ARTVAL User Guide

User Guide for the ARTerial eVALuation Computational Engine

Developed through NCDOT Research Project 2013-09: Delay and User Cost Estimation for Work Zones on Urban Arterials

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1. INTRODUCTION

This document provides guidance on the use of the ARTVAL (Arterial Evaluation) computational engine. The engine implements the Quick Estimation Method for Urban Streets (QEM-US) described in Highway Capacity Manual (HCM2010) as the core computational module for arterial street analysis [1], considers planning-level inputs, and provides work-zone evaluation modules developed for the state of North Carolina.

The engine was developed as part of NCDOT research project 2013-09 "*Delay and User Cost Estimation for Work Zones on Urban Arterials*". ARTVAL is a Microsoft Excel based engine coded in the Visual Basic for Applications (VBA) platform. The tool has a Graphical User Interface (GUI) to facilitate data entry and navigation throughout. The core of the tool is the QEM-US, which is the computational procedure for urban street facilities in Chapter 30 of the 2010 Highway Capacity Manual. Some modifications and enhancements to the methodology have been made to improve its usability by NCDOT. These changes have been documented in the final project report [2].

1.1 Overview of ARTVAL Base Methodology

ARTVAL is a computerized, worksheet-based environment designed to *faithfully implement* the operational analysis computations for urban street facilities in the 2010 Highway Capacity Manual. It incorporates the QEM-US procedure in Chapters 30 of HCM2010 for urban streets segments. It also contains additional modules to assist the user in estimating signal timing parameters based on Webster's signal timing method. ARTVAL includes a set of default values for a variety of analysis inputs that can be utilized in the absence of field data.

ARTVAL also includes a work zone analysis module that is developed based on findings from the "*Delay and User Cost Estimation for Work Zones on Urban Arterials*" project. This includes the incorporation of a method to adjust saturation headways based on the configuration of the work zone [3]. Finally, ARTVAL generates a variety of output performance measures for intersections and the urban street segments between those intersections.

ARTVAL is organized as a sequence of linked Excel worksheets, and can be used autonomously to analyze individual urban streets segments or an entire bi-directional facility. The user must define the individual segments and enter all necessary inputs required for each intersection and urban street segment, as defined in HCM 2010.

The computational engine is further designed to allow the user to revise inputs following the completion of an analysis. This feature allows for quick sensitivity analyses of different demand scenarios or geometric changes to the facility. However, the user is cautioned to ensure that all prior inputs are retained when using ARTVAL for extensive scenario evaluation. ARTVAL is not

a commercial-grade software product, and relies on the findings of NCDOT project 2013-009 "*Delay and User Cost Estimation for Work Zones on Urban Arterials*".

1.2 Document Organization

The next section focuses on the step-by-step input coding process of the ARTVAL tool. The analysis process starts with basic input of project summary information, and then requires detailed input of the facility configuration. Each of these components is discussed in detail. The document concludes by discussing the output performance measures generated by ARTVAL.

2. ARTVAL INPUT CODING PROCESS

When coding a new problem, the user must start with the basic file named *Generic_ARTVAL.xlsm*. **The first step is to create and save one (or preferably multiple) copies of the generic file,** since once an example problem has been coded, the generic version is no longer available for future use. The analyst can also edit an existing file. ARTVAL assists the user in data entry by distinguishing between "default values" and "facility specific" data categories using different color codes. Any Yellow back ground cell represent a facility specific input. On the other hand, green back ground cells indicate that the value is a default. More details on color coding and extra features are discussed throughout the coding process explanation.

There are five major steps to run the tool:

1- Global Facility Data Entry
2- Geometric and Demand Data Entry
3- Detailed Analysis Periods Data Entry
4- Signal Timing Data Entry
5- Performing Urban Street Analysis and Facility Performance Measures

Note that the user must follow the computational steps in this sequential order. The data entered in each step configure the necessary input data in subsequent steps.

IMPORTANT NOTE: The user should move between worksheets and steps <u>using the navigation buttons provided in the worksheets.</u> By pressing the buttons, all required changes and adjustments are automatically performed to configure the subsequent worksheets.

The ARTVAL tool requires the use of Visual Basic macros, which need to be enabled depending on the settings in the Microsoft Excel program. Figure 1 shows the message provided by Excel 2013 regarding enabling the macros.
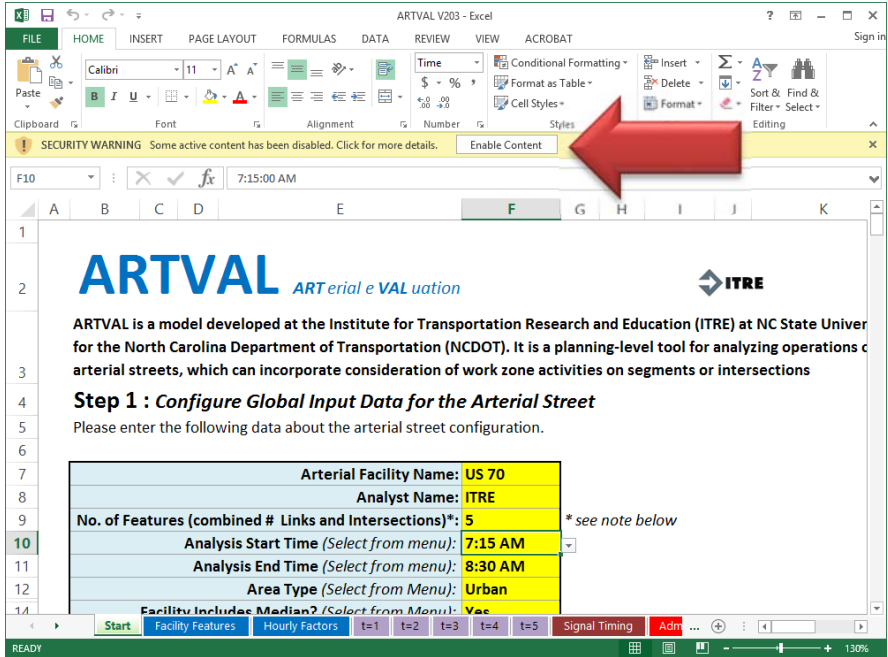
Figure 1 – Enabling macros in MS Excel

