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Study of Public Perception of Traffic Congestion in New Jersey

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Submitted by

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16. Abstract

The objective of this research project was to enhance the capabilities of the Congestion Analysis Model currently used by the NJDOT Bureau of Commuter & Mobility Strategies. The enhancements included development of a corridor-level congestion analysis and updated methodology for calculating congestion performance measures in support of the NJDOT asset management goals and analysis framework. The enhanced performance analysis model provides estimates of economic impact of congestion to supplement "Hot Spot" Analysis, such as the Bottleneck Identification and Ranking capabilities of the I-95 Corridor Coalition's Vehicle Probe Project (VPP) Suite, thereby helping to better understand economic impact of recurring bottlenecks. Additional benefits of the model enhancements include: (a) improved capabilities for identifying needs and analyzing impacts of congestion mitigation improvements on a corridor level; (b) improved capability to effectively present the benefits of specific improvement and express their monetary value; (c) improved ability to provide readily available input to capital programming and project development process; and (d) extended useful life of the Cost of Congestion Analysis Model by addressing the software compatibility issues and migration to more robust database and analytical software platform.

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EXECUTIVE SUMMARY

In order to quantify traffic congestion and its impacts on New Jersey's motorists, New Jersey Institute of Technology (NJIT) developed the New Jersey Congestion Analysis Model (NJCAM), a computer software tool that estimates congestion costs, travel delay, and mobility indicators for New Jersey highways. In 2003 and 2004 the NJCAM was used to develop quantitative measures of congestion presented in the final report for the study titled "*Alternative Performance Measures for Evaluating Congestion*".[1,2] The NJCAM software tool was delivered to the New Jersey Department of Transportation (NJDOT) and has since been used by the Department's Bureau of Commuter & Mobility Strategies in conjunction with the NJDOT Congestion Management System (CMS) to estimate costs of congestion on New Jersey highways resulting from recurring and non-recurring delays.

In the original version, the NJCAM estimated monetary impacts of congestion on a regional scale, providing summary reports by County, MPO, and for the entire State. However, since the NJCAM was first introduced, the Department and the Bureau of Commuter & Mobility Strategies have increasingly been focusing on identifying problem areas and analyzing potential congestion mitigation measures on a corridor level, so as to maximize the benefits of capital investments and support smart asset management strategies. In this context, it was desirable to enhance the NJCAM software tool to enable calculation of congestion related costs, as well as monetary benefits of potential improvements in specified highway corridors.

Meeting this need required expansion of the software code and modification of the calculation methodology that provided for the following new functionalities:

- Selection of desired corridor: either by specifying roadway SRI and milepost, or by selecting a set of highway links that are designated as part of a corridor, or by applying custom corridor selection criteria;
- Specification of evaluation parameters such as analysis year, cost of travel time, and congestion severity benchmarks.

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[1] "Mobility and the Costs of Congestion in New Jersey – 2003 Update", Report to Governor McGreevey's Blue Ribbon Commission on Transportation, New Jersey Institute of Technology, September 2003.

[2] Spasovic, L. and J. Rowinski, "Alternative Performance Measures for Evaluating Congestion", Final Report to the New Jersey Department of Transportation, New Jersey Institute of Technology, April 2004.

- Summary reports with tabulation and graphical presentation of key congestion performance measures for the selected corridor.

In addition to adding the corridor-level analysis capabilities, the enhancements of the NJCAM included revisions in the assumptions and methodology for calculating congestion indicators. In response to the comments from the stakeholders, the Bureau of Commuter & Mobility Strategies decided to consider as congestion-related delay the difference between the actual travel time and travel time at Level of Service C. In other words, it was adopted that the reference speed and travel time representing uncongested travel conditions reflect Level of Service C, rather than free-flow conditions as was the case in the previous version of the NJCAM. This should be considered when comparing the congestion indicators calculated using the new (enhanced) version of NJCAM to those produced with previous versions of the calculation tool.

Finally, the NJCAM software tool was redesigned in order to address the software compatibility issues, update the development platform, and improve the work flow and user interface. The application was redesigned in VB.NET and SQL Server Compact Edition (SQL CE) as database management platform, replacing Microsoft Access that was used in previous versions. The user interface was redesigned to enable more user-friendly data entry and importing of data tables from NJCMS. The new interface also gives the user more flexibility with choosing the value of analysis parameters and the types of reports to be generated. The redesigned software tool also features more streamlined analysis and reporting functionalities.

BACKGROUND

Traffic congestion has numerous negative effects on the mobility of people and goods, including longer and unreliable trip travel times, and significant mobile source air pollution and wasted fuel resulting from inefficient vehicle operation. Increased travel times can result in lost wages, decreased labor productivity, and increased costs of truck operations. It also impacts the manufacturing industry and the service sector by forcing businesses to keep larger inventories in order to safeguard against variability in delivery schedules, thus decreasing efficiency of just-in-time logistics. Furthermore, traffic congestion often leads to stress in drivers and passengers, which can adversely affect traffic safety, as well as their quality of life and labor productivity.

