# Express Lanes Time Of Day Model v2.1

## User Guide and Documentation



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## List of Terms

**A-B Node Set:** This is used to identify links in the ELToD Model.

**ELToD:** This is the acronym for the Express Lanes Time of Day Model.

**Distance:** A value of measure in the ELToD Model with the units of miles.

**EQUI:** This is the abbreviation for the equilibrium method for assignment in Cube Voyager.

**Express Lane:** Express Lanes are a type of managed lane, which use dynamic electronic toll pricing to maintain free flow traffic conditions through a corridor. Express Lanes are typically co-located within an existing limited access facility, but have fewer access points to manage congestion and provide reliable travel times.

**FSUTMS:** This is the acronym for Florida Standard Urban Transportation Model Structure.

**FType:** This is the facility type designation of a network link.

**General Use Lane:** This is a highway lane adjacent to an Express Lane.

**HOT:** This is the acronym for High Occupancy Toll.

**HOV:** This is the acronym for High Occupancy Vehicle.

**ITER:** This is the abbreviation for the iterative method for assignment in Cube Voyager.

**Key:** This is the term used by Citilabs to refer to an input variable.

**O-D:** Origin-Destination. This refers to trips in a trip matrix used in the assignment process.

**Parameter:** An ELToD Model input value that will define the output of a model scenario.

**Pull Link:** These are model network link(s) identified with A-B nodes specifically for data extraction to use in analysis of a project scenario.

**Segment:** In Florida, an express lane segment is the distance between an entry point to the express lanes and the next point of exit. Refer to the FDOT Express Lanes Handbook in the resource library of the Florida Express Lanes Website at http://floridaexpresslanes.com/resources/resource-library/ for additional information.

**SOV:** This is the acronym for Single Occupancy Vehicle.

**Time:** A value of measure in the ELToD Model with the units of minutes.

**Toll Link:** An express lane network link that has a toll value associated with it.

## List of Terms (Continued)

**Toll Value:** A cost (i.e. toll rate) associated with a Toll Link or Toll Segment in the ELToD Model. This could be a total cost per segment, per-mile or total trip cost to travel a specified distance in the model based on the defined express lanes links and segment numbers.

**V/C or VC:** This is an abbreviation of volume to capacity ratio.

**VDF:** This is the acronym for the Volume Delay Function.

**VTTR:** This is the acronym for Value of Travel Time Reliability, which is derived from stated preference survey data.

**VTTS:** This is the acronym for Value of Travel Time Savings (sometimes referred to as VOT or Value of Time).

# Chapter 1: Introduction

## Overview of the Express Lanes Time of Day (ELToD) Model v2.1

The ELToD Model is a forecasting tool developed to determine the percent share of traffic that chooses express lanes during each hour of the day. It estimates the volume of traffic on both general use and express lanes. In addition, it identifies the express lanes dynamic toll by hour based on traffic conditions. The model works in conjunction with Florida's travel demand models which provide the basis for the total corridor traffic. As such, the ELToD Model is a stand-alone application that follows Florida's Standard Urban Transportation Model Structure (FSUTMS), and is the Department's preferred tool for modeling express lanes. For details on the design approach, please refer to **Appendix A: ELToD Model Design Approach.**

Cube from Citilabs is the standard software package used for travel demand modeling in Florida. The ELToD Model is programmed in the Cube platform (currently v6.1.1). For hardware recommendations, please refer to specifications from Citilabs' Cube Voyager documentation. Due to the potential for unique characteristics with any toll forecasting project, users of the ELToD Model should have some experience with Cube software. All the script files are written in the Citilabs Cube language so users can modify the model for specific and unique project requirements. The model package also includes an Excel workbook to interpret model output in easy to read tabular and graphical displays.

## Use of the ELToD Model

The ELToD Model can be used for express lanes projects with several segments (i.e. accommodate a project with multiple ingress and egress locations). However, since the assignment algorithm identifies only one toll path for each origin-destination (O-D) pair, which is typically the longest possible toll path, the ELToD Model is most appropriate for traffic studies where it is reasonable to expect that the express lane users would enter the system at the earliest convenient point and exit the system at the last convenient point.

Past ELToD Model applications have generally featured between 30 to 80 external nodes for loading the subarea network. Using hundreds, or perhaps thousands, of external loading sites is possible, but these scales of models have not been tested, and it is unclear how model stability and performance will decline when using a higher number of loading sites.

Although the ELToD Model has been applied on multiple express lanes projects across Florida, it has not been tested for application to larger interconnected networks or multi-segment projects. Applications not tested include multiple express lane projects on a larger network, a combination of dynamic and static toll facilities, alternate non-tolled routes, or more than one pricing policy in the model. Future enhancements to the ELToD Model are planned to better accommodate this interaction between express lane systems, expansion of the network, and multiple pricing policies.

The model is currently designed to accommodate trip matrix input as either one 24-hour trip table or 24 one-hour trip tables. However, the experienced Cube software user may undertake script modifications to accommodate their desired input design and to apply the model for their own project application purposes. For technical details on the application, please refer to **Appendix B: ELToD Model Application Details**.

## Obtaining the ELToD Model

The ELToD Model can be requested through the FSUTMS website at: http://www.fsutmsonline.net/index.php?/model_pages/modDT1/index/.

## Document Organization

The remaining content is divided into three chapters plus technical appendices. The additional content is as follows:

**Chapter 2: Required ELToD Model Input Cube Keys and Definitions**

This Chapter lists the ELToD Model Cube key names and their specific definition as they relate to the model structure.

**Chapter 3: User Application Guide**

This Chapter guides the user through installation, set up and execution of the ELToD Model including screen shots from sample scenarios related to specific steps.

**Chapter 4: Output Model Files and Result Summary Workbook**

This Chapter provides a description of the ELToD Model's output files produced when a scenario is run. There is also a guide on how to set up and use the included Excel workbook to help the user summarize and visualize the model output files.

**Appendix A: ELToD Model Design Approach**

This Appendix summarizes the methodology behind the design of the ELToD Model.

**Appendix B: ELToD Model Application Details**

This Appendix provides additional technical details on the model application.

**Appendix C: ELToD Model Technical Design**

This Appendix provides technical details on the model structure.

**Appendix D: Determining Choice Model Coefficients for the ELToD Model**

This Appendix provides technical details on the choice model coefficients used in the application of the ELToD Model.

# Chapter 2: Required ELToD Model Input: Cube Keys and Definitions

This section lists the ELToD Model Cube keys and the associated file type or input value type in the order that they appear in a model scenario menu. The Cube keys are the actual input required to run the ELToD Model. The Cube keys include both links to actual files and input parameter values. The Cube keys may be unique to the user's specific project.

## Input Files

- **Network File (.net):** This is the project corridor input network file. This file is typically developed from a subarea extraction of a Cube-based (.net) regional network.
- **Toll Link File (.csv):** This is a file that includes the toll link's segment number, segment length, and minimum segment toll rate by direction. This information is required for each project segment. It overwrites any global toll policy inputs for the specified segments.
- **Directional Link File (.csv):** These are all the network links in the corridor for direction 1. This indicates to the model how to assign the hourly percent traffic distribution from the **Hourly Distribution File** for direction 1. These values must be integers.
- **Pull Link File (.csv):** This is the file that lists the links for "pulling" model output data from associated files to report results. The V/C ratios on the toll links identified as "pull" locations are used for calculating the toll costs based on the pricing policy curve.
- **Capacity Speed Link File (.csv):** This is an overwrite file for assigning capacity and speed to specified links. If the network links have the desired capacities and speeds, leave this file blank.
- **Express Lane Link File (.csv):** This is an optional input file that can overwrite the express lane links facility type attribute (e.g., FType) in the **Network File**.
- **Toll Link FTYPE Number (value):** This is a parameter for the facility type of all express lane links. This value must be an integer.
- **HOV Link FTYPE Number (value):** This is a parameter for the facility type of all HOV lane links. This value must be an integer. If HOV links do not exist in the network, this value is zero.
- **Trip Table Type:** This is a parameter to indicate trip table type. The current two types of trip tables for the ELToD Model are hourly or daily. If daily trip tables are provided, the ELToD Model will split them into 24 hourly trip tables. The user can modify the default script if other time periods are needed.

## Input Files (Continued)

- **Trip Table Factor (value):** This is a parameter for the global adjustment applied to the input trip table.
- **Trip Table File (.mat):** This is the location and file name of the input trip table (or group of tables).
- **Hourly Distribution File (.csv):** This is the hourly, directional distribution file that is used to represent the project corridor traffic distribution. It is an average estimate for the entire project being modeled. This key links a file to the model by a file path. Each record for each hour is a fraction of the entire day meaning that the total records of one distribution for one direction equals 1.0. This file is not needed if 24 one-hour trip tables are used.
- **Number of Zones (value):** This value is the total number of external nodes in the corridor network (i.e. the quantity of origins-destinations in the trip matrix). This value must be an integer.

## Assignment Parameters

- **Assignment Method:** This is a parameter for the type of assignment method to use in Cube Voyager. Currently, **ITER** (iterative) is recommended for use. But, the user can input EQUI (equilibrium) as an alternative selection. Please refer to **Appendix B: ELToD Model Application Details** for further information.
- **Maximum Iteration (value):** This is an input value to specify the maximum number of iterations in the model assignment. This value must be an integer. Refer to Cube help for a detailed definition.
- **Relative Gap (value):** This is an input value to specify the relative gap for model convergence. Refer to Cube help for a detailed definition.
- **Minimum Link Congested Speed (value):** This is a parameter for the **Minimum Link Congested Speed** that the volume delay function (**VDF**) can generate to prevent a fatal error from occurring. <u>Note:</u> A very small speed value results in a high travel time on the link. Under such conditions, the exponent function in the choice model will encounter a fatal error.
- **Use Cube Cluster (checkbox):** This is a parameter that allows the user to select the execution of **Cube Cluster** if it is installed.

## Toll Pricing Parameters

- **Minimum Per Segment Toll (value):** This is an input for the **Minimum Per Segment Toll** cost assigned to each segment identified in the **Toll Link File**. This will apply for any express lane network link and is a global model setting. To define different values, check the **Use Minimum Per Segment Toll in Network** key box.

- **Maximum Per Segment Toll (value):** This is an input for the **Maximum Per Segment Toll** cost assigned to each segment identified in the **Toll Link File**. This will apply for any express lane network link and is a global model setting.

- **Use Minimum Per Segment Toll in Network (checkbox):** This selection allows the user to enter different minimum toll values for each segment in the **Toll Link File**. If the box is checked, the values coded in the **Toll Link File** will be applied to the network and used instead of the value of the **Minimum Per Segment Toll** key.

- **Minimum Per Trip Toll (value):** This is a parameter for the minimum per trip toll for the entire project.

- **HOV Discount Rate (value):** This is an input with a value range from 0 to 1. A "0" means HOVs pay the same toll as SOVs, while a "1" means a toll free trip for HOVs. A value in between means the percent discount HOVs receive.

- **Toll Pricing Curve Exponent Coefficient (value):** This is the coefficient used to calculate the toll amount at any given volume-to-capacity (V/C) ratio.

- **VC Toll Offset (value):** This is a coefficient used in the calculation of a toll amount at a given V/C ratio. A higher value indicates a faster increase in the toll depending on other input values. This parameter shifts the volume delay curve to the left by the given number of V/C units, resulting in travel time increases observed at lower volumes.

## Volume Delay Function Parameters

These values define the volume delay function design applied in the model assignment step. For technical details on the volume delay function, please refer to **Appendix C: ELToD Model Technical Design**.

- **Volume Delay Function:** For this parameter, the user must choose either BPR or Akcelik. Note: A specified **VDF** other than the two options can be applied to the ELToD Model, but has to be coded in by the user.

- **Akcelik P (value):** This is a facility specific parameter. A larger value causes speeds to decrease more gradually when flow approaches capacity. Conversely, a smaller value causes speeds to decrease more rapidly when flow approaches capacity. The current value of 0.10 represents limited access facilities.

## Volume Delay Function Parameters (Continued)

- **Akcelik T (value):** For this parameter, the user must enter the T value. It is a parameter in the Akcelik formula that contributes to the shape of the volume delay curve. This value is the length of each time period modeled in hours. The ELToD Model is designed for one hour increments, therefore this value is currently "1".
- **Akcelik pb (value):** For this parameter, the user must enter the pb value. This is a parameter to influence the shape of the Akcelik curve where larger values shift the function left to influence the speed to decrease more rapidly when the flows approach capacity. Conversely, smaller values shift the function right to influence the speed to decrease more gradually when the flows approach capacity. This is a constant value multiplied by the **Akcelik T** value to calibrate the curve to observed traffic conditions (default = 0.10).
- **Akcelik Offset (value):** For this parameter, the user must enter the offset value. The larger (smaller) the offset value, the more the curve shifts left (right) to increase (decrease) modeled delay at a specific congestion level. This parameter in the Akcelik formula contributes to the shape of the volume delay curve by shifting the base of the curve from a travel time ratio of 1.0 (default = 0.10).
- **BPR Alpha (value):** This is an empirical coefficient in the BPR function that contributes to the shape of the volume delay curve. Alpha is based on the facility type and values were determined by forcing the curve to fit the speed/volume data at zero volumes and LOS E.
- **BPR Beta (value):** This is an empirical coefficient in the BPR function that contributes to the shape of the volume delay curve. Beta is based on the facility type and the value controls the exponential rate of change in the formula.
- **Use BPR Coefficients in Network (checkbox):** This is the box that is checked if the BPR coefficients are included as network attributes.

## Choice Model Coefficients

These parameters were originally estimated from the 95 Express Phase 1 study. The default values may be revisited on an individual project basis for new ELToD Model applications. Users can reference **Appendix D: Determining Choice Model Coefficients** for details on these coefficients and how they were developed. These are all numerical input values and are based on observed 95 Express Phase 1 flows.

- **Toll Constant File (.csv):** This is the file that includes the hourly toll constant values by direction used in the choice model for computing the traffic split between the general use and express lanes. These values were established using the 95 Express Phase 1 observed traffic flows.
- **Toll Coefficient (Beta_Toll):** This is a parameter for the β_Toll value in the choice model formula for the toll cost coefficient (with units of 1/$). This is the disutility of increasing the toll by one dollar.
- **Travel Time Coefficient (Beta_Time):** This is a parameter for the β_Time value in the choice model formula for the travel time coefficient (with units of 1/min). This is the disutility of increasing travel time by one minute.
- **Reliability Coefficient Ratio:** This is a parameter that defines the ratio of Value of Travel Time Reliability (VTTR) to Value of Travel Time Savings (VTTS). The product of this ratio and β_Time determines the reliability coefficient in the choice model, which is the disutility of increasing the standard deviation of travel time by one minute.
- **Reliability Time Coefficient:** This is a parameter for defining the rate at which the standard deviation of travel time in the model increases with respect to delay in the model. Larger parameter values cause the modeled standard deviation of travel time to increase faster as delay increases. Conversely, smaller parameter values cause the modeled standard deviation of travel time to increase slower as delay increases. The default value is 0.3.
- **Reliability Distance Coefficient:** This is a parameter for defining the rate at which the standard deviation of travel time in the model decreases with respect to trip distance in the model network. Larger parameter values cause the modeled standard deviation of travel time to decrease faster as trip distance increases. Conversely, smaller parameter values cause the modeled standard deviation of travel time to decrease slower as trip distance increases. This parameter must be between 0 and 0.5. The default value is 0.2.

## Choice Model Coefficients (Continued)

- **Perceived Time Coefficient Steepness:** This parameter determines how rapidly the travel time weights increase as the V/C ratio approaches the **Perceived Time Mid Point VC Ratio** for each network link. Larger parameter values cause the travel time weights to increase rapidly near the midpoint V/C ratio and then level off after the midpoint VC ratio. Conversely, smaller parameter values cause the travel time weight to increase gradually before and after the midpoint V/C ratio before eventually leveling off. The default value is 13.67.

- **Perceived Time Mid Point VC Ratio:** This parameter defines the V/C ratio at which the travel time weights reach their midpoint value. The default value is 0.693.

- **Perceived Time Max VC Ratio:** This parameter defines the maximum travel time weight for the model. The default value is 1.2.

- **Distance Penalty Y:** This is a parameter to identify the maximum distance penalty value used to discourage short express lane trips. This parameter is applied to all express lane trips with a distance lower than **Distance Penalty X1**. The default value is 0.55.

- **Distance Penalty X1:** This is a parameter to define the distance used to identify when the distance penalty starts to decrease at a linear rate. The default value is “2” with units of miles.

- **Distance Penalty X2:** This is a parameter to define the distance used to identify when the distance penalty no longer applies. The default value is “4” with units of miles.

- **One Express Lane Time Weight:** This parameter defines the travel time weight applied to express lane trips in a system with a single express lane per direction. The default value is 1.28 for projects with one express lane per direction. The user should enter “1” if no weight should be applied.

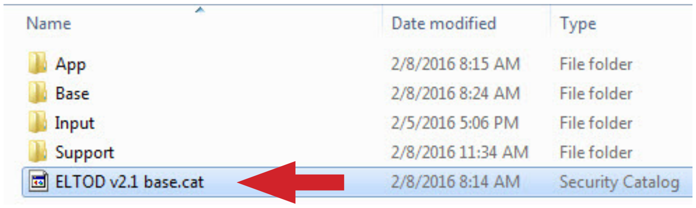
# Chapter 3: User Application Guide

This section describes the ELToD Model set up and the creation of project scenarios.

## Setting Up the ELToD Model

After downloading the model folder (ELToD_Model_v21.zip), unzip the model to the desired project folder. The ELToD Model can be run on any computer with Citilabs Cube Base and Cube Voyager installed. Once the user has unzipped the model to the desired folder, the structure should look similar to **Figure 1**.

**Figure 1:**
**Model Folder Structure Example**



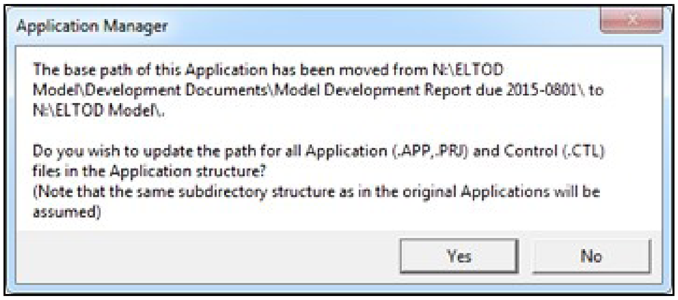

The model structure is based on a FSUTMS assignment process. It follows a Florida Cube Voyager assignment model structure including network and link attribute data characteristics.

The Base Scenario referred to in this manual includes a network with 34 external nodes (referred to as externals). It also includes other Base Scenario input files and data. Some data related to the logit choice model have been derived from previous calibration/validation work using 95 Express Phase 1 data. For technical details regarding the ELToD Model design, please refer to **Appendix C: ELToD Model Technical Design**.

## Running the ELToD Model

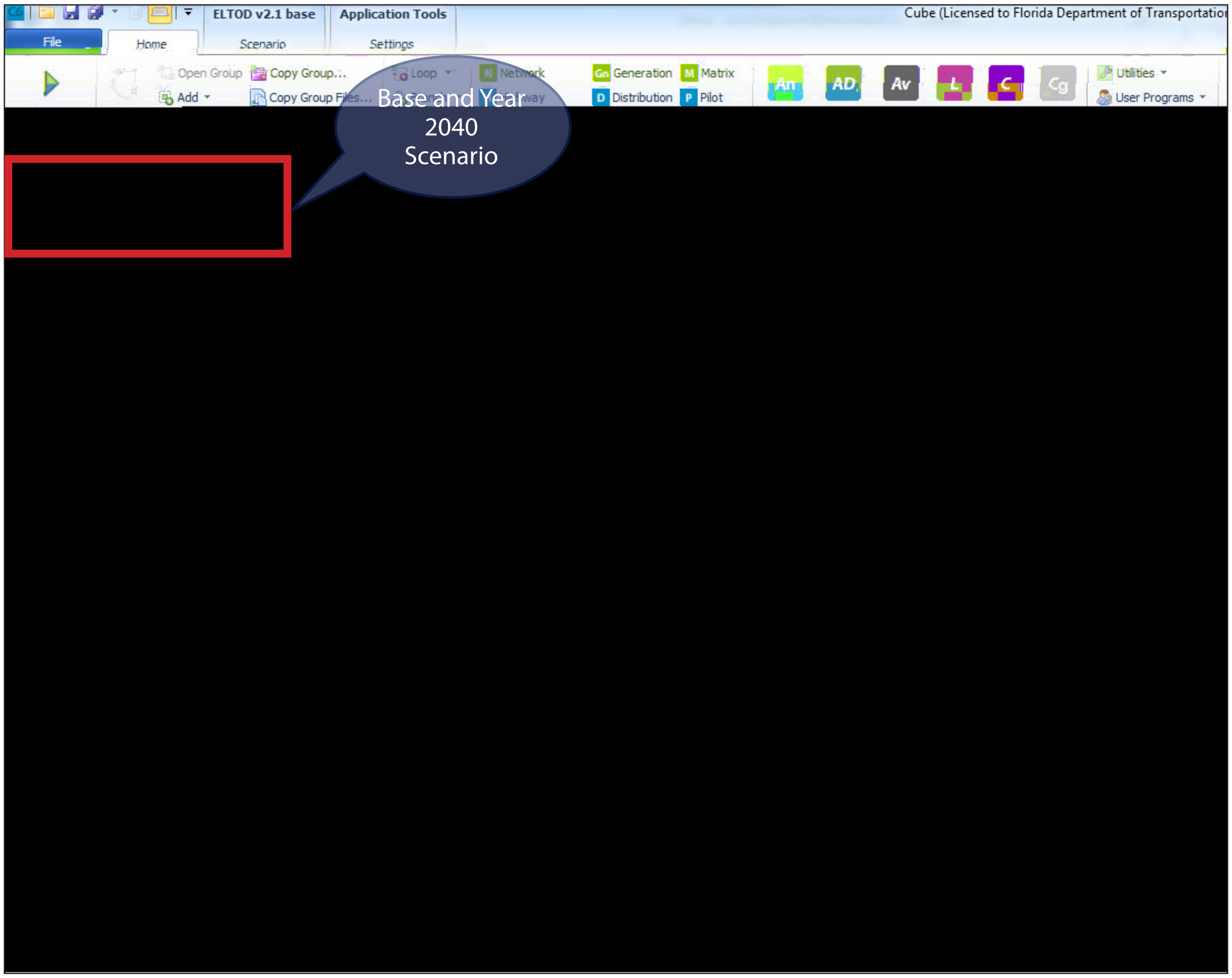
Execute the catalog file named ELTOD v2.1base.cat. This file is highlighted by an arrow in **Figure 1**. Once the catalog file begins to open, it will ask to update paths as shown in **Figure 2**. Select the appropriate choice based on the user desired set up structure. For more information on basic Cube application, please refer to the Cube Voyager Documentation.