Step 1: Global Facility Data Entry

The analysis process starts by entering global facility information. This step is shown in the "start" worksheet in ARTVAL. Figure 2 shows the schematic of the "Start" worksheet in ARTVAL.
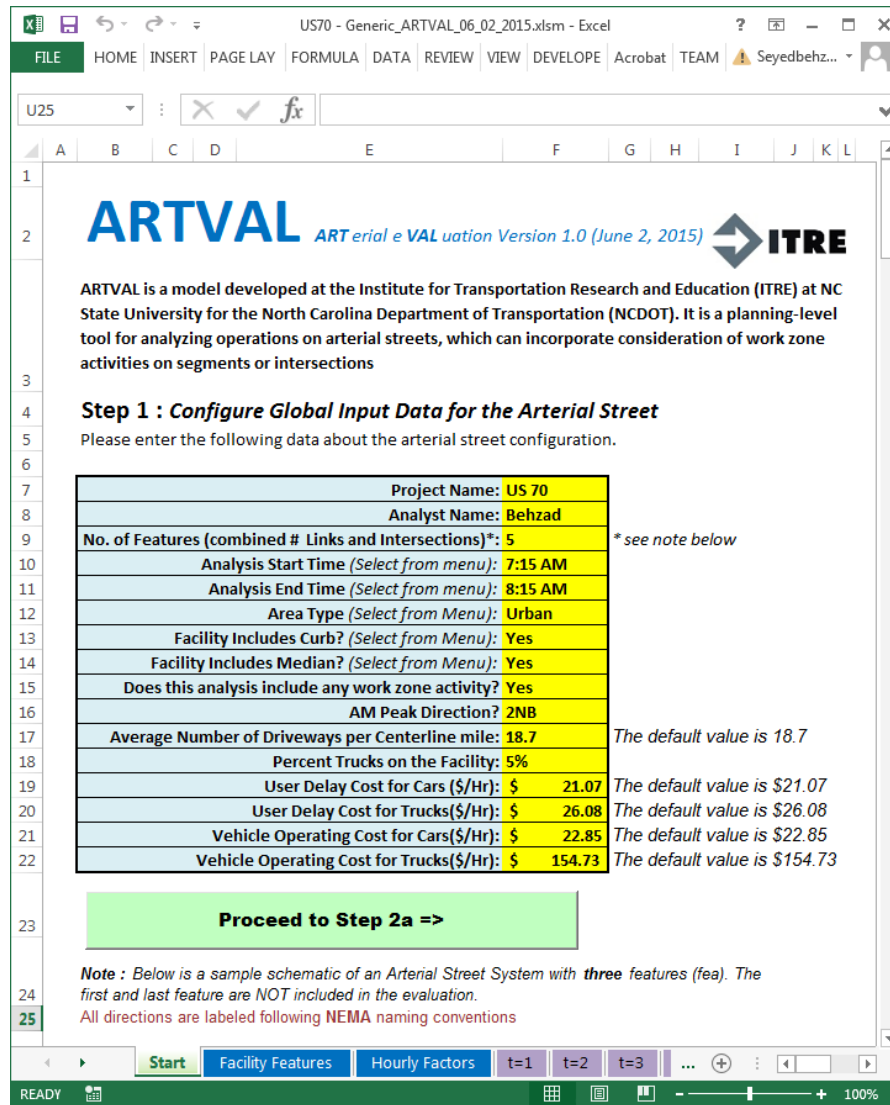
Figure 2 – *Start* **Worksheet in ARTVAL**

ARTVAL uses the concept of a "*feature*" as the smallest arterial street unit that should be defined. A feature can be either be an intersection or a link between two intersections. The HCM defines the combination of a link and the downstream intersection and as an urban street segment. In ARTVAL, the arterial street corridor should always start and end with intersections. The ARTVAL puts two dummy links at the beginning and end of facility so that the HCM procedures can be implemented. These dummy links are not completely part of analysis and ARTVAL will not provide performance measures. Figure 3 shows an example of an arterial street facility that has been coded in ARTVAL. As seen, the facility consists of three features (one link and two intersections). Two dummy links are added to the beginning and end of this facility, but these will not be part of analysis.

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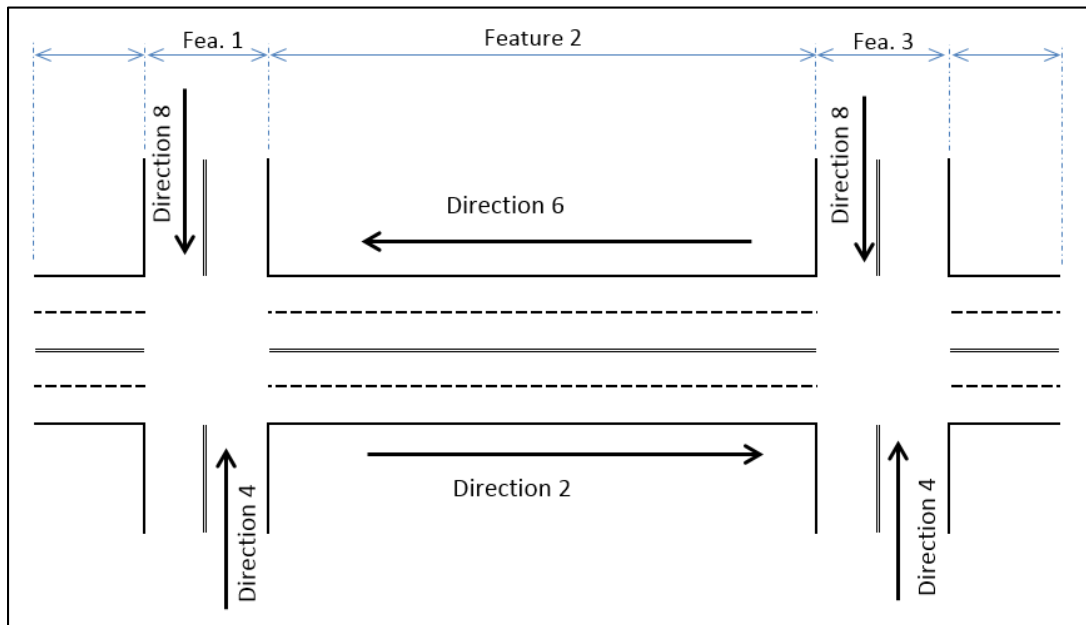
Figure 3 – Schematic and Definition of a Feature in ARTVAL

The following information must be provided by the user. In general, all yellow cells in ARTVAL must be filled with non-zero entries to avoid a crash of the software. Entering all yellow cells assures that the arterial is fully defined for analysis.