NJDOT is taking various measures to mitigate traffic congestion and its negative effects, including infrastructure improvements, highway capacity expansion, implementation of Intelligent Transportation Systems (ITS), expansion of transit options, and traffic demand management policies. In the time of growing needs for improvements in the transportation system and increasingly constrained financial resources to satisfy the needs, NJDOT is turning to asset management as the tool of rationalizing investments in transportation infrastructure. The key components of the asset management are:

- understanding the system and its performance,
- understanding the system's needs,
- understanding how each action will impact the system, and
- selecting and implementing the actions that provide the maximum benefit using the available resources.

To be able to gauge the level of success of the undertaken measures, NJDOT utilizes a number of information technology and management tools to quantify the congestion on New Jersey roadways. These tools include New Jersey Congestion Management System (NJCMS), probe vehicle data and analysis tools, such as I-95 Corridor Coalition Vehicle Probe Project (VPP) Suite, aerial imagery of critical interchanges and intersections, traffic analysis models and count data.

In order to quantify traffic congestion and its impacts on New Jersey's motorists, NJIT developed NJCAM, a computer software tool that estimates congestion costs, congestion related travel delay, and mobility indicators for New Jersey highways. In

2003 and 2004,[3,4] the NJCAM was used to develop quantitative measures of congestion presented in the final report for the study titled "*Alternative Performance Measures for Evaluating Congestion*". The study results were presented to the general public and received wide media coverage including several newspapers, television, and radio news programs. In addition, the report was distributed to transportation professionals and policy makers. NJCAM uses the data from NJCMS database to calculate travel delays and relevant congestion indicators, and then adds the demographic and socio-economic statistics to estimate economic impacts of congestion on the commuters in New Jersey. The NJCAM outputs include a variety of congestion indicators, such as: total travel delay due to congestion, total cost of congestion, Travel Rate Index (TRI), and Roadway Congestion Index (RCI). While the model has been in practical use for several years, a number of important enhancements were identified that would help better quantify the road congestion in New Jersey.

[3] "Mobility and the Costs of Congestion in New Jersey – 2003 Update", Report to Governor McGreevey's Blue Ribbon Commission on Transportation, New Jersey Institute of Technology, September 2003.

[4] Spasovic, L. and J. Rowinski, "Alternative Performance Measures for Evaluating Congestion", Final Report to the New Jersey Department of Transportation, New Jersey Institute of Technology, April 2004.

OBJECTIVES

NJDOT Bureau of Commuter & Mobility Strategies has been using the NJCAM in conjunction with the NJCMS to estimate annual costs of congestion on New Jersey highways resulting from recurring and non-recurring delays. In the original version, the NJCAM estimated monetary impacts of congestion on a regional scale, providing summary reports by County, MPO, and for the entire State. However, since the NJCAM was first introduced the Department and the Bureau of Commuter & Mobility Strategies have increasingly been focusing on identifying problem areas and analyzing potential congestion mitigation measures on a corridor level, so as to maximize the benefits of capital investments and support smart asset management strategies. In this context it was desirable to enhance the NJCAM software tool to enable calculation of congestion related costs, as well as monetary benefits of potential improvements in specified highway corridors. This required a software development effort that would expand the existing model by adding the following new features (functionalities):

- Selection of desired corridor: either by specifying roadway SRI and milepost by selecting a set of highway links that are designated as part of a corridor, or by applying custom corridor selection criteria;
- Specification of evaluation parameters such as analysis year, cost of travel time, and congestion severity benchmarks.
- Summary reports with tabulation and graphical presentation of key congestion performance measures for the selected corridor.
- In addition to adding the corridor-level analysis capabilities, another objective of this project was to address the NJCAM software compatibility issues, streamline the software development platform, improve the work flow and improve the user interface.

SUMMARY OF REVISIONS TO THE NEW JERSEY CONGESTION ANALYSIS MODEL (NJCAM)

Revisions of the Calculation Methodology

In order to better capture the impact of congestion from the user's perspective, the assumptions and calculation methodology was modified for the following performance indicators:

a) Vehicle recurring delay;

b) Wasted fuel due to congestion;

c) Disaggregation of congestion impacts by average commuter.

Changes in calculation methodology for each of these indicators are described in the following sections. A review of complete calculation methodology is provided in Appendix A.

Calculation of Vehicle Recurring Delay

The most significant change in the new (revised) version of NJCAM is the method of determining traffic delay that can be attributed to congestion. In previous versions of NJCAM, it was assumed that any increase in travel time above the free-flow travel time reflects a delay caused by congestion. Based on the previous research,[5] feedback from the stakeholders, and suggestions from related transportation planning forums, the Bureau of Commuter & Mobility Strategies determined that most motorists in New Jersey would not consider driving conditions reflecting levels of service A, B, and C as congested. Further deterioration in traffic conditions and related reduction in speed would be considered to be "congestion related", and these conditions are described by the levels of service D, E, and F.