**Figure 2:**
**File Path Update**




Once this is done, the model will open and display the model structure as shown in **Figure 3**.

**Figure 3:**
**Model "Home" Window**



As shown in the model structure Scenario Box (outlined in red in **Figure 3**), the Base Scenario includes only global Cube keys suggested for use in most ELToD Model applications. A scenario sample model for Year 2040 with populated keys is included.

**Figure 4** and **Figure 5** show the Base Scenario windows with only the suggested global input keys populated. The next section steps the user through the process of setting up a model scenario (referred to as a “child” in Cube) created from the Base Scenario.

**Figure 4:**
**Scenario Input Windows with Associated Steps 1 to 26**

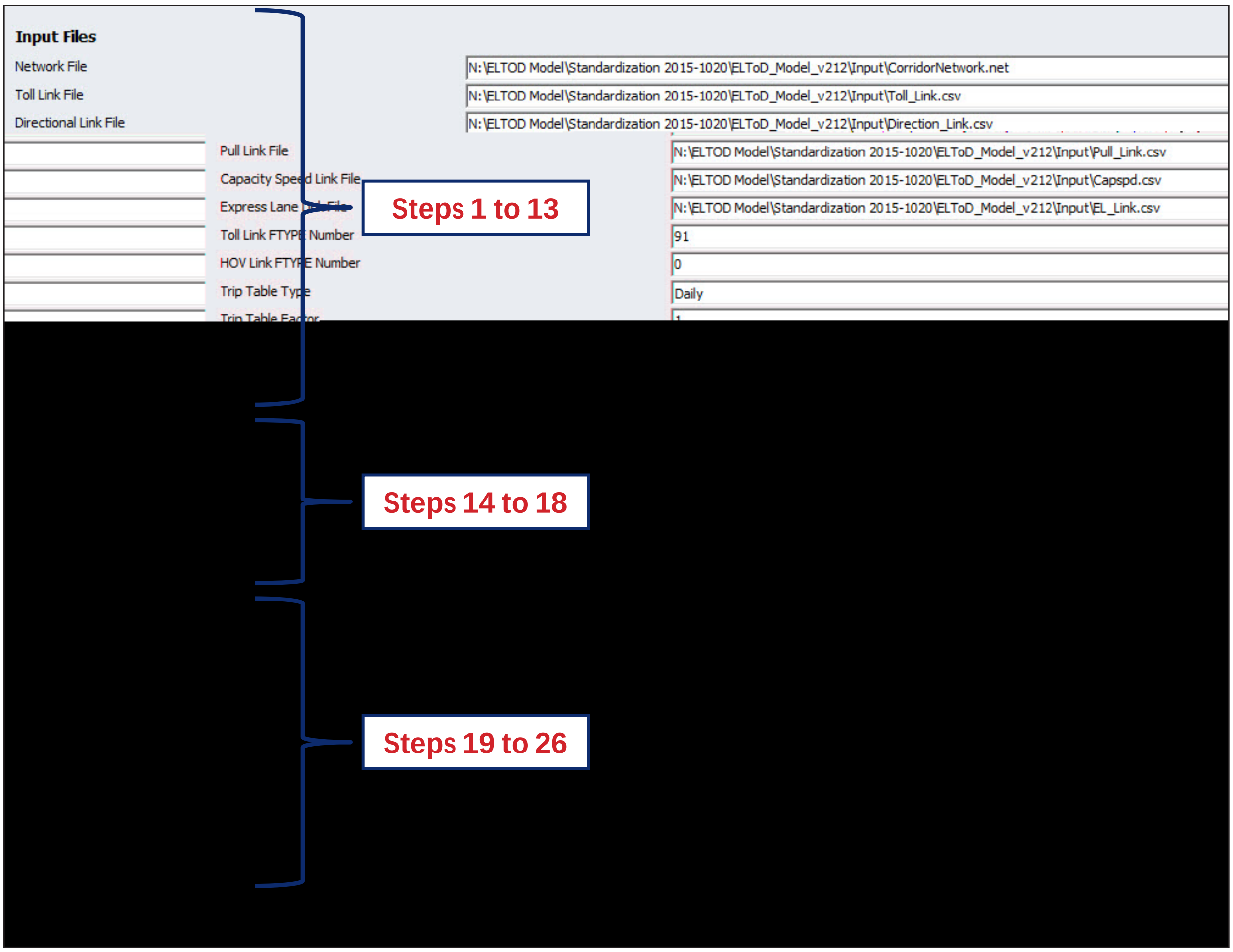
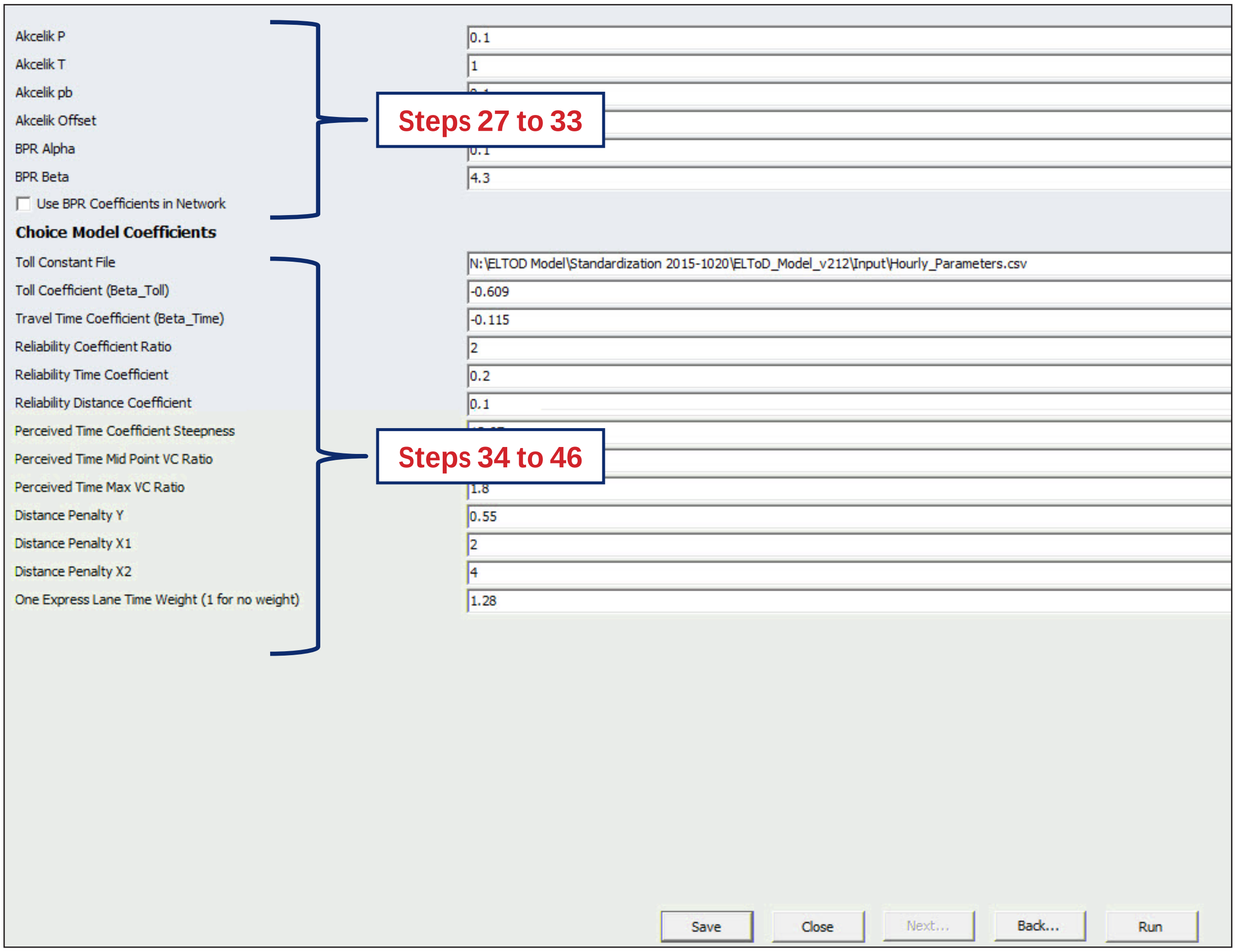


**Figure 5:**
**Scenario Input Windows with Associated Steps 27 to 46**

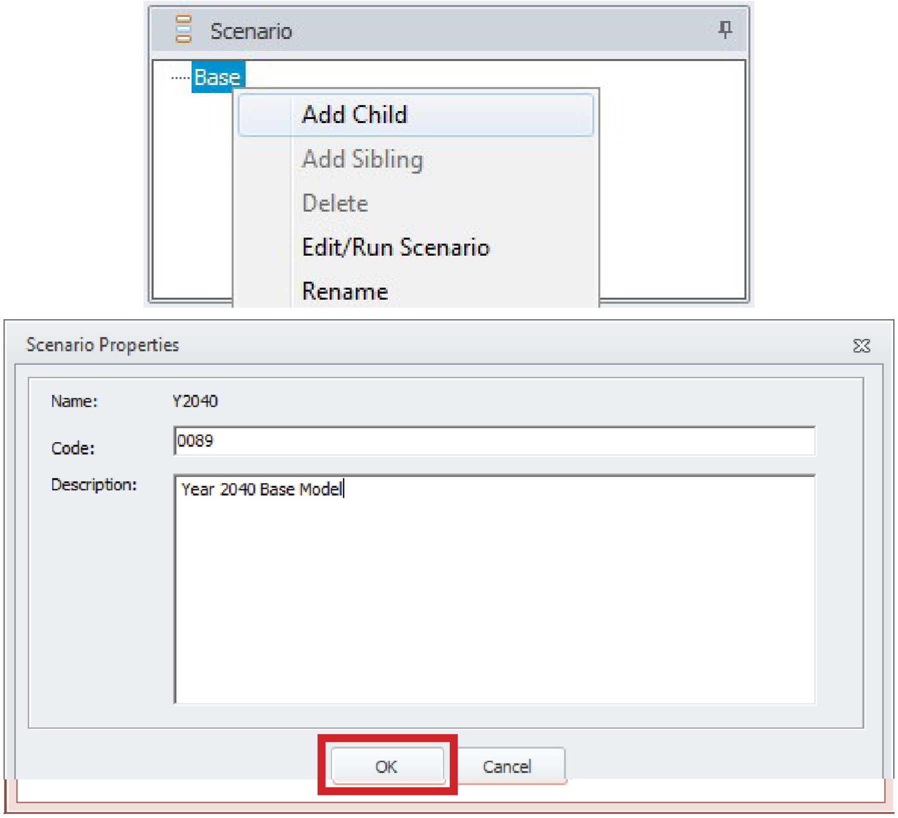


## Creating an ELToD Model Scenario

The following information steps the user through the process of creating a new project scenario. It is recommended that all input files be stored in the same folder (e.g. input files).

Following basic Cube procedures, create a child and name it appropriately. In this example, the model scenario is for future year 2040 (Y2040). Therefore, the input files in this example will be related specifically to this future year project scenario. **Figure 6** shows the creation of this child from the Base Scenario. The following steps detail the individual records required for populating the input fields (keys) of the Y2040 Scenario.

**Figure 6:**
**Creating a New Scenario from the Base**




Once the Scenario Properties window is completed, click "OK" as outlined in red in **Figure 6**. The Scenario – Y2040 input window opens (See **Figure 4** and **Figure 5** for an example.)

<u>**Step 1. Input Files:**</u> **Network File.** This is the network to be used for assigning the trip table. It is suggested this be a corridor level subarea network extracted from a larger regional demand model. **Figure 7** depicts the normal pop-up window for the file selection and **Figure 8** is an example of a network showing links and external nodes.

**Figure 7:**
**Pop-up Window for File Selection**

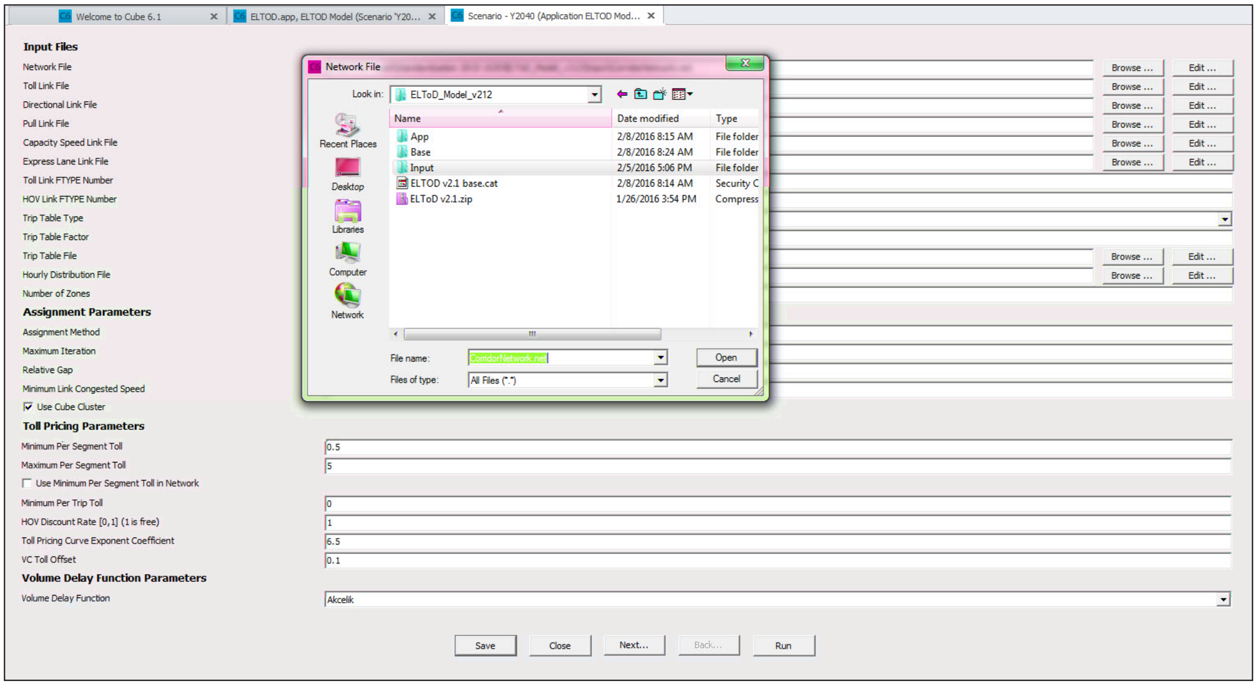
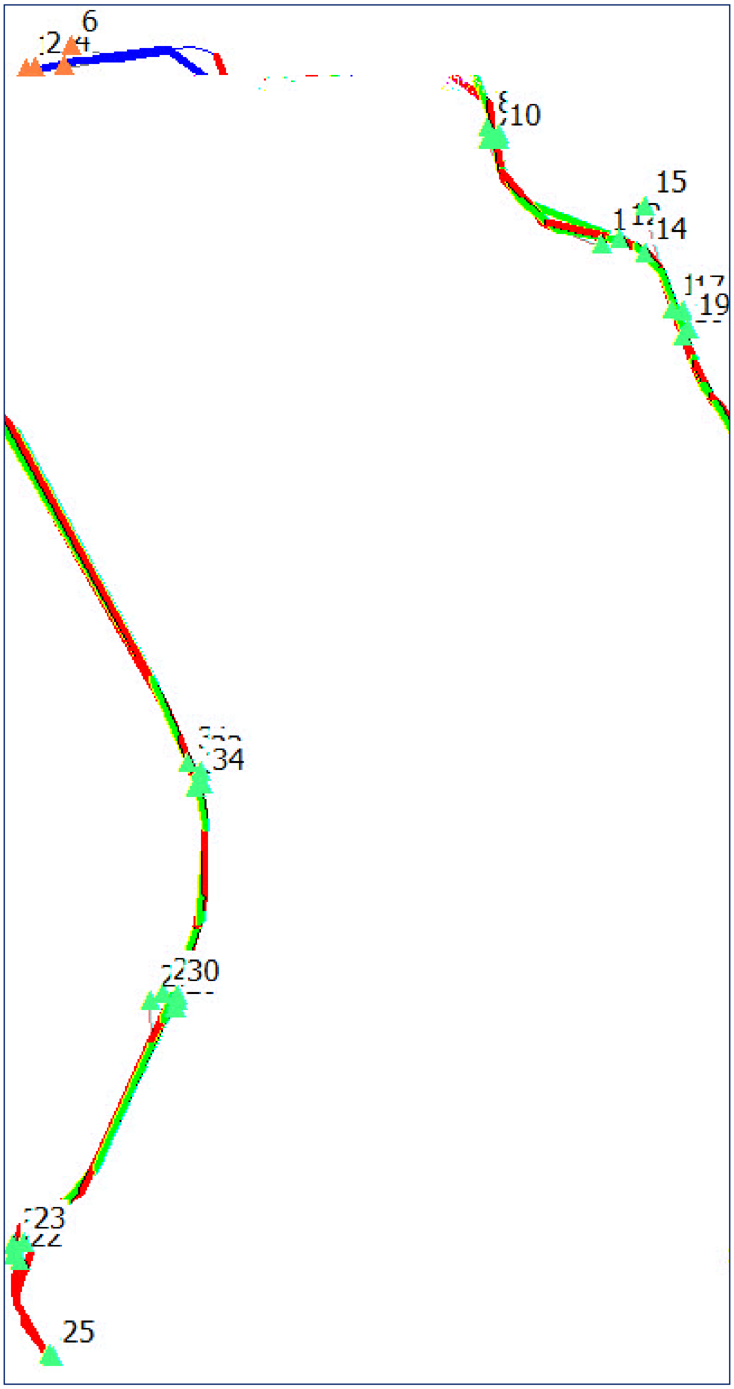


**Figure 8:**
**Network Example**



When creating a corridor network file from a demand model, it is recommended that the subarea network polygon be designed so that one external node is created for each entrance or exit ramp. This makes it easier to identify directionality in the model's input files. **Figure 9** and **Figure 10** are examples of using a polygon selection within Cube Voyager to select a project corridor and interchanges at cross streets for creating directional external nodes.

The network link attribute field names need to match the script coding or the user can populate the input **Capacity Speed Link File** to code speeds and capacities for the network links (See **Step 5**).

**Figure 9:**
**Corridor Polygon Example**

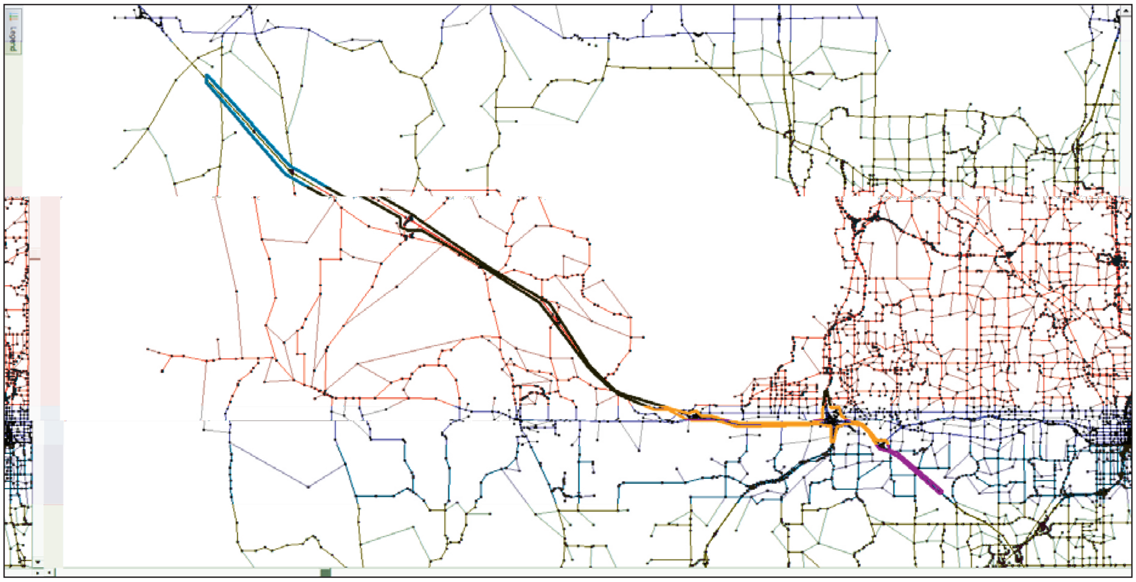
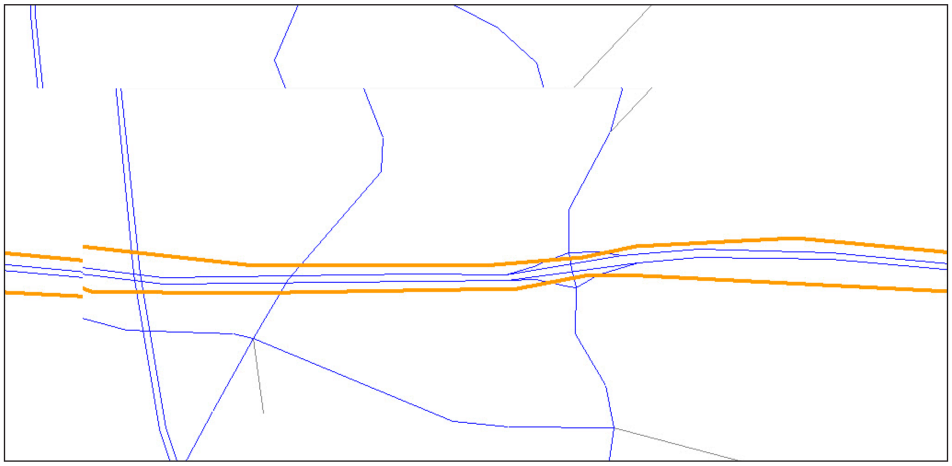


**Figure 10:**
**Interchange Polygon Selection Example**



**<u>Step 2. Input Files:</u> Toll Link File.** Navigate to the input files folder and select the file with the network express lanes toll segment data records. Only the express lanes pull links identified in upcoming **Step 4** are required. The required format is a .csv file. The information includes the link's A-B Nodes, the project's tolled segment number (TOLLSEGNUM), tolled segment distance (TOLLSEGLEN), and minimum segment toll (MINSEGTOLL). The minimum segment toll in this file is used if the **Use Minimum Per Segment Toll in Network** box is checked under **Step 21. Figure 11** is a sample of a typical file format.