1. **Project Name**: This cell contains the name of the analysis project
2. **Analyst Name**: This cell contains the name of the analyst
3. **No. of Features:** This is the sum number of the number of Links and Intersections. The analyst must enter the number of features that the subject arterial facility has in this cell. As an example in Figure 3 the number of features are **3** and not 5.
4. **Analysis Start Time (Select from menu):** This start time of the analysis. ARTVAL uses 15 minutes time increments. The user can select the start time from the coded combo box.
5. **Analysis End Time (Select from menu):** The end time of the analysis. ARTVAL uses 15 minutes time increments. The user can select the end time from combo box
6. **Area Type (Select from Menu):** Analyst selects the area type from the drop down menu.
7. **Facility Includes Median?** An option that allows ARTVAL to prefill the percent median in each segment. User can override or customize this value later in step 3.
8. **Does this analysis include any work zone activity?**: Select whether the analysis contains work zone or not by checking Yes/No from the provided combo box.
9. **AM Peak Direction?** Select the appropriate direction of peak traffic in the AM peak period. This information will be used to determine the appropriate default hourly demand factors in step 2.
10. **Average Number of Driveways per centerline mile**: Enter average number of driveways per centerline across the spatial limits of the arterial facility. The default value associated

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with "Urban area type" and "Suburban area type" are 18.7 and 9 driveways/ mile, respectively.

11. **Percent Trucks on the Facility:** The user needs to specify % trucks on the facility. This input will be used for User Cost analysis.
12. **User Delay Cost for Cars:** The cost associated with delay for cars.
13. **User Delay Cost for Trucks:** The cost associated with delay for trucks.
14. **Vehicle Operating Cost for Cars:** The cost associated with cars operations.
15. **Vehicle Operating Cost for Trucks:** The cost associated with trucks operations.

After providing the above information for the subject arterial facility, the user can proceed to step 2 by pressing "Proceed to Step 2a" button. By pressing this button, ARTVAL will configure subsequent worksheets based on the information provided in the "start" worksheet.

2.1 Step 2: Geometric and Demand Data Entry

Step 2 has two parts, the first (Step 2a in Figures 4 and 5 below) is related to demand and geometric information of the facility, and the second (Step 2b in Figure 6) is related to determining the hourly demand (AADT) distribution. The first part consists of four tables.

The first table contains "Basic Geometric Data" including feature type and length. A Dynamic graph is provided under this table to assist the user in configuring the arterial facility. After completing the required data entries in that first table, the user must press "Press Here to Configure the Arterial Facility" to adjust all subsequent tables in the worksheet. ARTVAL will use the information provided in the first table to customize the remaining data entry tables.

Figure 4 shows the schematic of this portion of Step 2 in the worksheet labeled "Facility Features". Note that there are four buttons provided at the top left corner of the worksheet that will allow the user to move between the steps. Also, if the user decides to add or delete any feature for any purpose he/she can press "Insert a Feature" or "Delete a Feature". By pressing those buttons, a window will open requesting the desired location of the new feature as well as the feature that needs to be deleted. There are some limitations on the use of this functionality including the fact that the user cannot delete the first or last feature of the facility.
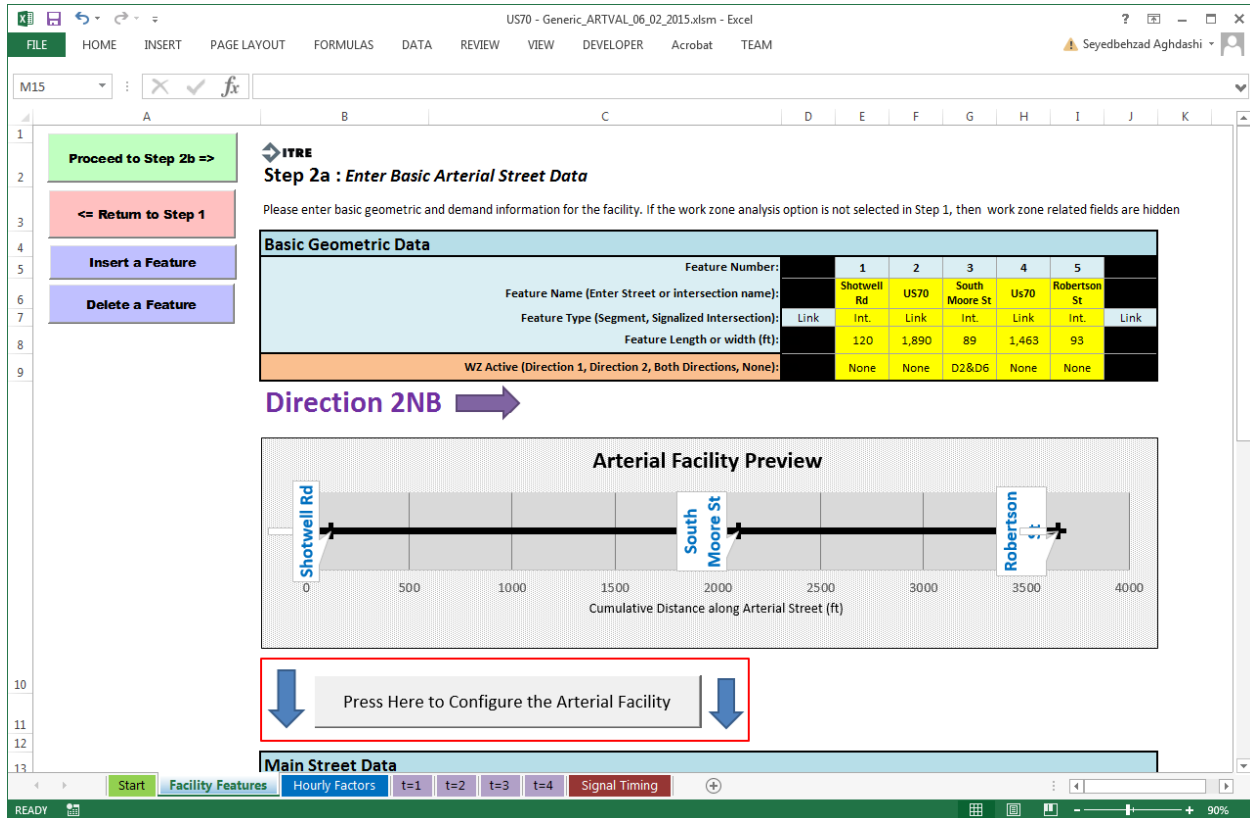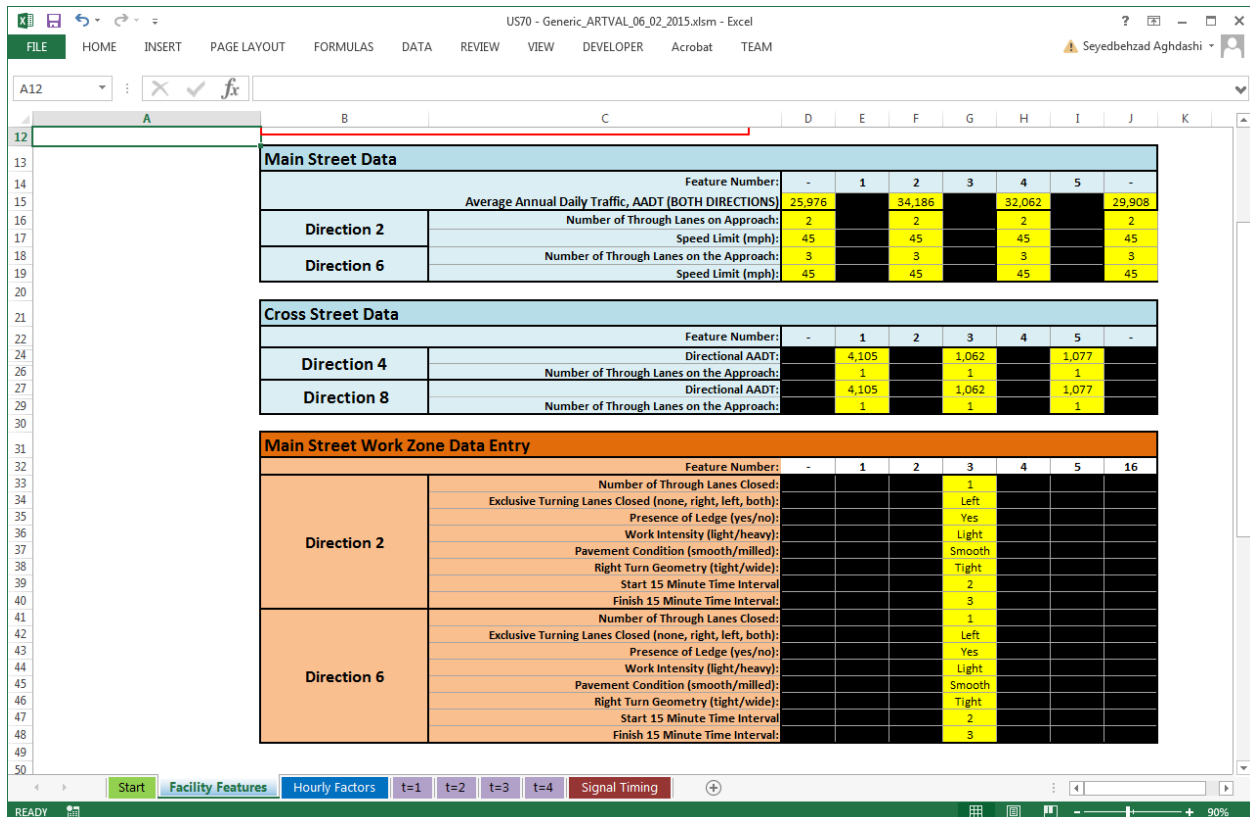
Figure 4 – Basic Geometric Data Entry in *Facility Features* Worksheet

