK ZONE INPUTS

Once the base facility has been fully configured, the user can begin to design the work zone(s) that will be analyzed. This process takes place entirely within the fifth panel, labeled "Step 5: Work Zone Inputs." Each WZ project can analyze up to three work zones at a time on a particular facility.

The work zone inputs panel consists of three core sections, and its general layout can be seen in Figure 16. The top section (1) displays a list of work zones currently contained in the project as well as the inputs specifying the basic spatial and temporal parameters of the work zone. Clicking on a work zone in the list will automatically populate the panel with all parameters that have been specified for that work zone. Additional work zones can be added or deleted using the respective buttons to the left of the list. Right-clicking on a work zone in the list presents the user with a popup window with two options. The first option allows the user to input a custom name for the work zone (limited to 13 characters), and the second option allows the user to "duplicate" an existing work zone. This can be especially useful if the analyst is creating multiple work zones that are very similar and only differ in a few easily changed parameters, thus preventing the user from having to recreate each work zone from scratch.

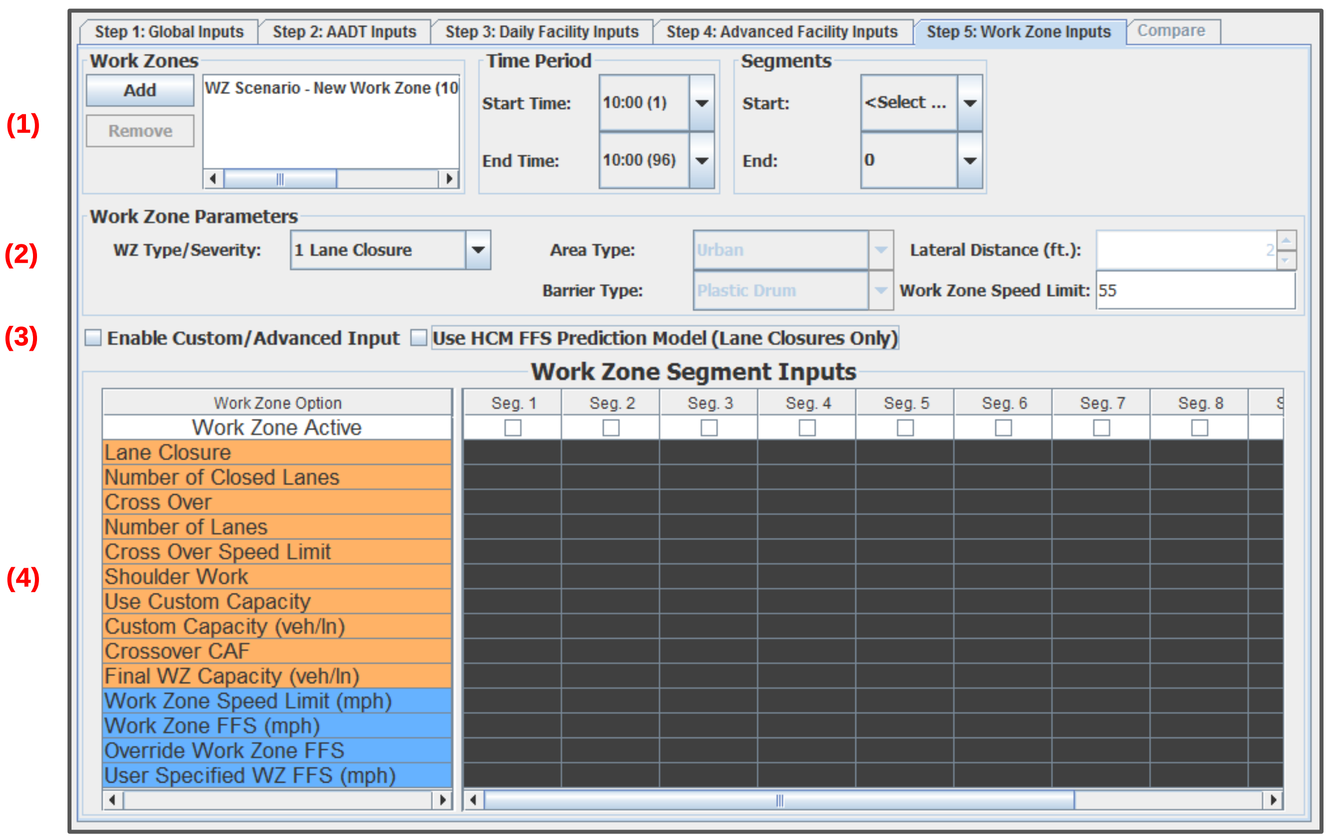


Figure 16: Layout of the work zone inputs panel.

Directly to the right of the work zone list, the user must configure the time periods and segments for which the work zone is active during the facility study period. Both the active time periods and segments must be specified before the user moves on to the second set of work zone parameters. By default, the start and end times are set to be the first and last analysis periods of the study period, but any continuous subset of periods can be selected using the drop down boxes. The user must also specify at least one segment in which the work zone is active. While these initial inputs only allow for the work zone to be specified over a contiguous set of segments, more complex work zone arrangements can be configured later using the *Advanced Input Table* (see section 2.6.1).

The middle section of the panel (2) allows the user to specify the work zone characteristics. This includes the severity of the work zone, as well as area type (urban or rural), barrier type, lateral distance, and work zone speed limit. **The default work zone free flow speed is the user specified work zone speed limit, but this value can be overridden using the Advanced Input Table as discussed below.** As a note, the lateral distance parameter refers to the separation distance from the edge of the travel lane to the work zone control device (barrier), and is sometimes known as "offset." The choices for work zone severity include shoulder closure, one or multi-lane closures, and crossovers. Note that the user is responsible for ensuring that at least one lane remains open on each segment, otherwise the analysis will give faulty results.

There are two checkboxes (3) just below the middle section of the panel that the analyst can use to expand on the basic analysis. The first checkbox allows the use to enable the *Advanced Input Table* (4) at the bottom of the panel. While this checkbox is disabled, the table will automatically fill with the work zone inputs for each segment and display the computed values for capacity and work zone free flow speed. At this point, these value are not editable, but the following section (2.6.1) will describe how to customize work zones using the table. The second checkbox allows the user to enable the use of the 3-107 prediction model for lane closures, a methodology which is included as part of the HCM 6th edition. Note that this methodology can only be used for lane closures, and that for some cases the computed value may not be appropriate, so the analyst should always use their best engineering judgement.

Continuing with our example facility developed in the previous steps, Figure 17 shows the facility with a one lane closure work zone active in segment 7. The *Advanced Input Table* reflects these inputs, and shows that the computed capacity in the segment is now 1937 veh/ln, and the free flow speed (FFS) is 64.1 mph.

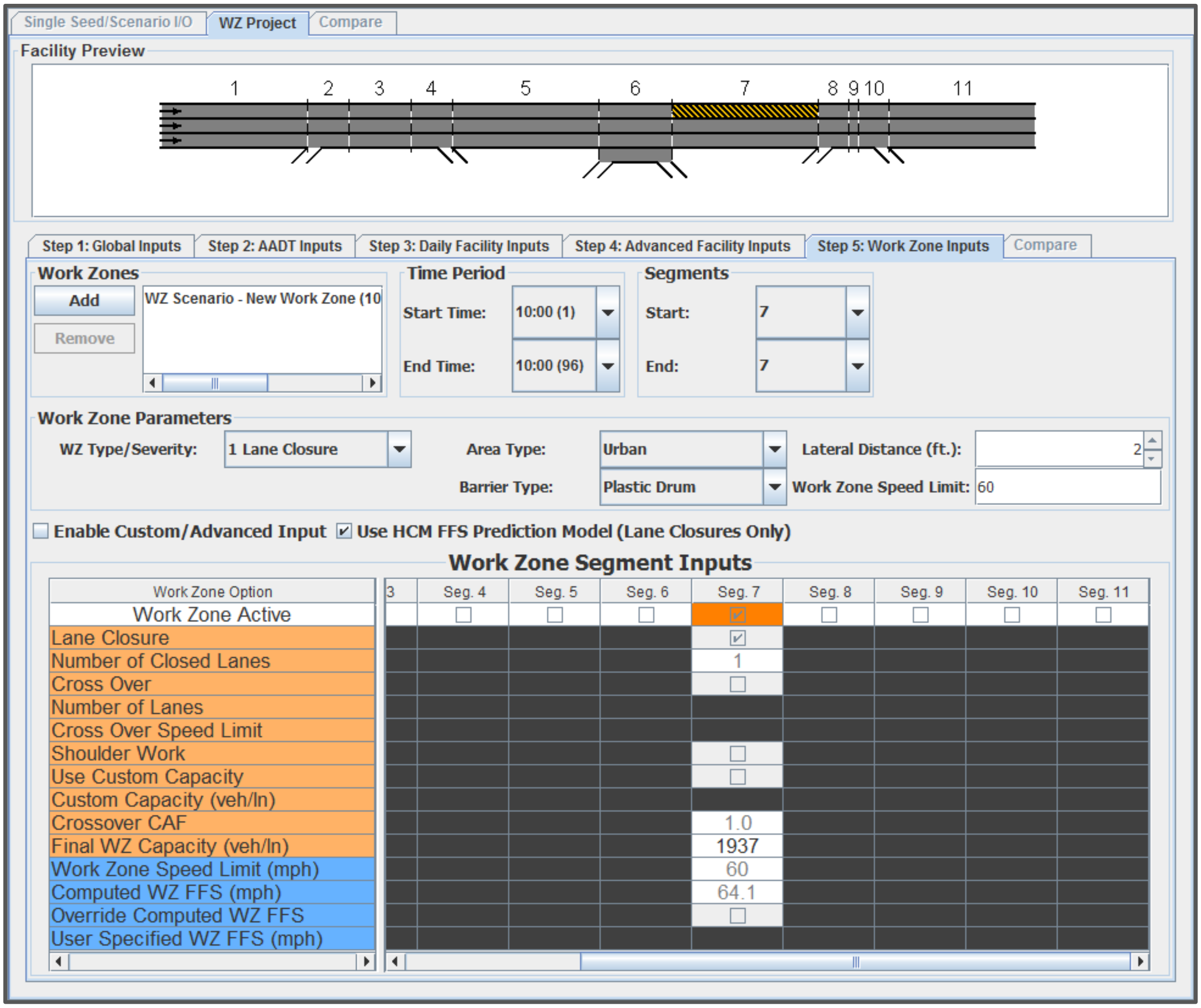


Figure 17: Work zone inputs panel with a shoulder closure work zone specified at segment 7.

2.6.1 DESIGNING COMPOUND AND CUSTOM WORK ZONES

Most basic work zones can be fully defined by the user using just the top two portions of the panel. However, for more complex work zones, the user can make use of the *Advanced Input Table* found in the bottom half of the panel. Editing this table is disabled by default, but custom input can be enabled using the check box found directly above the table. Enabling this functionality allows the user full customization of the spatial attributes of the work zone. The work zone no longer needs to be confined to a contiguous set of segments, and the severity/type of work zone can vary for different segments. A check box in the top row of the table indicates whether or not the work zone is active for each segment. The following 6 rows (with orange labels) allow the user to specify the work zone severity/type for each segment, as well as any parameters relevant to that type (i.e. speed limits for segments with crossovers). The next row, labeled “Custom Capacity,” allows the user to specify a capacity if the computed capacity (found in the “Final WZ Capacity” row) does not match data available for their specific facility. The next row, labeled “Crossover CAF,” displays the capacity adjustment factor due to a crossover if one exists in the segment.

Note that if the user specifies a custom capacity with a crossover selected as the work zone type, this factor will still be applied to the value, and the "Final WZ Capacity" row will reflect the product of the two values. For example, if the user specifies a custom capacity of 2000 and the segment has a crossover resulting in a crossover CAF of 0.95, the resulting "Final WZ Capacity" will be 2,000*0.95=1,900.

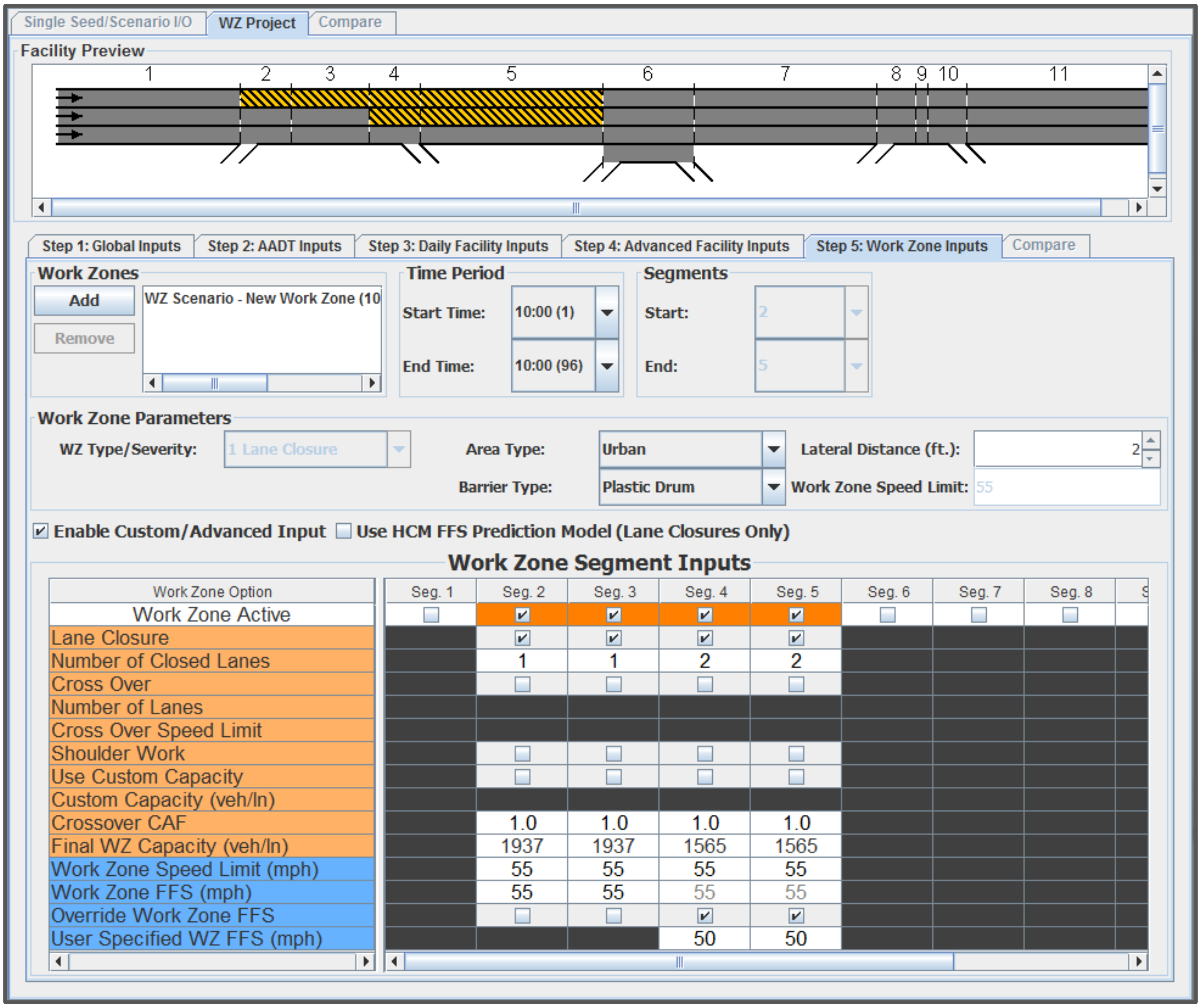


Figure 18: Compound work zone designed using the Advanced Inputs Table.

The final 4 rows of the table (labeled in blue) allow the user to view and set information about the work zone speed limit and free flow speed (FFS). The first row allows the user to specify a work zone specific speed limit for each segment in which the work zone is active. By default this value is then used as the work zone free flow speed. If the analyst has chosen to use the HCM 3-107 Prediction model for lane closures, the second row will be labeled "Computed WZ FFS (mph)" and will give the predicted value for free flow speed. The final two rows of the table allow an analyst to override the default or computed free flow speed value and specify a facility specific value. To do this, the analyst simply needs to mark the checkbox in the "Override Computed WZ FFS" row, and then enter a new work zone free flow speed in the row labeled "User Specified WZ FFS (mph).” Note that when the work zone FFS is being overridden, the value in the “Work Zone FFS (mph)” or “Computed WZ FFS” row will be greyed out to indicate it will not be used for the analysis.

When custom work zone parameters are enabled, some of the inputs in the top two sections will become disabled. However, “global” work zone inputs such as start/end times, area type, barrier type, and lateral distance can still be specified during the process. To demonstrate the capabilities of this table, a compound work zone consisting of a one lane closure expanding to a two-lane closure is shown in Figure 18.

After all work zones have been configured, the analyst should use the “Apply Changes and Proceed” button to move to the final step of the process.

2.7 STEP 6: COMPARE ANALYSIS AND REPORT GENERATION

The sixth and final step of the process allows the user to compare performance on the facility between the base scenario and each work zone included in the analysis. Figure 19 shows the *Compare* panel for the example with the shoulder closure work zone in segment 7.

The top left of the panel contains a list of all work zones included in the analysis. Each item of the list gives the name of the work zone, as well as some basic information about its start and end time, and the segments in which it is active. Selecting a work zone in the list will change the facility graphic display to reflect the characteristics of that particular work zone.

The bottom portion of the panel contains a table that displays the values of key performance measures for the base scenario and each work zone in the project. For each work zone, the differences between values for each measure will be displayed to the right of the value. By default, differences indicating worse performance are shown in red. Right-clicking on the comparison table will allow the user to specify how the differences are displayed: no differences, using +/- signs, or using colors.

Directly to the right of the work zone list is a set of buttons controlling the outputs available in the panel, as well as allowing access to more advanced outputs and even a comparison with a “Future” facility incorporating improvements gained once the work zone has been completed. The “Remove Selected” button allows the analyst to remove a work zone from the comparison as a way of distilling the output to only the most important information. Any work zone that has been removed can be added back to the panel by right-clicking on the work zone in the project navigator and selecting the “Add WZ Scenario to FREEVAL-WZ Panel Compare” option.