**Figure 11:**
**Toll Link File Example**

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | A | B | TOLLSEGNUM | TOLLSEGLEN | MINSEGTOLL |
| 2 | 191 | 207 | 1 | 5.1 | 0.25 |
| 3 | 205 | 190 | 1 | 5.5 | 0.25 |
| 4 | 195 | 159 | 2 | 10.4 | 0.25 |
| 5 | 178 | 194 | 2 | 10.5 | 0.25 |

The toll segments should be numbered based on the toll locations of project express lanes. Therefore, the user should be aware that this increases the distance of that toll segment without an additional toll cost. Thus, any "per mile" toll the ELToD Model calculates as output should be checked when used in conjunction with project scenarios that include untolled segments as described above.

**Step 3. Input Files:** **Directional Link File.** The user should enter the A-B Nodes of all the links in Direction 1. This should match the same "Direction 1" for any other geographic definition (e.g. north and south or east and west). Therefore, if all the links in Direction 1 are northbound, the hourly distribution columns should have northbound in the first column, then southbound in the second column. **Figure 12** is a sample record set for a **Directional Link File.**

**Figure 12:**
**Directional Link File Example**

| | A | B | C |
|---|---|---|---|
| 1 | A | B | Dir1 |
| 2 | 25 | 184 | 1 |
| 3 | 184 | 177 | 1 |
| 4 | 177 | 174 | 1 |
| 5 | 175 | 185 | 1 |
| 6 | 174 | 172 | 1 |
| 7 | 172 | 163 | 1 |
| 8 | 163 | 169 | 1 |
| 9 | 185 | 189 | 1 |
| 10 | 187 | 191 | 1 |
| 11 | 189 | 193 | 1 |
| 12 | 193 | 200 | 1 |
| 13 | 200 | 213 | 1 |
| 14 | 223 | 239 | 1 |
| 15 | 207 | 226 | 1 |
| 16 | 228 | 230 | 1 |
| 17 | 235 | 239 | 1 |
| 18 | 226 | 240 | 1 |
| 19 | 239 | 237 | 1 |

**Step 4. Input Files:** **Pull Link File.** Navigate to the input files folder and select the file with the link data records for the network which reflect the desired locations for the extraction of link data for analysis. The required format is a .csv file. The model network requires a **PULL Link** attribute to identify links for extracting data. This attribute is identified in the file by the link's A-B Nodes, a "1" in the PULL field, and the designated toll segment number (Seg) field. **Figure 13** is a sample record set for a two-segment Express Lane project. The pull links include both general use and express lanes. To capture the total corridor volume for one cut line, the selection of general use pull links should be adjacent to the express lane pull links in the network.

**Figure 13:**
**Pull Link File Example**

| | | A | B | C | D |
|---|---|---|---|---|---|
| | 1 | A | B | PULL | Seg |
| 1 | 2 | 191 | 207 | 1 | |
| 1 | 3 | 205 | 190 | 1 | |
| 1 | 4 | 189 | 193 | 1 | |
| 1 | 5 | 192 | 188 | 1 | |
| 2 | 6 | 195 | 159 | 1 | |
| 2 | 7 | 178 | 194 | 1 | |
| 2 | 8 | 209 | 161 | 1 | |
| 2 | 9 | 160 | 206 | 1 | |

**Step 5. Input Files:** **Capacity Speed Link File.** Navigate to the input files folder and select the file with the capacity and speed link data records for the network. The required format is a .csv file. **Figure 14** is a sample of a typical file. If the imported network links already have the appropriate capacity and speed data, only a blank file is required.

**Figure 14:**
**Capacity Speed Link File Example**

| | A | B | C | D |
|---|---|---|---|---|
| 1 | A | B | CAPACITY | SPEED |
| 2 | 1 | 101 | 1950 | 65 |
| 3 | 3 | 103 | 1950 | 65 |
| 4 | 5 | 100 | 1950 | 65 |
| 5 | 7 | 123 | 1950 | 65 |
| 6 | 9 | 117 | 1950 | 65 |
| 7 | 12 | 133 | 1950 | 65 |
| 8 | 13 | 134 | 1950 | 65 |
| 9 | 14 | 144 | 1950 | 65 |
| 10 | 17 | 146 | 1950 | 65 |
| 11 | 18 | 154 | 1950 | 65 |
| 12 | 21 | 165 | 1950 | 65 |
| 13 | 23 | 185 | 1950 | 65 |
| 14 | 25 | 184 | 1950 | 65 |
| 15 | 26 | 196 | 1950 | 65 |
| 16 | 29 | 210 | 1950 | 65 |
| 17 | 30 | 213 | 1950 | 65 |
| 18 | 32 | 236 | 1950 | 65 |
| 19 | 33 | 211 | 1950 | 65 |
| 20 | 100 | 2 | 1950 | 65 |
| 21 | 101 | 4 | 1950 | 65 |

**Step 6. Input Files:** **Express Lane Link File.** Navigate to the input files folder and select the file with the express lane facility type link data records for the network. The required format is a .csv file. This file specifically identifies all the express lane links with a unique facility type. This facility type is a required input value described in **Step 7**. If the express lanes are suitably coded in the scenario network, it is not necessary to populate this file. **Figure 15** is a sample record set.

**Figure 15:**
**Express Lane Link File Example**

| A | B | FTYPE | |
|---|---|---|---|
| 114 | 118 | 91 | |
| 118 | 120 | 91 | |
| 119 | 115 | 91 | |
| 120 | 124 | 91 | |
| 121 | 119 | 91 | |
| 124 | 135 | 91 | |
| 125 | 121 | 91 | |
| 131 | 125 | 91 | |
| 132 | 131 | 91 | |
| 135 | 141 | 91 | |
| 136 | 132 | 91 | |
| 141 | 151 | 91 | |
| 143 | 136 | 91 | |
| 151 | 155 | 91 | |
| 152 | 143 | 91 | |

**Step 7. Input Files:** **Toll Link FTYPE Number.** Enter the facility type number of the express lanes used for all express lane links for the corridor input network. If the FTYPE number was redefined in **Step 6**, this would be the input value for this step. For example, the sample model network express lanes are coded as FTYPE 91 following standard FSUTMS facility type coding practice.

**Step 8. Input Files:** **HOV Link FTYPE Number.** Enter the facility type number of the HOV links for the corridor input network. If there are no HOV links, enter "0" as is the case in the sample model.

**<u>Step 9. Input Files:</u>** **Trip Table Type.** Select either "Daily" or "Hourly" from the drop down menu. This tells the model whether the input trip matrix file will include one table covering 24 hours (daily) or 24 one-hour tables. In the sample model, "Daily" is used because the model only has one daily trip table for input. <u>Note:</u> As previously mentioned, this is a Cube Voyager model which is customizable such that period trip tables could also be used. However, the use of period trip tables requires modifying the script depending on the user's specific project needs.

**<u>Step 10. Input Files:</u>** **Trip Table Factor.** This is another customized input value used to evaluate different potential traffic demands or sensitivities. The default is a value of "1", meaning that the trip table is used without modifications. If any other value is included, the trip tables (O-D trips) are multiplied by this value thus increasing or decreasing the total trips loaded onto the corridor network. This feature could be used for sensitivity tests based on corridor demand.

**<u>Step 11. Input Files:</u>** **Trip Table File.** The user should navigate to the input files folder and select the associated trip matrix (O-D trip table) file for the input corridor network. The required format is a .MAT file. **Figure 16** is a sample of a typical file opened in Cube Voyager. <u>Note:</u> If 24 one-hour trip tables are provided by the user, they need to be placed in the scenario output folder.

**Figure 16:**
**Trip Matrix Example Associated with an Input Network**

C6 ELTOD.app, ELTOD Model (Scenario 'Tes... ✕ | C6 Scenario - Y2040 (Application ELTOD Mo... ✕ | C6 2040TripTable.MAT-*1 SOV (N:\ELTOD M... ✕

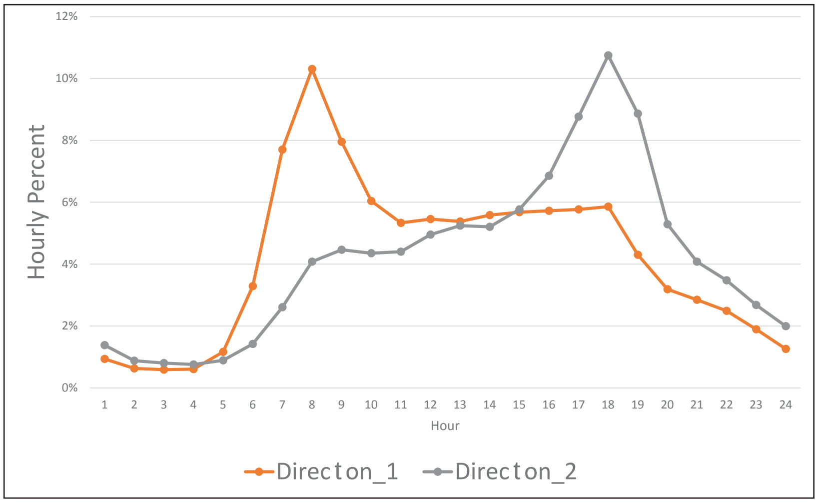
*1 SOV | 2 HOV | 3 TRK

| | Sum | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 193806.97 | 0.00 | 34209.96 | 0.00 | 5695.43 | 0.00 | 8332.58 | 0.00 | 6589.63 | 0.00 | 3999.68 | 3309.48 | 0.00 | 0.00 | 0.00 | 4296.76 |
| 1 | 34209.96 | 0.00 | 0.00 | 0.00 | 5695.43 | 0.00 | 0.00 | 0.00 | 5411.95 | 0.00 | 0.00 | 1955.85 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 8332.58 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1177.68 | 0.00 | 0.00 | 1353.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 5695.43 | 0.00 | 5695.43 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 7 | 3999.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 9 | 6589.63 | 0.00 | 5411.95 | 0.00 | 0.00 | 0.00 | 1177.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13 | 3309.48 | 0.00 | 1955.85 | 0.00 | 0.00 | 0.00 | 1353.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 14 | 4296.76 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 17 | 4208.78 | 0.00 | 2175.15 | 0.00 | 0.00 | 0.00 | 1662.18 | 0.00 | 0.00 | 0.00 | 354.45 | 0.00 | 0.00 | 0.00 | 0.00 | 17.00 |
| 18 | 13053.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21 | 15001.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 | 7058.84 | 0.00 | 1765.03 | 0.00 | 0.00 | 0.00 | 688.93 | 0.00 | 0.00 | 0.00 | 589.90 | 0.00 | 0.00 | 0.00 | 0.00 | 1173.85 |
| 24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 25 | 57374.60 | 0.00 | 10324.10 | 0.00 | 0.00 | 0.00 | 2109.28 | 0.00 | 0.00 | 0.00 | 1734.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2289.05 |
| 26 | 4987.34 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Step 12. Input Files:** **Hourly Distribution File.** The user should navigate to the input files folder and select the file with the hourly traffic percentage in each direction for the express lanes corridor being studied in the model network. The required format is a .csv file. **Figure 17** is a sample of a typical file. The user should define both geographic directions (1 and 2) (e.g. north and south or east and west) and be consistent with the directional data in other input files.

**Figure 17:**
**Hourly Distribution File Example and Graphical Representation**

| ;Hours | Direct on_1 | Direct on_2 |
|---|---|---|
| 1 | 0.0094 | 0.0139 |
| 2 | 0.0063 | 0.0088 |
| 3 | 0.0059 | 0.0081 |
| 4 | 0.0061 | 0.0076 |
| 5 | 0.0117 | 0.0089 |
| 6 | 0.0329 | 0.0142 |
| 7 | 0.0770 | 0.0261 |
| 8 | 0.1030 | 0.0408 |
| 9 | 0.0795 | 0.0447 |
| 10 | 0.0604 | 0.0435 |
| 11 | 0.0534 | 0.0440 |
| 12 | 0.0546 | 0.0495 |
| 13 | 0.0538 | 0.0525 |
| 14 | 0.0559 | 0.0520 |
| 15 | 0.0568 | 0.0577 |
| 16 | 0.0572 | 0.0685 |
| 17 | 0.0577 | 0.0877 |
| 18 | 0.0586 | 0.1074 |
| 19 | 0.0430 | 0.0886 |
| 20 | 0.0319 | 0.0529 |
| 21 | 0.0285 | 0.0408 |
| 22 | 0.0249 | 0.0348 |
| 23 | 0.0190 | 0.0268 |
| 24 | 0.0126 | 0.0200 |




**Step 13. Input Files:** **Number of Zones.** The user should enter the total number of external zones (the size of the trip table) being used in the model.

**Step 14. Assignment Parameters:** **Assignment Method.** The user should enter any assignment method available in Cube Voyager here but due to the design of the model, it is recommended to use the ITER method unless there is a specific reason for selecting a different application.

**Step 15. Assignment Parameters:** **Maximum Iteration.** The user should enter a maximum number of iterations for the assignment to run for reaching equilibrium. The suggested value is 100 for a typical corridor network. Larger networks may require more iterations.

**Step 16. Assignment Parameters:** **Relative Gap.** The current model design suggests using the default value of 0.000001.

**Step 17. Assignment Parameters:** **Minimum Link Congested Speed.** The current model design suggests using the default value of 1.

**Step 18. Assignment Parameters:** **Use Cube Cluster.** The user should check this box if Cube Cluster is installed and it is desired to execute the program during the assignment.

**Step 19. Toll Pricing Parameters:** **Minimum Per Segment Toll.** The user should enter a minimum toll cost here for the express lanes project. This is also referenced in **Chapter 2**. Currently, Florida policy dictates the use of segment toll per Florida's Express Lanes Handbook. This value in Florida is currently a $0.50 minimum for interstate projects.

**Step 20. Toll Pricing Parameters:** **Maximum Per Segment Toll.** The user should enter a maximum toll cost here for the express lanes project. This is also referenced in **Chapter 2.**

**Step 21. Toll Pricing Parameters:** **Use Minimum Per Segment Toll in Network.** The user would check this box if the minimum segment toll from the **Toll Link File** is to be used. This is also referenced in **Chapter 2.**

**Step 22. Toll Pricing Parameters:** **Minimum Per Trip Toll.** This is the minimum toll charge for any O-D trip that uses the express lanes where the computed segment toll is less than this minimum trip toll. This is not the current Florida express lanes toll policy.

**Step 23. Toll Pricing Parameters:** **HOV Discount Rate [0,1] (1 is free).** When more than one trip table is used (and one table represents HOV), the user should enter "0" if HOVs should be charged the same toll as any other vehicle, enter "1" if HOVs are not charged a toll to use the express lanes. Any value entered between 0 and 1 represents the percent discount HOVs receive.

**Step 24. Toll Pricing Parameters:** **Toll Pricing Curve Exponent Coefficient.** This value influences how fast a toll escalates as the congestion level increases in the express lanes. A value of 6.5 is the current default and reflects a reasonable escalation rate.

**Step 25. Toll Pricing Parameters:** **VC Toll Offset.** This value represents the maximum allowable congestion related to the maximum toll.

Step 26. Volume Delay Function Parameters: **Volume Delay Function.** The user can select either BPR or Akcelik from the drop down menu. If the user wants to apply a **VDF** other than BPR or Akcelik the user needs to edit the key and the assignment script.

Step 27. Volume Delay Function Parameters: **Akcelik P.** This value is used as input to the formula if the Akcelik Function is selected in **Step 26**. Even if not used, the user must enter a value (the key cannot be empty). This is also referenced in **Chapter 2**.

Step 28. Volume Delay Function Parameters: **Akcelik T.** This value is used as input to the formula if the Akcelik Function is selected in **Step 26**. Even if not used, the user must enter a value (the key cannot be empty). This is also referenced in **Chapter 2**.

Step 29. Volume Delay Function Parameters: **Akcelik pb.** This value is used as input to the formula if the Akcelik Function is selected in **Step 26**. Even if not used, the user must enter a value (the key cannot be empty). This is also referenced in **Chapter 2**.

Step 30. Volume Delay Function Parameters: **Akcelik Offset.** This value is used as input to the formula if the Akcelik Function is selected in **Step 26**. Even if not used, the user must enter a value (the key cannot be empty). This is also referenced in **Chapter 2**.

Step 31. Volume Delay Function Parameters: **BPR Alpha.** This value is used as part of the input to the formula if the BPR Function is selected in **Step 26**. Even if not used, the user must enter a value (the key cannot be empty). This is also referenced in **Chapter 2**.

Step 32. Volume Delay Function Parameters: **BPR Beta.** This value is used as part of the input to the formula if the BPR Function is selected in **Step 26**. Even if not used, the user must enter a value (the key cannot be empty). This is also referenced in **Chapter 2.**

Step 33. Volume Delay Function Parameters: **Use BPR Coefficients in Network.** The user should check this box if the network has link attributes for BPR Alpha and Beta.

__Step 34. Choice Model Coefficients:__ **Toll Constant File.** The user should navigate to the input files folder and select the file with the hourly toll constants values for the toll choice model. The required format is a .csv file. These values are typically derived from observed express lane flows. Users can refer to **Appendix D: Determining Choice Model Coefficients** for additional guidance on estimating new values. **Figure 18** is a sample of a typical file.

**Figure 18:**
**Hourly Toll Constant File Data Example**

| | A | B | C |
|---|---|---|---|
| 1 | A | B | Dir1 |
| 2 | 25 | 184 | 1 |
| 3 | 184 | 177 | 1 |
| 4 | 177 | 174 | 1 |
| 5 | 175 | 185 | 1 |
| 6 | 174 | 172 | 1 |
| 7 | 172 | 163 | 1 |
| 8 | 163 | 169 | 1 |
| 9 | 185 | 189 | 1 |
| 10 | 187 | 191 | 1 |
| 11 | 189 | 193 | 1 |
| 12 | 193 | 200 | 1 |
| 13 | 200 | 213 | 1 |
| 14 | 223 | 239 | 1 |
| 15 | 207 | 226 | 1 |
| 16 | 228 | 230 | 1 |
| 17 | 235 | 239 | 1 |
| 18 | 226 | 240 | 1 |

__Step 35. Choice Model Coefficients:__ **Toll Coefficient (Beta_Toll).** The user should enter a negative numerical value representing the project users' disutility of tolls. This value represents the toll coefficient in a logit model, typically estimated based on stated or revealed preference survey data.

__Step 36. Choice Model Coefficients:__ **Travel Time Coefficient (Beta_Time).** The user should enter a negative numerical value representing the project users' disutility of travel time. This value represents the travel time coefficient in a logit model, typically estimated based on stated or revealed preference survey data.

**Step 37. Choice Model Coefficients: Reliability Coefficient Ratio.** The user should enter a positive numerical value based on a ratio of a project's defined VTTR and VTTS. Observations on the 95 Express Phase 1 corridor suggests a value of 2.65. Users can refer to **Appendix D: Determining Choice Model Coefficients** for additional guidance on estimating a new value.

**Step 38. Choice Model Coefficients: Reliability Time Coefficient.** The user should enter a value based on the project's measured reliability. National research from the Strategic Highway Research Program 2 (SHRP2) L04 Report suggests a value of 0.30. Users can refer to **Appendix D: Determining Choice Model Coefficients** for additional guidance on estimating a new value.

**Step 39. Choice Model Coefficients: Reliability Distance Coefficient.** The user should enter a value based on the project's measured reliability. A value of 0.2 is consistent with national research from the SHRP2 L04 Report. Users can refer to **Appendix D: Determining Choice Model Coefficients** for additional guidance on estimating a new value.

**Step 40. Choice Model Coefficients: Perceived Time Coefficient Steepness.** The user should enter a value based on the project's V/C or LOS data. A study of the 95 Express Phase 1 corridor used a value of 13.67 based on research documented in the SHRP2 L04 Report. Users can refer to **Appendix D: Determining Choice Model Coefficients** for additional guidance on estimating a new value.

**Step 41. Choice Model Coefficients: Perceived Time Mid Point VC Ratio.** The user should enter a value based on the project's V/C or LOS data. A study of the 95 Express Phase 1 corridor used a value of 0.693. Users can refer to **Appendix D: Determining Choice Model Coefficients** for additional guidance on estimating a new value.

**Step 42. Choice Model Coefficients: Perceived Time Max VC Ratio.** The user should enter a value based on the project's V/C or LOS data. A study of the 95 Express Phase 1 corridor used a value of 1.2. Users can refer to **Appendix D: Determining Choice Model Coefficients** for additional guidance on estimating a new value.