The second and third tables in this worksheet (Figure 5, tables shown in blue color) require information on the segment AADTs, number of lanes, speed limit, as well as the directional AADTs on the minor approaches to each signalized intersection. In order to model a T-Intersection, the user needs to drastically reduce the directional AADT value for one of the minor approaches, and fill this value with **"1"** for both **directional AADT** and **Number of Lanes**. It is not advised to enter zero "0" in any cells in the engine.

If the analyst selected to model a work zone in step 1, the fourth table will be invoked, and configured based on the location of the work zone entered in the first table. In this example, the user had specified in Step 1 that the analysis contains a work zone (see Figure 2). Then in Step 2, (Figure 4) the user had specified that the work zone is located on Feature 3 and only in Direction 6. Thus, the fourth table enables data entry for the third feature as shown in Figure 5.

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Figure 5 – Demand and Work Zone Data Entry in *Facility Features* Worksheet

By pressing "Proceed to Step 2b" located on top left side of "Facility Features" worksheet (see Figure 4), the user will be redirected to the "Hourly Factors" worksheet, where he/she can enter the desired hourly factor for AADT (see Figure 6). The yellow cells are editable, and time periods that are associated with this analysis, are highlighted in darker yellow. The user must ensure that the sum of hourly AADT factors for each direction is 100% as shown at the bottom of the table. Based on the entered values, the graph located on the right side of the worksheet will display the AADT distribution.