Hence, in the revised NJCAM only the travel delay relative to the maximum travel time at LOS C is counted as a congestion-related vehicle recurring delay. The recurring delay is calculated for each highway link, for each hour of the day. If speed and travel time on a link reflect LOS A, B, or C, the recurring delay will be considered to be equal

[5] Spasovic, L. and J. Rowinski, "Alternative Performance Measures for Evaluating Congestion", Final Report to the New Jersey Department of Transportation, New Jersey Institute of Technology, April 2004.

to zero. For this reason, the 'maximum' function is used in the formula for calculating recurring delay as follows:

$$D_{i,h}^{(r)} = \text{Max}\left[\left(\frac{L_i}{S_{i,h}} - t_{i,LOS(C)}\right) \times VOL_{i,h}, 0\right], \quad S_{i,h} > 0 \tag{1}$$

where:

$D_{i,h}^{(r)}$ – Total vehicle-hours of recurring delay on link i during hour h.

Max – Largest value assumed by a real-valued continuous function defined on a closed interval

L_i – Length of the link i [mi].

$S_{i,h}$ – Estimated average (congested) speed on link i during hour h [mph].

$t_{i,LOS(C)}$ – The maximum travel time on link i that corresponds to LOS C [h/veh].

$VOL_{i,h}$ – Total vehicle volume on link i during hour h [veh].

The link length (L_i), estimated average congested speed ($S_{i,h}$), and total hourly vehicle volume by link and by hour of the day ($VOL_{i,h}$), are obtained from NJCMS database. The maximum travel time corresponding to LOS C $\left(t_{i,LOS(C)}\right)$ on link i is calculated using the following formula:

$$t_{i,LOS(C)} = \frac{t_{i,(f)}}{p_{LOS(C)}} \tag{2}$$

where:

$t_{i,LOS(C)}$ – The maximum travel time on link i that corresponds to LOS C [h/veh].

$t_{i,(f)}$ – Free-flow travel time on link i.

$p_{LOS(C)}$ – User-defined percent of free-flow speed corresponding to LOS C.

It is suggested that the percent of free-flow speed corresponding to LOS C be set to values suggested in the Highway Capacity Manual as follows:

a) For freeways, minimum speed reflecting LOS C is 96% of the free-flow speed

b) For arterials, the minimum speed reflecting LOS C is 77% of the free-flow speed

The calculated delay, by link and hour of the day, is then aggregated to obtain total recurring delay attributed to congestion for a highway segment, corridor, or region (e.g. a county, MPO, or statewide), and it can be summarized by facility type and peak period (e.g. morning peak period and/or afternoon peak period).

Calculation of Fuel Consumption and Wasted Fuel

In NJCAM the fuel consumption is calculated as a function of vehicle speed on a link during each hour of the evaluation, and it is estimated for two generic vehicle types: autos and trucks. It is assumed that reduced speed due to congestion would result in higher fuel consumption. The difference between the fuel consumption when there is no congestion and fuel consumption when traffic is congested is referred to as "wasted fuel due to congestion." As in the case of travel delay, in the new version of NJCAM the congested conditions are described by the LOS D, E, and F. The LOS is determined based on the estimated average (prevailing) speed on a link in a given hour of the day obtained from the NJCMS database.

The NJCAM also distinguishes between the wasted fuel caused by *recurring congestion*, and that caused by *non-recurring congestion* (e.g. due to traffic incidents such as motor-vehicle crashes, disabled vehicles, blocked roadway, work zones, special events, adverse weather, etc.). The 'maximum' function is used in the calculation formula to ensure that 'wasted fuel' is considered only when vehicles travel at speeds lower than the minimum speed at LOS C. It is assumed that both the actual speed and the speed at the LOS C are sub-optimal in terms of fuel efficiency.

With all parameters taken into consideration, the amount of wasted fuel due to recurring congestion is calculated based on the following formula:

$$rG_{v,i,h} = Max\left[\left(g_v(S_{i,h}) - g_v(S_{i,LOS(C)})\right), 0\right] \times VOL_{i,h}^{(v)} \times L_i \qquad (3)$$

where:

$rG_{v,i,h}$ – Total gallons of fuel wasted due to recurring congestion by vehicle type v on link i during hour h.

$g_v(S)$ – Fuel consumption of vehicle type v at speed S. The calibrated fuel

consumption functions $g_v(S)$ for two vehicle types, autos and trucks, are discussed in Appendix A, NJCAM Calculation Methodology.

$S_{i,h}$ – Estimated average (congested) speed on link i during hour h [mph].

$S_{i,LOS(C)}$ – Minimum speed at LOS C on link i.

$VOL_{i,h}^{(v)}$ – Total volume (number of vehicles) of vehicle type v on link i during hour h.

L_i – Length of the link i [mi].

The non-recurring delay is delay caused by the reduction in travel speed due to traffic incidents, relative to the average (congested) speed in prevailing travel conditions without incidents. Thus, the amount of wasted fuel due to non-recurring congestion is calculated as a difference in fuel consumptions in average (recurring) traffic conditions and traffic conditions caused by an incident:

$$nG_{v,i,h} = Max\left[\left(g_v\left(S_{i,h}^{(nr)}\right) - g_v\left(S_{i,h}\right)\right), 0\right] \times VOL_{i,h}^{(v)} \times L_i \quad (4)$$

where:

$nG_{v,i,h}$ – Total gallons of fuel wasted due to non-recurring congestion by vehicle type v on link i during hour h.