**Step 43. Choice Model Coefficients: Distance Penalty Y.** The user should enter a value to identify the maximum penalty value applied to all express lane trips with a distance lower than **Distance Penalty X1**. 1. A default value of 0.55 is suggested.

**Step 44. Choice Model Coefficients: Distance Penalty X1.** The user should enter a value to identify when the distance penalty starts to decrease at a linear rate. A default value of 2 miles is suggested.

**Step 45. Choice Model Coefficients: Distance Penalty X2.** The user should enter a value to identify the distance when the **Distance Penalty Y** no longer should be applied. A default value of 4 miles is suggested.

The distance penalty Cube keys, Y, X1, and X2, can be used to reduce the number of short express lane trips. The distance penalty coefficient, as specified by Y, will decrease at a linear rate as the toll lane distances go from X1 to X2 miles (e.g. trips greater than X2 miles receive no penalty).

**Step 46. Choice Model Coefficients: One Express Lane Time Weight.** The user should enter a value based on the project's number of express lanes per direction. The default value is 1.28 for projects with one express lane per direction. The user should enter "1" if the project has no segments with one express lane per direction.

The completed scenario example windows are shown in **Figure 19** and **Figure 20**.

**Figure 19:
Scenario Window 1 Example**

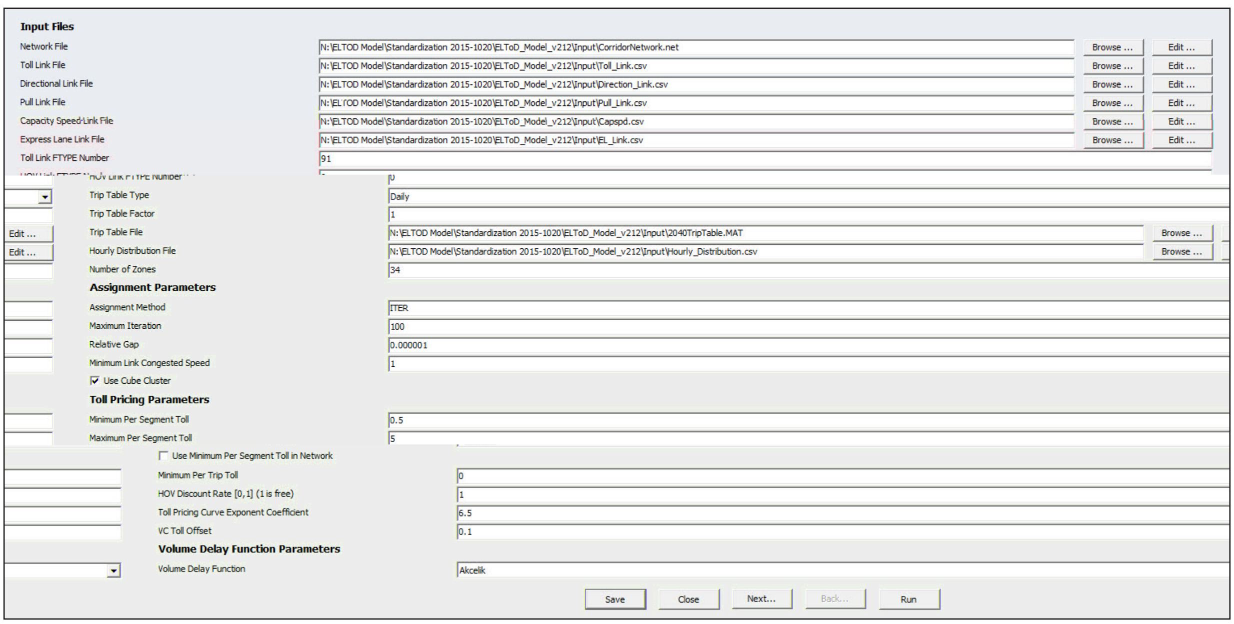
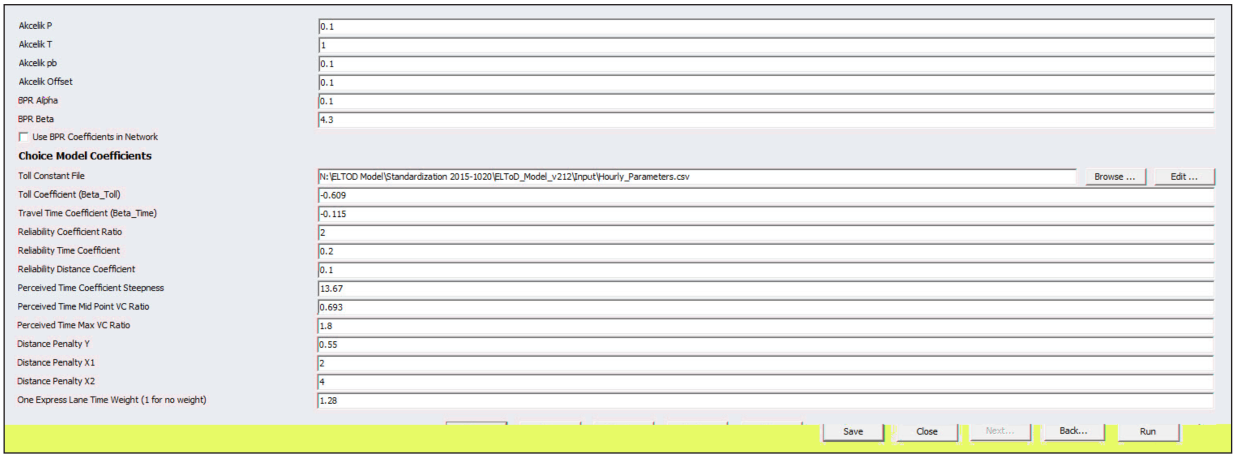


**Figure 20:
Scenario Window 2 Example**




Now the ELToD Model is ready to run. The buttons outlined in red on **Figure 21** indicate two ways the model can be executed.

**Figure 21:
ELToD Model**

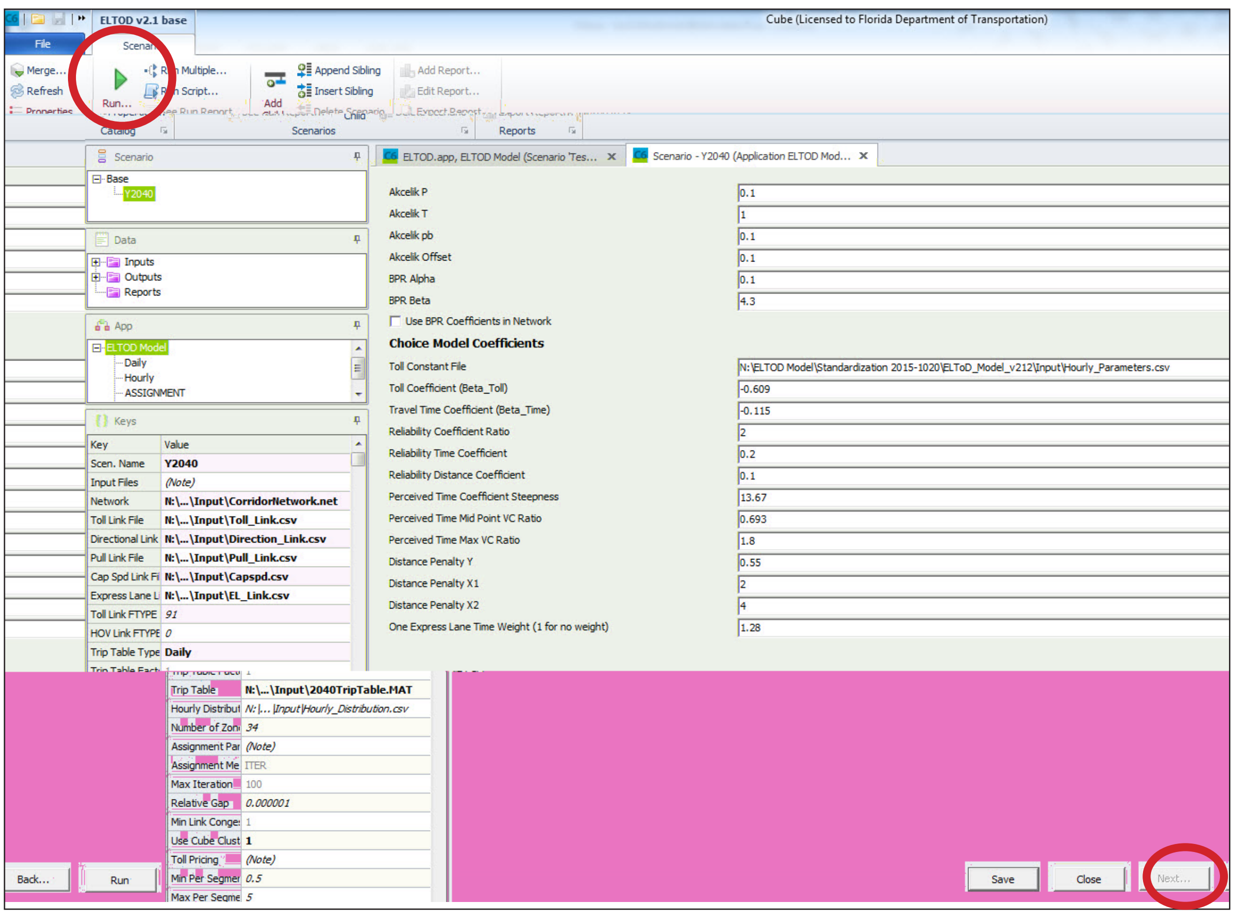
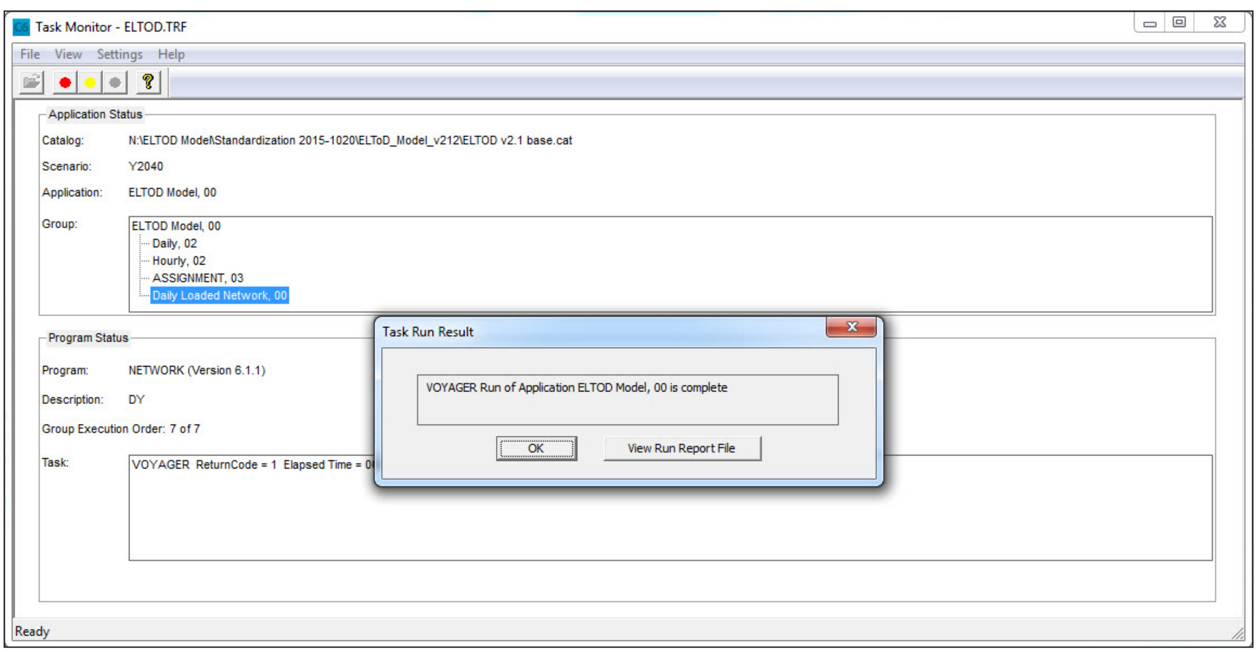


**Figure 22** is a screen capture taken during the model execution. **Figure 23** is a screen capture taken when the ELToD Model has successfully completed a run.

**Figure 22:**
**Screenshot of Model Running**

**Figure 23:**
**Screenshot of Completed ELToD Model**



Once the model runs successfully, the user can now examine the output files including the loaded network and hourly data files. The hourly data files can be managed by the accompanying workbook. This output workbook is based on the user's project needs, but can be customized as needed. It is further documented in **Chapter 4**.

# Chapter 4: Model Output Files and Result Summary Workbook

## Model Output Files

The model produces 24 output files for each model scenario corresponding to the 24 time periods of the model. The following is a list and description of the important model output files. The "#" indicates there is one file produced for each hour modeled.

- **CAL_TOLL#.PRN:** These are log files that record the results of the toll calculation steps for all iterations.
- **LOADED_AM.NET:** This is the loaded network of the AM time period which includes hours 8 to 10. The hours can be changed in the script by the user based on the definition of an AM time period.
- **LOADED_DY.NET:** This is the daily loaded network.
- **LOADED_HOUR#.NET:** These are the loaded networks for each hour period.
- **LOADED_MD.NET:** This is the loaded network of the mid-day time period which includes hours 11 to 15. The hours can be changed in the script by the user based on the definition of a mid-day time period.
- **LOADED_NT.NET:** This is the loaded network of the nighttime period which includes the time periods from **Loaded_NT1** and **Loaded_NT2**.
- **LOADED_NT1.NET:** This is an intermediate loaded network for nighttime network calculations which includes hours 19 to 24. The hours can be changed in the script by the user based on the definition of a night time period.
- **LOADED_NT2.NET:** This is an intermediate loaded network for nighttime network calculations which includes hours 1 to 7. The hours can be changed in the script by the user based on the definition of a night time period.
- **LOADED_PM.NET:** This is the loaded network of the PM time period which includes hours 16 to 18. The hours can be changed in the script by the user based on the definition of a PM time period.
- **Parameters.PRN:** This is a log file of all the input key values.
- **REV#.CSV:** These are the revenue calculations from the revenue matrix by hour.
- **REV#.MAT:** These are the revenue matrices that show toll and revenue by zone pairs.

- **RUNDETAIL_HOV#.PRN:** This is a log file for assigned HOV trips by hour for all iterations.
- **RUNDETAIL_SOV#.PRN:** This is a log file for assigned SOV trips by hour for all iterations.
- **RUNLOG#.PRN:** This is a general log file generated by Cube by hour for all iterations.
- **SKIM#.MAT:** This is the choice model calculation log file in matrix format by hour. The skims include express lanes share for SOV, total volume for SOV, general use lanes volume for SOV, express lanes volume for SOV.
- **SL#.MAT:** This is the select link output matrix by hour (if scripted).
- **Trip Table #.MAT:** These are the output trip tables (volume matrices) by hour.
- **VDF#.PRN:** These are the log files of the Volume Delay Function calculations by hour for all iterations.
- **VOL#.CSV:** These are the pull links output file data by hour.

## Using the Result Summary Workbook

The outputs from the ELToD Model can be summarized in a spreadsheet format for analysis purposes. A "Result Summary" Excel file is provided to the user as an example for viewing model output files in a tabular and graphical format. This workbook for model analysis was designed for easier review of select model outputs as specified by the user. It is designed to extract specific data from the full model output folder and can be modified by any user with basic Excel knowledge without impact to the Cube ELToD Model.

There are three required inputs for the ELToD_Result Summary [date].xlsm Excel workbook to extract data from the ELToD Model output files (see **Steps 1 to 3**). Make sure when the Excel workbook is open macros are enabled. Once the input is updated appropriately, the macro is run to update the workbook (See **Step 4**).

The ELToD Model Result Summary Workbook includes the following worksheets:

- **Summary:** Hourly pull link model output data from the user's choice of network links summarized in tables and graphs.
- **EL Detail:** Logit model calculation details for one hour which includes all the values used to calculate the express lanes share.
- **Toll_Cal:** Toll cost on express lane links as selected for one hour by tolling location.

- **VDF_Cal:** VDF values for each iteration and network link for one hour.
- **Loaded:** This is the detailed records from the model output that populate the Summary worksheet.

The workbook can be updated in four steps, described in the following paragraphs.

## Prepare Summary Worksheet to Populate with Model Output

**Step 1. Identify Output Directory:** On Line 4 of the Summary worksheet (see **Figure 24**), enter the location (folder) of the output files from the ELToD Model run that the user wants to summarize. (i.e. Location of the output files for a specific project alternative and forecast year).

**Step 2. Identify One Hour of Output Details:** On Line 5 (1-Hr Detail) of the Summary worksheet (see **Figure 24**), enter the hour ending number that represents one hour from the 24 assignment periods the user wants to pull detailed model results for (e.g. hour 8 = 7:00 AM to 8:00 AM). This will populate the XL_Detail, Toll_Cal, and VDF_Cal worksheets for assisting the user in analysis of model results.

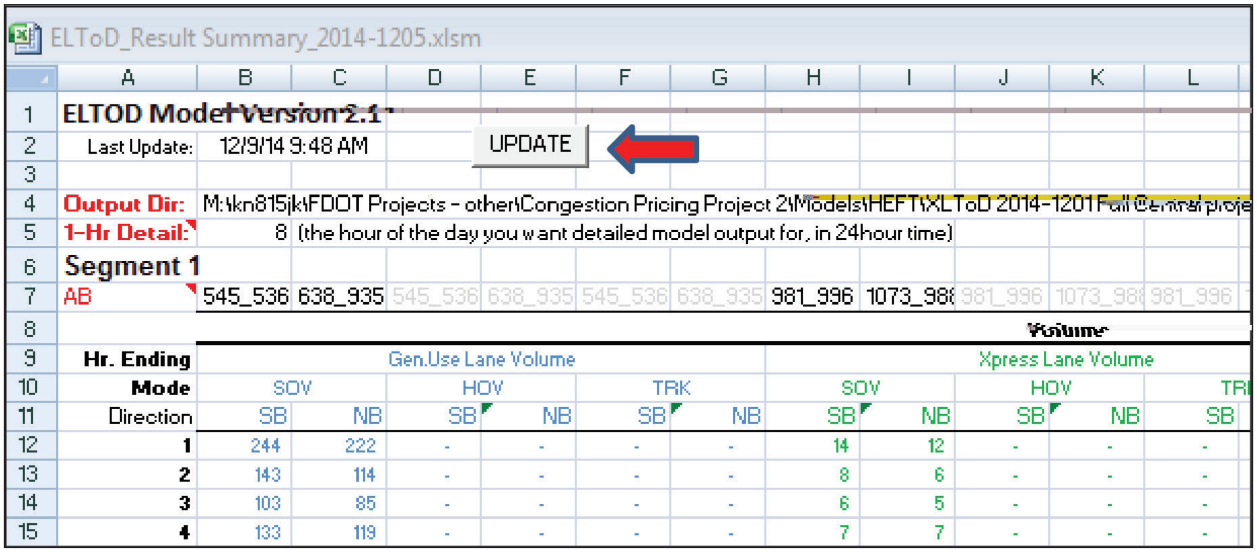
**Step 3. Identify the Pull Link A-B Nodes:** On Line 7 (AB) of the Summary worksheet (see **Figure 24**), enter the A node and B node numbers for each "Pull" link for each defined project segment, by direction. This populates the Summary worksheet. The model output data is pulled from the link data and summarized by hour and direction including:

- Volume
- Time of Day Percent
- Express Lanes Share
- V/C Ratio
- Congested Speed
- Tolls
- Revenue (an estimate based only on toll multiplied by express lane volume)

The Summary worksheet reads from the Loaded worksheet. The Loaded worksheet is populated based on the A-B nodes input for this step and data is pulled from all 24 Vol[hr].CSV output files. Note: This must be done to report volumes for each segment link (A-B node combination) the user needs. If more than one project segment is desired, the user will need to copy the rows from "Segment 1" (Lines 6 to 36) and paste them below the last segment listed and edit the title accordingly. The user also needs to update the graphs to match the new data source for each segment.

**<u>Step 4. Update the Workbook:</u>** Once the updates for these lines have been completed, click the "update" button at the top of the Summary Worksheet as shown by the red arrow in **Figure 24**.

**Figure 24:**
**Summary Worksheet Entry Example**



## Workbook Output Results

The current workbook summarizes the information in tabular and graphical form. All of the data sets are for 24 one-hour periods by direction derived from the ELToD Model output files. The data column headers are static and should be modified based on the user's project design nomenclature.

**Figure 25** is a sample of output from a model with three Trip Table Types (SOV, HOV, Trucks). Note: There are no vehicles for Trucks (TRK) in the Express Lanes due to the prohibition of trucks in the express lanes during the assignment process.

**Figure 25:**
**Summary Worksheet Example (Hourly Traffic Volume)**

| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ELTOD Model Version 2.1 | | | | | | | | | | | | |
| 2 | Last Update: | 1/19/16 8:42 AM | | | | | | UPDATE | | | | | |
| 3 | | | | | | | | | | | | | |
| 4 | Output Dir: | G:\Forecasting\ELToD Documents and Reference\ELToD_Model_v212\Base\Y2040 | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | |
| 6 | Segment 1 | South | | | | | | | | | | | |
| 7 | AB | 189_193 | 192_188 | 189_193 | 192_188 | 189_193 | 192_188 | 191_207 | 205_190 | 191_207 | 205_190 | 191_207 | 205_190 |
| 8 | | | | | | | | | | Volume | | | |
| 9 | Hr. Ending | Gen.Use Lane Volume | | | | | | Xpress Lane Volume | | | | | |
| 10 | Mode | SOV | | HOV | | TRK | | SOV | | HOV | | TRK | |
| 11 | Direction | NB | SB | NB | SB | NB | SB | NB | SB | NB | SB | NB | SB |
| 12 | 1 | 436 | 645 | 20 | 29 | 27 | 40 | 27 | 40 | 35 | 51 | - | - |
| 13 | 2 | 295 | 411 | 13 | 19 | 18 | 26 | 18 | 25 | 23 | 33 | - | - |
| 14 | 3 | 275 | 376 | 13 | 17 | 17 | 23 | 17 | 23 | 22 | 30 | - | - |
| 15 | 4 | 285 | 353 | 13 | 16 | 18 | 22 | 18 | 22 | 23 | 28 | - | - |
| 16 | 5 | 544 | 416 | 25 | 19 | 34 | 26 | 34 | 26 | 43 | 33 | - | - |
| 17 | 6 | 1,375 | 596 | 69 | 30 | 96 | 41 | 250 | 108 | 122 | 53 | - | - |

[redacted]

**Figure 26** shows the graphical representation of the hourly traffic volumes as a percent of the total for daily volumes defined pull link locations. Each facility type is represented separately for the hourly distribution of the total daily volume.