In the absence of actual facility-specific hourly demand (AADT) data, the user can press "Insert Single Peak Defaults" and "Insert Dual Peak Defaults" to populate the table with single peak and dual peak default AADT distribution developed from North Carolina data.
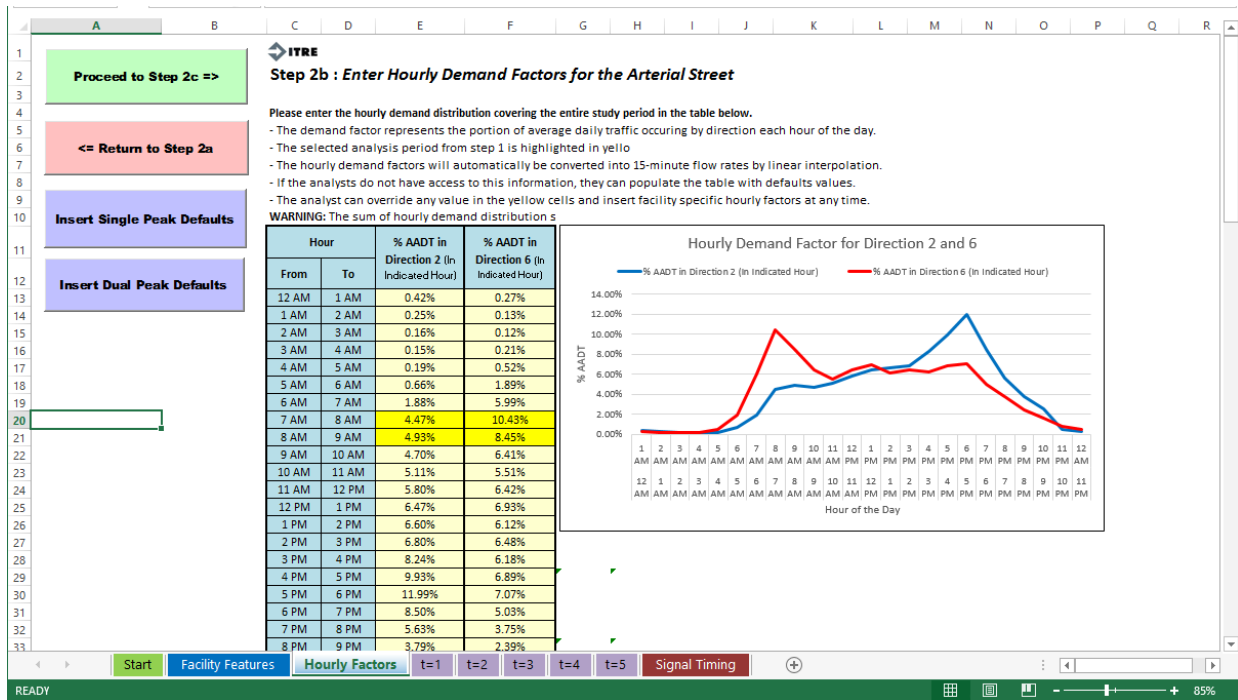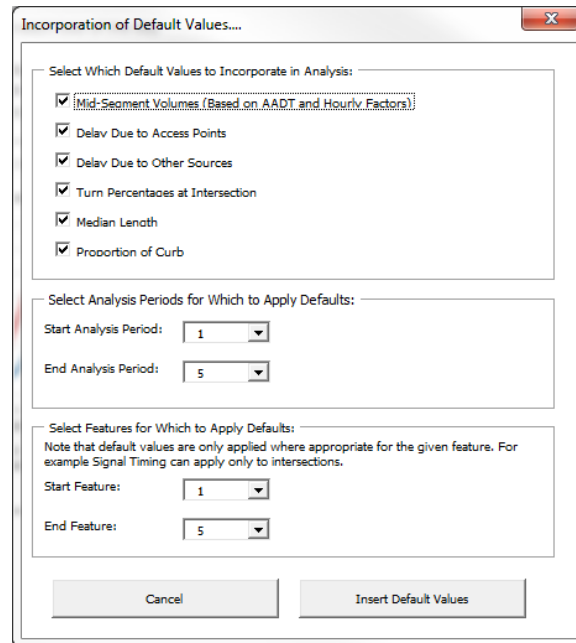
Figure 6 – Hourly AADT Distribution Data Entry in *Hourly Factors* Worksheet.

By pressing "Proceed to Step 3" button in the Hourly Factors worksheet the user can proceed to the next step. A form appears requesting that the user specify, which data items he/she wants to enter manually, and which ones default. In general, the analyst can elect to default all further entries. The default values in this form are:

1. **Mid-Segment Volumes**: Computed based on entered AADT and hourly demand distribution.
2. **Delay Due to Access Points**: This item prefills the input tables in step 3 with an average delay value based on the number of access points by area type (see final report).
3. **Delay Due to Other Sources**: This will prefill the input tables in step 3 with 0 sec/veh value as a default.
4. **Turn Percentages at Intersections**: Enabling this option will invoke a methodology described in the project final report to automatically estimate the turn percentages based on approach demand using a gravity model method.
5. **Median Length**: Based on the entered value in the "Start" worksheet, the tables in step 3 will be prefilled with the appropriate value.
6. **Proportion of Curb**: Based on the entered value in the "start" worksheet, the tables in step 3 will be prefilled with the appropriate value.

The user may specify the temporal and spatial limits for applying these default parameters. Those limits can be inserted in the second and third section in the "Incorporation of Default Values" form

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shown in Figure 7. Defaults can be applied for all time periods and features, or the user may only elect to enter defaults for some periods, while manually entering others.

Figure 7 – Incorporation of *Default Values Configuration Form*

2.2 Step 3: Detailed Analysis Periods Data Entry

In this step, ARTVAL provides detailed input tables for each 15 minutes analysis period. Users can move between worksheets "t=1", "t=2" … depending on the temporal size of the analysis. Any cell in green background indicates that the value is a default. If a default value is overridden by the user, then the background automatically turns yellow. This functionality is dynamic. Figure 8 shows a detailed study period input table for the first time period (t=1) in the analysis.

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Figure 8 – Detailed Input for *t=1* Worksheet, first 15 min Analysis Period

As an illustration, all values provided in the entry labeled "Mid-Segment 15 minute Flow Rates Per Hour" in Figure 8 are the default values, which in this case is equal to AADT times the hourly factor. If the user changes this cell value to specify field measured flow rates, then that cell is shown with a yellow background. Figure 9 illustrates this effect. After completion of this step, the user can select the "Signal Timing" tab to proceed to Step 4.
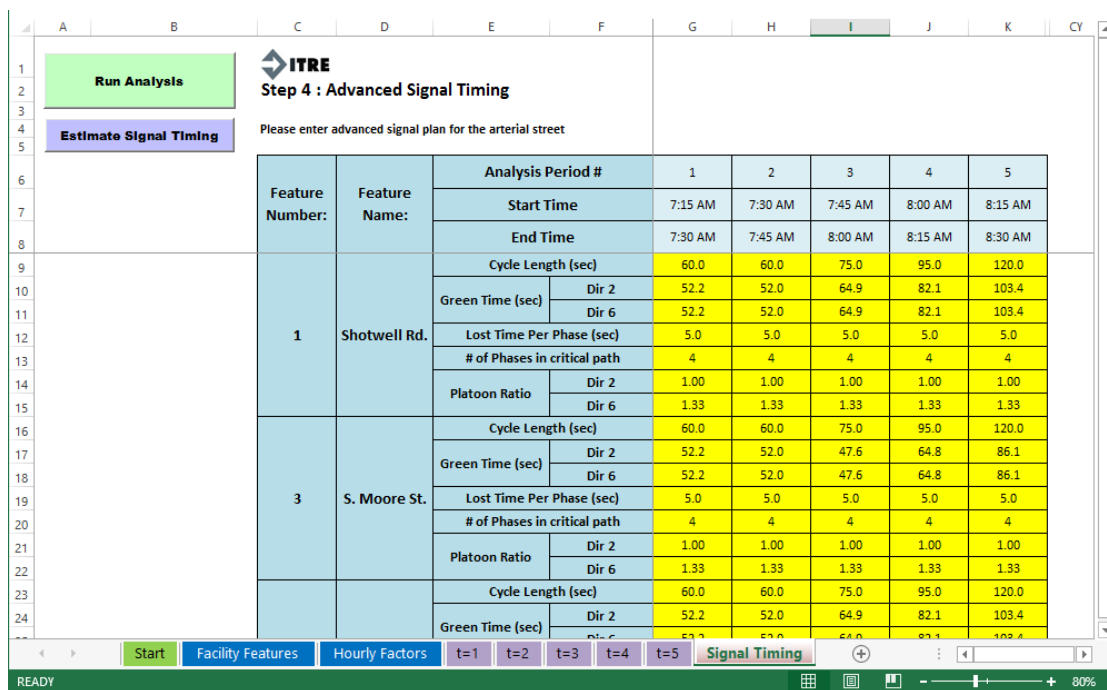