$g_v(S)$ – Fuel consumption of vehicle type v at speed S.

$S_{i,h}^{(nr)}$ – Estimated average (congested) speed on link i during hour h in travel conditions caused by a traffic incident (in mph).

$S_{i,h}$ – Estimated average (congested) speed on link i during hour h [mph].

$VOL_{i,h}^{(v)}$ – Total volume (number of vehicles) of vehicle type v on link i during hour h.

L_i – Length of the link i [mi].

Calculation of Cost of 'Lost' (Unproductive) Time for Commuters

The congestion induced delay and costs are difficult to relate to until they are expressed relative to a subject group, such as per capita, per driver, or per trip. Since NJCMS is a

link-based database and contains no origin-destination information, disaggregation by average trip or by traveler (driver) is difficult and practically cannot be done based on the NJCMS data alone. To better capture the impact of congestion that would be more intuitive to general public, the previous version of NJCAM used a disaggregation category defined as “affected persons.” An affected person was defined as a person who lives or works in an analysis region (e.g. a county, an MPO, or the State) and therefore experiences congestion within that region on a daily basis.

After reviewing the current congestion reporting practice, and discussions with the NJDOT Bureau of Commuter & Mobility Strategies, it was concluded that previously used definition of affected persons was too broad. It included people who may not be traveling on a daily basis, and especially during peak hours. As a result, the average cost of congestion per affected person was an underestimate of the true user cost experienced by the peak hour commuters. To address this shortcoming, the new version of NJCAM disaggregates congestion measures by “***commuter.***” Commuters are defined in NJCAM as workers who travel during morning peak hours or afternoon peak hours. The data for estimating number of daily commuters by county, MPO, or for the entire State can be obtained from the National Household Travel Survey (NHTS) database, or from the U.S. Census Transportation Planning Products Program (CTPP).

The aforementioned data sources provide estimated number of commuter trips by the hour of day (looking at either departure or arrival times). It should be noted that the estimate of the number of commuters used in the analysis should be consistent with peak hours (both morning and afternoon) selected as the analysis period for calculation purposes in NJCAM.

Upgrade of the NJCAM to VB.NET

Earlier versions of NJCAM were developed using Microsoft Access versions ‘2000’ and ‘2003’. Due to compatibility issues, NJCAM was not functioning after installing new versions of Access. To avoid similar problems in the future, NJCAM was redesigned in VB.NET development framework and the database was migrated to SQL Server Compact Edition (SQL CE) database management platform. The VB.NET provides greater flexibility to develop powerful Windows-based desktop applications and allows designing more user-friendly graphical user interface. Object-oriented programming approach will allow easier software maintenance and deployment, and will make it easier to develop and deploy any future expansion of the software. SQL CE is a compact, simplified version of Microsoft SQL Server. It is file-based and optimized for mobile and desktop applications with embedded database. It is free and can be easily deployed on Windows desktop computers without a standard SQL server installation.

As SQL CE is embedded in the application, it eliminates dependency on software versions of MS Access or SQL server installed on the user's desktop computer.

Change in User Interface and Process Flow

In response to a request by NJDOT, the user interface was redesigned to enable more user-friendly data-entry and importing of data-tables from NJCMS. The new interface also gives the user more flexibility with choosing the values of analysis parameters and the types of reports to be generated.

The process flow has been changed to streamline the analysis and reporting functions. In particular, the calculation procedure has been separated from the aggregation procedure and reporting function. This change allows the user to generate different levels of reports without repeating the calculations.

This section provides an overview of modifications in the user interface and process flow. A more detailed description is provided in Appendix B User Manual.

Modification of the Process Flow

NJCAM has been redesigned partially in order to improve and streamline the process flow. Revisions of the calculation process and inclusion of additional NJCMS tables in the model database increased the complexity of the data flow and application itself. The application process flow has been modified in order to accommodate these revisions, improve the user's flexibility in interaction with the model, and eliminate unnecessary steps in analysis.

Figure 1 shows the process flow. Before performing an analysis, the user has to first make sure that all input data and analysis parameters (both general and county-specific) are correct and current (first three steps in Figure 1). After completing data input steps, the user can run the congestion analysis model, which calculates Measures of Effectiveness (MOEs) on a link level (MOEs are described in Appendix A). In the next step if the user wants to create a custom corridor report, the user has to define custom corridor before generating the report. In the next step, the user selects a type of report (county summaries, MPO summaries, one page State summary, or user defined custom corridor summary), and then runs an aggregation procedure. The reports are saved in an Excel spreadsheet. In the final but optional step, the user can display data in tabular format on the screen or can export data into Excel spreadsheet, DBF file, or Comma Separated Value (CSV) file.