**Figure 26:**
**Graph of General Use (GU) and Express Lanes (EL)**
**Hourly Percent Volumes for Northbound (NB)**

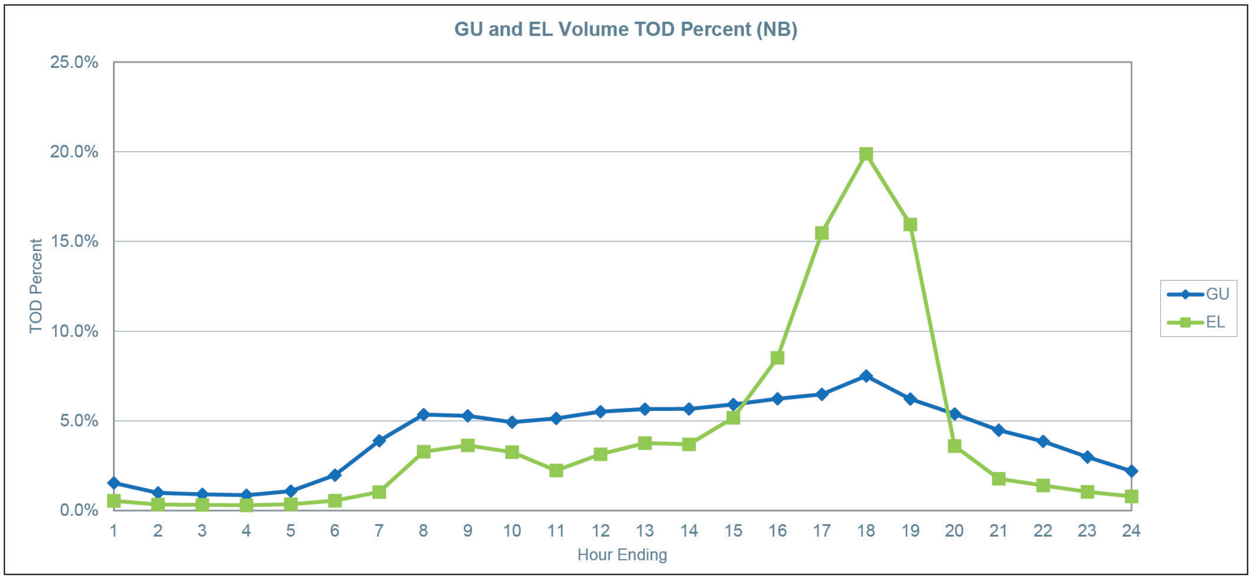



**Figure 27** shows the graphical representation of the diverted hourly traffic volumes to the express lanes as a percent of the total traffic for defined pull link locations. This is an hourly percentage of express lanes based on the total of both general use and express lanes volume.

**Figure 27:**
**Graph of Diversion Percent from General Use (GU) to Express Lanes (EL)**

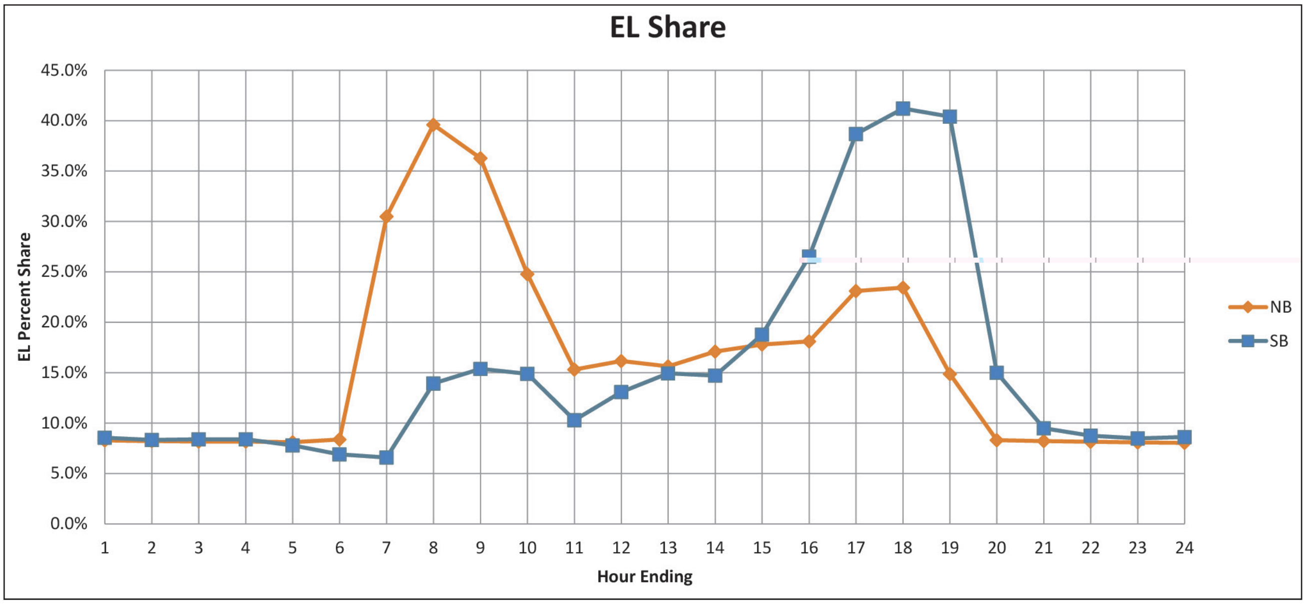


**Figure 28** shows the graphical representation of the hourly speeds for General Use (GU) and Express Lanes (EL) for defined pull link locations.

**Figure 28:**
**Graph of General Use (GU) and Express Lane (EL) Hourly Speeds by Direction**

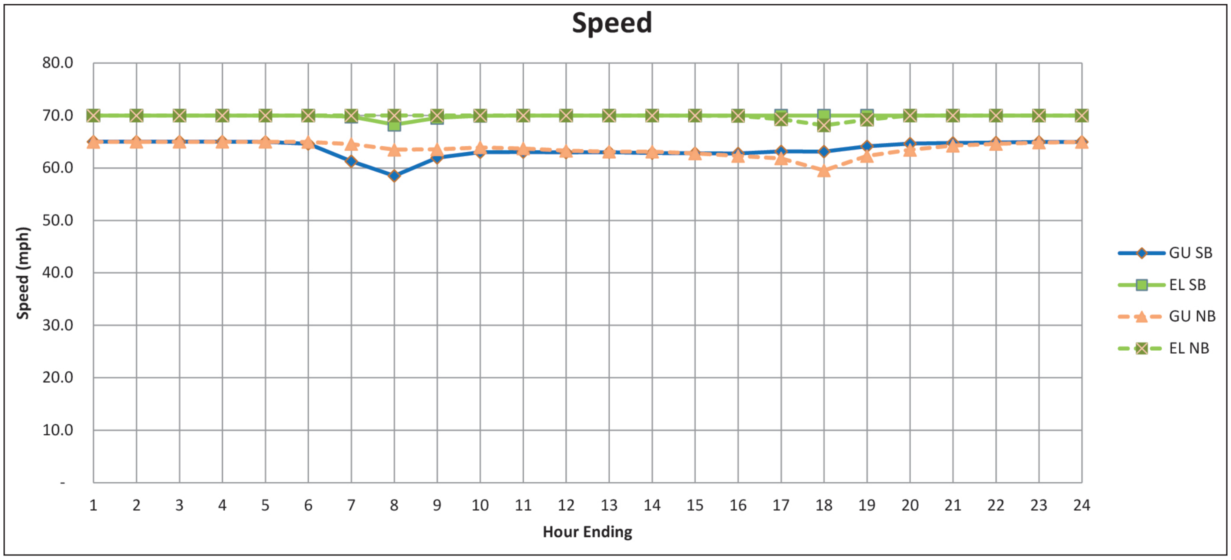



**Figure 29** shows the graphical representation of the hourly volume/capacity (V/C) ratios for General Use (GU) and Express Lanes (EL) for defined pull link locations.

**Figure 29:**
**Graph of General Use (GU) and Express Lane (EL) Hourly V/C Ratios by Direction**

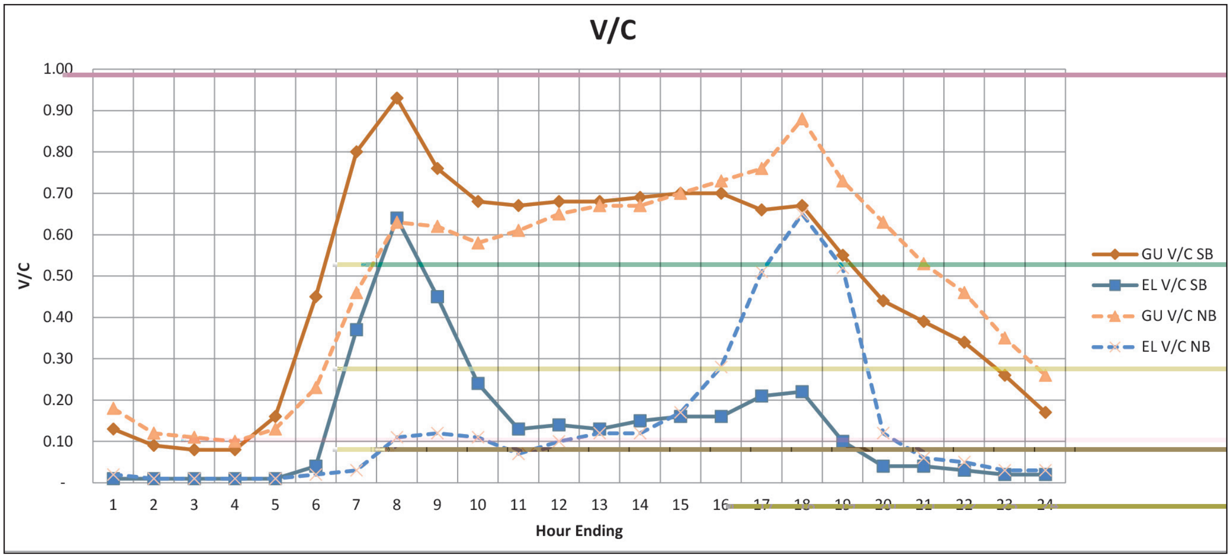
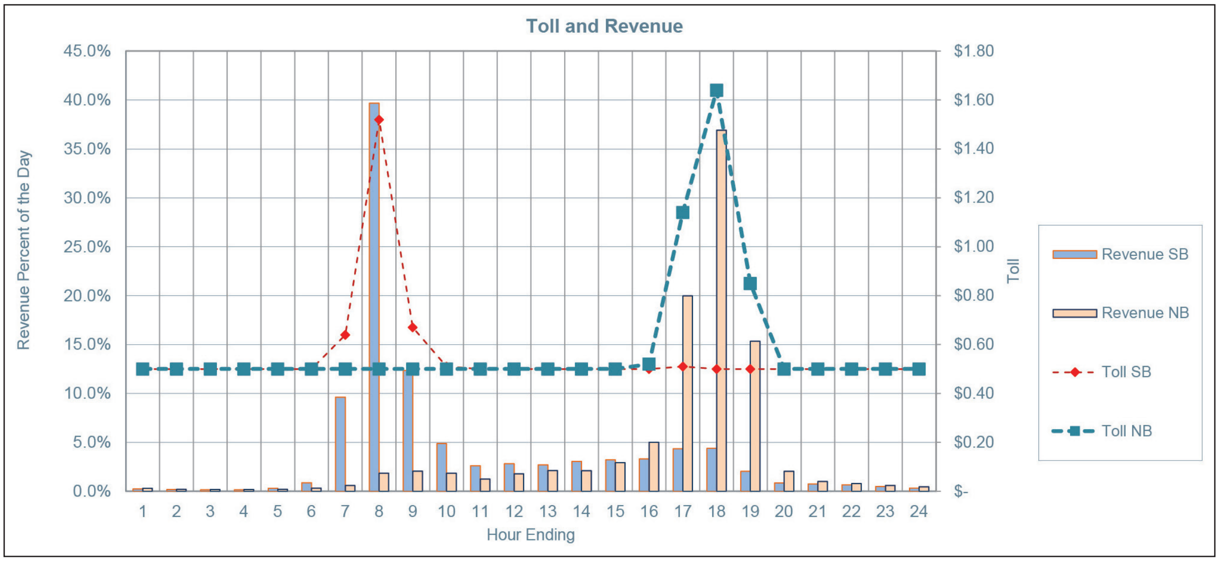


**Figure 30** shows the graphical representation of the hourly revenue estimate as a percentage of the daily total and the actual toll for Express Lanes pull link locations. Note: If the **Minimum Per Trip Toll** parameter is used, this toll is not reflected in the toll and revenue reporting here. Only the segment tolling is reported in the output. Therefore, the user will need to obtain an accurate revenue output directly from the matrix output file produced by the model.

**Figure 30:**
**Graph of Hourly Revenue and Tolls by Direction**



# Appendix A: ELToD Model Design Approach

The ELToD Model is a static traffic assignment model designed to estimate the split of project traffic between general use and express lanes with 24 one-hour time periods. The model also estimates the associated toll rates for the express lanes based on the defined toll pricing policy and related model input such as Value of Travel Time Savings (VTTS) and minimum tolls. The model incorporates a binary logit choice model that influences the split of traffic between general use and express lanes. The toll rates change based on the congestion level for each iteration. The base outputs of the model are v/c ratios, congested speed, traffic volumes and toll rates by hour and by direction.

Modeling the user's choice between the general use and express lanes under a dynamic toll condition remains the center piece of the model design. Currently, the standard practice for modeling toll users' behavior is the discrete choice model. It is a probability model widely used to study the economic behavior of consumers. The choice model estimates user's choice probability on express lanes using inputs such as time savings, toll rates, and origin-destination (O-D) pairs. The choice model includes reliability, measured by the standard deviation in travel time. This was established using an evaluation of collected preference survey data from the 95 Express Phase 1 corridor in year 2012.

Once the choice model parameters including VTTS are defined for the project to be modeled, the ELToD Model disaggregates the trip matrix input into 24 one-hour trip tables. Then, assignment is run for each time period with the choice model being executed in the assignment step. As with other assignment models, the ELToD Model runs through multiple iterations to reach the convergence point. Toll rates are recalculated at the end of each iteration based on the congestion level in the express lanes.

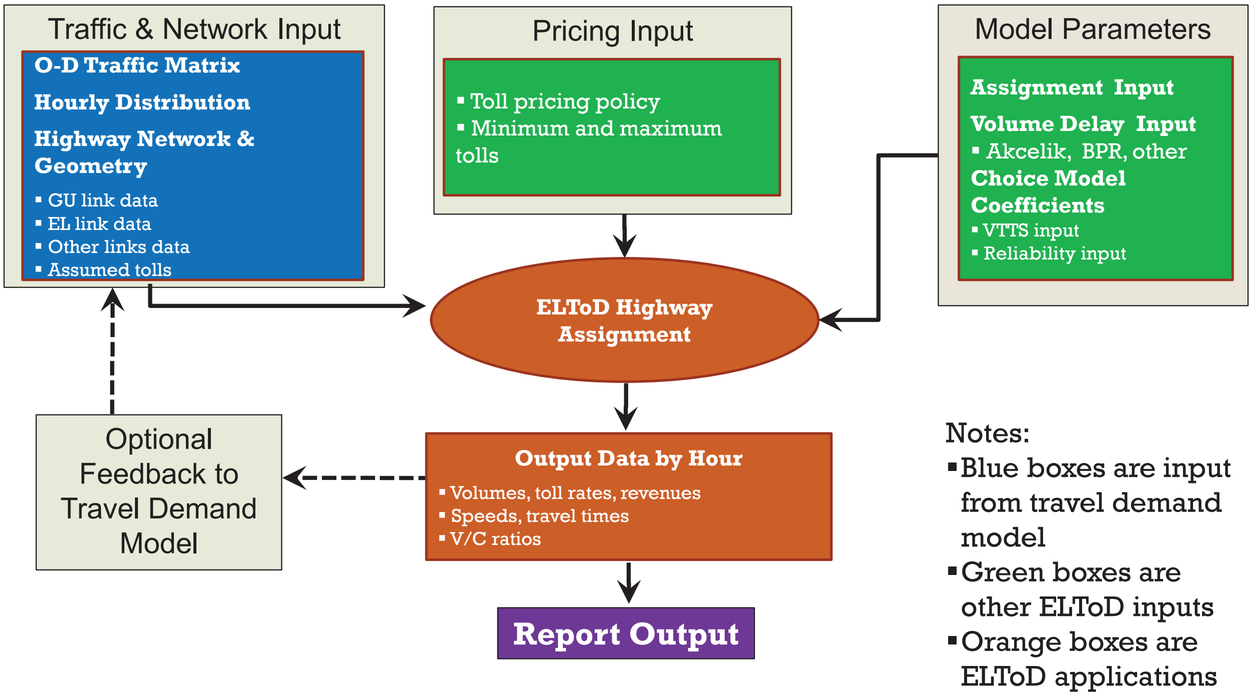
The suggested approach to obtain express lanes traffic estimates with the ELToD Model is accomplished through a two-step process. With the need to provide traffic and toll forecasts by hour and direction, the forecasting process can utilize two modeling tools; a Travel Demand Model (TDM) and the ELToD Model, a time-of-day custom express lanes model. The TDM is used for producing an input network and trip matrix for the ELToD Model. It establishes the base corridor traffic demand. Potential diversion out of the project corridor is assumed to be considered by the demand model. **Figure 31** provides a flow chart showing the general data requirements for running the ELToD Model.

The ELToD Model procedure uses four primary sets of inputs:

1. Total estimated subarea project traffic (in a matrix layout)
2. Hourly distribution of total traffic within the project corridor (by direction)
3. Geometric configuration of the subarea network links: link lengths, free flow speed, lane capacity, link facility type
4. Toll costs: Pricing policy curve including toll rate limits (minimum and maximum toll rates)

The hourly trip distribution is based on observed traffic data and held constant (i.e. the ELToD Model currently does not include peak spreading). A separate peak-spreading procedure would need to be applied to determine the extent of peak spreading that would occur given projected hourly traffic volumes, toll rates and lane capacities.

**Figure 31:**
**ELToD Modeling Flowchart**



# Appendix B: ELToD Model Application Details

The ELToD Model is a Cube-based model designed for use in corridor-level traffic and revenue studies that feature a binary choice between a non-toll and a tolled path. At a minimum, users should know how to update keys and create new scenarios in Cube. Users may also need to read and edit the model scripts.

Basic O-D demand and network capacity assumptions are required for each ELToD Model application. The ratio of traffic volume to network capacity, based on the static assignment of the toll choice model, produces link-level travel time, toll cost, and reliability calculations. In certain cases, the user may need to adjust parameters for calculating vehicle delay and reliability benefits, but the user must ensure the toll policy curve, especially the allowed minimum and maximum tolls, is appropriate for the given study.

It is suggested that preference survey data are used to update the toll choice model for each ELToD Model application. The model has default toll choice assumptions including VTTS assumptions based on a recent study of the 95 Express Phase 1 corridor in Miami-Dade County.

## Study Area Guidelines

The ELToD Model is suited for study areas that feature a binary choice between a non-toll and tolled path. This does not imply that ELToD Model networks need to be small in scale. The project corridor should contain one express lane facility and the adjacent parallel competing facilities. The parallel facilities included should be limited to those that directly compete with the express lanes. The network may contain non-toll links for connecting external loading zones to the study corridor (e.g. collector-distributor roads or auxiliary lanes).

## Model Inputs and Parameters

### Demand

There are two general approaches for developing ELToD Model trip matrices. One approach is to develop these matrices from a subarea assignment of a regional TDM. If appropriate traffic data are available, the user can refine these subarea matrices by applying O-D matrix estimation techniques. The second approach is to independently build O-D trip matrices for input to the model based on the subarea network and external nodes (which would be the O-D nodes). Previous ELToD Model studies have shown that the model forecasts are relatively sensitive not only to the overall demand in the study area but also to the specific O-D patterns. This suggests that efforts to enhance the input matrices may be worth the extra development time and cost.

Since the ELToD Model performs hourly assignments, the model ultimately requires 24 one-hour trip matrices. While users can directly estimate and input 24 one-hour trip matrices, a typical approach is to estimate daily or period trip matrices and provide global factors by direction for converting these aggregate matrices into hourly trip matrices. The hourly distribution table should be organized differently depending on whether the input matrices are specified at the daily or period level. If the input trip matrices are daily, then the factors in the hourly table should sum to 100%. If the input trip matrices are for periods, then the factors for each period should sum to 100%. The user may need to update the time period definitions in the model scripts based on the approach utilized. The sample model includes only input options for either a daily trip matrix or 24 one-hour trip matrices.

The current trip matrix input design allows for three separate matrix types, defined as SOV, HOV, and truck. If the user desires to have more than one vehicle type as input, these can be included as a typical Cube Trip Matrix design. The HOV was included to allow these trips to potentially be non-toll vehicles, representative of "exempt" HOV2+ in the 95 Express Phase 1 corridor.