Figure 9 – Replacing Defaults with Facility Specific Entries in *t=1* Worksheet

2.3 Step 4: Signal Timing Data Entry

In this step, the user specifies signal timing data for each intersection and for each 15 minutes analysis period. All cells with yellow background must be filled as shown in Figure 10. The details of signal timing in ARTVAL consists of:

1. **Cycle Length**: which is in seconds.
2. **Green Time for each Direction**: which is the actual green time in seconds.
3. **Lost Time per Phase**: which is in seconds.
4. **Number of Phases in Critical Path:** which varies by coordination configuration.
5. **Platoon Ratio**: which is used to describe the quality of signal progression for the corresponding movement group. It is computed as the demand flow rate during the green indication divided by the average demand flow rate. Values for the platoon ratio typically range from 0.33 to 2.0.

The user can invoke the signal timing wizard to fill this table based on default parameters values provided in ARTVAL using Webster's signal timing method. Table 1 provides ARTVAL's default values for "Number of Critical Phases", "Lost Time", and "Platoon Ratio" for peak and nonpeak directions. This is done by clicking the "*Estimate Signal Timing*" button located in the top left corner of the "*Signal Timing*" worksheet. Figure 11 shows a schematic of this wizard. The top two sections of the wizard provide options for the user to select the temporal and spatial limits that the wizard should fill with signal timing data.

Figure 10 –Detailed Data Entries for *Signal Timing* Worksheet

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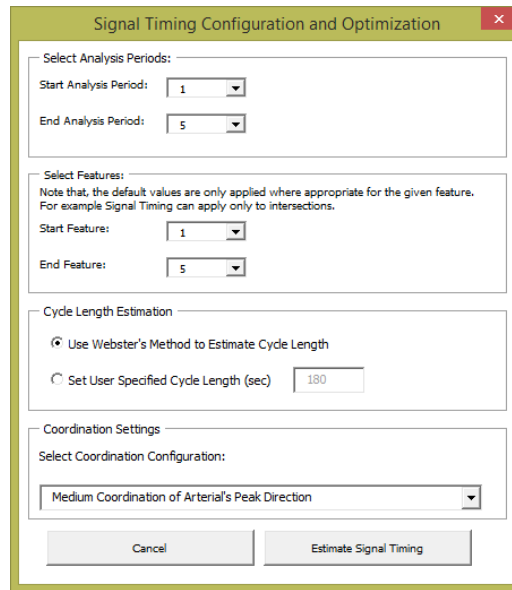at North Carolina State University

Figure 11 – Signal Timing Wizard Form

In the third section of the wizard, the user may choose between specifying an input cycle length or use Webster's optimal cycle length formula. This feature helps the user configure various signal timing plans by time of day. The signal coordination section of the wizard form gives four options to estimate what the platoon ratios in Figure 9 should be. Finally Table 1 below depicts the default values for some of the signal timing and coordination parameters listed in Figure 11.

Table 1 – Default Values for Signal Timing Parameters in Figure 11

Signal Coordination Configuration	Number of Critical Phases	Lost Time Per Phase (sec)	Platoon Ratio in Peak Direction	Platoon Ratio in Off-Peak Direction
Free Running Arterial	4	5	1.00	1.00
Medium Coordination of Arterial's Peak Direction	4	5	1.33	1.00
High Coordination of Arterial's Peak Direction	4	5	1.67	1.33
Super Street Coordination	2	5	2.00	2.00

2.4 Step 5: Performing Urban Street Analysis and Facility Performance Measures

After entering all signal timing inputs in Step 4, the user can execute the Quick Estimation Method for Urban Streets (QEM-US) described in Chapter 30 of the 2010 Highway Capacity Manual by pressing the "*Run Analysis*" button as shown in Figure 10. ARTVAL then un-hides all the output worksheets automatically. There are three types of outputs generated by ARTVAL:

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2.4.1 Detailed analysis period output