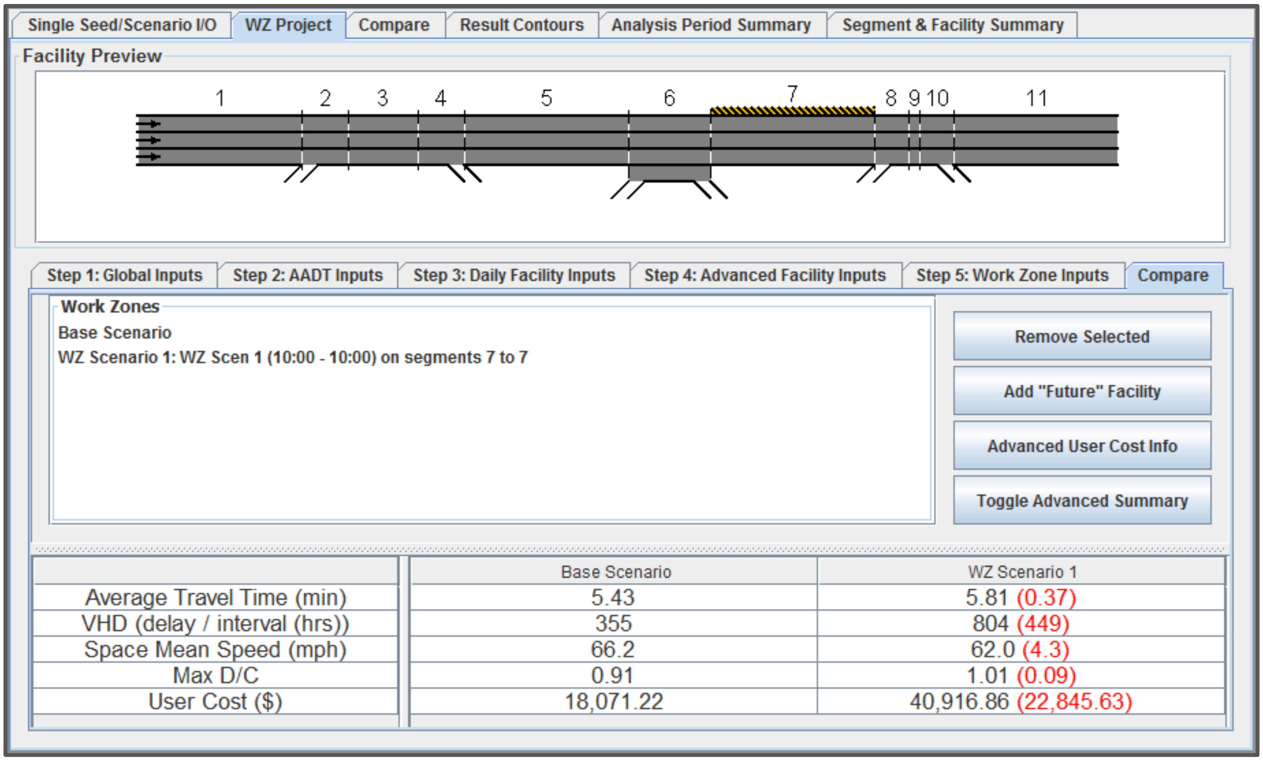


Figure 19: Compare panel for the final step of the analysis.

The "Toggle Advanced Summary" button expands the base set of outputs given in the compare table to the set of twelve outputs listed in Table 1.

Performance Measure	Description
Average Travel Time* (min)	Average travel time experienced by each vehicle traveling the facility in the study period.
VMTD (veh-miles / interval)	Vehicle miles traveled as if all demand had been served in the study period.
VMTV (veh-miles / interval)	Vehicle miles traveled of the vehicles actually served during the study period.
PMTD (p-miles / interval)	Passenger miles traveled as if all demand had been served in the study period.
PMTV (p-miles / interval)	Passenger miles traveled of the vehicles actually served during the study period.
VHT (travel / interval (hrs))	Vehicle hours traveled by all served vehicles during the study period.
VHD* (delay / interval (hrs))	Vehicle hours of delay experienced by all served vehicles during the study period
Space Mean Speed* (mph)	Space mean speed of the study period calculated by dividing served vehicles miles travelled by total vehicles hours of travel.
Reported Density (pc/mi/ln)	The average density on the facility in passenger cars per mile per lane.
Max D/C*	Maximum demand-to-capacity ratio at any segment during the study period.
Max V/C	Maximum volume-to-capacity ratio at any segment during the study period.
User Cost* ($)	Total user cost incurred over the course of the study period.
Max Hourly User Cost ($)	Maximum user cost of incurred during a single analysis period of the study period.

Table 1: List of performance measures in the advanced summary comparison table. Those with an asterisk are included in the base summary.

2.7.1 USER COST OUTPUTS

The "Advanced User Cost Info" button allows the user to view an expanded set of user cost outputs as well as specify custom values used in the computation of these costs. Clicking the button will bring up a new window with both the user cost inputs and the computed cost for each hour of the study period. On the right side of the window, the analyst will find input fields for user delay and vehicle operating costs for both cars and trucks. A set of default values for North Carolina are always displayed beneath the input table *(4)*. The left side of the window contains the hourly breakdown of user costs for the base scenario as well as for each work zone in the project. The analyst should note that if the study period does not both begin and end at an even hour mark, certain hour bins may only contain costs for a portion of the hour. For example, for a study period from 2pm to 8:30pm, the final bin referring to the 8-9pm hour would only contain the costs for the first half hour which falls within the study period. Figure 20 displays this window for the example facility and work zone shown in Figure 19.

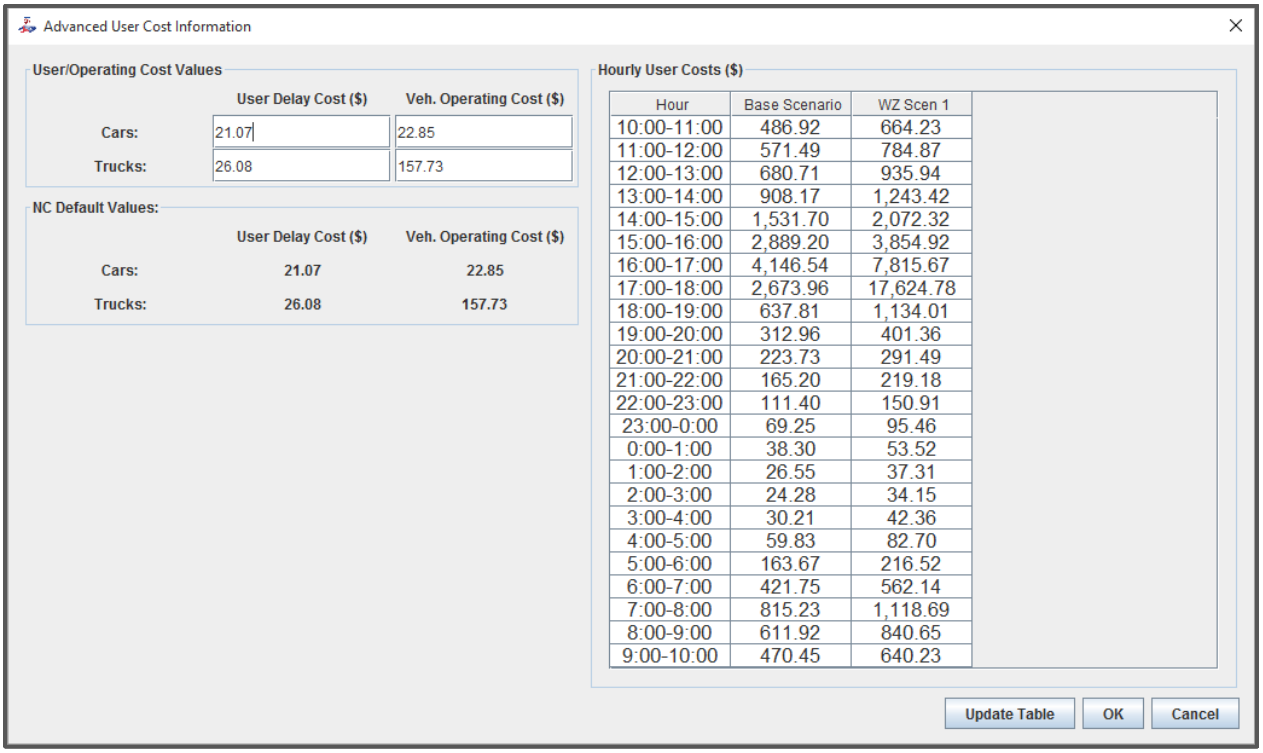


Figure 20: Advanced user cost information available to the analyst.

2.7.2 ADDING A "FUTURE" FACILITY

If the user has access to the predicted improved facility conditions that will exist upon completion of the work zone, he or she can import a facility representing these conditions to compare the before and after effects and assess the costs leading to any improvements. This "Future" facility will need to be created using the same process as conducted in Steps 1 – 4, or done separately using the core HCM methodology found in FREEVAL-2015e. A simple way to accomplish this process is to export the base facility of the WZ project (see Section 3.6) and then make the changes representing the improvements (e.g. adding a lane or increasing capacity) using FREEVAL-2015e. The "Future" facility functionality allows any facility saved in the SEED (.seed) format of the core engine to be imported and compared.

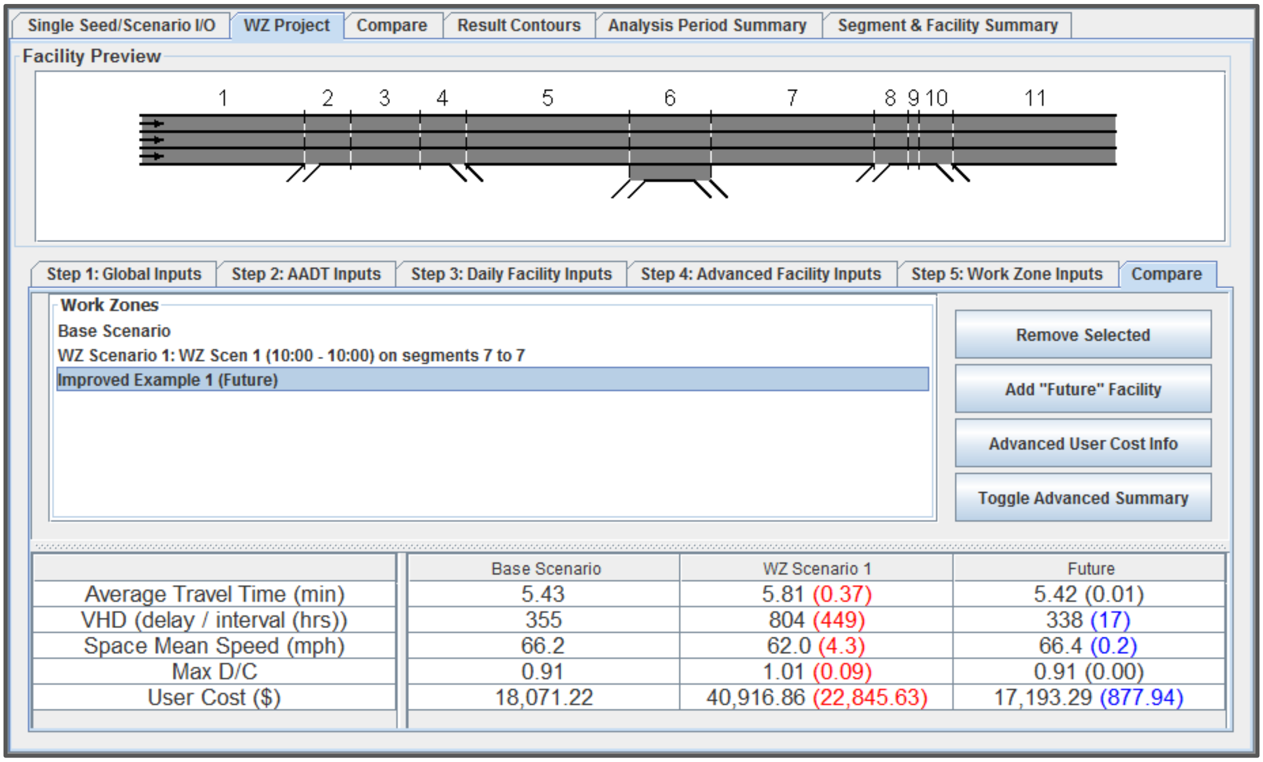


Figure 21: Compare panel with an imported "Future" facility

2.8 CREATING A PDF REPORT

After completing the work zone analysis, the user can choose to generate a PDF summary report. The report generator window can be opened using the "Create PDF Report" button in the FREEVAL-WZ toolbar (refer to Figure 2). Due the wide ranging scope of analysis possible in FREEVAL-WZ, the report generator was designed to be fully customizable with a large number of options. However, a subset of the options constituting a *default report* will always be given when the window is opened.

The generator window is effectively divided into four sections, and the general layout can be seen in Figure 22. The left side of the window contains all of the options for customizing the report content, while the right side contains a preview display for the document. As values for parameters are adjusted, the user can press the "Update Preview" button at the bottom of the panel to view the changes. The report preview has zoom options to allow for more detailed views when necessary, and the user can view different pages using the +/- page index buttons or by using the mouse scroll wheel while hovering over the preview.

The top portion of the left side of the panel allows the user to specify a report name, a file save location, and project information such as names for the analyst, project, and overall scenario. Below the *Report Information* section, the user will find the *Report Content* section. This panel allows the user to adjust the font style and size of the report, and contains check boxes that can be used to mark various types of content for inclusion in the report. The bottom section allows the user to customize any contours that are included in the report, which will be discussed in depth in Section 2.8.1.

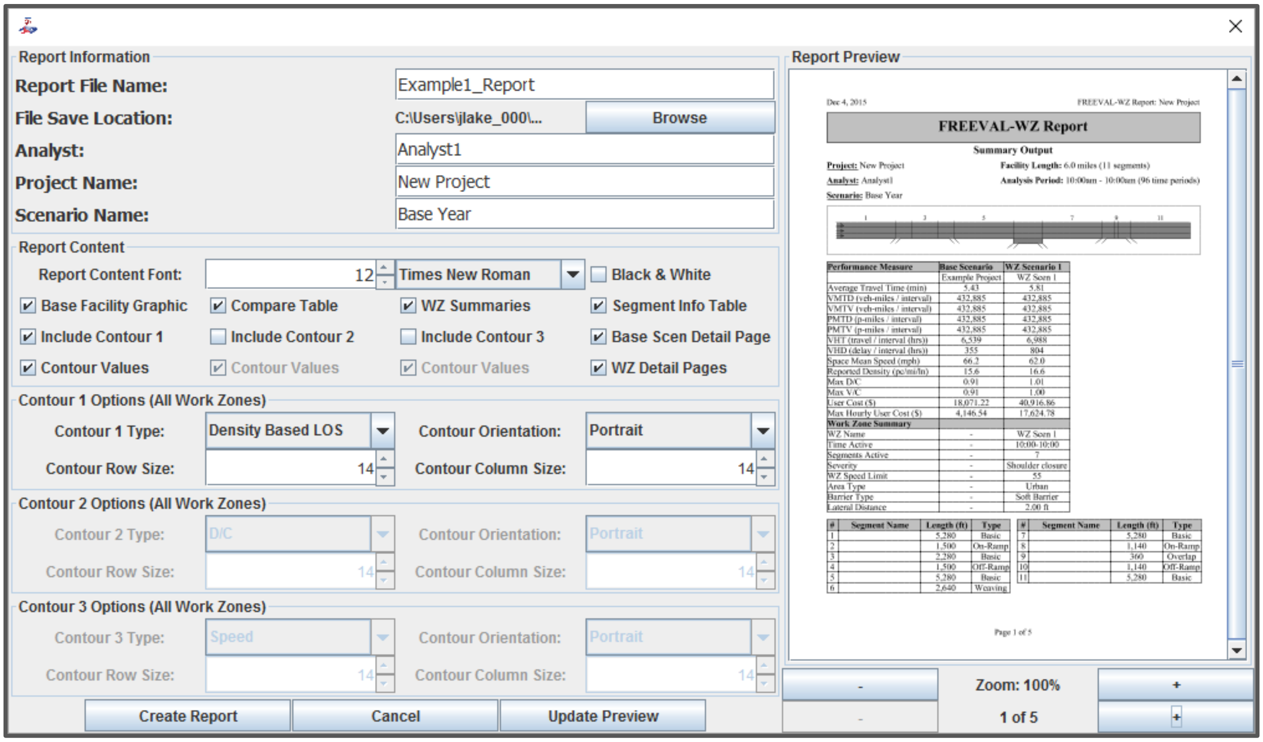


Figure 22: Options for creating the summary PDF report.

Table 2 details the content inclusion options of the PDF generator. Content that is included in the *default report* is marked with an asterisk. Beyond specifying which content is included in the report, the window also allows a number of additional options. The user can specify the font type and size, and indicate whether the report should be generated in black and white only.

Content	Description
Facility Graphic*	Graphic showing the geometric layout of the base facility.
Comparison Table*	Comparison table of performance measures for the base scenario and each work zone. Measures included are those in Step 6 of the analysis.
WZ Summaries*	Table providing a basic summary of each work zone. Includes name, time periods active, segments active, severity, WZ speed limit, area type, barrier type, and lateral distance.
Segment Info Table*	Provides information (name, length, type) of each facility segment.
Facility Contours* (One Density LOS)	Table giving the color-coded performance measure value for each segment in each time period. For each contour type, a contour is given for the base scenario and for each work zone scenario. Up to three different contour types can be included.
Base Facility Details	One page detailed summary of the Base Scenario. Includes global properties and AADT information.
Work Zone Details	One page detailed summary for each work zone. Includes work zone parameters, detailed comparison table, and user cost information.

Table 2: Options available for inclusion in the PDF Summary Report

2.8.1 CUSTOMIZING CONTOUR TABLES

The user can specify up to three types of contour plots to be included in the summary report. Available contour types are speed, total density, influence area density, density based LOS, demand based LOS, D/C, V/C, and queue percentage. Marking an “Include Contour” check box will enable the “Contour Values” check box directly below, as well as activate the respective “Contour Options” panel. The “Contour Values” check box indicates if text values for the performance measure will be printed in the contour table. The user may wish to remove these in the case that the values become too small or too clustered to read.