### Network

ELToD Model networks are typically developed from a subarea extract of a Cube-based (.net) regional network. Basic capacity and free flow speed assumptions are required. The user also needs to indicate which links are HOT or HOV-only (if applicable), the direction of travel, and which links should be used for setting the toll rates and reporting outputs.

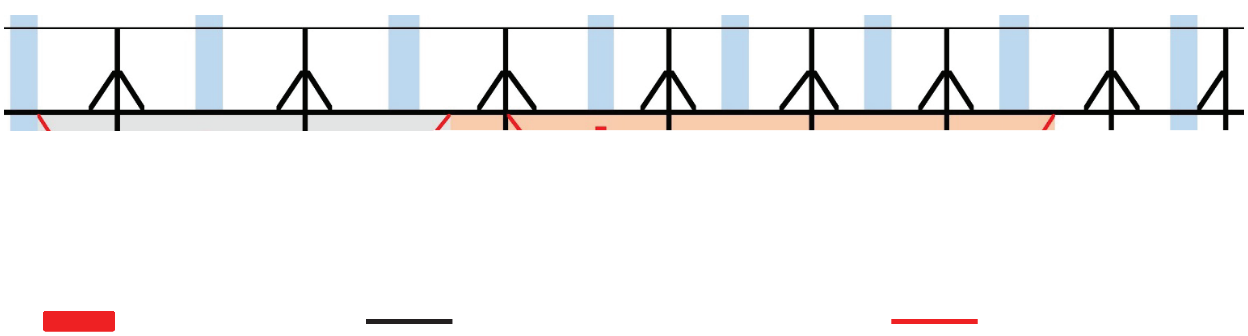
The ELToD Model network must be a Cube-compatible file (.net). The network file will typically contain some but not all of the required data. A network can be used for defining the basic network geometry and lookup tables are included for creating/overwriting the supply assumptions. The **Capacity Speed Link** File is used to overwrite the network capacity and speed assumptions for any specified network links. The **Express Lanes Link File** can be used to overwrite supply assumptions for express lanes specifically.

Supply assumptions can be read directly from the network if the user so prefers but the input network link attribute field names need to be reflected in the Network Script File. In either case, the user must ensure that the model code is consistent with the intended design. Relevant fields in the network links may include:

- **Free Flow Speed:** This is the base speed for the ELToD Model which is designated as SPEED for the network links. For planning applications, free-flow speed is defined as 5 miles per hour greater than the posted speed.
- **Distance:** The length of each link for the ELToD Model network. This is typically in miles.
- **Lanes:** The number of lanes for each link in the ELToD Model network.
- **Type:** The facility type (by numerical value) for each link in the ELToD Model network. Toll links should have their own facility type number. HOV-only links should also have their own facility type number; zero should be used for HOV-only lanes. Note: The FSUTMS Facility Type for toll links is 90-99 and for HOV links is 80-89.
- **Capacity:** The capacity of each ELToD Model network link. This is required to be an hourly capacity per lane.

For each tolling segment and each direction (typically north and south or east and west), the user needs to identify a pair of parallel non-toll and toll links that will be used for calculating tolls and preparing summary reports. For example, if there are "n" toll segments, then the user typically needs to prepare a file that has "n" x 4 rows and indicates a non-toll and toll "pull" link for each user-defined project segment and direction. This indicates to the model what links to pull for reporting specific desirable output. The user can also customize the scripts for their individual project needs. For example, **Figure 32** is a two-segment project and the user may want to pull data at the gantry locations. This would be done by specifying the A-B nodes for those links.

**Figure 32:**
**Two-Segment Express Lanes Project Example**



Toll costs by segment and direction are calculated based on the volume to capacity ratio of exactly one link, the “pull” link. To aid the toll cost calculations, the user needs to prepare a lookup table (the **Toll Link File**) that associates the full length of the toll segment with the “pull” link and optionally specifies a minimum toll for that segment. Fields in this file include:

- **A:** the A node of the pull link
- **B:** the B node of the pull link
- **TOLLSEGNUM:** the toll segment number
- **TOLLSEGLEN:** the distance of the tolled segment, which should be greater than or equal to the distance of the “pull” link typically in miles
- **MINSEGTOLL:** the minimum toll users pay for using this segment, an optional field

The network file determines the direction of link flow (flow goes from A to B nodes). However, the user must ensure the network and trip matrix are compatible and do not create circuitous paths between certain origin and destination points during assignment. A circuitous path is when previous O-D trips that used parallel facilities are NOT included with the network. To satisfy the trip, unlikely paths with a “reverse” direction may be defined for them. **Figure 33** and **Figure 34** are examples of how the same O-D trips between “zone” groups (indicated by the orange triangles) could create incorrect trips if they are included in a subarea network that cannot accommodate them.

**Figure 33:**
**Regional Network Path**

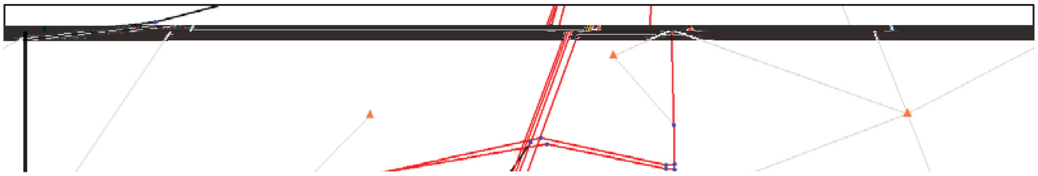


**Figure 34:**
**Subarea Network Path**

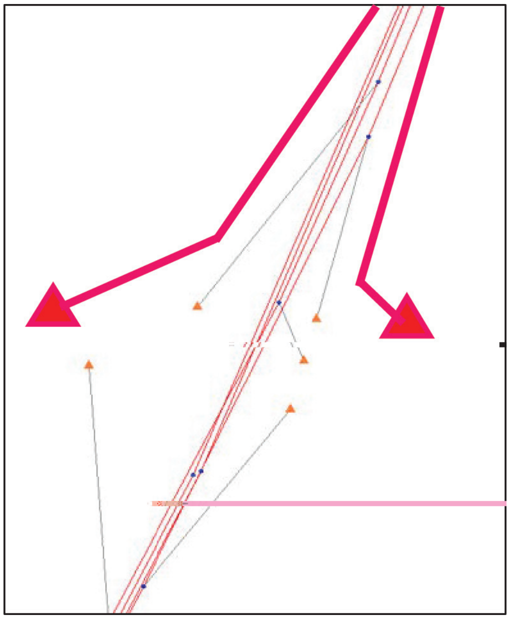
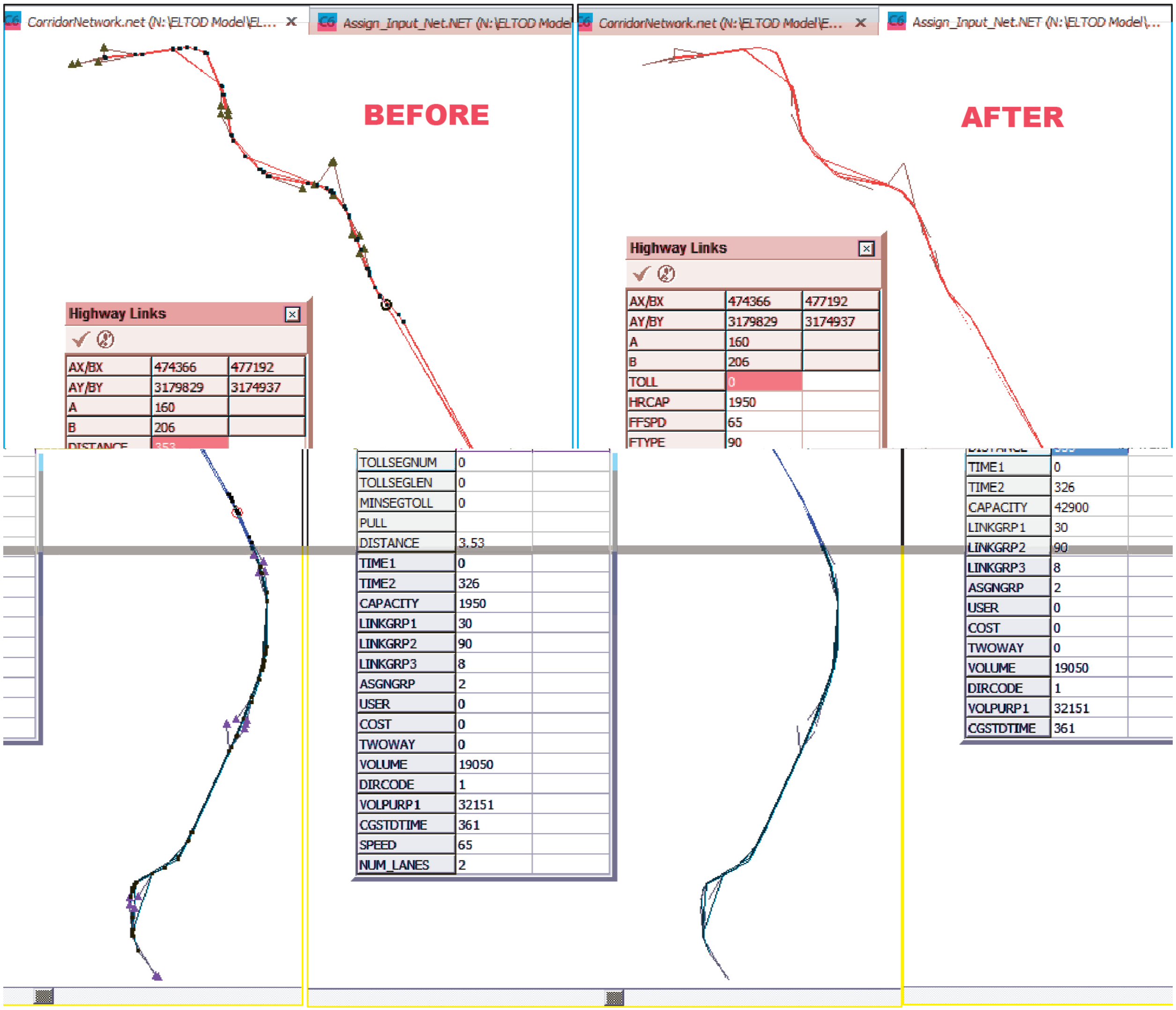


**Figure 35** shows a sample link attribute record set for the unloaded and loaded networks in Cube Voyager.

**Figure 35:**
**Before and After ELToD Model Network Development for Assignment**




### Toll Choice Model

The toll choice model calculates the split of general use and express lane trips. A complete re-estimation of the choice model could be considered before an ELToD Model application, when a more detailed understanding of local travel behavior would improve the current calibration.

Short of doing a complete model re-estimation, individual aspects of the choice model can be updated on a case-by-case basis. In particular, the VTTS assumption should be reviewed for each new application. If data is not available for updating the VTTS assumption, then a new stated and/or revealed preference survey should be conducted.

The VTTS assumption can be updated by adjusting choice model coefficient keys.

If observed express lane data is available, then the **toll constants** should be re-estimated for the study area. In other cases, the user may want to adjust the toll constants based on a methodology described in **Appendix D: Determining Choice Model Coefficients**. These constants may be adjusted in the **Toll Constants** File. Unique constants can be specified for each hour, but the user should only do this if data is available to support it.

The distance penalty keys, **Distance Penalty Y**, **Distance Penalty X1**, and **Distance Penalty X2**, can be used to reduce the number of short express lane trips. The distance penalty, as specified by Y, will be applied until the trip distance reaches the **Distance Penalty X1** value. Then, **Distance Penalty Y** will decrease at a linear rate as the toll lane distances go from X1 to X2 miles (e.g. trips greater than X2 miles receive no penalty).

### Pricing Policy Curve

The pricing policy curve can be specified in terms of a minimum and maximum per segment toll or a minimum and maximum toll rate. In either case, the toll increases from the minimum to a maximum value as the "pull" link V/C ratio increases from zero to one. The current pricing policy curve applies a basic power function, raising the V/C ratio of the express lane "pull" link to a user-defined exponent. This results in a fraction, between 0 and 1 that is used to perform an interpolation between the minimum and maximum toll values. The user can also specify a **V/C Toll Offset**, which adds a constant to the calculated V/C ratio.

When modeling toll by segment, the user must either set global minimum and maximum tolls or define a minimum toll for each segment by checking the Use **Minimum Per Segment Toll in Network** key box and enter segment-level minimum toll values in the **Toll Link File.**

The user can also specify a minimum per trip toll. This parameter is useful for applying a relatively large marginal cost for entering the system, while applying a low marginal cost for using several toll segments. However, if this parameter is used, then all link-based calculations of toll and revenue may not be valid and the user will need to rely on matrix skims of toll and revenue. The ELToD Model will check if the total of tolls encountered between a zone pair is less than the minimum per trip toll. If it is, the minimum per trip toll is applied. However, the toll rate on the links as reported is less than the true tolls paid by the vehicles travelling between the zone pair if the minimum per trip toll is used.

If the model includes an HOV trip table, then the user must define a discount rate for these trips by entering a value between 0 and 1 into the **HOV Discount Rate** key -- "0" represents a 0 percent discount (i.e. HOV trips pay the full price) and "1" represents a 100 percent discount (i.e., HOV trips pay no toll).

### Volume Delay Function (VDF)

The ELToD Model supports either BPR or Ackelik Volume Delay Functions (**VDFs**). The Ackelik function has traditionally been used for ELToD Model applications. The user must specify the preferred **VDF** in the **Volume Delay Function** key. If the Ackelik function is preferred, then the user can change the **Akcelik T**, **Akcelik pb**, and **Akcelik Offset** to adjust the relationship between V/C and delay based on any specific project needs. The **Akcelik Offset** parameter adds a constant to the modeled V/C ratio. If the BPR function is preferred, then the user should change the **BPR Alpha** and **BPR Beta** parameters to adjust the relationship between V/C and delay.

## Model Execution

The ELToD Model can be run using Cube Cluster, which is specifically scripted to execute 8 one-hour assignments simultaneously. Thus, the 24 one-hour assignments are grouped into three batches of eight parallel assignments. Users should be aware there are eight copies of the assignment script. This means changes made to one script need to be replicated in the other assignment script files for consistency.

Traffic assignment is solved using a custom Method of Successive Averaging (MSA) weighting scheme. Therefore, users should leave the assignment key set to **ITER** or else the custom weighting scheme and Cube's attempts at solving for a user equilibrium will conflict. Furthermore, it should be noted that the Frank-Wolfe method for traffic assignment (**EQUI**) is not valid in this approach because its underlying assumptions are violated by the inclusion of a toll choice model in the assignment process.

The MSA method must assign a predetermined, non-zero weight to each model iteration, including early iterations that are inconsistent with the true solution. This fact has implications for ELToD Model users. First, users should run the model for a large number of iterations to decrease the weight given to early iterations (typically this corridor level model runs quickly, especially with Cube Cluster, less than an hour for an assignment). Second, users should examine the model output to determine if the impedance values from early iterations distorted the final average. If this happens, users should force the ELToD Model to run more iterations or adjust the starting assumptions. For example, the maximum toll can be decreased to prevent problematic high tolls from appearing during the second iteration.

The traffic assignment terminates when one of two conditions are satisfied:

- The relative gap measure, based on Cube's internal calculation of relative gap, is lower than the user-specified cutoff, or
- The assignment has reached the maximum number of allowable iterations.

Cube's calculation of relative gap is not valid because the model uses the custom MSA-weighting scheme. Therefore, it is recommended that an unusually low relative gap cutoff is specified (less than 0.000001) and the maximum number of iterations is set to a suggested value of 100.

### Prepare Network

The network is prepared for assignment in the first model step. The model reads in the network and related lookup tables. It performs some data checks and provides default assumptions for any link attribute data not included in the network. It renames the network fields in accordance with the nomenclature used in subsequent model steps.

Users should ensure that the network-processing scripts read in all of the required data, which may come from the network itself or from related lookup tables. The network-processing scripts validate some aspects of the input data, and they provide default assumptions for links that are missing certain data. For example, these scripts may apply a default speed of 45 mph for links that are missing speed data. In some cases, the network scripts may contain hardcoded data or hardcoded instructions for modifying individual links.

The user should carefully validate the output networks, once assignment has run, to confirm that input data were loaded and processed correctly.

### Prepare Trip Tables

The demand inputs are prepared during the second model step. In many cases, the model converts period trip matrices into hourly trip matrices based on the table of hourly factors.

The direction of flow between origins and destinations is also determined during the second model step.

### Run Assignment

Traffic assignment occurs during the third model step. Traffic assignment primarily involves the application of five models:

- A dynamic pricing model based on toll link V/C, which calculates toll costs
- A traffic delay model based on link V/C, which calculates travel times
- A reliability model based on standard deviation of travel time, which calculates reliability benefits
- The path choice model, which traces one non-toll path and one toll path for each O-D pair and calculates impedance skims
- The toll choice model, which calculates the split of non-toll and toll trips for each O-D pair based on the impedance skims

The key assumptions of the path choice model are hardcoded in the assignment script. The non-toll path is always the shortest path, based on time, that can be traced without using any toll links. To determine the toll path, the model first traces the shortest path, based on time, using any link in the network. In certain cases, this toll trace will replicate the non-toll trace even though there were toll links between the origin and destination. This typically happens when the network is uncongested and the non-toll path is shorter in terms of distance than the toll path. For these cases, the model uses a "forced" express lane path that is traced using an artificially fast "dummy speed" for express links. The user can increase the "dummy speed" if needed.

It should be noted that the use of a "forced" express lane path infrequently results in abrupt (discontinuous) cost changes between assignment iterations and can impact model stability. However, revealed 95 Express Phase 1 travel data indicate that people use the express lanes even when there is zero time savings; therefore, some type of default toll path is needed.

The traffic assignment can be multi-class if truck trip matrices or HOV matrices are specified. The HOV matrices typically represent vehicles that are charged a reduced (or zero) toll when using the express lanes. The truck trip matrices often represent vehicles prohibited from using toll lanes or HOV lanes, if HOV lanes are included as a network facility type. Currently, the model is designed to prohibit any truck trips from using Express Lanes.

Cube Cluster has been implemented in the model to aid in reducing run times but utilizes multiple identical scripts.

### Prepare Model Outputs

"Loaded" (output) model networks, including period and daily networks, are saved in Cube-compatible formats during the fourth model step.

The loaded networks are useful for visualizing and understanding model results at a link-level. These link-level results are complemented by a series of O-D impedance and revenue skims generated during the final iteration. The model also produces detailed text files that report link-level impedances and O-D traces for every iteration. These text files are useful for conducting a detailed assessment of model convergence and behavior.

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# Appendix C: ELToD Model Technical Design

## Supply Side

The supply side relationship between traffic volume and travel times is represented by Akcelik curves that estimate the section travel times separately for the general use and express lanes in each direction. These curves were developed based on queuing theory to more accurately represent congestion levels in over-capacity conditions. The Akcelik curves are calculated in the model by:

Ratio of congested time to free flow time =

$$= (\frac{1}{S} + (g_{pb} \times g_T \times ((VoC + g_{AkcelikOffset} - 1) + ((VoC + g_{AkcelikOffset} - 1)^2$$

$$+ (8 \times g_P \times \left(\frac{VoC + g_{AkcelikOffset}}{c \times g_T}\right)))^{0.5}))) / (\frac{1}{S})$$

Congested Time = Free Flow Time x Travel Time Multiplier

Where:

- $g_T$ is the **Akcelik T**, the length of the time period in hours (default = 1)
- $S$ is the free flow travel speed for the facility (mph)
- $g_{pb}$ is the **Akcelik pb**, a constant value multiplied by the Akcelik T value to calibrate the curve to observed traffic conditions
- [redacted]

Default parameters for the Akcelik curves are shown in **Figure 36**.

**Figure 36:**
**Akcelik Parameters**

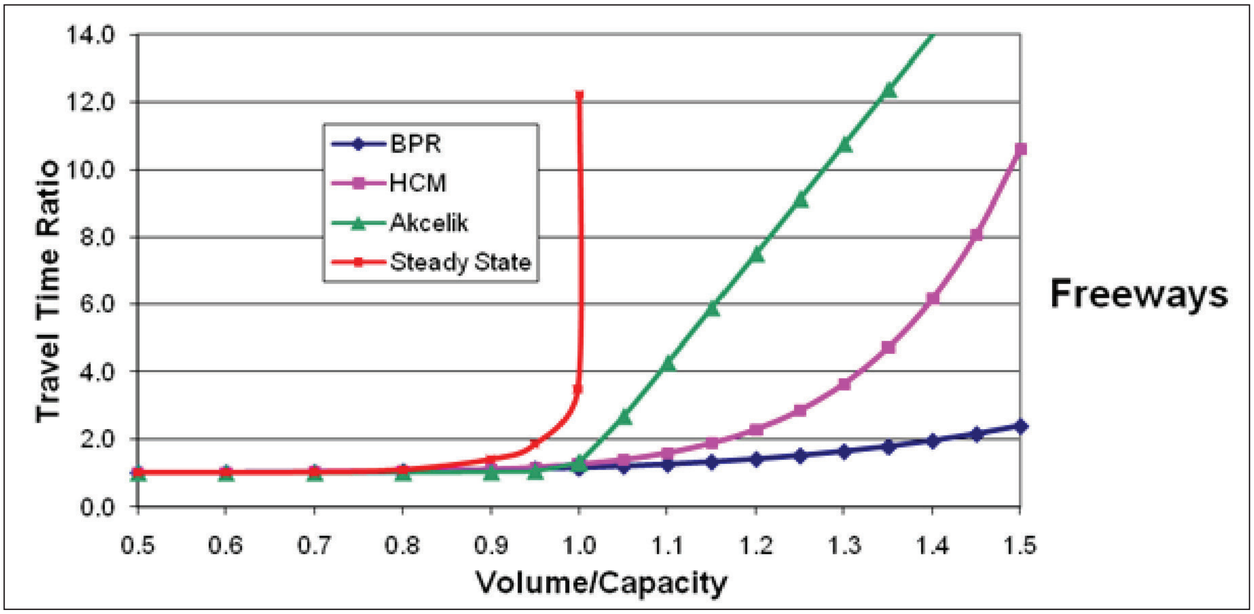
Parameters for the Akcelik Volume-Delay Functions[1] - Default Values

| Facility Type (FT) | FSUTMS FT Number | Free Flow (S) (mph) | Facility-Specific Parameter (J) | Time Length (T) (hours) |
|---|---|---|---|---|
| Freeway | 10-19, 80-89 | 65 | 0.1 | 1.0 |
| Toll Facility | 90-99 | 65 | 0.1 | 1.0 |
| Multi-Lane Highway | 20-29 | 50 | 0.2 | 1.0 |
| One-Way Street | 60-69 | 50 | 0.2 | 1.0 |
| Major Arterial | 30-34, 70-74 | 50 | 0.4 | 1.0 |
| Minor Arterial | 35-39, 75-79 | 40 | 0.8 | 1.0 |
| Collector | 40-59 | 30 | 1.6 | 1.0 |

[1]Akçelik , Rahmi. Travel Time Functions for Transport Planning Purposes: Davidson's Function, its Time-Depend Form and an Alternative Travel Time Function. In *Australian Road Research* , 21(3), September 1991, pp 49-59.