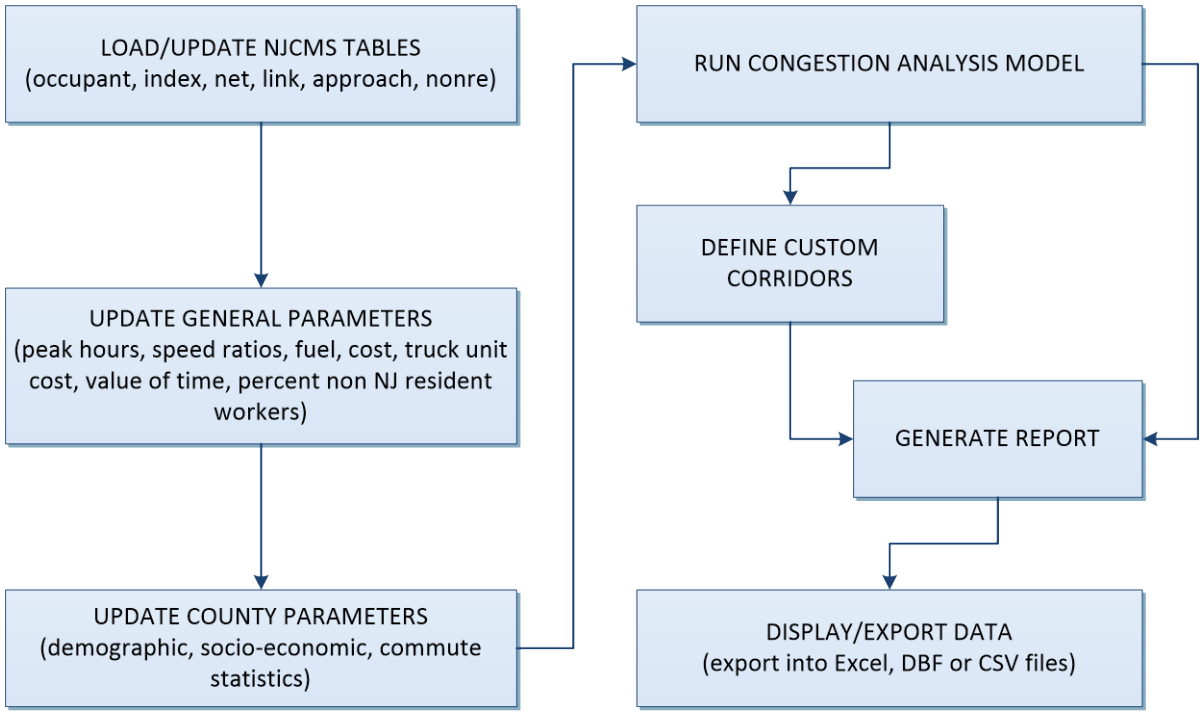

Figure 1 – NJCAM Version 4.0.1 general process flow

Modification of the User Interface

To facilitate implementation of the new process flow and related data integration, the user interface has been modified.

NJCAM Startup Screen

Figure 2 shows the new design of the “NJCAM Startup” Screen, the opening screen of the application. The screen is divided into two parts, “Navigation Bar” on the left part of the screen, and “Work Area” on the right part of the screen. From this screen, the user can select to update the database (including roadway network data from NJCMS and analysis parameters), run the analysis, define custom corridors, generate reports, or quit the application. The default selected screen at application start up is the “About” screen.