The “Contour Options” panel allows the user to select the contour type, and specify whether it is oriented in “Portrait” or “Landscape.” Facilities with larger numbers of segments will likely fit better in Landscape, while facilities with long study periods will likely fit better in Portrait. Below these two options, the user is given the ability to adjust the size of both the rows and the columns of the contour table.

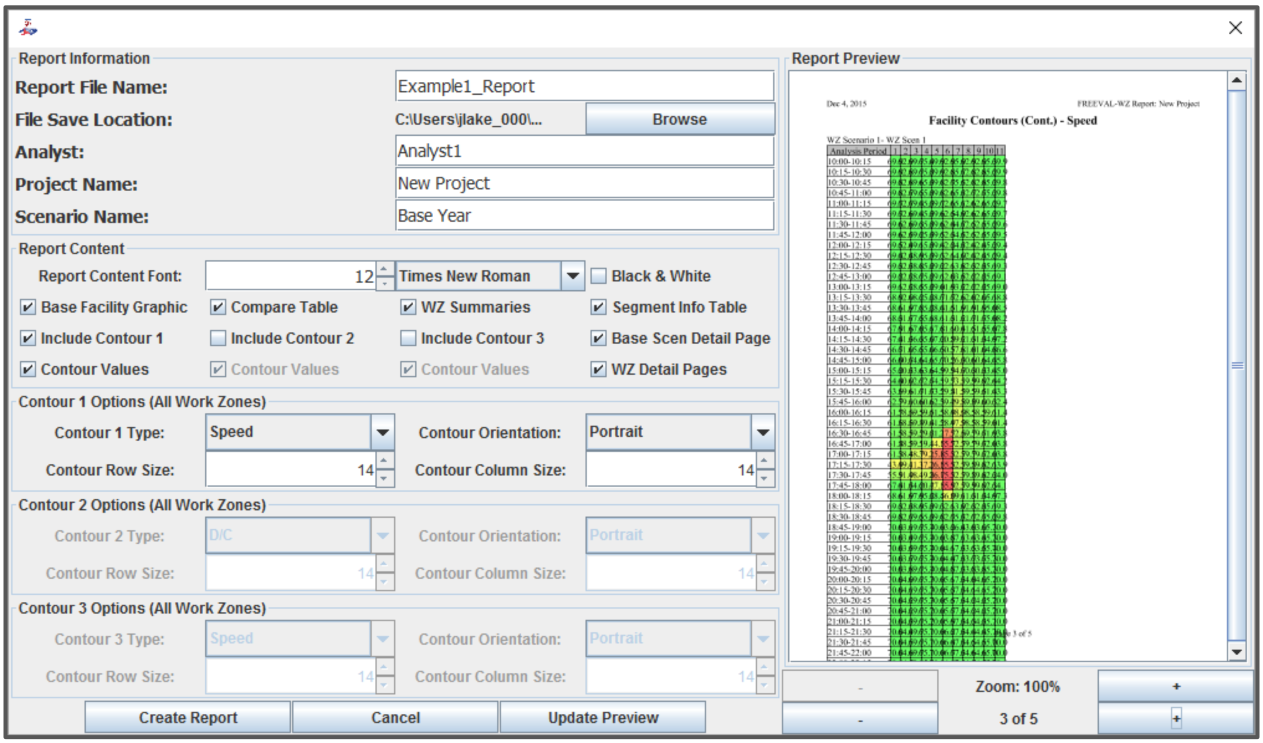


Figure 23: PDF report with contour table improperly sized.

As mentioned previously, the wide range of facility sizes and study periods available in FREEVAL-WZ requires the inclusion of customization options to help with report creation. One of the principle areas where these options come into play is with the contour tables. Facility sizes can range from one segment to 50+, and study periods can have anywhere between 1 and 96 individual analysis periods. When possible, the facility generator will fit as many of the contours as possible onto one page, but due to the high variance between sizes, even fitting one contour onto a single page can be challenging. Figure 23 shows an example of this issue, where a facility with only 11 segments, but 96 analysis periods (covering 24 hours) does not fit on a single page. The ability to adjust the row and columns sizes for each contour was included specifically to help address this issue. It is clear from looking at Figure 23 that the row height needs to be decreased, and the column width should be increased. Entering a value of "6" for row height, and "24" for column width allows the contour to fit nicely on a single page. However, if the user were to end here, he or she would notice that the text contour values have largely become unreadable, and thus might choose remove the values by un-checking the "Contour Values" box. Taking these steps results in a much clearer contour as shown in Figure 24.

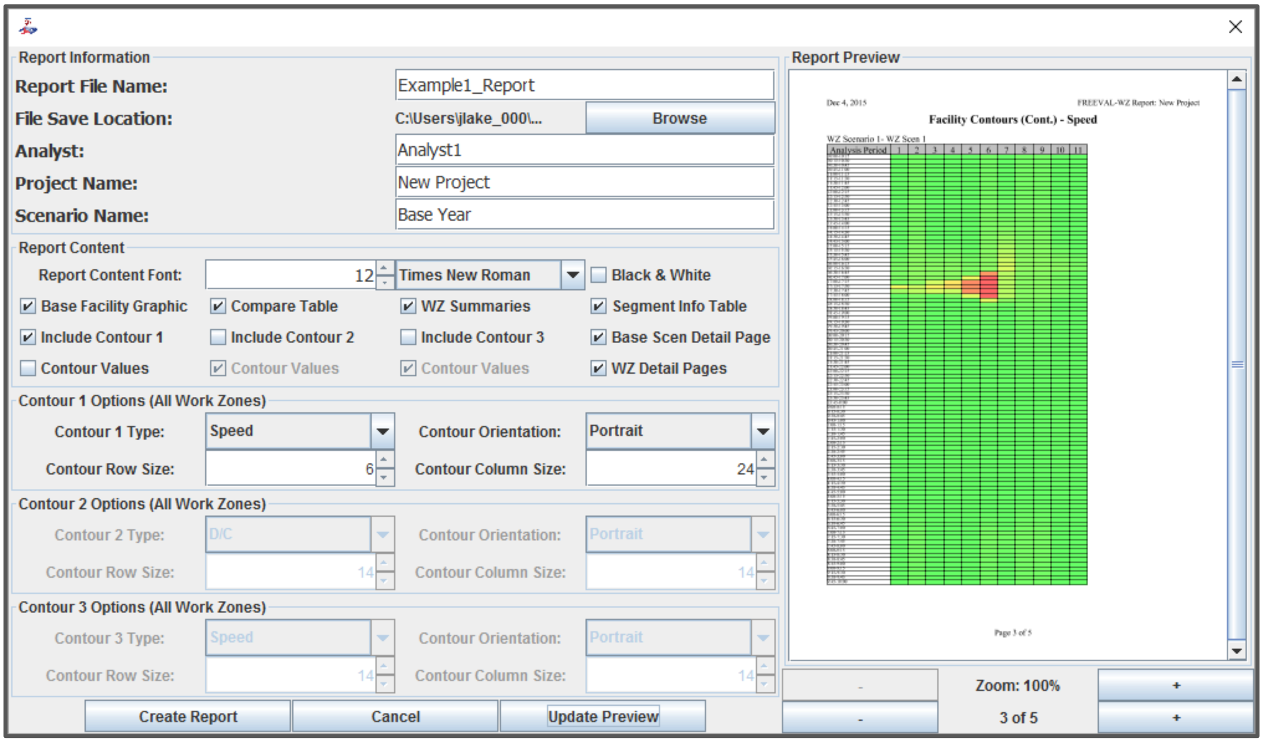


Figure 24: PDF report with adjusted row and column sizes for the contour table.

3 ADDITIONAL SOFTWARE FEATURES AND CAPABILITIES

In the interest of keeping the discussion of Section 2 as simple as possible, a number of FREEVAL-WZ's more advanced features were not mentioned or only referred to briefly. This section will serve to describe those additional features that have been made available to ease, customize, and expand the analysis capabilities of the software.

3.1 ENABLING THE AUTO SAVE FUNCTION

Some users may wish to have their work automatically saved as they move forward through the process of creating and analyzing a Work Zone project. FREEVAL-WZ enables the user to do this by, saving the facility each time the "Apply Changes and Proceed" is pressed. The option can be turned on and off by selecting the *Autosave on Proceed* option, with a checkbox next to the option indicating that it is currently active (see Figure 25). Note that in the event that the button is pressed and the facility has not yet been saved (i.e. no save file exists), the user will be prompted to specify a save file name and location. Once this has been done however, the project will be saved automatically with no more input from the user. Also note that as a facility must first be created before it can be saved, **the analyst must have at least proceeded to step 2 in the process before this functionality can be enabled.**

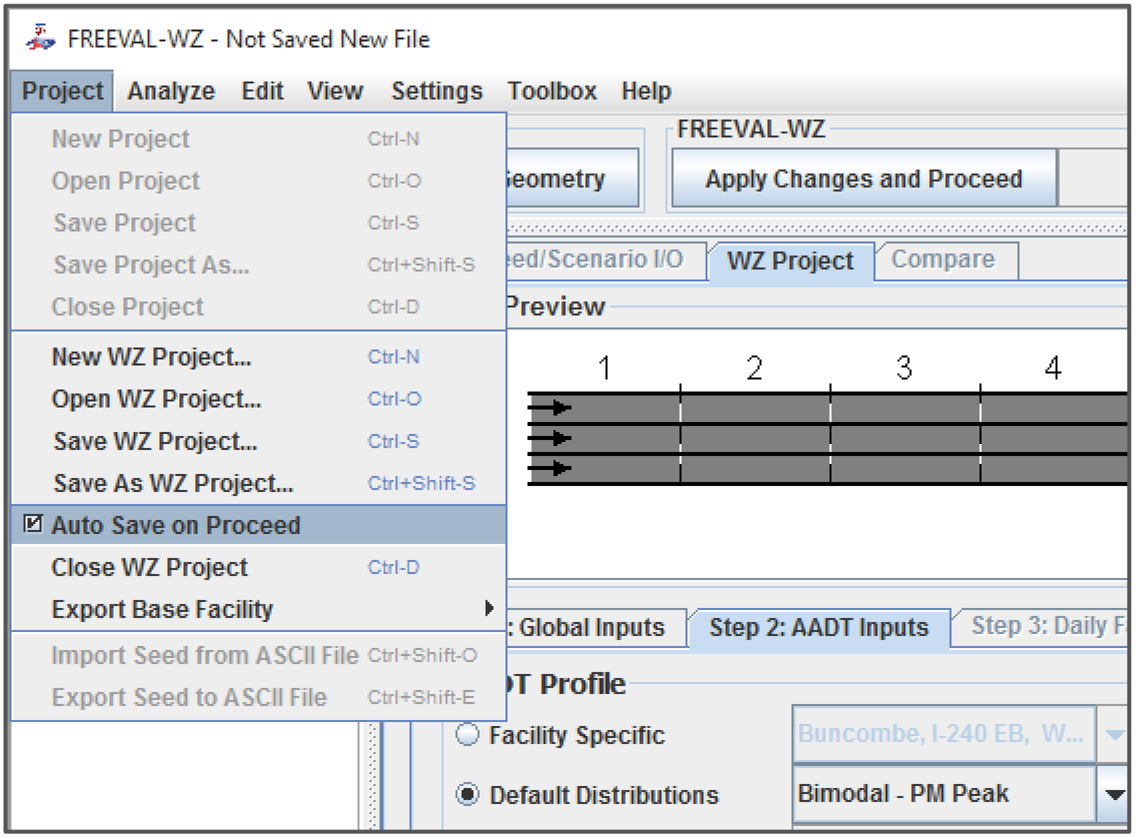


Figure 25: Enabling the ***Autosave on Proceed*** option.

3.2 MOVING BACK AND FORTH BETWEEN PROCESS STEPS

Throughout the discussion of Section 2, it was assumed that the analyst was only moving forward through the analysis. However, FREEVAL-WZ has been designed in a way such that the user can return to a previously completed step at any point during the analysis. For example, if while verifying the facility performance in Step 4 the analyst notices that the AADT value should be increased, he or she can return to Step 2 to adjust it accordingly. If any changes are made at a previous step, the user should use the "Apply Changes and Proceed" button in the WZ toolbar to implement these changes going forward.

FREEVAL-WZ will seek to preserve any values entered or work done in subsequent steps when possible, but the user will still need to review the steps before returning to the step from which they backtracked. Returning to the example situation of the previous paragraph, once the user has increased the AADT value, he or she will need to proceed through Step 3 again before returning to Step 4. In this scenario, nothing in Step 3 would have changed, so the user can pick back up the process where it was left off. However, in the event that a more complicated change is made (such as the ones discussed in section 3.3), the user may be required to adjust some of the parameters entered in a previously completed step. **A number of warning messages have been implemented throughout the software to warn the analyst in situations where this may occur.**

3.3 ADD/DELETE SEGMENTS AND TIME PERIODS

Both the number of segments and analysis periods can be changed at any point when conducting analysis in FREEVAL-WZ. However, since doing so will change the core facility, the analysis process will automatically return to *Step 3: Daily Inputs*. This process is not reversible, so the user may wish to save a version of the WZ project, or export the base facility for future use. To add or delete segments in the facility, use the "Edit Facility Geometry" button in the WZ toolbar (see Figure 22). Alternatively, the analyst can select the "Edit" option in the menu bar at the top of the program and select the appropriate option.

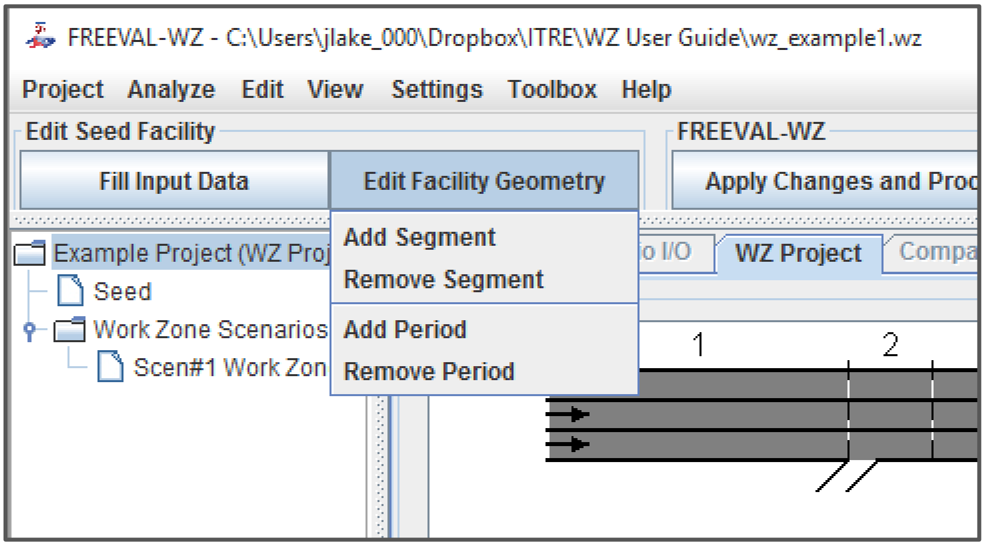


Figure 26: The options for adding or deleting segments or time periods are found in the "Edit Facility Geometry" option.

Once the correct option has been selected, a dialog will appear prompting the user for the relevant information (see Figure 27). When adding a segment, the User must specify the position of the segment(s) by indicating which segment it (they) will be added before. The user also specifies the number of segments that will be added. To delete a segment (or multiple segments), the user will specify the range (inclusive) of segments that will be deleted. To delete a single segment, the first and last segment of the range should be the same.

The easiest way for the user to adjust the number of periods is through the "Step 1: Global Inputs" panel. The user can adjust the start and end period boxes to alter the study period. Alternatively, the user can add or delete periods using dialogs similar to those for adding and deleting segments. In the "Add Period" dialog, the user must specify the number of periods that will be added, and whether or not they will be added to the beginning or end of the current study period. For example, if the current study period is from 4:00pm-6:00pm, adding 4 periods at the end will increase the number of analysis periods from 8 to 12 and change the study period from 4:00pm-7:00pm. Similarly, when deleting time periods, the user specifies the number of periods to be deleted and whether they will be deleted from the beginning or end of the current study period.

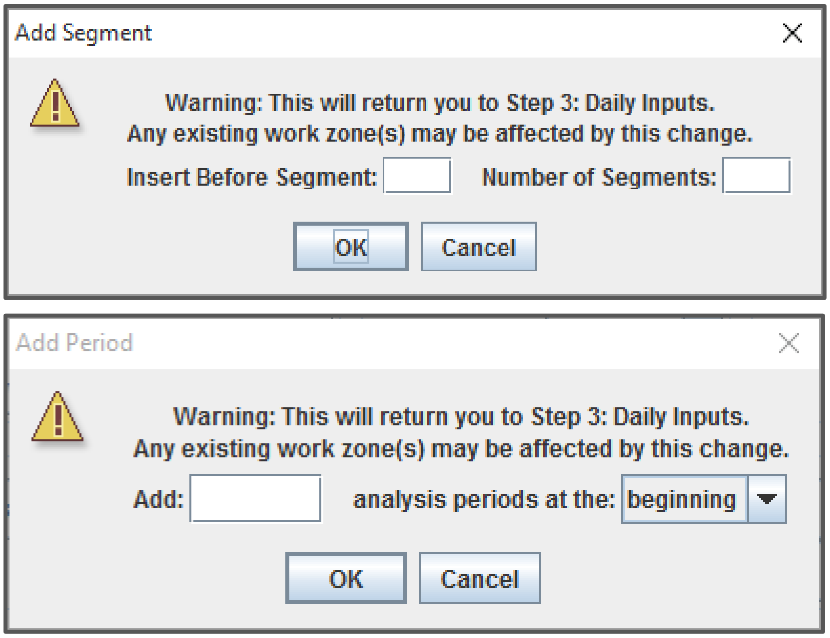


Figure 27: Dialogs for adding segments or time periods.

3.4 EXTENDED OPERATIONAL ANALYSIS USING FREEVAL-2015E

Once Step 6 has been completed (see Section 2.7), the operational-level analysis possible using the core FREEVAL-2015e engine is made available to the user. This analysis consists of a set of tabs that will be added to the main window just below the WZ toolbar. The seed facility and work zone scenarios can be edited and analyzed using the *Single Seed/Scenario I/O* table, which provides in depth configuration options for analysis period and segment inputs. For more information of this type of analysis, the user should refer to the FREEVAL-2015e User Guide.