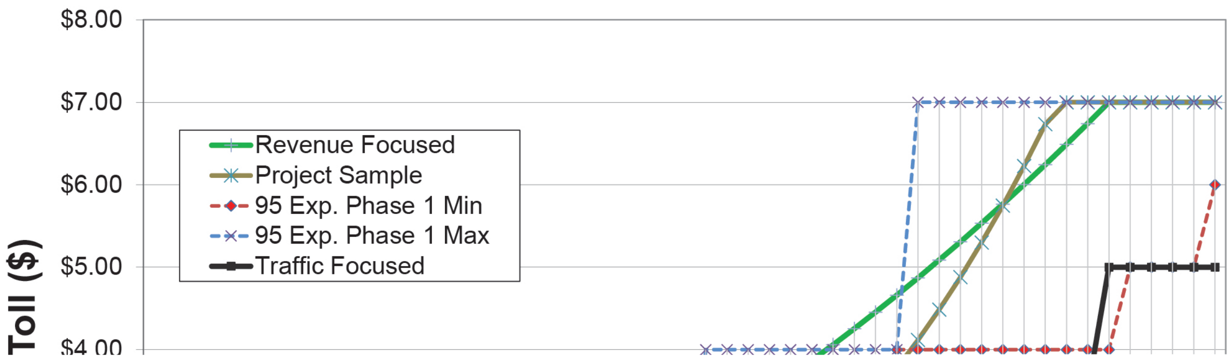
The result of these curves is that travel times equal the section length divided by the free flow speed for low volumes and increase dramatically as volumes approach or exceed the hourly capacity. **Figure 37** illustrates the Akcelik curve along with other widely used curves.

**Figure 37:**
**Volume/Capacity Curves**



Toll rates are computed for each hour and direction based on the express lane's volume to capacity ratio using power curves (power curves rather than splines or other piecewise linear forms are used to avoid discontinuities that could prevent convergence of the equilibration process). Power curves can be used to represent a wide range of tolling policies, from those that increase tolls gradually as traffic increases throughout the range, to those that are intended to maintain a certain level of service and thus increase rapidly as the limits of that level of service are approached. The rates are set so they fall within a specified minimum to maximum toll range, with a shape determined by a specified power curve exponent. **Figure 38** displays a sample of toll policy curves set with a LOS E limit. The 95 Express Phase 1 minimum and maximum curves as applied in the field are step functions shown for comparative purposes.

**Figure 38:**
**Toll Policy Curve Examples**



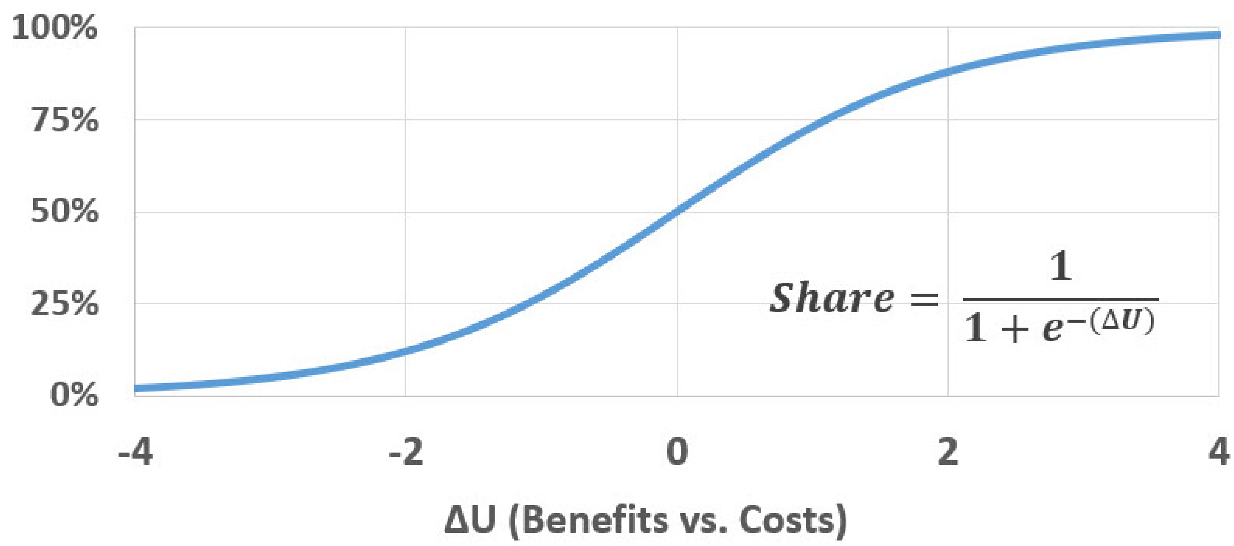
## Demand Side

The demand side is represented by a binary logit-based toll route choice model. The general form of this probability model is:

$$P(EL) = \frac{1}{1 + e^{-(\Delta U)}}$$

Where EL represents the express lanes and Δ U represents the change in utility. The utility is primarily a function of travel time, toll, and reliability. **Figure 39** represents the change in the express lanes share as the utility changes.

**Figure 39:**
**Express Lanes Share vs. Change in Utility (Benefits vs. Costs)**




The defined choice model predicts the express lane share for each origin-destination (O-D) pair when running the ELToD Model based on:

- **Time**: This variable is the travel time saved from using the express lanes instead of the general use lanes. "Time" enters the choice model as the weighted time from using the express lanes minus the weighted time from using the general use lanes. (Travel time weights are discussed in **Appendix D: Determining Choice Model Coefficients**).
- **Toll**: This variable is the cost to use the express lanes. "Toll" enters the choice model as the toll paid from using express lanes minus the toll paid from using the general use lanes. Since conventional general use lanes are free, this expression is simplified to the express lane toll minus zero.

- **Reliability:** This variable is the reduction in the standard deviation of travel time from using the express lanes instead of the general use lanes. "Reliability" enters the choice model as the standard deviation of travel time from using the express lanes minus the standard deviation of travel time from using the general use lanes. (Note that travel time weights are not used for measuring reliability).
- **Toll Constant:** This parameter can capture fixed or aggregate effects based on the network, time-of-day, or traveler characteristics.

For each O-D pair, the express lane share in the ELToD Model can be calculated from the following choice model equation:

$$Express\ Lane\ Share = \frac{1}{1 + e^{(-1 * (\beta\_Constant + \beta\_Time * Time + \beta\_Toll * Toll + \beta\_Reliability * Reliability))}}$$

- **β_Constant:** This parameter determines the express lane share when time, toll, and reliability have a net zero effect.
- **β_Time:** This parameter is for the travel time coefficient in the choice model equation defined in the ELToD Model as the **Travel Time Coefficient** (with units of 1/min). This is the disutility of increasing travel time by one minute.
- **β_Toll:** This parameter is for the toll cost coefficient in the choice model equation defined in the ELToD Model as the **Toll Coefficient** (with units of 1/$). This is the disutility of increasing the toll by one dollar.
- **β_Reliability:** This parameter is the disutility of increasing the standard deviation of travel time by one minute. It can be calculated from a Reliability Ratio (defined in the ELToD Model as the **Reliability Coefficient Ratio**) and the travel time coefficient. It indicates the disutility of one unit (one minute) of standard deviation.

"**β_Constant**," "**β_Time**," "**β_Toll**," "**β_Reliability**," are all estimated values. The latter three values determine the relative importance of **time**, **toll**, and **reliability**, while **β_Constant** has a fixed value. The measures for **time**, **toll**, and **reliability** represent differences between levels on the express lanes and the general use lanes. These calculation measures are represented by the general form of:

Measure = Express Lane Value - General Use Lane Value

The differences in travel **time** and **reliability** result primarily from the congestion in the general use lanes. For facilities with conventional general use lanes, the **toll** is non-zero only on the express lanes and the amount of **toll** is determined dynamically based on congestion levels in the express lanes.

In an iterative process, the ELToD Model calculates the express lane share, assigns traffic to the general use and express lanes, and then updates the measures for **time**, **toll**, and **reliability** based on the average traffic flow across all iterations. The iterative process continues until convergence.

The (model calculated) values for **time**, **toll**, and **reliability** are generally highest during the peak periods. For many O-D pairs, **time** and **reliability** grow faster than **toll** as congestion increases, causing the (model calculated) express lane share to reach its maximum value during one of the peak periods.

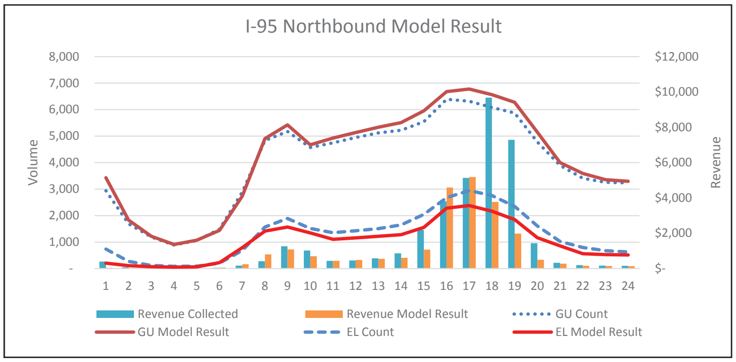
To calibrate the choice model and validate the ELToD Model to observed data, the choice model coefficients for the Express Lanes Share Equation were derived from a 2011 joint stated and revealed preference survey effort conducted in Southeast Florida (Miami area) as part of a full traffic and revenue study on I-75. The revealed preference survey was conducted on customers of the 95 Express Phase 1. This was to better understand driver behavior and develop a basis for incorporating reliability into a discrete toll choice modeling equation. The intent was that the newly formulated choice model equation could serve as the basis for estimating traffic and revenue on other express lane projects around the state. From over two thousand completed surveys, the time and cost coefficients from the study reflected a VTTS of approximately $11.30/hour for I-95, with the lower bound at just over eight dollars per hour and the upper bound just above fourteen dollars per hour. This is an important parameter for tolled project evaluations.

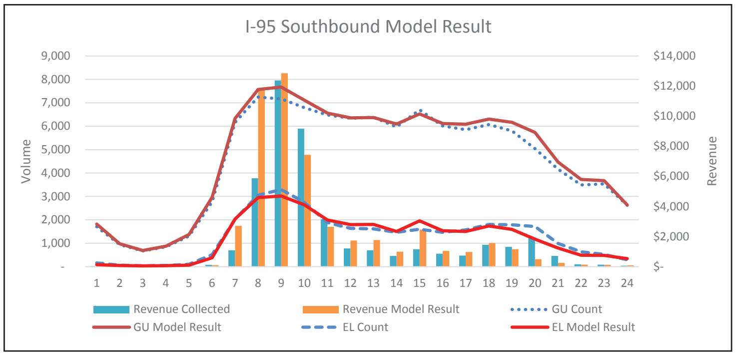
The ELToD Model was calibrated/validated using the following 95 Express Phase 1 corridor data from years 2011 and 2012:

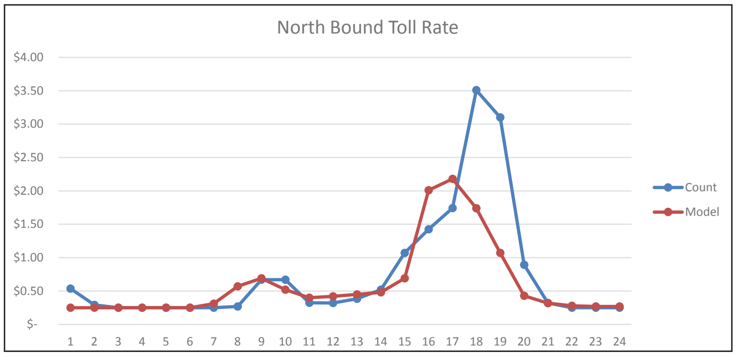
- Traffic volumes on the express lanes and general use lanes
- Percentage of total vehicles eligible to use the express lanes estimated from Bluetooth O-D data
- Average express lanes toll cost
- Average express lanes time savings (compared to the general use lanes)
- Average daily collected revenue

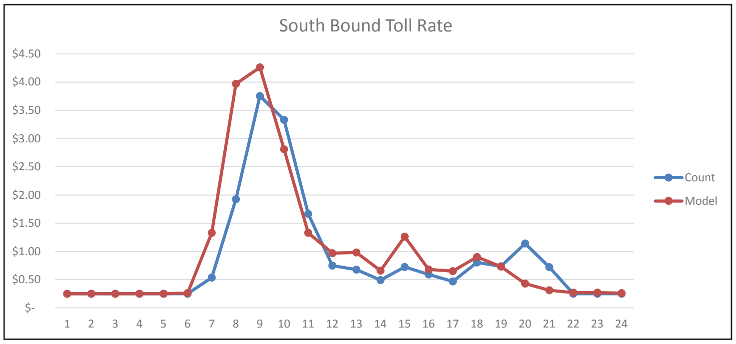
The calibration and validation resulted in an 11.6% difference between 61,663 observed average weekday transactions and 54,496 model produced transactions. Also, there was only an 8.0% difference between the average weekday revenue (observed $79,692 vs. model $73,286). **Figure 40** displays the comparison of hourly traffic volumes and toll rates between the model and observed data by direction. Because the supply and demand functions are both highly non-linear, the simultaneous solution of these functions is most conveniently found using an iterative method.

**Figure 40:**
**Comparison of 95 Express Hourly Volumes, Revenue, and Tolls**



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# Appendix D: Determining Choice Model Coefficients

The choice model used in the ELToD Model is designed from a binary logit probability model. The model estimates the toll (express lane) share for each origin-destination (O-D) pair based on the **toll constants**, **time**, **toll**, and **reliability**. Technical details on the choice model can be found in **Appendix C: ELToD Model Technical Design**. The ELToD Model allows the user to input values (Cube keys) in defining the choice model by updating certain model input parameters including the choice model coefficients that are unique for each project. This appendix provides guidance for the ELToD Model user on how some of these coefficient values can be revised according to a new project. The general equation of the choice model is:

$$Express\ Lane\ Share = \frac{1}{1 + e^{(-1*(\beta\_Constant + \beta\_Time*Time + \beta\_Toll*Toll + \beta\_Reliability*Reliability))}}$$

Where:

- **β_Constant:** This parameter determines the express lane share when time, toll, and reliability have a net zero effect.
- **β_Time:** This parameter is for the travel time coefficient in the choice model equation defined in the ELToD Model as the **Travel Time Coefficient** (with units of 1/min). This is the disutility of increasing travel time by one minute.
- **β_Toll:** This parameter is for the toll cost coefficient in the choice model equation defined in the ELToD Model as the **Toll Coefficient** (with units of 1/$). This is the disutility of increasing the toll by one dollar.
- **β_Reliability:** This parameter is calculated from a Reliability Ratio (defined in the ELToD Model as the **Reliability Coefficient Ratio**) and the travel time. The measures for time, toll, and reliability represent differences between the values on the general use and the express lanes in the ELToD Model.

## Key Data Sources

The data for calibrating the toll choice model come from several sources, including:

- Express lanes in Florida,
- Florida-based toll surveys,
- National research on toll roads, and
- Socioeconomic and trip data.

Over time, more express lane systems will open in Florida, however, the South Florida 95 Express Phase 1 project is currently the best available source for observed data. For this reason, the ELToD Model was calibrated to the 95 Express Phase 1 traffic flows. This appendix describes how an ELToD Model user can employ surveys, socioeconomic data, national research, and professional judgment to adjust the ELToD Model coefficients for studies elsewhere in Florida.

Some calibration data came from stated preference surveys, which are useful for understanding how drivers make tradeoffs between travel time and tolls. RSG has conducted a number of stated preference surveys in Florida, including surveys completed in 2007 that considered several areas around the state.

Stated preference surveys can also measure how drivers make tradeoffs among time, toll, and reliability. However, it is challenging to ask respondents about reliability. Sometimes the stated answers are inconsistent with observed behavior. To avoid this problem, a reliability coefficient was calibrated using observed 95 Express Phase 1 traffic flows and national research on pricing and reliability, including the S2-C04-RW-1 and S2-L04-RR-1[1] reports for the Strategic Highway Research Program (SHRP). The SHRP2 C04 and L04 reports are major, peer-reviewed studies sponsored by the Transportation Research Board, a member of the National Academies. The SHRP2 C04 report provides mathematical descriptions of highway user behavioral responses to congestion, travel time reliability, and pricing. The SHRP2 L04 report provides guidance for producing measures of reliability performance and using reliability to produce revised estimates of travel patterns.

Willingness to pay a toll in order to save time (or improve reliability) varies from driver to driver. For the same driver, this willingness can vary from trip to trip. However, at an aggregate level, this willingness is correlated with basic socioeconomic data and trip characteristics. Therefore, socioeconomic data and trip characteristics should be investigated for new projects and choice model coefficients should be updated accordingly.

The following sections of this appendix provide details to an ELToD Model user on how to update specific choice model coefficients for new projects.

1 http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2163 and http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2193

## Toll Constants

A **toll constant** defines the express lane share from fixed or aggregate effects based on the network, time-of-day, and/or driver characteristics. Unlike the coefficients for **time**, **toll**, and **reliability**, which can be estimated from stated preference surveys, **toll constants** should be calibrated from observed express lane traffic flows and then refined using professional judgment. Until new express lane systems open in Florida, the **toll constants** in the ELToD Model are currently based on the 95 Express Phase 1 project. This section explains how the 95 Express Phase 1 **toll constants** can be adjusted for new studies.

### Defining Model Periods

Each hour of the day must be assigned to one of four recommended periods by direction. An ELToD Model user will need to exercise some judgment in defining the periods. The Peak Period (PK) is generally associated with heavy congestion and a relatively high number of commuting and business-related auto trips. The Off-peak Period (OP) is generally associated with medium to heavy congestion and some commuting and business-related auto trips. The Evening or Early Morning Period (EEM) is generally associated with light to medium congestion and some work-related trips. The Overnight Period (ON) is generally associated with very light to no congestion and few auto work or business trips. **Figure 41** defines the periods including attributes that differentiate the periods.

If the general use lanes are not very congested during the traditional peak hours (e.g., 6:00 AM to 9:00 AM), then a user can define these hours as part of the "OP" period. These same hours could be defined as part of the "PK" period for future year scenarios that do anticipate congested general use lanes.

**Figure 41:**
**Model Period Definitions and Attributes**

| Period | Congestion | Typical V/C Ratios | Reliability | Work & Commute Trips |
|---|---|---|---|---|
| PK | Heavy | > 0.8 | Major Concern | Many Auto |
| OP | Medium to Heavy | 0.5 to 0.8 | Some Concern | Some Auto |
| EEM | Light to Medium | 0.25 to 0.5 | Minor Concern | Some Auto |
| ON | Very Light | < 0.25 | No Concern | Few Auto |

### Overnight Toll Constant

During the middle of the night, when the express lane time and reliability benefits are minimal, the **toll constant** has a simple interpretation. It defines the express lane share when there are virtually no time and reliability benefits when choosing to use the express lanes. The overnight express lane share can vary from location to location. Several fixed and aggregate factors can be assumed to influence the overnight express lanes share. Some of those factors include:

- **Facility Factors:**
    - Interchange density and express lane access points
    - Whether the facility is currently non-toll or tolled
- **Traffic Factors:**
    - Vehicle fleet (distribution of vehicle classes such as passenger cars, light duty trucks, heavy duty trucks, etc.)
- **User Factors:**
    - Average trip length

The overnight express lanes share for 95 Express Phase 1 is approximately 11 percent, which translates to a -1.94 **toll constant**. For systems where the overnight express lanes share is expected to be less than 11 percent, the **toll constant** will be less than -1.94. The overnight share for new express lane systems in Florida is expected to be between 8 percent and 11 percent. This is based on observed data from 95 Express Phase 1 and 595 Express during the overnight hours where 595 Express had the lowest volumes and 95 Express had the highest volumes.

To calculate the overnight **toll constant**, an expected overnight hour for the express lanes share must be chosen. The midnight hour is suggested based on the assumption that the midnight hour would be representative of the lowest hourly volume of the day. Once the midnight express lanes share (ON Toll Share) is assumed, a new overnight **toll constant** can be computed by:

$$ON_{New} = LN\left(\frac{ON\ Toll\ Share}{1.0 - ON\ Toll\ Share}\right) - \beta\_Toll * MinToll$$

Where:

- **MinToll:** The minimum toll for the express lanes project (e.g. $0.25).
- **β_Toll:** This is the **Toll Coefficient** defined as part of the Value of Travel Time Savings (VTTS).

### Other Periods

Travel decisions are less complicated at night than during the day. There are generally no travel time or reliability advantages to using the express lanes during the overnight hours. However, there may be driving comfort to using the express lanes. Even if there is a small time advantage, drivers should have a good understanding of the time saved.