Worksheets "t=1", "t=2", etc. … display some input data echo as well as the detailed output of the associated analysis period, in both directions. The output table produces all applicable performance measures for each feature as well as for the entire facility. Figure 12 shows a schematic of the detailed analysis period output worksheet by feature (link and intersection).
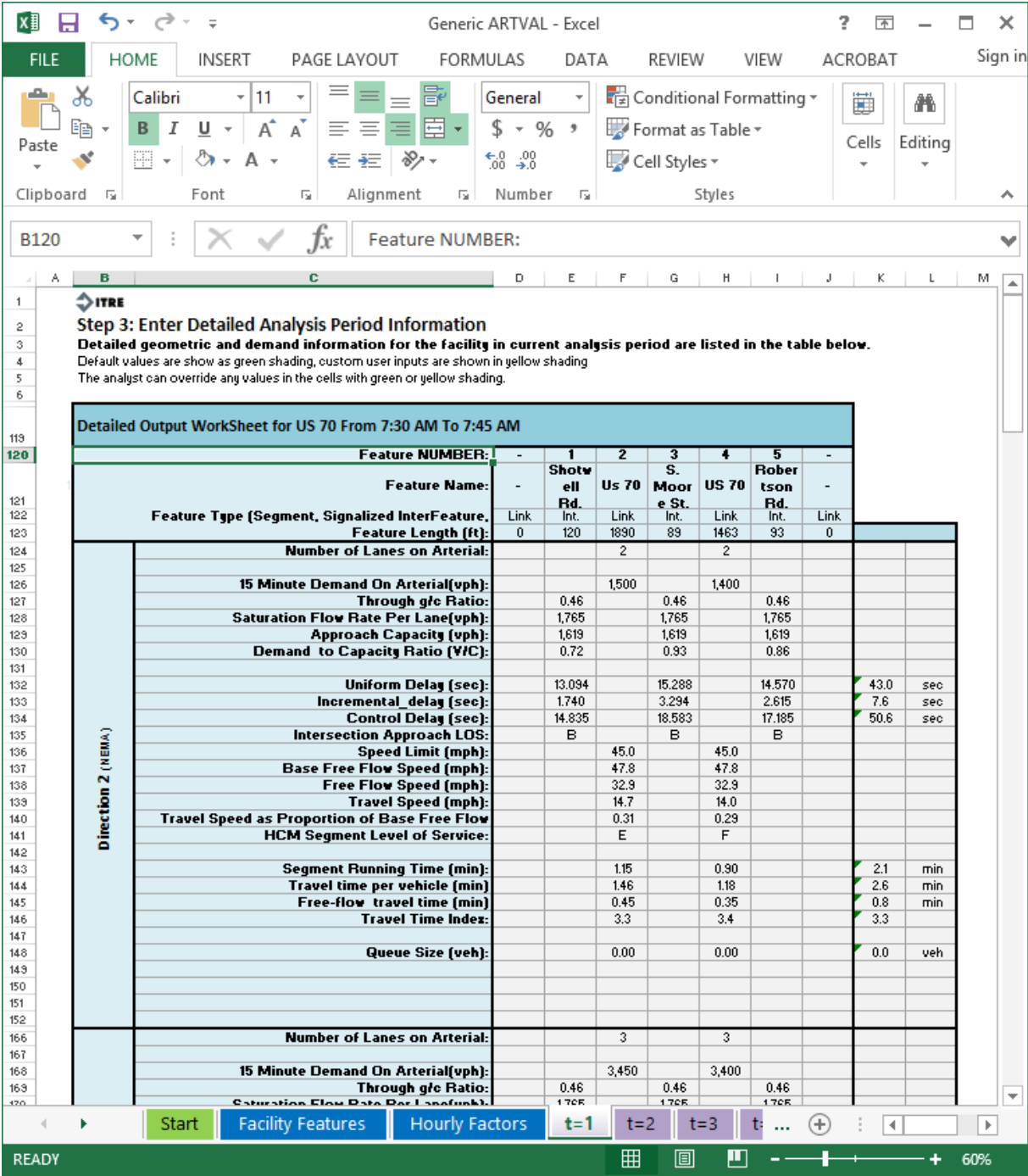

Figure 12 – Detail Analysis Period Output by Feature in "t=1" Worksheet

2.4.2 Facility summary output

In the "*Facility Summary*" worksheet, ARTVAL aggregates the outputs across all analysis periods, and provides performance measure output summarized across all analysis periods. The output provides information for each feature in the study period, as well as facility-level performance. Figure 13 shows a schematic of this output for the subject facility. The user can access this output by clicking on the "Facility Summary" tab in ARTVAL.
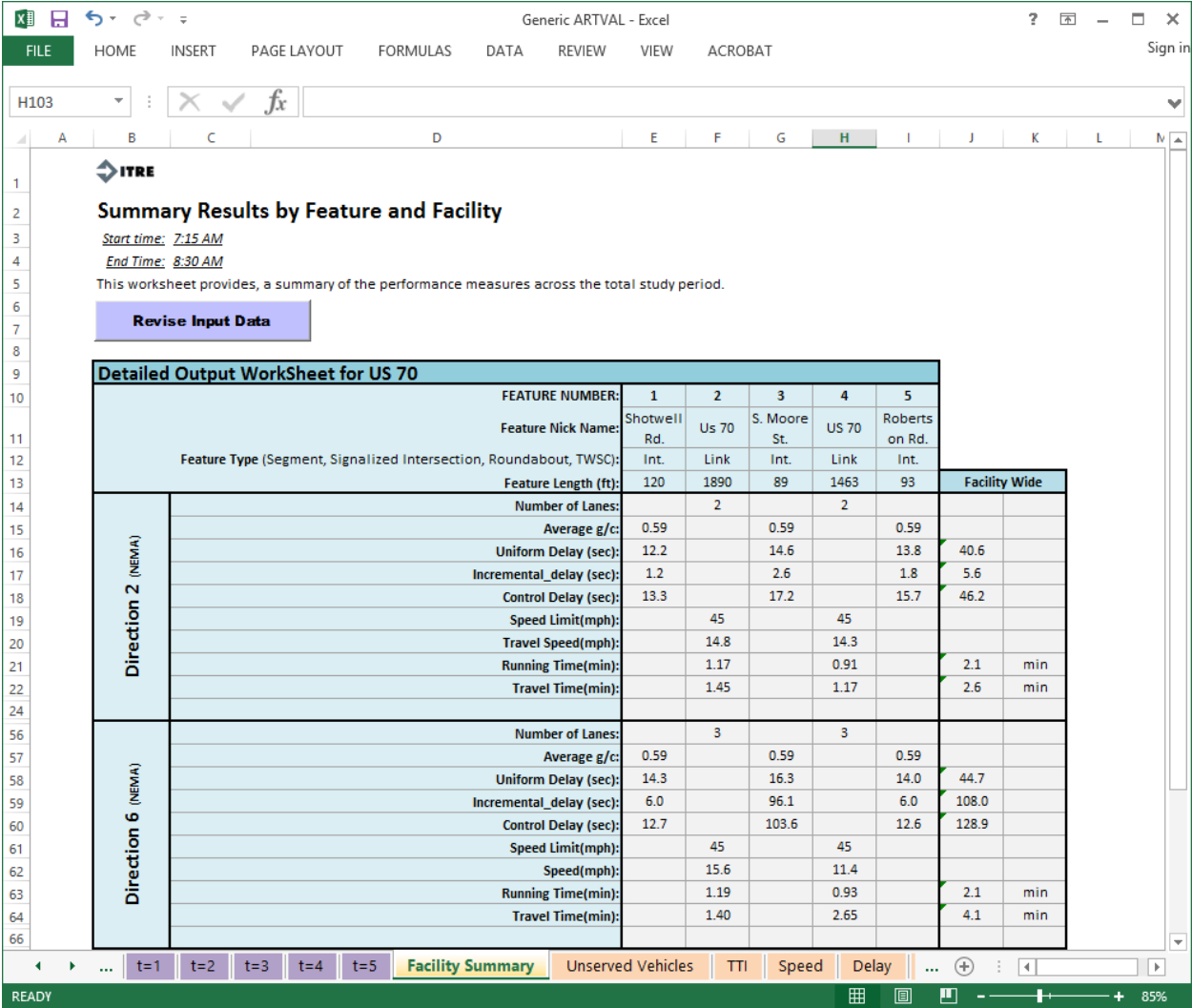