3.5 COPY AND PASTING DATA INTO OTHER SOTFWARE PROGRAMS

Most of the tables in FREEVAL-2015e can be copied to the system clipboard and then pasted into other programs such as Microsoft Excel or Microsoft Word. To do this, simply right click on the desired table and select the “Copy Table to Clipboard” option. Additionally, some tables containing output values can also have subsets of cells selected and copied using the standard “Ctrl+C” and “Ctrl+V” keyboard shortcuts.

3.6 EXPORTING THE BASE FACILITY

Once a facility has been created in Steps 1 and2, it is possible “export” the base facility to a seed or ASCII file. This can served to make a backup copy of the facility, or a standard version of the facility that can be imported when creating additional WZ projects (see Section 2.1).

In order to create a seed of ASCII file of the base facility, the user should navigate to the “Export Base Facility” submenu of the Project drop down menu. This provides two options, one for each file format. Once the user chooses the appropriate option, he or she will be prompted for a file name and save location.

3.7 ANALYZING MORE THAN THREE WORK ZONES

In the event that the analyst wishes to analyze more than three work zones on a facility, he or she will need to create a separate work zone project using the base facility. If the user did not initially start from a base facility file, one can be created using the *Export Base Facility* option of the "Project" drop down menu (see Section 3.6). The user should export the facility using the "As Seed" option. Next the user should create a new FREEVAL-WZ project, **making sure to mark the "Use Included Facility Demands" option when importing the facility from the seed file.** This process effectively creates a duplicate WZ project that will allow the user to design another set of work zones. Comparison between work zones of the two projects can then be conducted using summary PDF reports created from each.

4 CASE STUDY

This section contains a case study conducted on a stretch of I-40 east outside of Raleigh, NC in which the analysis is used to help determine an appropriate start time for an upcoming work zone. The case study focuses on the work zone portion of the analysis and assumes that the process of creating and calibrating the base facility has previously been completed.

Three work zones are analyzed in this case study. Each consists of a one-lane closure lasting for four hours in one segment (segment 32) located 10.5 miles downstream of the start of the facility. The work zones are each given different start times (and end times) in order to determine the least cost solution for the active construction.

4.1 BASE FACILITY

The base facility used for the case study is a 12.5 mile section of I-40 eastbound outside of Raleigh, NC. The study period consists of 16 hours from 2:00pm to 6:00am. The geometric layout of the base facility is shown in Figure 28. Under base conditions there is no breakdown due to congestion (i.e. no segments with LOS F) on the facility, but a mild bottleneck does naturally occur during peak hours on segment 32 due to a lane drop.

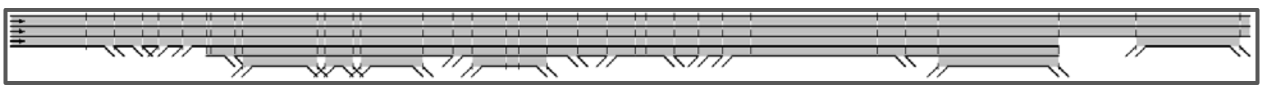


Figure 28: Geometric layout of the I-40 eastbound base facility.

For the case study, the facility is specified to have a *Bimodal-PM Peak* (75th Percentile) AADT distribution, with a bidirectional AADT of 120,000, a directional factor of 0.5, and a facility wide growth factor of 1.0.

4.2 WORK ZONE CONFIGURATION

Each work zone is specified to be a one lane closure in segment 32 that lasts for four hours. The three work zones are each given different start times: 8pm, 9pm, and 10pm. The area type for each is urban, the barrier type is "Plastic Drum," lateral distance is 2 feet, and the work zone speed limit is 55 mph. A summary of the parameters for each work zone is shown in Table 3. All three work zones use the 3-107 FFS prediction model.

Name	Time Periods Active	Location	Severity	Area Type	Barrier Type	WZ Speed Limit	Lateral Distance
"WZ1: 8pm"	8pm – 12am	Seg. 32	1 lane closure	Urban	Plastic Drum	55	2 ft
"WZ2: 9pm"	9pm – 1am	Seg. 32	1 lane closure	Urban	Plastic Drum	55	2 ft
"WZ3: 10pm"	10pm – 2am	Seg. 32	1 lane closure	Urban	Plastic Drum	55	2 ft

Table 3: Summary of parameters for the three work zones of the I-40 east case study.

Figure 29 shows the “Step 5: Work Zone Inputs” panel with all three work zones created and configured.

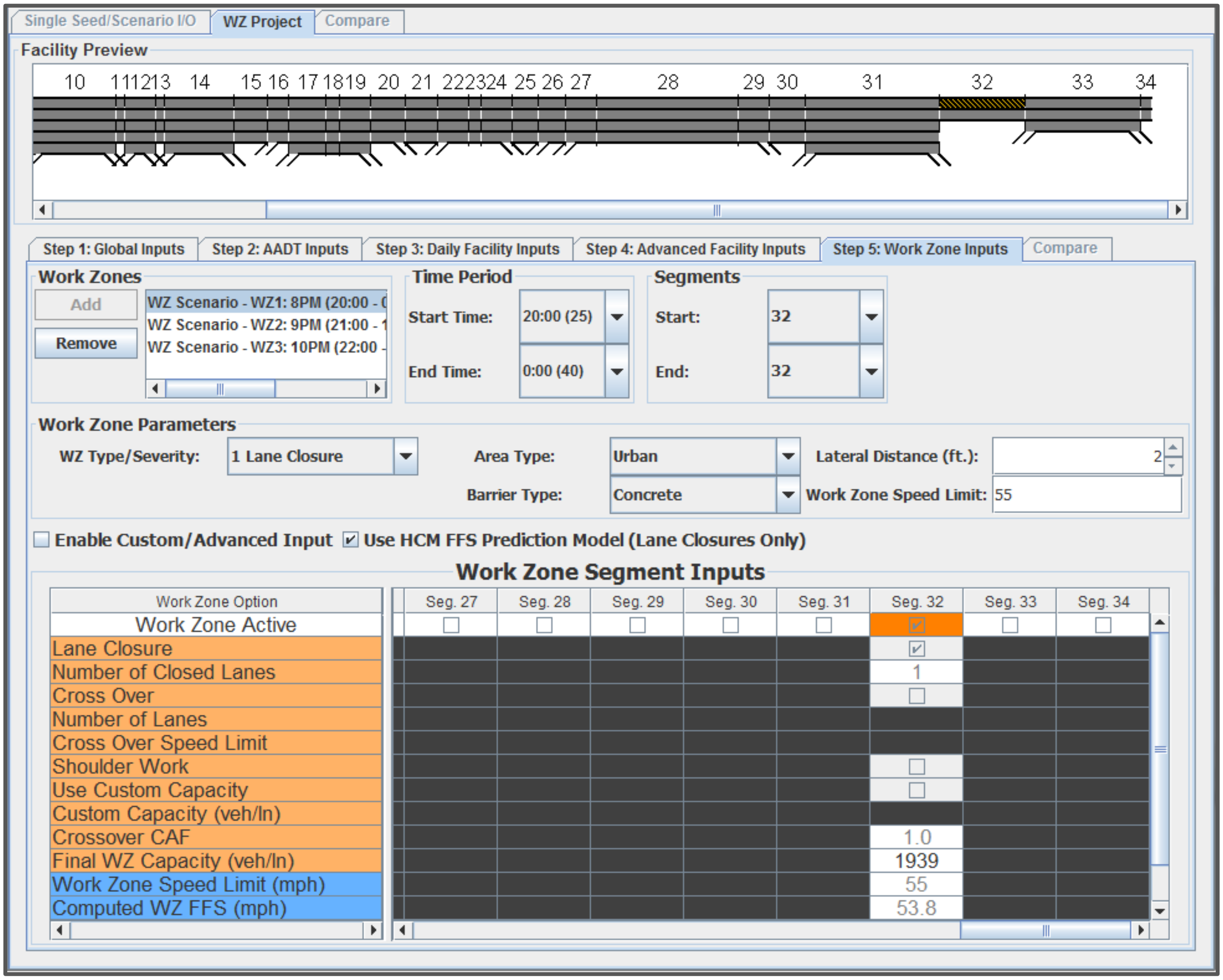


Figure 29: Case study project with three four-hour one lane closure work zones configured with different start times.

4.3 COMPARISON AND ANALYSIS

Figure 30 shows the compare panel of FREEVAL-WZ listing the comparisons and performance measure differences between the base scenario and the three work zones. It is clear from the figure that all three work zones lead to an increase in both vehicle hours of delay (VHD) and user cost. Further, both VHD and user cost performance measures indicate that the third work zone scenario which is active from 10pm-2am is the best choice of the three. The analyst can also take this information and combine it with outside information, such as costs relating to construction taking place at these hours, and decide if this is indeed the optimal choice.

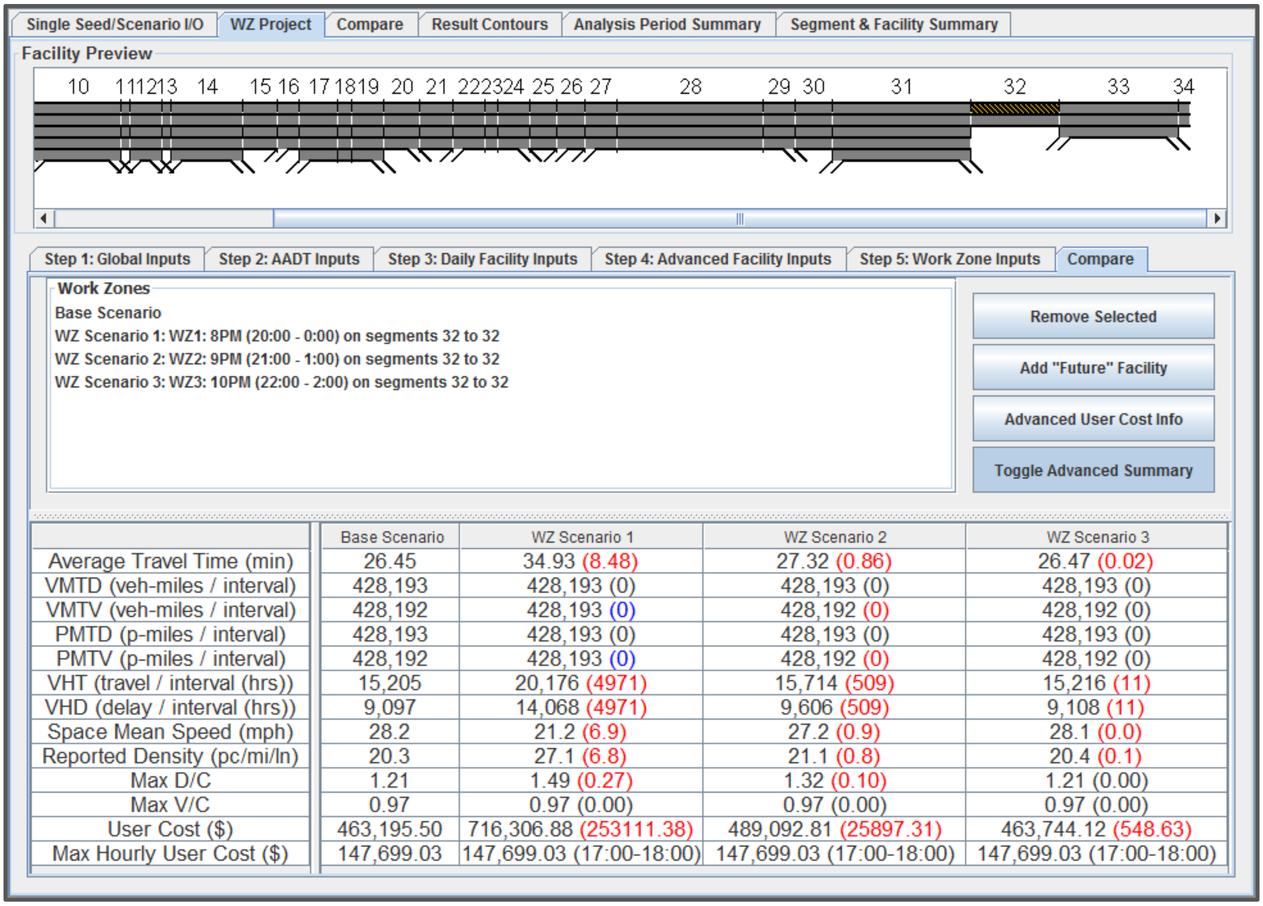
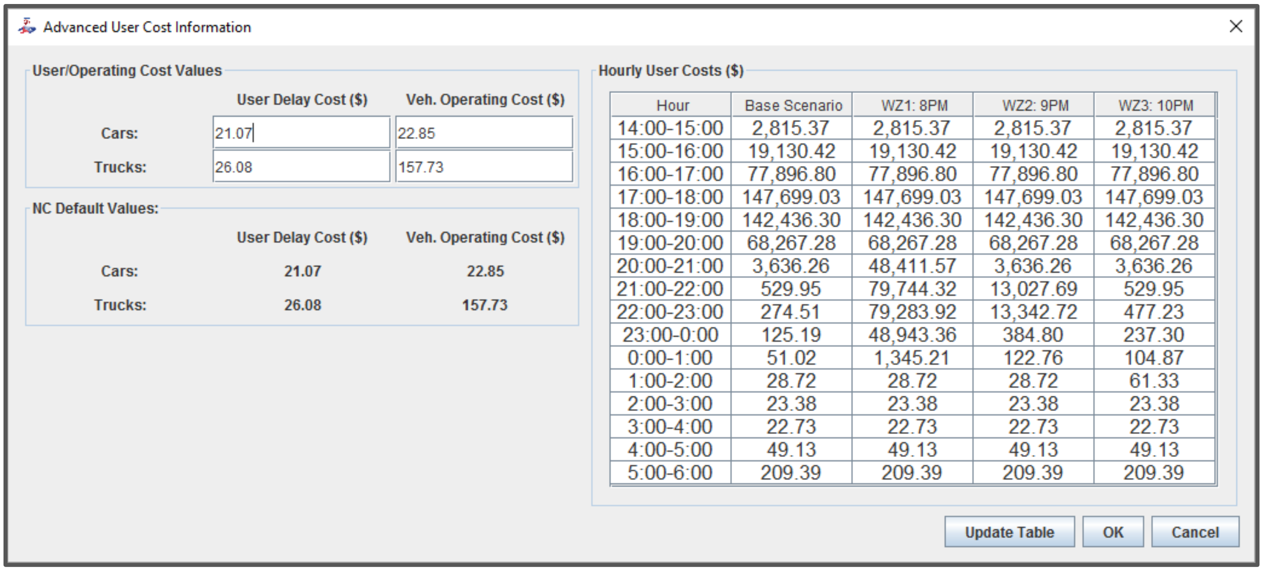


Figure 30: Compare panel for the I-40 case study work zones.

Figure 31 shows the in depth look at the user costs incurred by the base facility and each work zone during each hour of the study period. The analyst may look at this and note that user costs are actually lowest during the four hours between 12am and 4am. Based on this, the user could choose to revise the analysis and reschedule one of the work zones so that it falls in these hours to see if any further improvement can be gained. This is indeed the case, as a work zone with the above parameters scheduled from 1am – 5am results in a user cost of $182.81, a 50% improvement over the previous lowest cost option!



Hour	Base Scenario	WZ1: 8PM	WZ2: 9PM	WZ3: 10PM
14:00-15:00	2,815.37	2,815.37	2,815.37	2,815.37
15:00-16:00	19,130.42	19,130.42	19,130.42	19,130.42
16:00-17:00	77,896.80	77,896.80	77,896.80	77,896.80
17:00-18:00	147,699.03	147,699.03	147,699.03	147,699.03
18:00-19:00	142,436.30	142,436.30	142,436.30	142,436.30
19:00-20:00	68,267.28	68,267.28	68,267.28	68,267.28
20:00-21:00	3,636.26	48,411.57	3,636.26	3,636.26
21:00-22:00	529.95	79,744.32	13,027.69	529.95
22:00-23:00	274.51	79,283.92	13,342.72	477.23
23:00-0:00	125.19	48,943.36	384.80	237.30
0:00-1:00	51.02	1,345.21	122.76	104.87
1:00-2:00	28.72	28.72	28.72	61.33
2:00-3:00	23.38	23.38	23.38	23.38
3:00-4:00	22.73	22.73	22.73	22.73
4:00-5:00	49.13	49.13	49.13	49.13
5:00-6:00	209.39	209.39	209.39	209.39

Figure 31: Advanced User Cost information panel for the I-40 case study work zones.

5 EXAMPLE 1

The previous case study example demonstrated FREEVAL-WZ's built-in feature to populate a facility's demands using a single AADT value and distribution. The example of this section will start from a facility that already has demands, which will allow the process to move directly to Step 4. The example facility is included as an ASCII file (.txt) in the "Example" folder packaged with FREEVAL-WZ, and is the similar to the one created in Section 2.

Since this facility has already been calibrated, this analysis will make use of the demands that exist in the facility file. In order to do this, the "Use Included Facility Demands" option is selected when creating a new WZ project as shown in Figure 32.