During the day, there can be many advantages to using the express lanes and drivers may misperceive these advantages. For example, two different drivers in the 95 Express corridor might give two different estimates of the time saved from using the express lanes during the AM peak period, but these same users might give comparable estimates when asked about using the express lanes during the overnight hours.

Thus, driver heterogeneity is more important during the day because the travel decisions are more complicated. Further, the mix of drivers with their preferences and biases can change throughout the day in ways that are difficult to model explicitly. One way to mitigate these and other challenges is to employ different **toll constants** throughout the day.

In addition to the overnight **toll constant**, three other **toll constants** were established for the 95 Express Phase 1. The final constants are presented in **Figure 42**.

**Figure 42:**
**95 Express Phase 1 Toll Constants by Period**

| Period | I-95 Constant |
|---|---|
| PK | 0 |
| OP | - 0.45 |
| EEM | - 0.84 |
| ON | - 1.94 |

For new studies, the EEM, OP, and PK **toll constants** can be estimated from a new ON constant and the 95 Express Phase 1 constants. The new EEM, OP, and PK **toll constants** are assumed to equal the respective 95 Express Phase 1 **toll constants** plus the difference between the new ON **toll constant** and the 95 Express Phase 1 ON **toll constant** multiplied by a dampening factor. A dampening factor of 0.47 is recommended[2]. The new **toll constants** can be calculated by:

$$TollConstant_{New} = TollConstant_{I95} + 0.47 * (ON_{New} - ON_{I95})$$

2 User heterogeneity is (probably) less important during the middle of the night than during the day. However, since the ELToD Model uses a scale parameter of one for all periods, including the middle of the night, it is reasonable to assume that any adjustment to the midnight constant should be dampened for the other periods. A dampening factor of 0.47 was selected since the observed midnight shares can be obtained using the EME constant and a scale parameter of 2.11.

## Value of Travel Time Savings

Drivers' Value of Travel Time Savings (VTTS) has a direct influence on their use of express lanes. With all other considerations equal, drivers with higher values of time are more likely to use express lanes at a given toll and travel time savings than are other drivers with lower values of time. Past research has shown that values of time vary from region to region and facility to facility as a result of different trip types and driver characteristics.

In the ELToD Model, VTTS is reflected indirectly through two input parameters – the **Travel Time Coefficient (β_Time)**, and the **Toll Coefficient (β_Toll)**. These two parameters have generalized units of utilities/minute and utilities/$, and the implied VTTS is equal to a time coefficient divided by a cost coefficient. Multiplying this ratio by 60 converts the value to $/hour. The value implied by the default parameters should be changed to reflect each specific project application.

When possible, a stated preference survey, or other local research, should be used to estimate a VTTS for the study area. Then, new values for **β_Time** and **β_Toll** can be calculated from the VTTS estimate.

When it is not possible to conduct additional research for a study area, an ELToD Model user can approximate a VTTS, as well as new values for **β_Time** and **β_Toll,** from aggregate socioeconomic and trip data. The method for calculating VTTS is based on a logit toll choice model that was developed using stated choice survey data from several locations in Florida. All surveys used the same questionnaire, were collected during the same time period in 2007, and the survey locations were selected to represent a range of travel markets. The logit model that was estimated using these data represents the effects of two important determinants for values of time: trip lengths and household incomes. Three inputs can be used for estimation: average trip length in the facility's corridor, average household income of travelers in the corridor, and the CPI adjustment from 2007 (the year the surveys were conducted) to the base model application year.

Based on only average corridor trip length, driver household income, and a consumer price index (CPI), a user can calculate an estimated VTTS for the corridor, along with the associated values for the ELToD Model **β_Time** and the **β_Toll** using an Excel Workbook by following a few easy steps for data input as shown in **Figure 43**.

**Step 1. Identify Average Corridor Trip Length:** A user should indicate the average corridor trip length in miles in cell C19. This is the average door-to-door length of trips that are made in the corridor. This value must be greater than one mile.

**Step 2. Identify Average Corridor Income:** Users should enter the average corridor traveler income in cell C21. This is the average income of all travelers who make trips in the corridor.

**<u>Step 3. Identify CPI:</u>** A user should enter the CPI adjustment factor in cell C23 for the base model year. The Bureau of Labor Statistics[3] can be referenced to determine the CPI.

Once a user enter these three values, the output values in the spreadsheet will automatically update. These include the **β_Time** and **β_Toll** parameters required for ELToD choice model coefficient input. **Figure 43** shows an example of the workbook's input and output.

**Figure 43:**
**VTTS Workbook Input and Output Example**

| | A | B | C |
|---|---|---|---|
| 1 | | **Time/Cost Coefficients** | |
| 2 | | | |
| 3 | | **INPUTS** | |
| 18 | | ***Facility Characteristics*** | |
| 19 | | Average corridor trip length (mi.) | 10.0 |
| 21 | | Average corridor traveler household income (Base model year $) | 70,000 |
| 23 | | CPI adjustment (2007->Base model year) | 1.15 |
| 25 | | Calculated corridor traveler household income (2007 $) | 60,870 |
| 39 | | | |
| 40 | | **OUTPUTS** | |
| 42 | | *Aggregate Values* | |
| 43 | | Value of Travel Time Savings (Base model year $/hr) | 14.63 |
| 44 | | Beta_Time: ELToD time coefficient | 0.129 |
| 45 | | Beta_Toll: ELToD cost coefficient* | 0.529 |
| 46 | | CTOLL (For FSUTMS-style assignment) | 0.041 |

## Value of Travel Time Reliability

Express lanes provide more reliable travel times than general use lanes. Peak period speeds on the general use lanes change every day, and the speeds may be high on "good" days and low on "bad" days. On the other hand, express lane speeds are generally higher than in the general use lanes every day. Therefore, some people may use the express lanes to avoid having to budget extra time for more unreliable conditions in the general use lanes.

The ELToD Model measures reliability in terms of the standard deviation of travel time. There are other measures of reliability, but standard deviation was selected since it is one of the simplest reliability measures and recent national research, including SHRP2 C04-RW-1 and SHRP2 L04-RR-1, used the standard deviation measure. This national research serves as an important reference for measuring and valuing reliability.

3 http://data.bls.gov/cgi-bin/cpicalc.pl?cost1=1&year1=2007&year2=2015

### Valuing Reliability

A value of travel time reliability (VTTR) can be calculated in much the same way that VTTS is calculated (see **Value of Travel Time Savings**). The VTTR is reflected by the logit choice model **Reliability Coefficient, (β_Reliability)**, and the **Toll Coefficient (β_Toll)**. The VTTR can be specified in terms of $/minute or $/hour, indicating how much money drivers would pay to reduce the standard deviation of their travel time by one unit.

The ratio of value of reliability to value of time is called the "reliability ratio." If the reliability ratio is known (or assumed), then the value of **β_Reliability** can be calculated based on the **Travel Time Coefficient (β_Time)**. In the ELToD Model, the Cube key for the reliability ratio is the **Reliability Coefficient Ratio**. This is a simple and convenient approach for calculating **β_Reliability** as shown by:

$$\beta\_Reliability = ReliabilityRatio * \beta\_Time$$

Where:

- **Reliability Ratio:** The ratio of value of reliability to value of time.
- **β_Time:** This parameter is for the travel time coefficient in the choice model equation defined in the ELToD Model as the **Travel Time Coefficient** (with units of 1/min).

The SHRP2 C04 report indicates that the reliability ratio tends to decrease proportionally with trip distance. It was also inferred from the SHRP2 C04 report that a reliability ratio of 3.0 may be appropriate for short trips and a reliability ratio of 0.5 may be appropriate for long trips.

A reliability ratio of 2.65 was established for 95 Express Lanes Phase 1, which features 7.2 miles of express lanes. The following equation can be used to calculate a reliability ratio for new studies. The average trip distance used for the new study should be the same average trip length used in calculating the VTTS assumption.

$$ReliabilityRatio = Min\left(Max(2.65 * \left(\frac{7.2}{AvgDistance}\right), 0.5), 3\right)$$

- **AvgDistance:** This value is the average trip length in the project corridor. The value can be estimated from the O-D trip table(s) used for the ELToD Model input.

For certain studies, the VTTR could be estimated from a stated preference survey. In theory, this approach could yield an accurate **β_Reliability** for the study corridor. However, it can be challenging to ask survey participants about reliability, and it is generally helpful to consider revealed preference data when estimating a VTTR. If a stated preference survey is used, the estimated value of **β_Reliability** should be compared against the national research on reliability ratios. A reliability ratio outside the range of 0.5 to 3.0 should be reviewed carefully.

### Measuring Reliability

The SHRP2 L04-RR-1 Report indicates that the standard deviation of travel time can be estimated at the route level using:

$$Reliability = \gamma_r \times \left(Time_{Congested} - Time_{FreeFlow}\right) \times (Distance)^{-\eta_r}$$

Where:

- $\gamma_r$ = **Reliability Time Coefficient** by route
- $\eta_r$ = **Reliability Distance Coefficient** by route.

The formula assumes that the standard deviation of travel time grows proportionally with delay, which is the difference between the congested and free-flow travel times. For a given delay, the formula assumes that the standard deviation of travel time decreases with trip distance according to a power function. The report states that the value for $\gamma_r$ is generally between 0.2 and 0.3 and the value for $\eta_r$ is between 0 and 0.5 depending on the correlation of link-level travel times in the route.

A relatively high value for $\gamma_r$ (0.67) and a low value for $\eta_r$ (0.09) were estimated for the 95 Express Phase 1 corridor, suggesting that travel time uncertainty is unusually significant in this corridor and travel times are highly correlated across links. If these parameters cannot be re-estimated for the study corridor, then it is suggested the user select a value of 0.3 for $\gamma_r$ and a value of 0.2 for $\eta_r$.

### Travel Time Data for Measuring Reliability

Trip traces capturing observed individual vehicle O-D travel times from beginning to end points are generally the most accurate way to measure corridor-level travel times. If several months of trip traces are available, then these data should be used to measure the standard deviation of travel time and re-estimate the parameters in the reliability equation.

An alternative approach is to use detector or speed data to estimate the corridor-level travel times. A series of detectors, all having recorded vehicle speeds at the same time, could be used to estimate the corridor-level travel time. This approach is most accurate when there is at least one detector or speed measurement between all important interchanges and ramps in the corridor.

In either approach, an ELToD Model user should collect at least 3 months of travel time data, preferably 6 to 12 months of travel time data, for as many hours of the day as possible. At the very least, a user should collect travel time data for an hour in each of the following periods: early morning, AM peak, late morning, middle of the day, early afternoon, PM peak, and late evening.

High measured speeds should be rounded down to the assumed free flow speed in the corridor. The ability to exceed the speed limit actually makes a trip more reliable since drivers could "speed" to recover time. Including high speeds that can be considered outliers in the data set could increase the modeled travel time variability and make express lane trips seem less reliable. Very low speeds may indicate problems with the data collection or processing. These observations should be reviewed carefully.

### Estimating New Parameters

To estimate new parameters for use in the reliability equation, a user will first need to tabulate congested and free flow travel times as well as trip distances for general use entrance-exit ramp pairs for several time periods (e.g., hours of the day). For multi-segment facilities, a user should tabulate the travel times and trip distances for several entrance-exit pairs, ideally each entrance-exit pair. A standard deviation of travel time can be calculated for each entrance-exit pair for each time period from N congested travel time observations by the following formula:

$$StdDeviation_{i,j,t} = \sqrt{\frac{1}{N-1}\sum_{k=1}^{N}\left(Time_{Cong\ i,j,t,k} - \frac{1}{N}\left(\sum_{l=1}^{N} Time_{Cong\ i,j,t,l}\right)\right)^2}$$

Where:

- **i** = entrance ramp
- **j** = exit ramp
- **t** = time period
- **N** = total observations for I, j, t set
- **l, k** = an individual observation

If more than one entrance-exit pair is used, then a user can optionally assign a weight $(w_{i,j})$ to each entrance-exit pair based on its share of total demand. If no weight is calculated, then the weight is assumed to be 1.

A user can estimate new values for $\gamma_r$ and $\eta_r$ through maximum-likelihood estimation or by solving the following mathematical algorithm, which minimizes the total weighted squared error between the measured and predicted standard deviation of travel time for all entrance-exit pairs and time periods. This algorithm can be implemented in Excel Solver, a tool in the Excel Program, for solving mathematical algorithms.

$$Minimize: w_{i,j} * \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{t=1}^{T}\left(StdDeviation_{i,j,t} - \gamma_r \times \left(Time_{Cong\ i,j,t} - Time_{Free\ i,j,t}\right) \times \left(Dist_{ij}\right)^{-\eta_r}\right)^2$$

0.5 $\qquad Subject\ to: \gamma_r > 0, 0 \leq\ n_r \leq$

Where:

- $w_{i,j}$ = a weighting value
- **i** = entrance ramp
- **j** = exit ramp
- **t** = time period
- $\gamma_r$ = **Reliability Time Coefficient** by route
- $\eta_r$ = **Reliability Distance Coefficien**t by route
- $Distij$ = The distance from entrance ramp to exit ramp (i to j)

## Travel Time Weights

Many drivers dislike traveling on congested roads. They may feel discomfort from congested conditions such as a decreased level of safety due to diminished driving conditions, dislike of stop-and-go conditions, or become anxious about not arriving on time for an appointment. The ELToD Model reliability measure, the standard deviation of travel time, can capture concerns about on-time arrival.

The SHRP2 L04 Report suggests that **travel time weights**, based on link volume-to-capacity (V/C) ratios, can be used to model drawbacks from traveling on congested roads, including travel on the general use and express lanes. These weights are small when the level of service (LOS) is good (LOS A) to fair (LOS D) and should increase when the level of service is poor (LOS E to LOS F). **Figure 44** shows the **travel time weights** by LOS classification.

**Figure 44:**
**Travel Time Weights from the SHRP2 L04 Report**

| Travel Time Conditions | LOS | V/C | We |
|---|---|---|---|

The 95 Express Phase 1 calibration was completed using the default travel time weights from the SHRP2 Report. However, the maximum weight was capped at 1.20, or the weight that correspond with LOS E. The LOS E limit was selected for a few reasons. Once links reach LOS F, the modeled reliability benefits grow large, and it becomes important to avoid any

overlap between the reliability and perceived time effects. However, when links are in the LOS C to LOS E range, the modeled reliability benefits will be smaller, and the **travel time weights** can help describe the full benefit of using the express lanes.

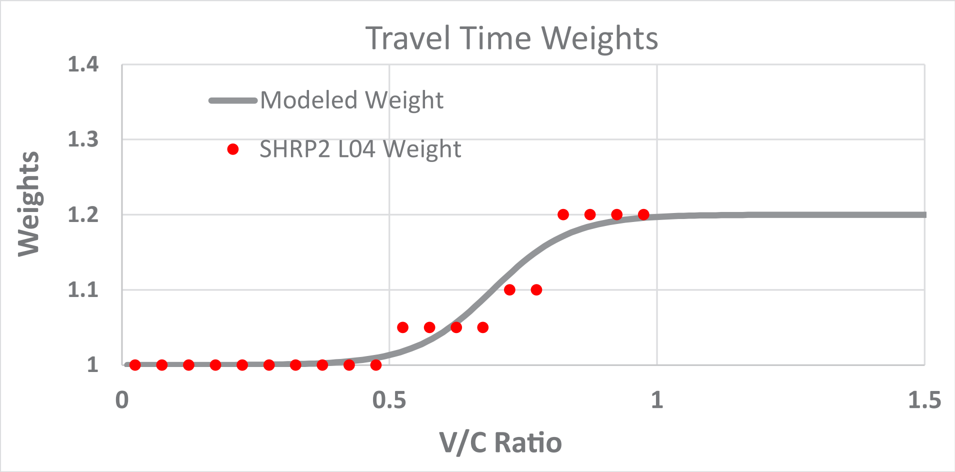
A logistic function was designed to estimate **travel time weights**. **Figure 45** shows the modeled weights and those from the SHRP2 L04 Project in relation to the V/C ratio. An ELToD Model user is encouraged to apply this same function for new studies. If desired, users may adjust the weighting levels based on local research or professional judgment. The function in equation form is:

$$Travel\ Time\ Weight = \frac{Max - 1}{\left(1 + e^{(-k*(v/c - Mid))}\right)} + 1$$

Where:

- **Max:** This parameter defines the maximum **travel time weight** for the model.
- **k:** This parameter determines how rapidly the **travel time weights** increase as the V/C ratio approaches the midpoint value for each network link.
- **v/c:** This is the V/C ratio for which the **Travel Time Weight** is being calculated.
- **Mid:** This variable defines the V/C ratio at which the **travel time weights** reach their midpoint value.

**Figure 45:**
**Graph of Travel Time Weights based on V/C Ratios**



## Distance Penalty (Short Trips on Express Lanes)

A penalty can be applied to trips that may use the express lanes for a short distance. In some ways, the **distance penalty** acts as a second constant since its value is fixed for each O-D pair unless the toll path changes. However, unlike the **Toll Constant (β_Constant)**, different O-D pairs can have different **distance penalties**. Typically, most O-D pairs will have no penalty. The express lanes share formula with a **distance penalty** included is:

$$Express\ Lane\ Share = \frac{1}{1 + e^{(-1 * (\beta_{Constant} + \beta_{Time} * Time + \beta_{Toll} * Toll + \beta_{Reliability} * Reliability - DistancePenalty))}}$$

Where:

- **β_Constant:** This parameter determines the express lane share when **time**, **toll**, and **reliability** have a net zero effect.
- **β_Time:** This parameter is for the travel time coefficient in the choice model equation defined in the ELToD Model as the **Travel Time Coefficient** (with units of 1/min). This is the disutility of increasing travel time by one minute.
- **β_Toll:** This parameter is for the toll cost coefficient in the choice model equation defined in the ELToD Model as the **Toll Coefficient** (with units of 1/$). This is the disutility of increasing the toll by one dollar.
- **β_Reliability:** This parameter is calculated from a Reliability Ratio (defined in the ELToD Model as the **Reliability Coefficient Ratio**) and the **travel time coefficient**. It indicates the disutility of one unit (one minute) of standard deviation.
- **Distance Penalty:** This parameter is a penalty applied to trips that may use the express lanes for a short distance to discourage short express lane trips.

The measures for **time**, **toll**, and **reliability** represent differences between the levels on the express lanes and the general use lanes in the ELToD Model.

Without a **Distance Penalty**, the choice model may over-predict the number of people who are willing to use the express lanes for a short distance. One reason is that value of time, and other cost/benefit tradeoffs, can change for very short trips. Another reason is that people may fail to fully consider using the express lanes if they have to enter and exit within a very short distance.

These effects can be observed for toll roads in Florida, but they cannot be observed for express lanes in Florida since no system currently features tightly spaced entry and exit points. Based on previous project experience on toll roads in Florida, a 0.55 penalty, representing approximately five minutes, is recommended for express lane trips shorter than two miles.

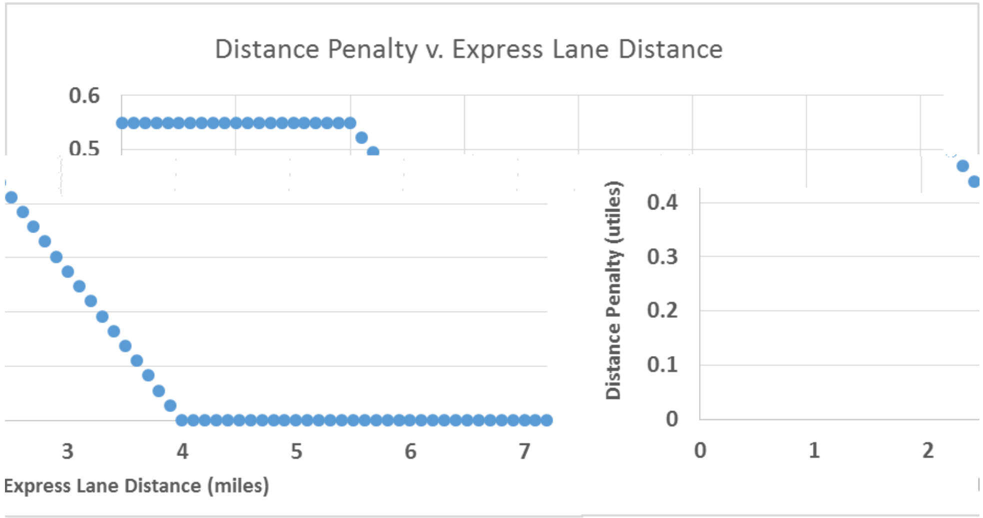
Also, a penalty that decreases linearly from 0.55 is recommended for trips between two miles and four miles. **Figure 46** displays this relationship between a **distance penalty** of 0.55 and the express lane distance but this graph would change if a new **Distance Penalty Y** is calculated. A new **Distance Penalty Y value** can be calculated by:

$$Distance\ Penalty\ Y_{New} = Time\ Penalty * \beta\_\mathrm{Time}$$

Where:

- **Time Penalty:** The penalty in time (minutes) which must be a negative value.

**Figure 46:**
**Modeled Distance Penalty**




- **β_Time:** This parameter is for the travel time coefficient in the choice model equation defined in the ELToD Model as the **Travel Time Coefficient** (with units of 1/min).

## One Express Lane

When there is only one express lane, vehicles cannot pass each other and can contribute to overall lower speeds in the express lanes. Currently, there are no facilities in Florida that feature one express lane for the length of the corridor. However, for facilities outside of Florida with only one express lane, the speed may decrease by 10 mph to 15 mph during the peak period. An ELToD Model User can attempt to directly model the decrease in speed and reliability from having one express lane, but it is recommended that a travel time weight of 1.28 be applied for all periods to represent the possibility of a 15 mph decrease in speed. The Cube key addressing this lane reduction in the ELToD Model is **One Express Lane Time Weight**.