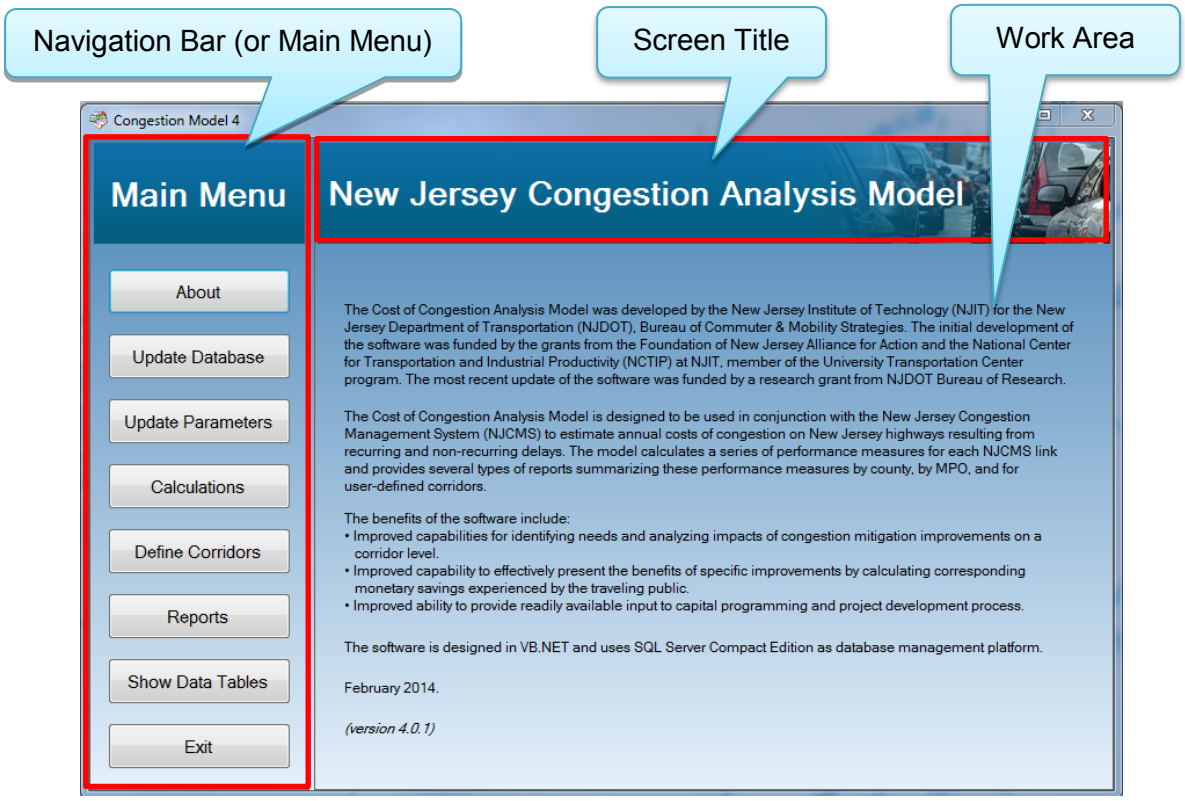

Figure 2 – Startup screen of New Jersey Congestion Analysis Model

Roadway Network Database Update Screen

Clicking on the “Update Database” button in the “Navigation Bar” takes the user to the roadway network database update screen shown in Figure 3. This screen allows the user to load NJCMS output files by clicking on the appropriate “Select File” button. The “Open File…” dialog box appears to allow the user to select the appropriate file as shown in Figure 4. In order to prevent loading wrong files, please verify the title of the “Open File…” Dialog box and select the correct file. Clicking on the “Update Database” button allows the user to load data from the Excel spreadsheet, DBF file, or CSV files.