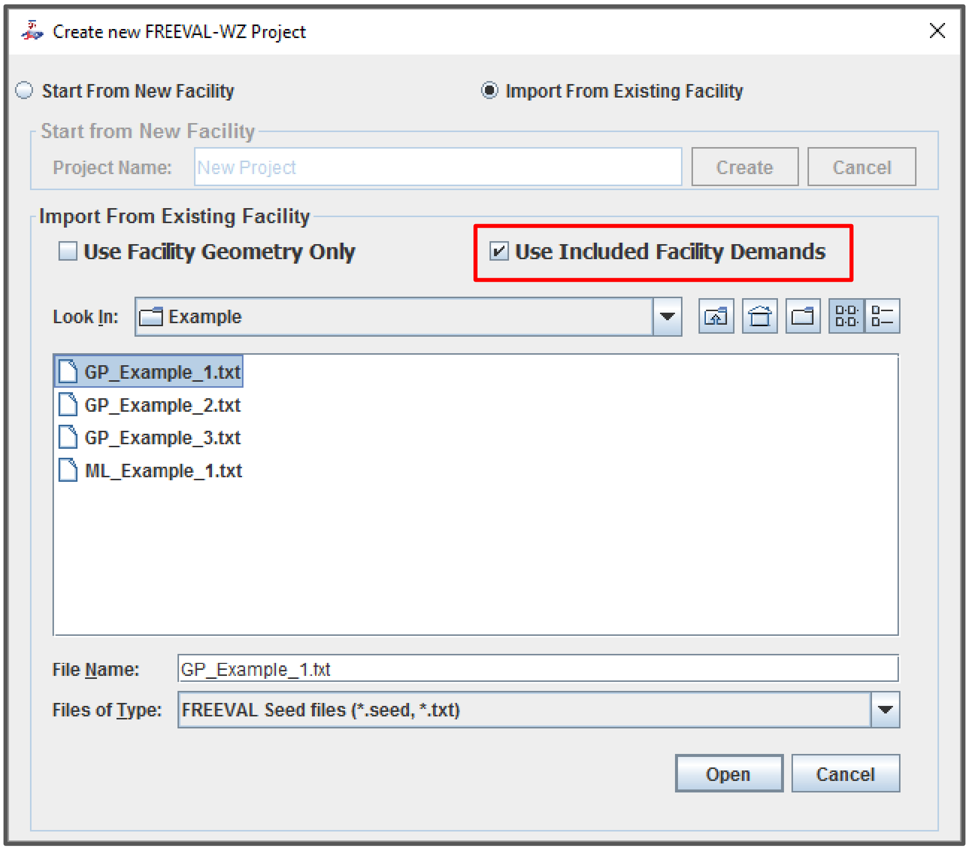


Figure 32: Creating a new WZ project that uses demands as specified in the facility template file.

With the project created using this method, FREEVAL-WZ opens directly to Step 4. Since this facility has already been calibrated, no inputs are needed for Step 4 (as noted in Section 2.5, Step 4 is an optional step), and the analysis can proceed directly to Step 5 to design the work zones. This analysis will consider the impacts of two work zones as summarized in Table 4. The work zones both last for the entire study period, and will be used to compare the impacts of work zones with differing severities and lengths. The first work zone is a one lane closure contained to only segment 6 of the facility, while the second work zone is a shoulder closure spans both segments 5 to 7. The first work zone uses the 3-107 FFS prediction model, while the second work zone uses overrides the default WZ FFS value to be the speed limit of 60 mph.

Name	Time Periods Active	Location	Severity	Area Type	Barrier Type	WZ Speed Limit	Lateral Distance
"WZ1"	5pm – 6:15pm	Seg. 6	1 Lane Closure	Urban	Concrete	55	2 ft
"WZ2"	5pm – 6:15pm	Seg. 5-7	Shoulder closure	Urban	Concrete	60	2 ft

Table 4: Summary of the work zone inputs for Step 5.

Figure 33 shows the inputs for these work zones entered into Step 5.

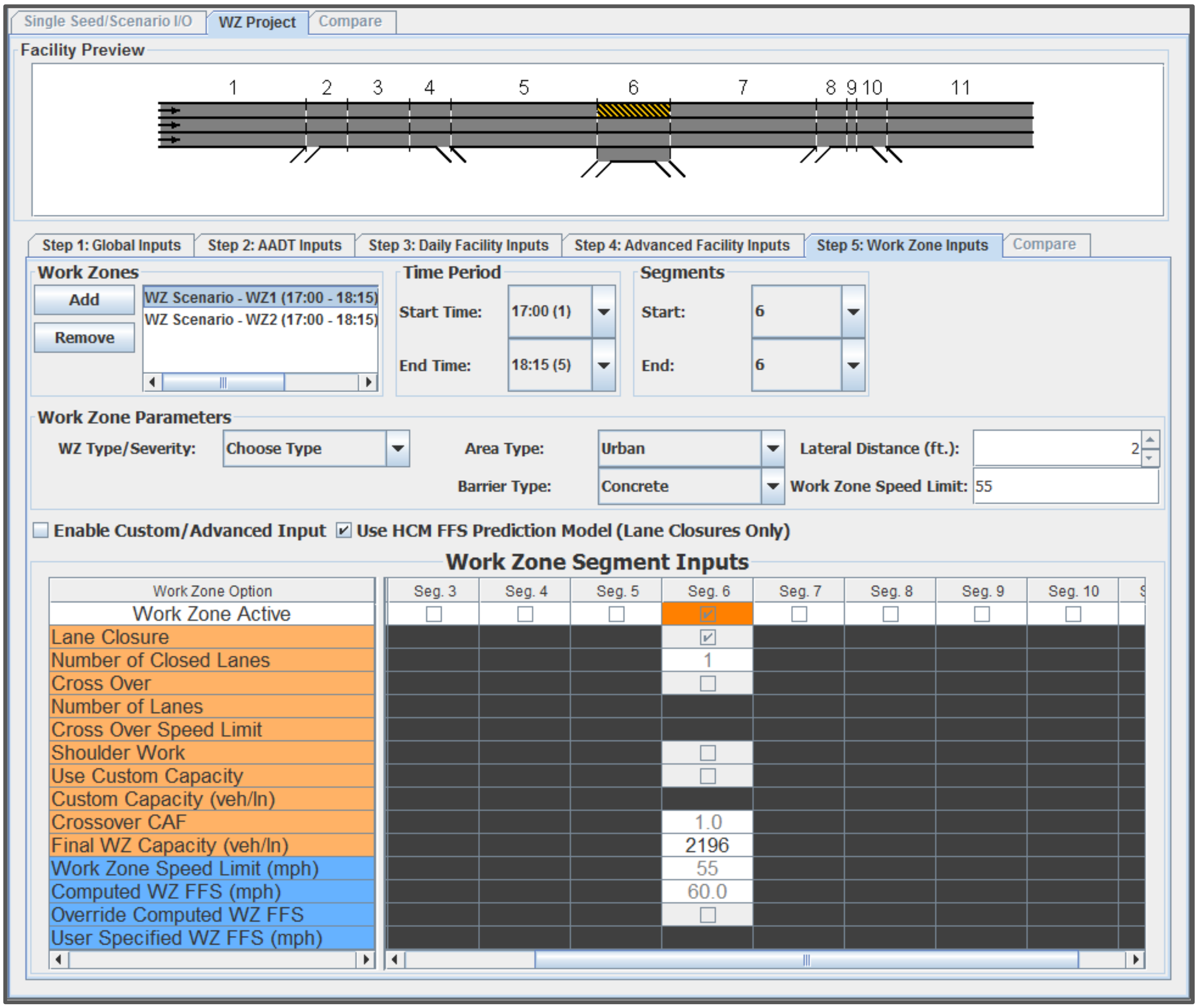


Figure 33: Work zone design panel with the inputs for the two work zones.

Figure 34 shows the comparison between the two work zones. From this analysis, it can be seen that the longer less severe work zone incurs a significantly smaller increase in User Cost, dropping from $1,553.30 for the single segment one lane closure all the way to $60.27 for the three segment shoulder closure. This could indicate that if the work can be completed under either configuration, work zone scenario 2 is the better option.

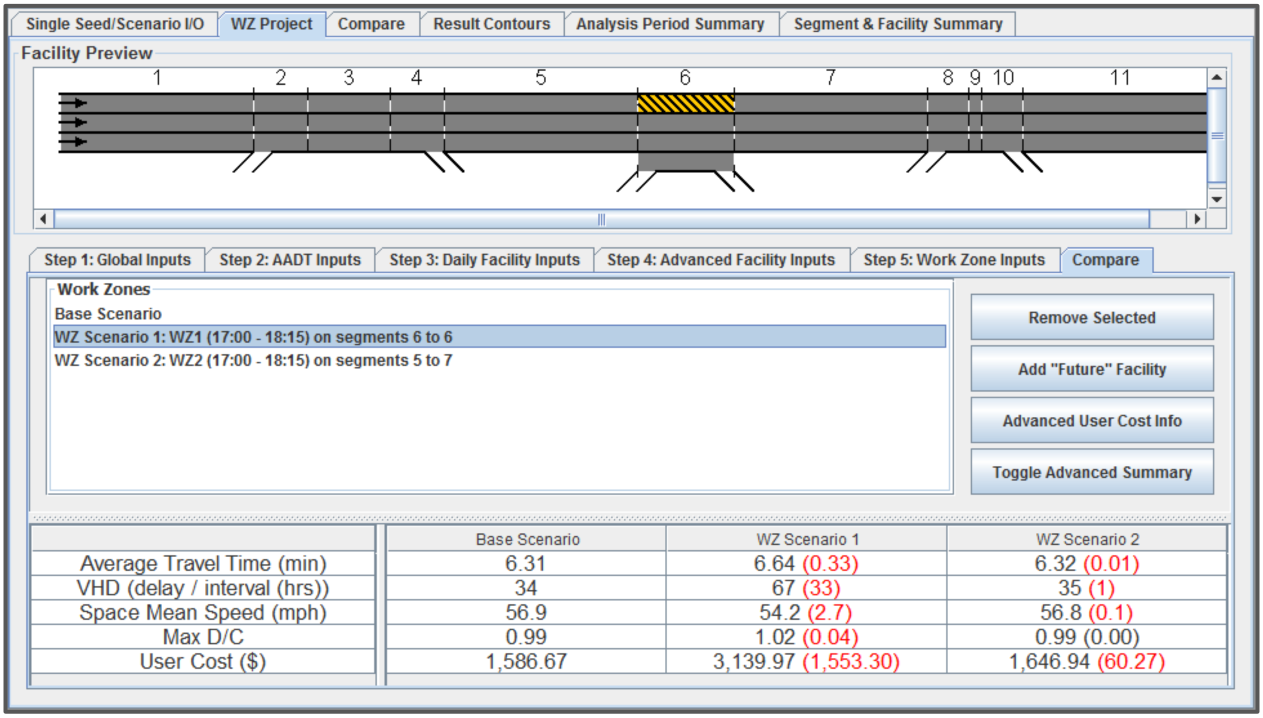


Figure 34: Comparison analysis of the two work zones.

6 EXAMPLE 2

Both examples up to this point have used FREEVAL-WZ's basic work zone creation functions. The purpose of this example is to create a compound work zone using the advanced work zone design functionality of the software. The facility for this example is created from scratch, consisting of a "pipeline" of 8 basic three lane segments. The global inputs used for Step 1 in the creation of this facility are shown in Figure 35.

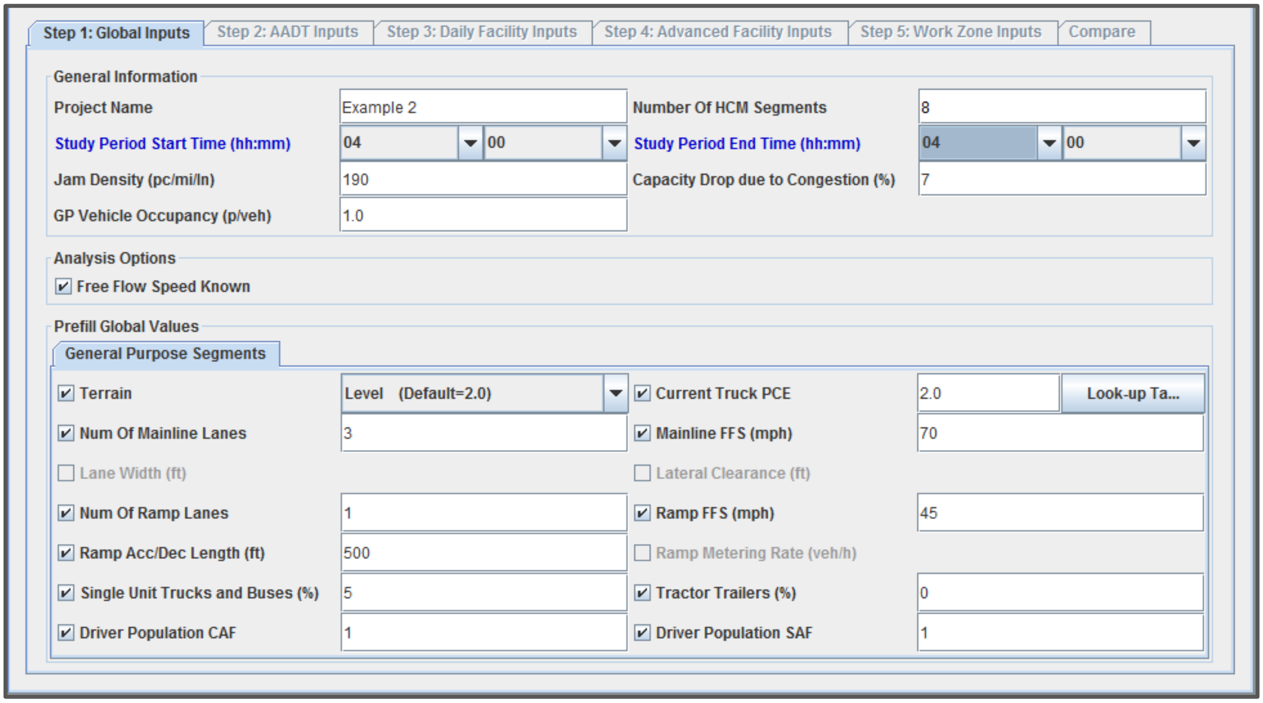


Figure 35: Global inputs to create the "pipeline" facility.

For this simple facility, the Bidirectional AADT is 120,000 vehicles per day, and it follows a Unimodal-Average distribution for the study period. These values are specified in Step 2, and the rest of the AADT inputs are left as the default values. For Step 3, no inputs are needed as the facility has no ramps. Since Step 4 is optional and the facility does not need to be calibrated, the analysis can proceed directly to Step 5. A summary of the global and AADT inputs used to create the facility are given in Table 5.

Parameter	Value
Number of Segments	8
Study Period	4am – 4am (24 hours)
Bidirectional AADT	120,000
Directional Factor	0.5
Facility Growth Factor	1.0
AADT Distribution Type	Unimodal – Average

Table 5: Summary of global and AADT inputs for the facility.

For this example, the analysis will look at the impacts of a single work zone. Unlike the previous examples, the work zone created in this case will use the "Advanced Input" capabilities to create a work zone that does not have a uniform severity. The work zone will span the two mile stretch from segments 3 to 6, and will consist of a shoulder closure in segments 3 and 4, and a one lane closure in segments 5 and 6. The work zone speed limit is specified to be 60 mph, and the work zone free flow speed in each segment is overridden to be 60 mph. Figure 36 shows the work zone created in the Work Zone Inputs panel of Step 5, and Table 6 provides a summary of the inputs.

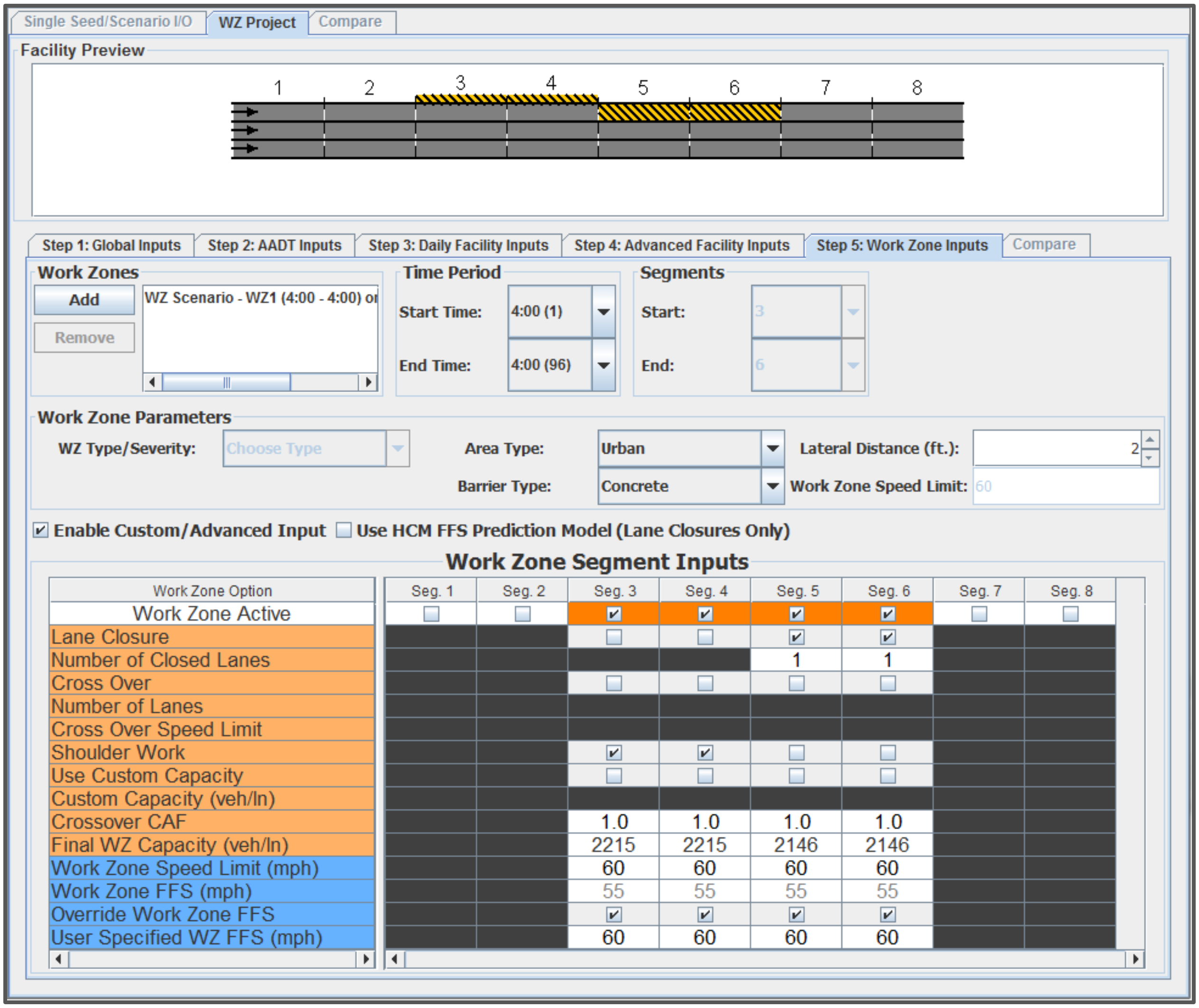
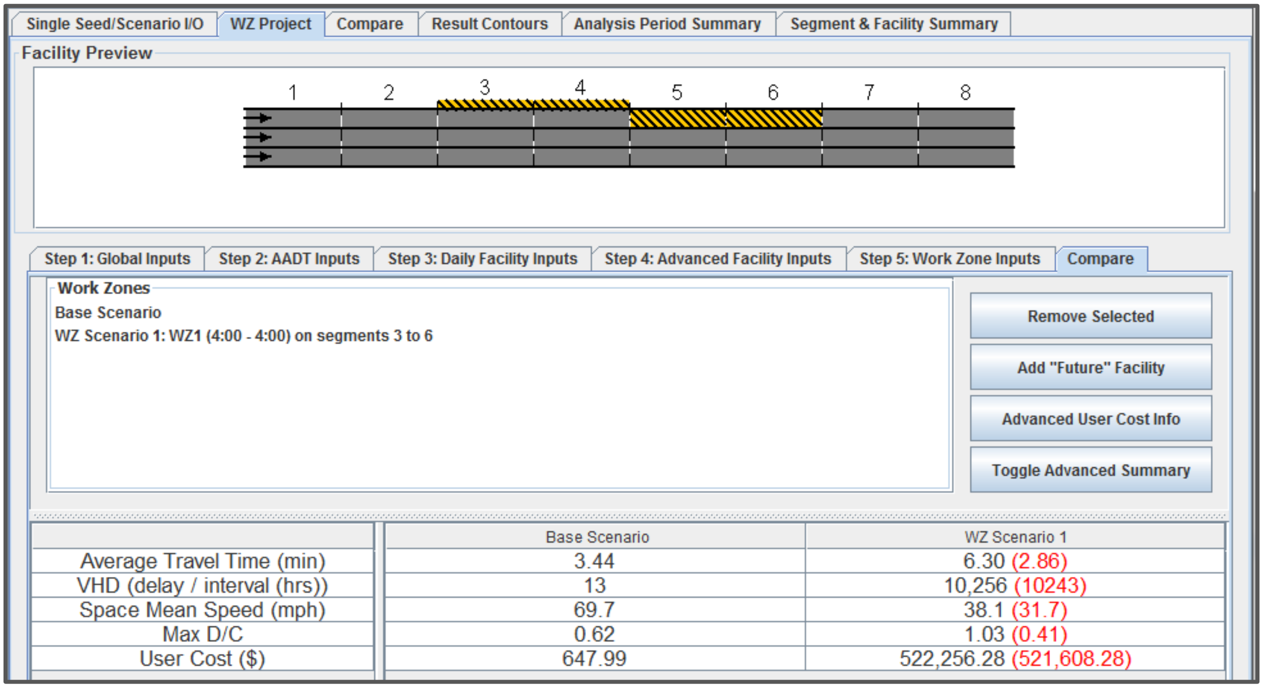