Figure 13 – *Facility Summary* Worksheet

2.4.3 Performance measure contours

Along with the detailed and summary performance measure outputs, ARTVAL produces several performance measure contours in a color coded format *(MS Excel's standard color code format)*. The color coded performance measures include "Unserved Vehicles" (number of vehicles that could not discharge during the simulation), "TTI (Travel Time Index)", "Average Travel Speed", "Control Delay", "LOS Int." (Intersection LOS) , and "LOS HCM Segment". As an illustration, Figure 14 depicts the Travel Time Index (TTI) contour output for the subject facility.
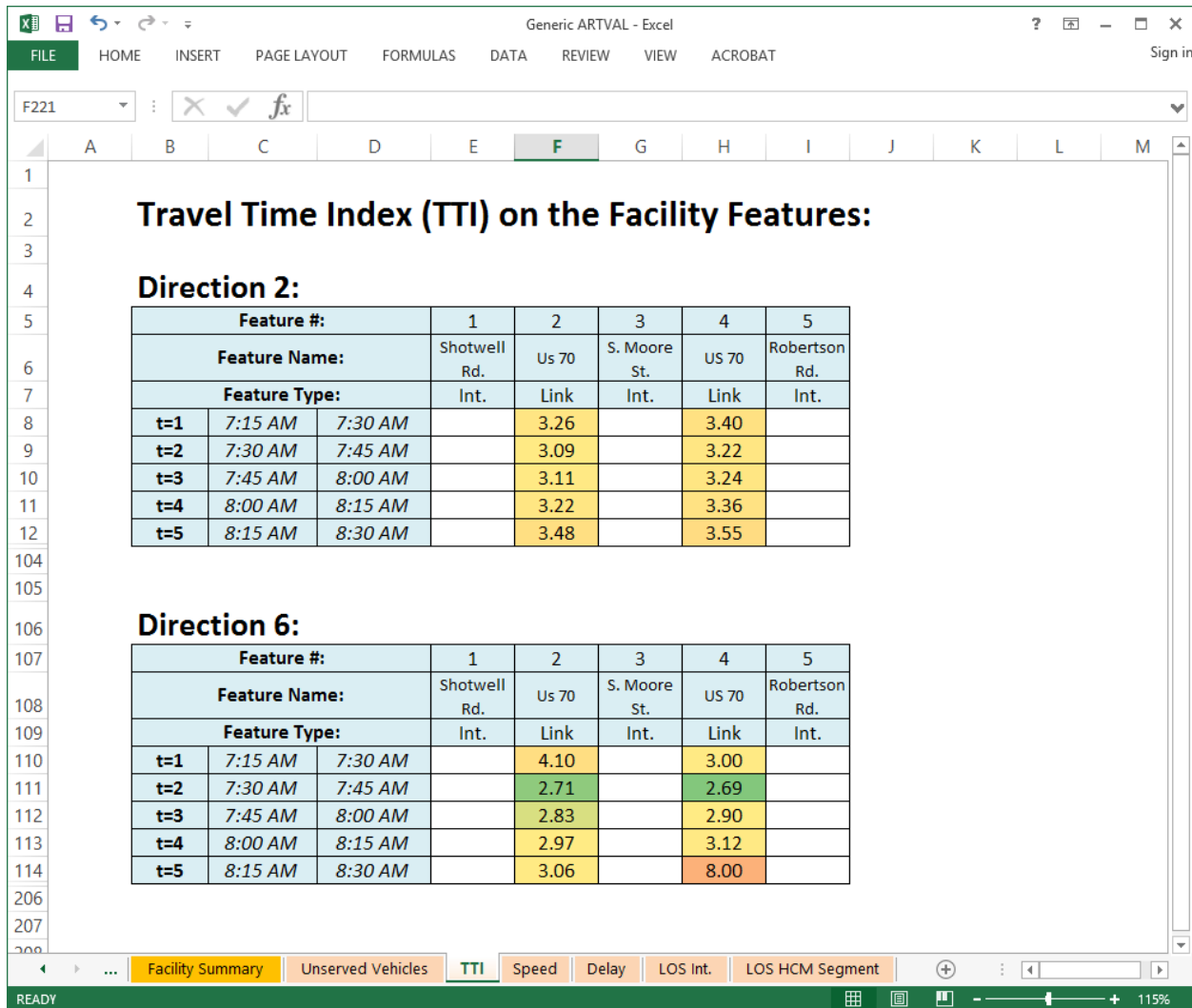

Figure 14 – Travel Time Index (TTI) contour output

After exploring all the outputs, and wanting to modify some of the inputs, the user may press the "Revise Input Data" button in the "*Facility Summary*" worksheet and will be redirected to the input pages. By pressing that button, ARTVAL reconfigures the worksheets to the previously-described input mode.

NOTE: It is recommended that the user saves the file after performing any additional analyses or revising inputs. Especially if the user wants to change inputs and compare the performance measures for different scenarios.

3. Acknowledgements

4. References

1. Highway Capacity Manual, Transportation Research Board, Washington DC, 2010

2. Schroeder Bastian, Nagui Rouphail, Billy Williams, Ali Hajbabaie, Behzad Aghdashi, Sangkey Kim, Kambiz Tabrizi, and Brian Narron, "NCDOT Project 2013-09: Delay and User Cost Estimation for Work Zones on Urban Arterials - Final Project Report", Raleigh NC, 2015

3. Hajbabaie, Ali, SangKey Kim, Bastian Schroeder, Seyedbehzad Aghdashi, Nagui Rouphail, Tai-Jin Song and Kambiz Tabrizi, "*Estimating Saturation Headways at Work Zones on Urban Arterials*", Accepted for Presentation at the 94th Annual Meeting of the Transportation Research Board, Washington, DC, January 2015.