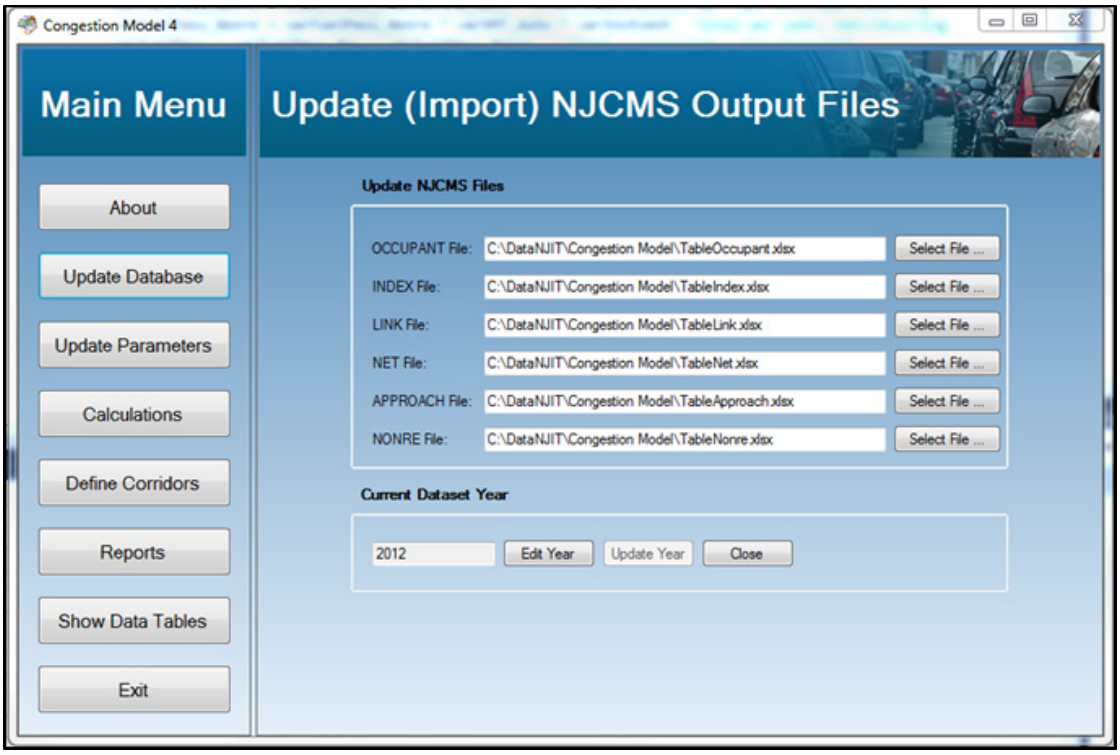

Figure 3 – Roadway network database update screen

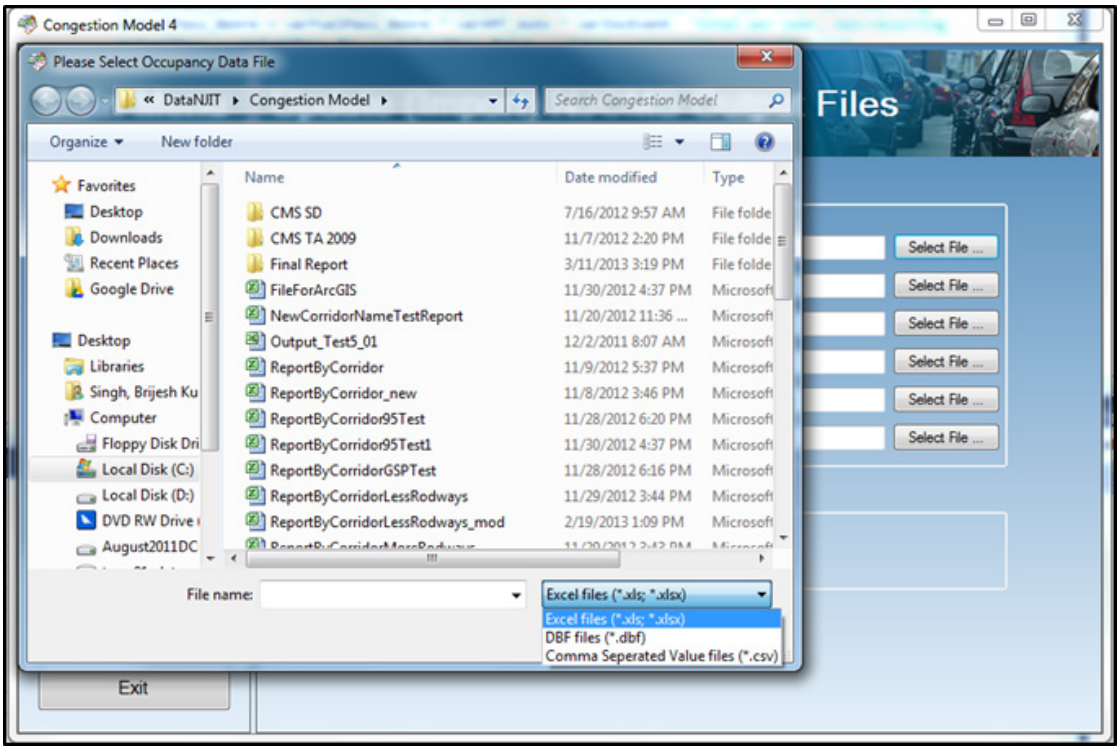

Figure 4 – Select roadway database file to load into the application

After the file has been successfully loaded, a dialog box displays the message shown in Figure 5. A path to the location of the loaded file is also saved and displayed in a text box next to the file description and the “Select File” button. These paths serve as references to the user indicating locations and file names of the NJCMS tables that are currently loaded in the NJCAM.

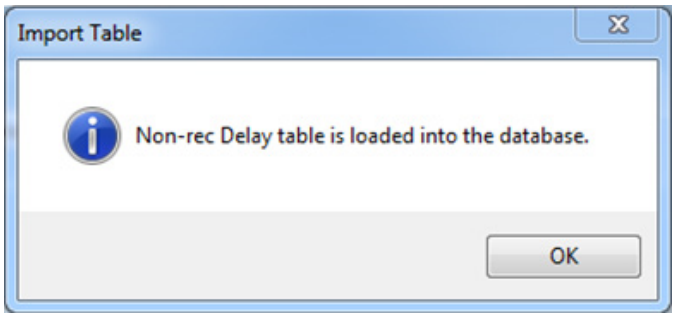

Figure 5 – File import confirmation dialog box

On the screen shown in Figure 3, the user can also reference the model year of the roadway network dataset currently loaded in the database.

Update Parameters Screen

The Parameter Update screen, shown in Figure 6, can be accessed from the main menu by clicking on the “Update Parameters” button. The user is allowed to update values for speed ratios (needed for the level of service on network links), and select a.m. and p.m. peak hours. The user has the flexibility in selecting the actual start and end hours for peak periods. The user can also specify the number of days per year considered in the analysis, as well as the statewide average fuel costs, per-mile truck operating cost, statewide average hourly wage, value of time as a percent of average wage and number of commuters in New Jersey.