Figure 36: Compound shoulder closure/one lane closure work zone created using the advanced inputs table.

Name	Time Periods Active	Location	Severity	Area Type	Barrier Type	WZ Speed Limit	Lateral Distance
"WZ1"	4am – 4am	Seg. 3-6	Shoulder closure / 1 Lane Closure	Urban	Concrete	60	2 ft

Table 6: Summary of the work zone inputs shown in Figure 36.

Figure 37 shows the summary output for the work zone, highlighting the increased delay and user cost caused by the introduction of the work zone.



	Base Scenario	WZ Scenario 1
Average Travel Time (min)	3.44	6.30 (2.86)
VHD (delay / interval (hrs))	13	10,256 (10243)
Space Mean Speed (mph)	69.7	38.1 (31.7)
Max D/C	0.62	1.03 (0.41)
User Cost ($)	647.99	522,256.28 (521,608.28)

Figure 37: Performance measure summary comparing the base facility to the work zone scenario.

7 APPENDIX A: LIST OF FACILITY SPECIFIC AADT DISTRIBUTIONS

	County	Route #	Direction(s)	Location
1	Buncombe	I-240	EB/WB	West of NC 191 (Brevard Rd)
2	Buncombe	I-40	EB/WB	East of SR 1200 (Wiggins Rd)
3	Burke	I-40	EB/WB	West of SR 1734 (Carolina St)
4	Cumberland	I-95	NB/SB	North of I-295/US 13
5	Guilford	I-40 Bus	EB/WB	West of I-40 & I-40 Bus Split
6	Forsyth	I-40	EB/WB	East of NC 66
7	Johnston	I-40	EB/WB	West of NC 242
8	Mecklenburg	I-277	NB/SB	South of US 29 (Graham St)
9	Nash	I-95	NB/SB	South of NC 33
10	Surry	I-77	NB/SB	South of NC 89 (West Pine St)
11	Pender	I-40	EB/WB	West of NC 210
12	Randolph	I-73/ I-74	NB/SB	North of New Hope Church Rd
13	Alamance	I-40/ I-85	EB/WB	West of SR 1928 (Jimmie Kerr Rd)
14	Davie	I-40	EB/WB	East of SR 1410 (Farmington Rd)
15	Mecklenburg	I-85	NB/SB	West of US 29
16	Mecklenburg	I-485	EB/WB	East of I-77
17	New Hanover	I-40	EB/WB	West of NC 132 (College Rd)
18	Northampton	I-95	NB/SB	North of NC 48
19	Warren	I-85	NB/SB	North of US 1
20	Wake	I-40	EB/WB	0.22 Mile West of Aviation Pkwy (284.5)
21	Durham	I-40	EB/WB	0.85 Mile West of Fayetteville Rd (274.8)
22	Wake	I-540	EB/WB	0.68 Mile West of Leesville Rd (6.0)
23	Wake	I-440	EB/WB	0.29 Mile East of Wake Forest Rd (9.8)
24	Wake	I-440	EB/WB	0.33 Mile West of Western Blvd (2.1)
25	Wake	I-40	EB/WB	0.76 Mile West of E Garner Rd (304.1)
26	Wake	I-40/440	EB/WB	0.72 Mile North of US-70

8 APPENDIX B: BASE EXAMPLE PDF REPORT

Dec 4, 2015 FREEVAL-WZ Report: New Project

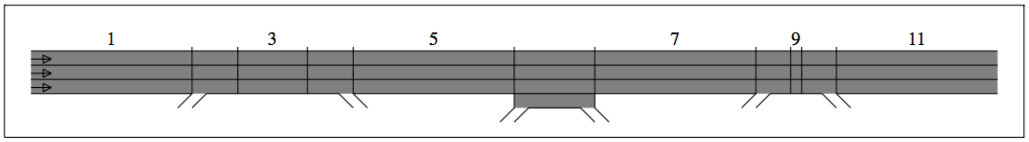
FREEVAL-WZ Report

Summary Output

Project: New Project **Facility Length:** 6.0 miles (11 segments)

Analyst: Analyst1 **Analysis Period:** 10:00am - 10:00am (96 time periods)

Scenario: Base Year



Performance Measure	**Base Scenario**	**WZ Scenario 1**
	Example Project	WZ Scen 1
Average Travel Time (min)	5.43	5.81
VMTD (veh-miles / interval)	432,885	432,885
VMTV (veh-miles / interval)	432,885	432,885
PMTD (p-miles / interval)	432,885	432,885
PMTV (p-miles / interval)	432,885	432,885
VHT (travel / interval (hrs))	6,539	6,988
VHD (delay / interval (hrs))	355	804
Space Mean Speed (mph)	66.2	62.0
Reported Density (pc/mi/ln)	15.6	16.6
Max D/C	0.91	1.01
Max V/C	0.91	1.00
User Cost ($)	18,071.22	40,916.86
Max Hourly User Cost ($)	4,146.54	17,624.78
Work Zone Summary		
WZ Name	-	WZ Scen 1
Time Active	-	10:00-10:00
Segments Active	-	7
Severity	-	Shoulder closure
WZ Speed Limit	-	55
Area Type	-	Urban
Barrier Type	-	Soft Barrier
Lateral Distance	-	2.00 ft

#	**Segment Name**	**Length (ft)**	**Type**
1		5,280	Basic
2		1,500	On-Ramp
3		2,280	Basic
4		1,500	Off-Ramp
5		5,280	Basic
6		2,640	Weaving

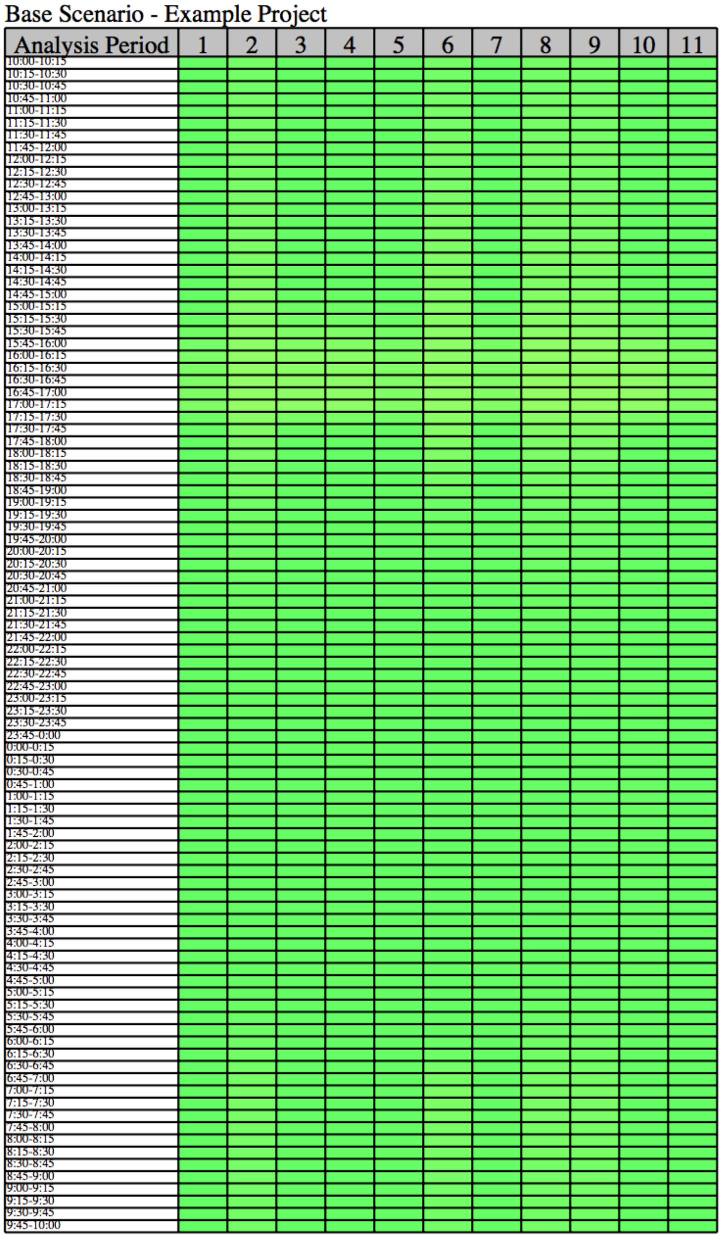
#	**Segment Name**	**Length (ft)**	**Type**
7		5,280	Basic
8		1,140	On-Ramp
9		360	Overlap
10		1,140	Off-Ramp
11		5,280	Basic

Page 1 of 5

Dec 4, 2015 FREEVAL-WZ Report: New Project

Facility Contours - Speed

Base Scenario - Example Project

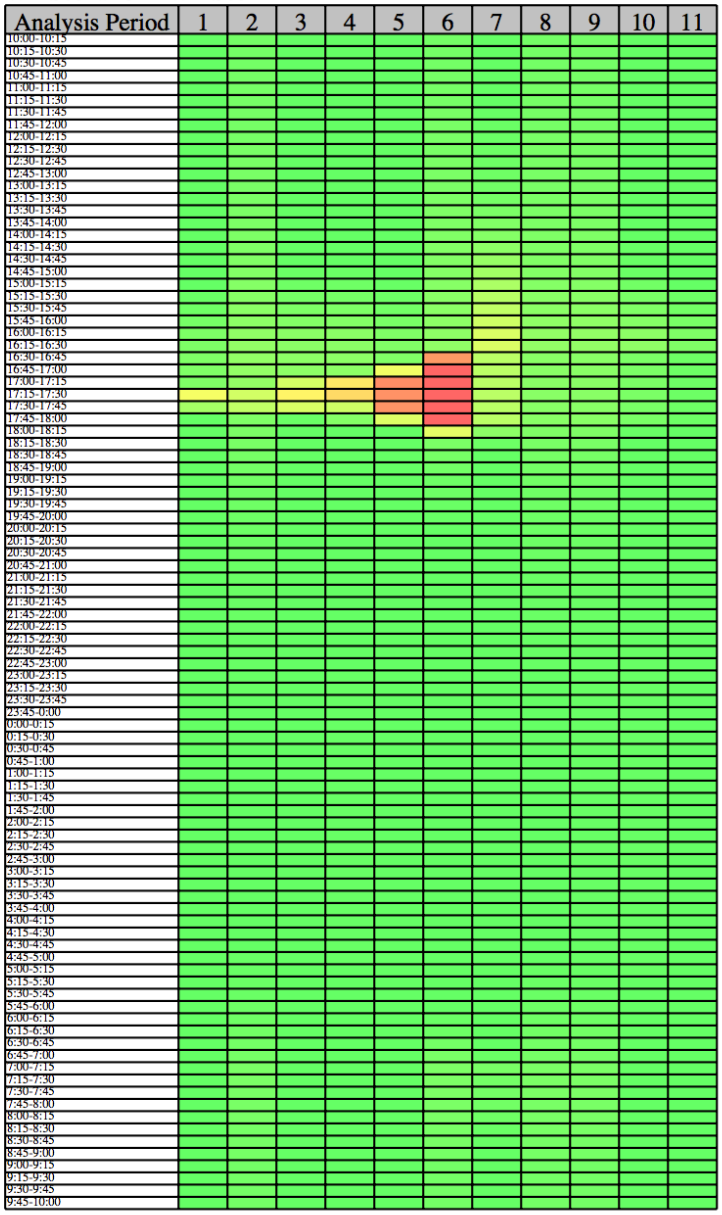


Page 2 of 5

Dec 4, 2015 FREEVAL-WZ Report: New Project

Facility Contours (Cont.) - Speed

WZ Scenario 1- WZ Scen 1



Page 3 of 5

Dec 4, 2015 FREEVAL-WZ Report: New Project

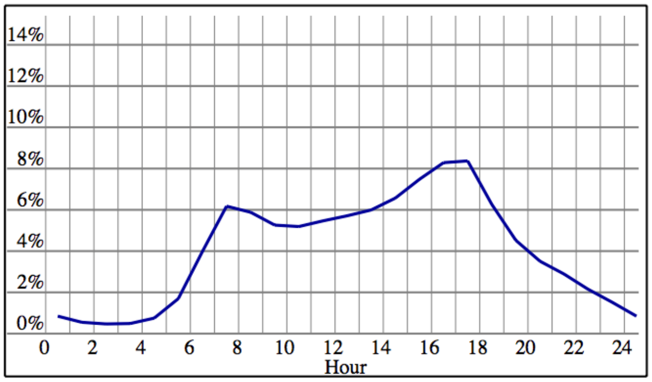
Input Summary
Base Scenario - Example Project

Study Period: 10:00am - 10:00am

Global Property	Value
Jam Density	190.00
Capacity Drop	7.00%
Future	Val

AADT Input Parameter	Value
Bidirectional AADT (vpd)	141,000
Directional Factor	0.50
Facility Wide Growth Factor	1.00

AADT Distribution: Bimodal - PM Peak - Average



Hour	%
0-1	0.85
1-2	0.55
2-3	0.47
3-4	0.49
4-5	0.75
5-6	1.70
6-7	3.98
7-8	6.18
8-9	5.88
9-10	5.26
10-11	5.19
11-12	5.46

Hour	%
12-13	5.71
13-14	5.99
14-15	6.57
15-16	7.48
16-17	8.29
17-18	8.37
18-19	6.26
19-20	4.52
20-21	3.51
21-22	2.89
22-23	2.15
23-24	1.52

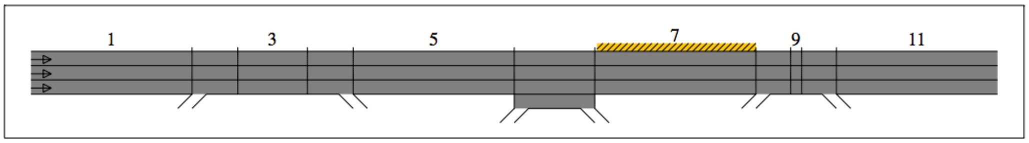
Segment Daily Input Values:

#	Type	L(ft)	NL	On AADT	Off AADT
1	B	5,280	3	-	-
2	ONR	1,500	3	15,000	-
3	B	2,280	3	-	-
4	OFR	1,500	3	-	12,000
5	B	5,280	3	-	-
6	W	2,640	4	11,000	10,000
7	B	5,280	3	-	-
8	ONR	1,140	3	13,000	-
9	R	360	3	-	-
10	OFR	1,140	3	-	15,000
11	B	5,280	3	-	-

Page 4 of 5

Dec 4, 2015 FREEVAL-WZ Report: New Project

WZ Scenario 1 - WZ Scen 1



Active Time Period: 10:00am - 10:00am
Area Type: Urban
Lateral Distance(ft): 2.0
Barrier Type: Soft Barrier
Work Zone Speed Limit: 55

Performance Measure	Base Scenario	WZ Scenario 1	Comparison
Name	Example Project	WZ Scen 1	-
Average Travel Time (min)	5.43	5.81	0.37
VMTD (veh-miles / interval)	432,885	432,885	0
VMTV (veh-miles / interval)	432,885	432,885	-0
PMTD (p-miles / interval)	432,885	432,885	0
PMTV (p-miles / interval)	432,885	432,885	-0
VHT (travel / interval (hrs))	6,539	6,988	449
VHD (delay / interval (hrs))	355	804	449
Space Mean Speed (mph)	66.2	62.0	-4.3
Reported Density (pc/mi/ln)	15.6	16.6	1.1
Max D/C	0.91	1.01	0.00
Max V/C	0.91	1.00	0.00
User Cost ($)	18,071.22	40,916.86	22,845.63
Max Hourly User Cost ($)	4,146.54	17,624.78	-

Work Zone Parameters in Active Segments:

	Type/Severity	Computed Capacity	WZ Speed Limit	Computed FFS
Segment 7	Shoulder closure	2006	55	67

Hour	User Cost ($)
10:00-11:00	664.23
11:00-12:00	784.87
12:00-13:00	935.94
13:00-14:00	1,243.42
14:00-15:00	2,072.32
15:00-16:00	3,854.92
16:00-17:00	7,815.67
17:00-18:00	17,624.78
18:00-19:00	1,134.01
19:00-20:00	401.36
20:00-21:00	291.49
21:00-22:00	219.18

Hour	User Cost ($)
22:00-23:00	150.91
23:00-0:00	95.46
0:00-1:00	53.52
1:00-2:00	37.31
2:00-3:00	34.15
3:00-4:00	42.36
4:00-5:00	82.70
5:00-6:00	216.52
6:00-7:00	562.14
7:00-8:00	1,118.69
8:00-9:00	840.65
9:00-10:00	640.23

Page 5 of 5

9 APPENDIX C: CASE STUDY EXAMPLE PDF REPORT

Dec 30, 2015 FREEVAL-WZ Report: I-40 Case Study

FREEVAL-WZ Report

Summary Output

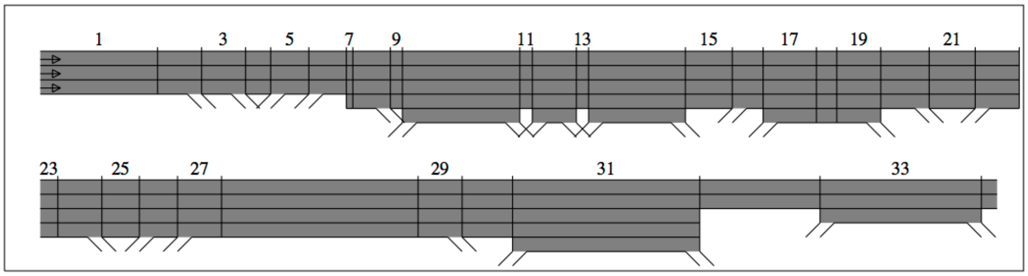
Project: I-40 Case Study

Analyst: ITRE

Scenario: Base Year

Facility Length: 12.5 miles (34 segments)

Analysis Period: 14:00pm - 6:00am (64 time periods)

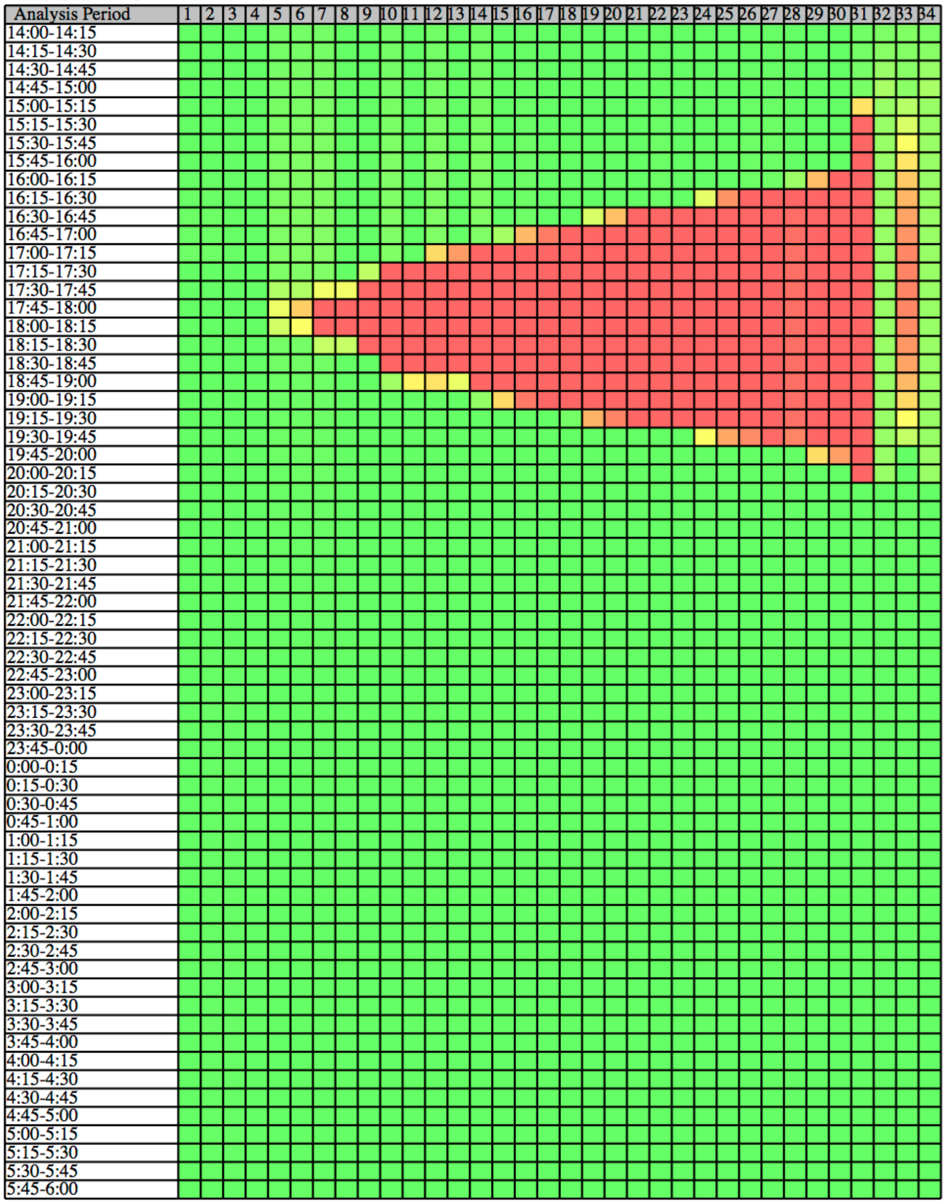


Performance Measure	**Base Scenario**	**WZ Scenario 1**	**WZ Scenario 2**	**WZ Scenario 3**
	I-40 EB	WZ1: 8PM	WZ2: 9PM	WZ3: 10PM
Average Travel Time (min)	26.45	34.93	27.32	26.47
VHT (travel / interval (hrs))	15,205	20,176	15,714	15,213
VHD (delay / interval (hrs))	9,097	14,068	9,606	9,105
Space Mean Speed (mph)	28.2	21.2	27.2	28.1
Reported Density (pc/mi/ln)	20.3	27.1	21.1	20.4
Max D/C	1.21	1.49	1.32	1.21
Max V/C	0.97	0.97	0.97	0.97
User Cost ($)	463,195.50	716,306.88	489,092.81	463,596.81
Max Hourly User Cost ($)	147,699.03	147,699.03	147,699.03	147,699.03
Work Zone Summary				
WZ Name	-	WZ1: 8PM	WZ2: 9PM	WZ3: 10PM
Time Active	-	20:00-0:00	21:00-1:00	22:00-2:00
Segments Active	-	32	32	32
Severity	-	1 lane closure	1 lane closure	1 lane closure
WZ Speed Limit	-	55	55	55
Area Type	-	Urban	Urban	Urban
Barrier Type	-	Soft Barrier	Soft Barrier	Concrete
Lateral Distance	-	2.00 ft	2.00 ft	2.00 ft

FREEVAL WZ V20151217 Page 1 of 6

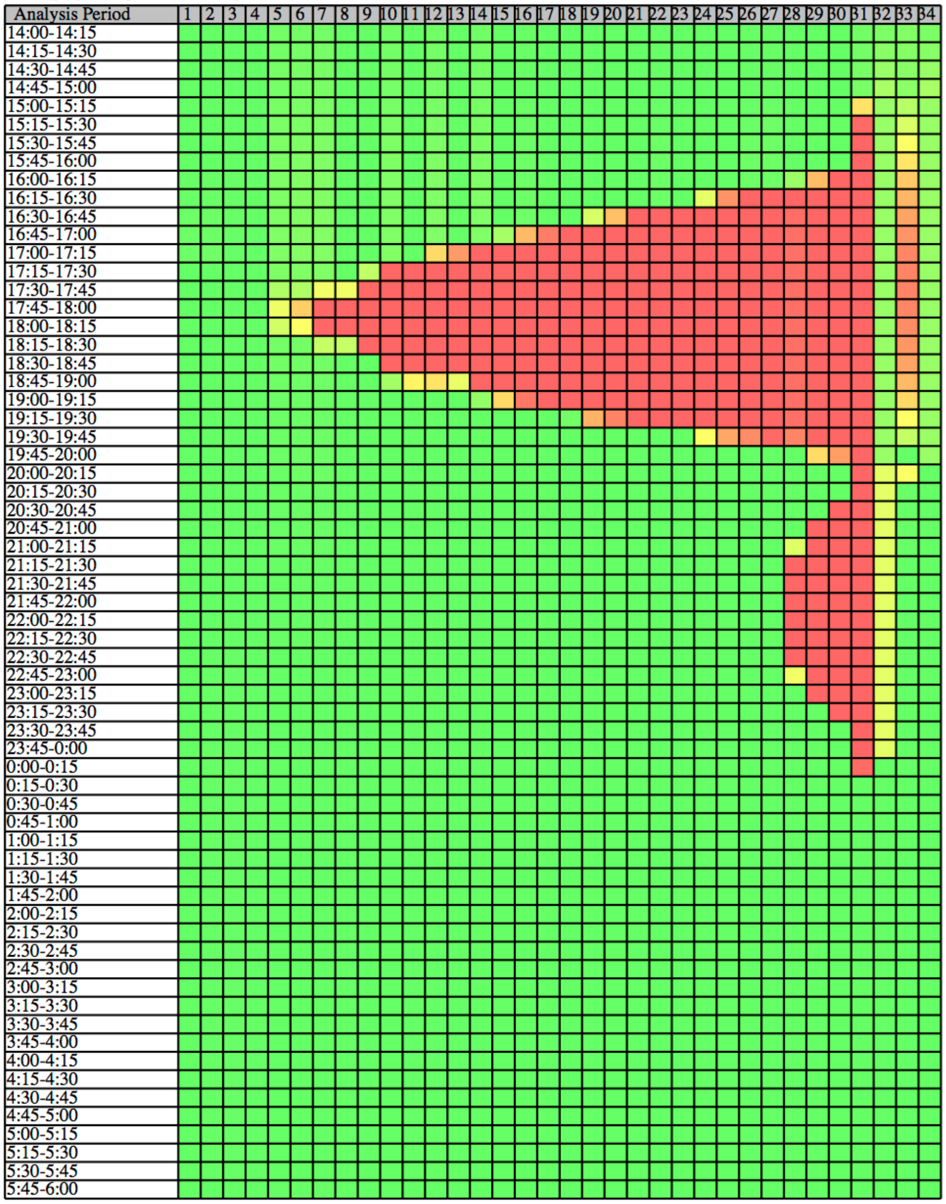
Facility Contours - Speed

Base Scenario - I-40 EB



Facility Contours (Cont.) - Speed

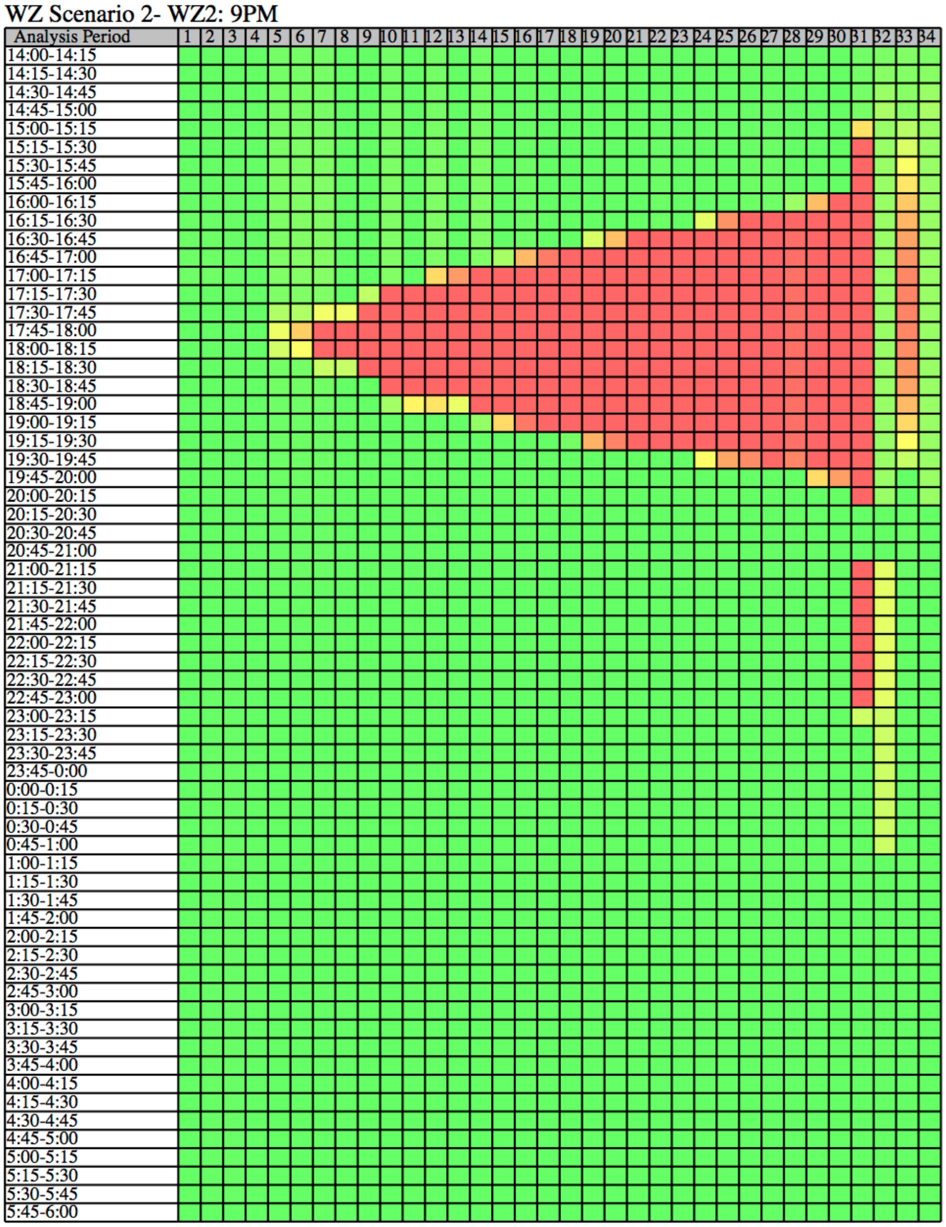
WZ Scenario 1- WZ1: 8PM



Dec 30, 2015 FREEVAL-WZ Report: I-40 Case Study

Facility Contours (Cont.) - Speed

WZ Scenario 2- WZ2: 9PM

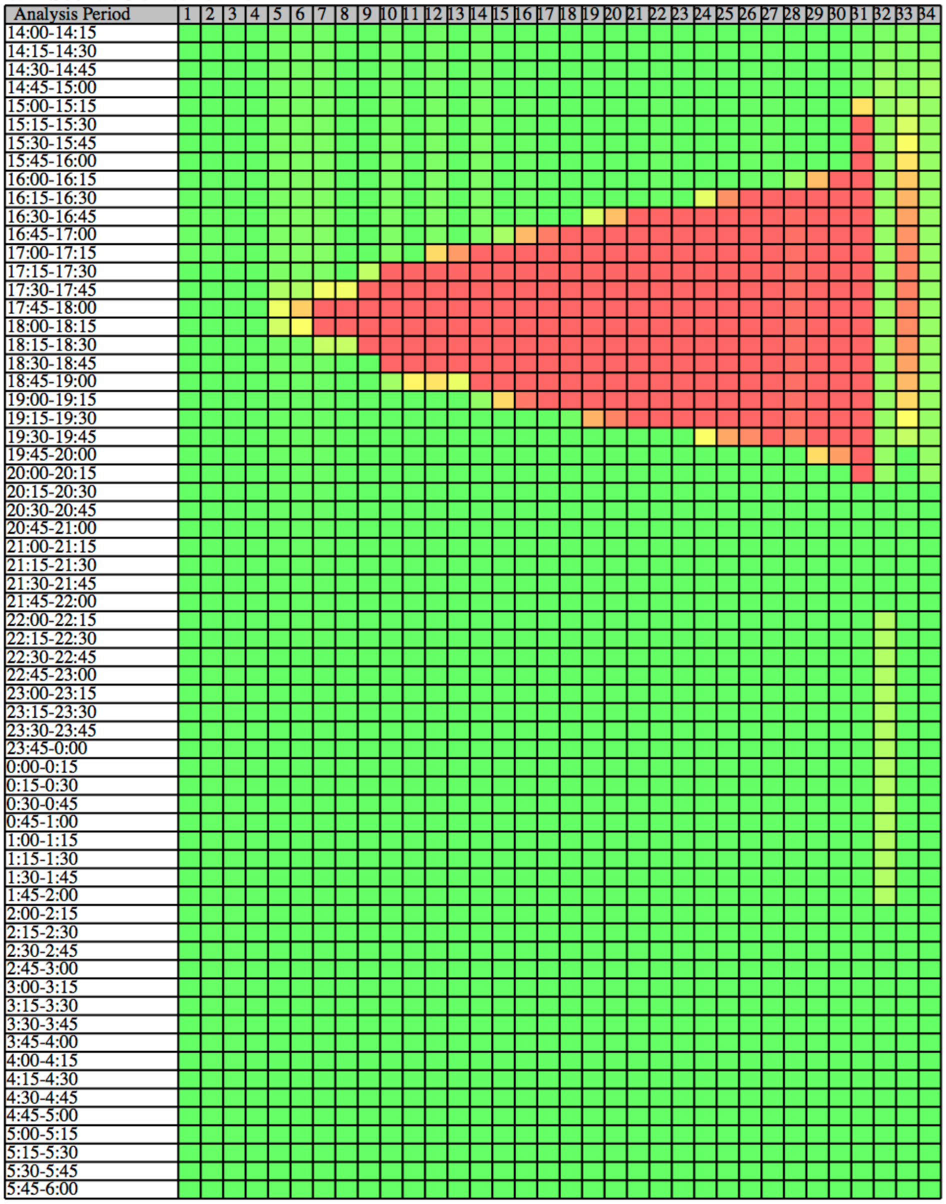


FREEVAL WZ V20151217 Page 4 of 6

Dec 30, 2015 FREEVAL-WZ Report: I-40 Case Study

Facility Contours (Cont.) - Speed

WZ Scenario 3- WZ3: 10PM



FREEVAL WZ V20151217 Page 5 of 6

Dec 30, 2015 FREEVAL-WZ Report: I-40 Case Study

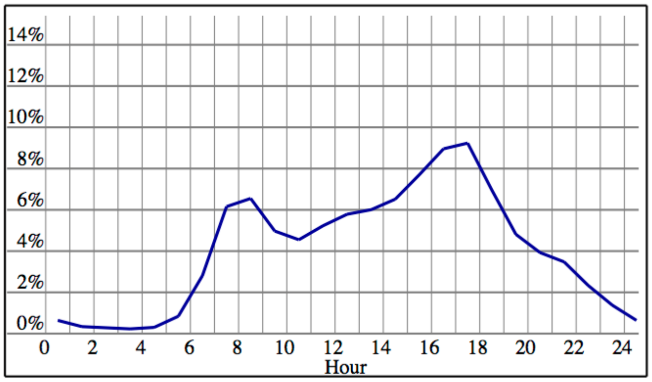
Input Summary
Base Scenario - I-40 EB

Study Period: 14:00pm - 6:00am

Global Property	Value
Jam Density	190.00
Capacity Drop	7.00%
Number of Segments	34

AADT Input Parameter	Value
Bidirectional AADT (vpd)	120,000
Directional Factor	0.50
Facility Wide Growth Factor	1.00

AADT Distribution: Bimodal - PM Peak - 75th Percentile



Hour	%
0-1	0.64
1-2	0.34
2-3	0.28
3-4	0.23
4-5	0.30
5-6	0.84
6-7	2.81
7-8	6.16
8-9	6.55
9-10	4.97
10-11	4.55
11-12	5.23

Hour	%
12-13	5.79
13-14	6.01
14-15	6.52
15-16	7.71
16-17	8.96
17-18	9.23
18-19	6.96
19-20	4.81
20-21	3.93
21-22	3.48
22-23	2.33
23-24	1.38

Segment Daily Input Values:

#	Type	L(ft)	NL	On AADT	Off AADT
1	B	4,000	3	-	-
2	OFR	1,500	3	-	10,000
3	OFR	1,500	3	-	10,000
4	B	855	3	-	-
5	ONR	1,300	3	10,000	-
6	ONR	1,280	3	10,000	-
7	R	220	4	-	-
8	OFR	1,280	4	-	10,000
9	B	410	4	-	-
10	W	4,000	5	10,000	10,000
11	B	430	4	-	-
12	W	1,500	5	10,000	10,000
13	B	415	4	-	-
14	W	3,300	5	10,000	10,000
15	B	1,600	4	-	-
16	ONR	1,050	4	10,000	-
17	ONR	1,817	5	10,000	-
18	B	693	5	-	-
19	OFR	1,500	5	-	10,000
20	OFR	1,650	4	-	10,000
21	B	1,570	4	-	-
22	ONR	1,500	4	10,000	-
23	B	600	4	-	-
24	OFR	1,500	4	-	10,000

#	Type	L(ft)	NL	On AADT	Off AADT
25	B	4,000	3	-	-
26	OFR	1,500	3	-	10,000
27	OFR	1,500	3	-	10,000
28	B	855	3	-	-
29	ONR	1,300	3	10,000	-
30	ONR	1,280	3	10,000	-
31	R	220	4	-	-
32	OFR	1,280	4	-	10,000
33	B	410	4	-	-
34	W	4,000	5	10,000	10,000

FREEVAL WZ V20151217 Page 6 of 6

10 APPENDIX D: EXAMPLE 1 PDF REPORT

Dec 30, 2015 FREEVAL-WZ Report: Example 1

FREEVAL-WZ Report

Summary Output

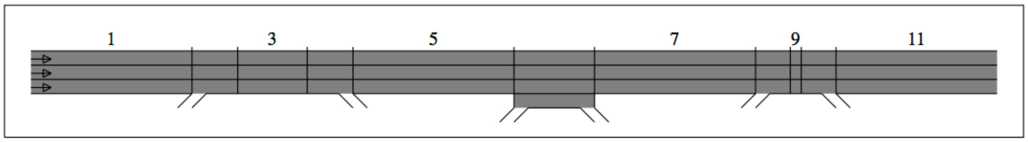
Project: Example 1

Analyst: ITRE

Scenario: Base Year

Facility Length: 6.0 miles (11 segments)

Analysis Period: 17:00pm - 18:15pm (5 time periods)

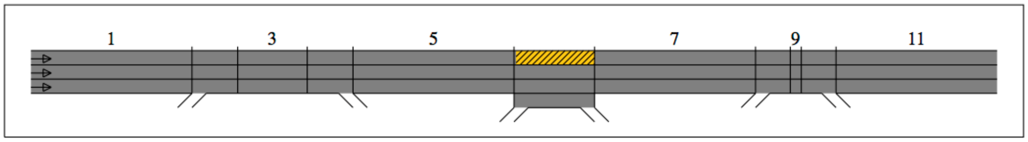


Performance Measure	Base Scenario	WZ Scenario 1	WZ Scenario 2
	Example 1	WZ1	WZ2
Average Travel Time (min)	6.31	6.64	6.32
VHT (travel / interval (hrs))	659	692	660
VHD (delay / interval (hrs))	34	67	35
Space Mean Speed (mph)	56.9	54.2	56.8
Reported Density (pc/mi/ln)	28.4	30.8	28.5
Max D/C	0.99	1.02	0.99
Max V/C	0.99	0.94	0.99
User Cost ($)	1,586.67	3,139.97	1,646.94
Max Hourly User Cost ($)	1,461.98	3,002.23	1,522.26
Work Zone Summary			
WZ Name	-	WZ1	WZ2
Time Active	-	17:00-18:15	17:00-18:15
Segments Active	-	6	5-7
Severity	-	1 lane closure	Shoulder closure
WZ Speed Limit	-	55	45
Area Type	-	Urban	Urban
Barrier Type	-	Concrete	Concrete
Lateral Distance	-	2.00 ft	2.00 ft

FREEVAL WZ V20151217 Page 1 of 3

Dec 30, 2015 FREEVAL-WZ Report: Example 1

WZ Scenario 1 - WZ1



Active Time Period: 17:00pm - 18:15pm
Area Type: Urban **Barrier Type:** Concrete
Lateral Distance(ft): 2.0 **Work Zone Speed Limit:** 55

Performance Measure	Base Scenario	WZ Scenario 1	Comparison
Name	Example 1	WZ1	-
Average Travel Time (min)	6.31	6.64	0.33
VMTD (veh-miles / interval)	37,522	37,522	0
VMTV (veh-miles / interval)	37,522	37,523	0
PMTD (p-miles / interval)	37,522	37,522	0
PMTV (p-miles / interval)	37,522	37,523	0
VHT (travel / interval (hrs))	659	692	33
VHD (delay / interval (hrs))	34	67	33
Space Mean Speed (mph)	56.9	54.2	-2.7
Reported Density (pc/mi/ln)	28.4	30.8	2.3
Max D/C	0.99	1.02	0.00
Max V/C	0.99	0.94	0.00
User Cost ($)	1,586.67	3,139.97	1,553.30
Max Hourly User Cost ($)	1,461.98	3,002.23	1,540.24

Hour	User Cost ($)
17:00-18:00	3,002.23
18:00-19:00	137.74

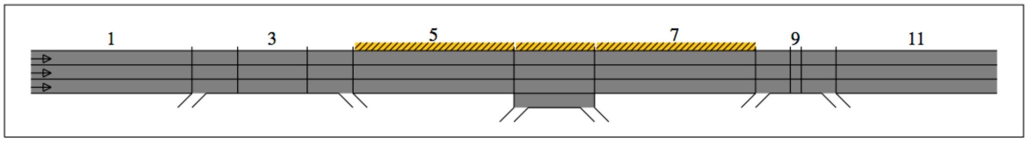
Work Zone Parameters in Active Segments:

	Type/Severity	Computed Capacity	WZ Speed Limit	Computed FFS
Segment 6	1 lane closure	2196	55	60

FREEVAL WZ V20151217 Page 2 of 3

Dec 30, 2015 FREEVAL-WZ Report: Example 1

WZ Scenario 2 - WZ2



Active Time Period: 17:00pm - 18:15pm
Area Type: Urban **Barrier Type:** Concrete
Lateral Distance(ft): 2.0 **Work Zone Speed Limit:** 45

Performance Measure	Base Scenario	WZ Scenario 2	Comparison
Name	Example 1	WZ2	-
Average Travel Time (min)	6.31	6.32	0.00
VMTD (veh-miles / interval)	37,522	37,522	0
VMTV (veh-miles / interval)	37,522	37,522	0
PMTD (p-miles / interval)	37,522	37,522	0
PMTV (p-miles / interval)	37,522	37,522	0
VHT (travel / interval (hrs))	659	660	1
VHD (delay / interval (hrs))	34	35	1
Space Mean Speed (mph)	56.9	56.8	0.0
Reported Density (pc/mi/ln)	28.4	28.5	0.0
Max D/C	0.99	0.99	0.00
Max V/C	0.99	0.99	0.00
User Cost ($)	1,586.67	1,646.94	60.27
Max Hourly User Cost ($)	1,461.98	1,522.26	60.27

Hour	User Cost ($)
17:00-18:00	1,522.26
18:00-19:00	124.68

Work Zone Parameters in Active Segments:

	Type/Severity	Computed Capacity	WZ Speed Limit	Computed FFS
Segment 5	Shoulder closure	2215	45	60
Segment 6	Shoulder closure	2228	45	60
Segment 7	Shoulder closure	2215	45	60

FREEVAL WZ V20151217 Page 3 of 3

11 APPENDIX E: EXAMPLE 2: PDF REPORT

Jun 17, 2016 FREEVAL-WZ Report: Example 2

FREEVAL-WZ Report

Summary Output

Project: Example 2

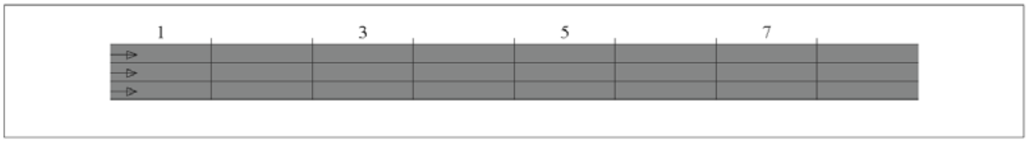
Analyst: ITRE

Scenario: Base Year

Facility Length: 4.0 miles (8 segments)

Analysis Period: 4:00am - 4:00am (96 time periods)

WZ Project File: Example2.wz



Performance Measure	Base Scenario	WZ Scenario 1
	Example 2	WZ1
Average Travel Time (min)	3.44	6.30
VHT (travel / interval (hrs))	3,442	6,303
VHD (delay / interval (hrs))	13	10,256
Space Mean Speed (mph)	69.7	38.1
Reported Density (pc/mi/ln)	12.5	25.1
Max D/C	0.62	1.03
Max V/C	0.62	0.99
User Cost ($)	647.99	522,256.28
Max Hourly User Cost ($)	166.78	161,689.91
Work Zone Summary		
WZ Name	-	WZ1
Time Active	-	4:00-4:00
Segments Active	-	3-6
Severity	-	Compound
WZ Speed Limit	-	60
Area Type	-	Urban
Barrier Type	-	Concrete
Lateral Distance	-	2.00 ft

FREEVAL WZ V20160525 Page 1 of 3

Jun 17, 2016 FREEVAL-WZ Report: Example 2

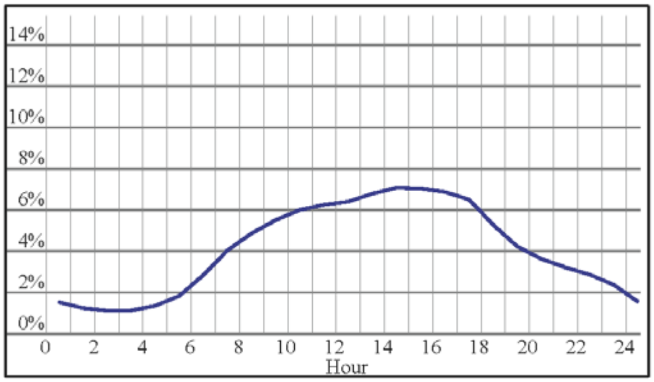
Input Summary
Base Scenario - Example 2

Study Period: 4:00am - 4:00am

Global Property	Value
Jam Density	190.00
Capacity Drop	7.00%
Number of Segments	8

AADT Input Parameter	Value
Bidirectional AADT (vpd)	120,000
Directional Factor	0.50
Facility Wide Growth Factor	1.00

AADT Distribution: **Unimodal - Average**



Hour	%
0-1	1.54
1-2	1.24
2-3	1.11
3-4	1.12
4-5	1.35
5-6	1.83
6-7	2.85
7-8	4.04
8-9	4.87
9-10	5.51
10-11	6.00
11-12	6.25

Hour	%
12-13	6.40
13-14	6.79
14-15	7.08
15-16	7.04
16-17	6.88
17-18	6.50
18-19	5.28
19-20	4.23
20-21	3.62
21-22	3.21
22-23	2.87
23-24	2.37

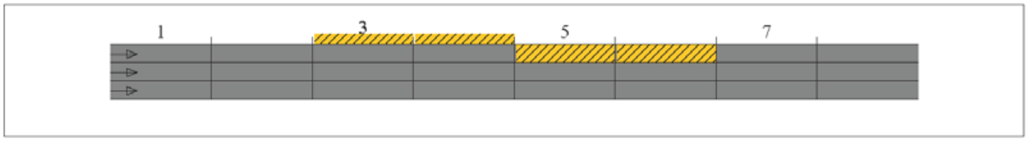
Segment Daily Input Values:

#	Type	L(ft)	NL	On AADT	Off AADT
1	B	2,640	3	-	-
2	B	2,640	3	-	-
3	B	2,640	3	-	-
4	B	2,640	3	-	-
5	B	2,640	3	-	-
6	B	2,640	3	-	-
7	B	2,640	3	-	-
8	B	2,640	3	-	-

FREEVAL WZ V20160525 Page 2 of 3

Jun 17, 2016 FREEVAL-WZ Report: Example 2

WZ Scenario 1 - WZ1



Active Time Period: 4:00am - 4:00am

Area Type: Urban **Barrier Type:** Concrete

Lateral Distance(ft): 2.0 **Work Zone Speed Limit:** 60

Performance Measure	Base Scenario	WZ Scenario 1	Comparison
Name	Example 2	WZ1	-
Average Travel Time (min)	3.44	6.30	2.86
VMTD (veh-miles / interval)	240,028	240,028	0
VMTV (veh-miles / interval)	240,028	239,968	-60
PMTD (p-miles / interval)	240,028	240,028	0
PMTV (p-miles / interval)	240,028	239,968	-60
VHT (travel / interval (hrs))	3,442	6,303	2,861
VHD (delay / interval (hrs))	13	10,256	10,243
Space Mean Speed (mph)	69.7	38.1	-31.7
Reported Density (pc/mi/ln)	12.5	25.1	12.5
Max D/C	0.62	1.03	0.41
Max V/C	0.62	0.99	0.37
User Cost ($)	647.99	522,256.28	521,608.28
Max Hourly User Cost ($)	166.78	161,689.91	161,523.12

Hour	User Cost ($)
4:00-5:00	223.76
5:00-6:00	323.00
6:00-7:00	481.10
7:00-8:00	636.27
8:00-9:00	773.19
9:00-10:00	936.75
10:00-11:00	1,094.21
11:00-12:00	1,201.39
12:00-13:00	1,350.10
13:00-14:00	6,034.31
14:00-15:00	33,710.64
15:00-16:00	105,230.93

Hour	User Cost ($)
16:00-17:00	161,689.91
17:00-18:00	158,467.34
18:00-19:00	46,837.74
19:00-20:00	896.58
20:00-21:00	505.91
21:00-22:00	449.97
22:00-23:00	391.11
23:00-0:00	300.14
0:00-1:00	208.69
1:00-2:00	174.39
2:00-3:00	162.72
3:00-4:00	176.09

Work Zone Parameters in Active Segments:

	Type/Severity	WZ Capacity	WZ Speed Limit	WZ FFS
Segment 3	Shoulder closure	2215	60	60
Segment 4	Shoulder closure	2215	60	60
Segment 5	1 lane closure	2146	60	60
Segment 6	1 lane closure	2146	60	60

FREEVAL WZ V20160525 Page 3 of 3

12 REFERENCES

1. Aghdashi B., B. J. Schroeder, J. L. Trask, C. Yoem, N. M. Rouphail, "*NCDOT Project 2015-09 Draft Final Report: Planning-Level Extensions to NCDOT Freeway Analysis Tools*", December 2015
2. Trask L., B. Aghdashi, B. Schroeder, And N. Rouphail "*Freeway Facilities And Reliability Analysis Computational Engine For The Hcm 6th Edition: A Guide For Multimodal Mobility Analysis*", NCHRP 03-115 Deliverable, Submitted for approval.
3. Yeom, C., A. Hajbabaie, B. Schroeder, C. Vaughan, X. Xuan, and N. Rouphail. *Innovative Work Zone Capacity Models from Nationwide Field and Archival Sources*. Presented at the 94th Annual Meeting of the Transportation Research Board, Washington, D.C., 2014.
4. Schroeder B., N. Rouphil, S. Sajjadi, T. Fowler, "NCDOT Project 2010-08 Final Report, *Corridor-Based Forecasts of Work-Zone Impacts for Freeways*" August 9 2011.