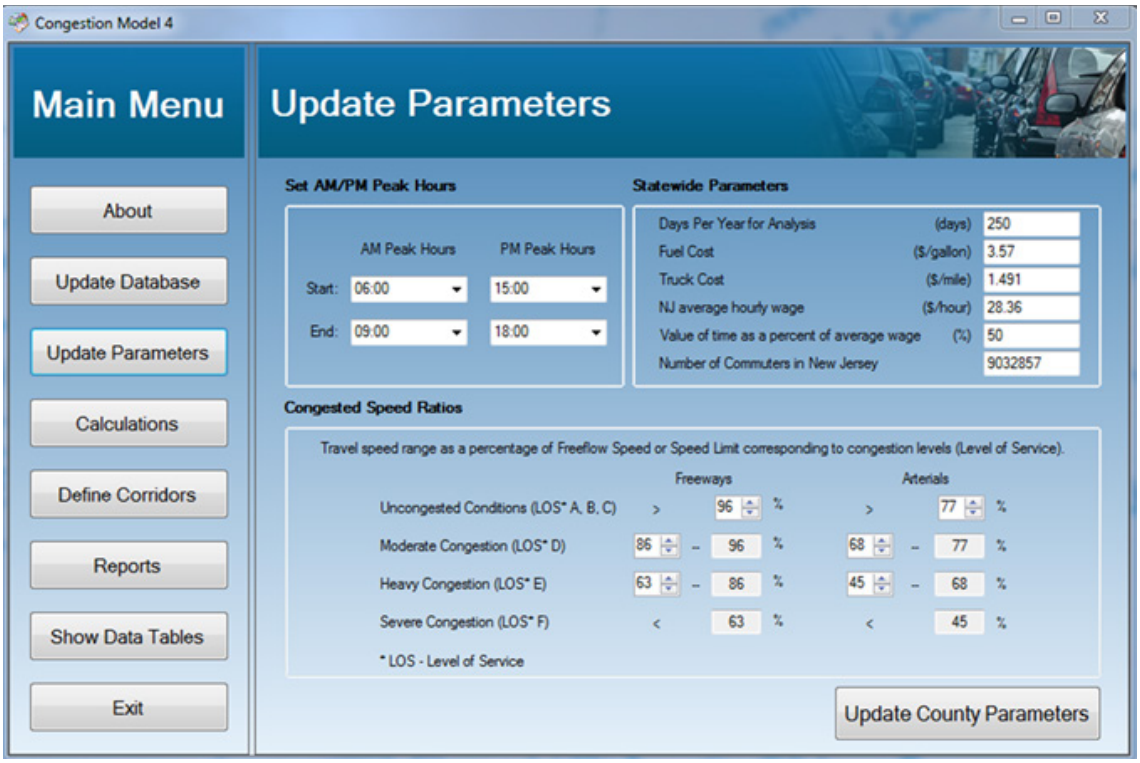

Figure 6 – Parameters and analysis setting update screen

From this screen, the user can access the “County Parameter Update” form, shown in Figure 7, by clicking on the “Update County Parameters” button. On this form, the user can browse through the county-specific parameters and update the values for each county. The parameters include:

- Average county hourly wage per worker (dollars / hour);
- Percent of travel within the county by county residents [%];
- Number of commuters (Commuters include employed county residents and non-residents commuting to the county for work).

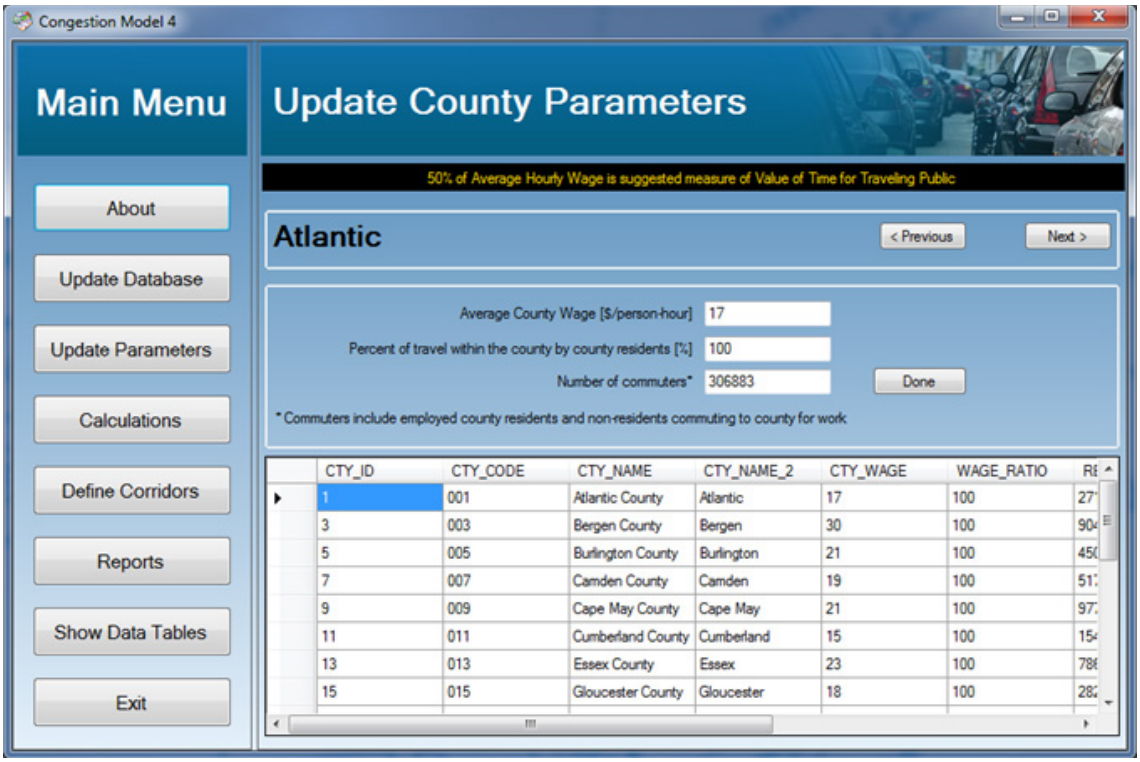

Figure 7 – County parameter update screen

Executing the Calculation Procedure

After updating the network database, county statistics, and analysis settings, the user can access the “Calculation of Performance Measures” screen by clicking on the “Calculations” button on the “Navigation Bar”. The user can execute the calculation procedure by clicking on the “Run Calculation Procedure” button on the “Calculation of Performance Measures” screen, as shown in Figure 8. The progress bar appears on the screen which updates the user about the status of the calculation procedure. During this process all performance and congestion measures are calculated on the link level and saved in the model database.

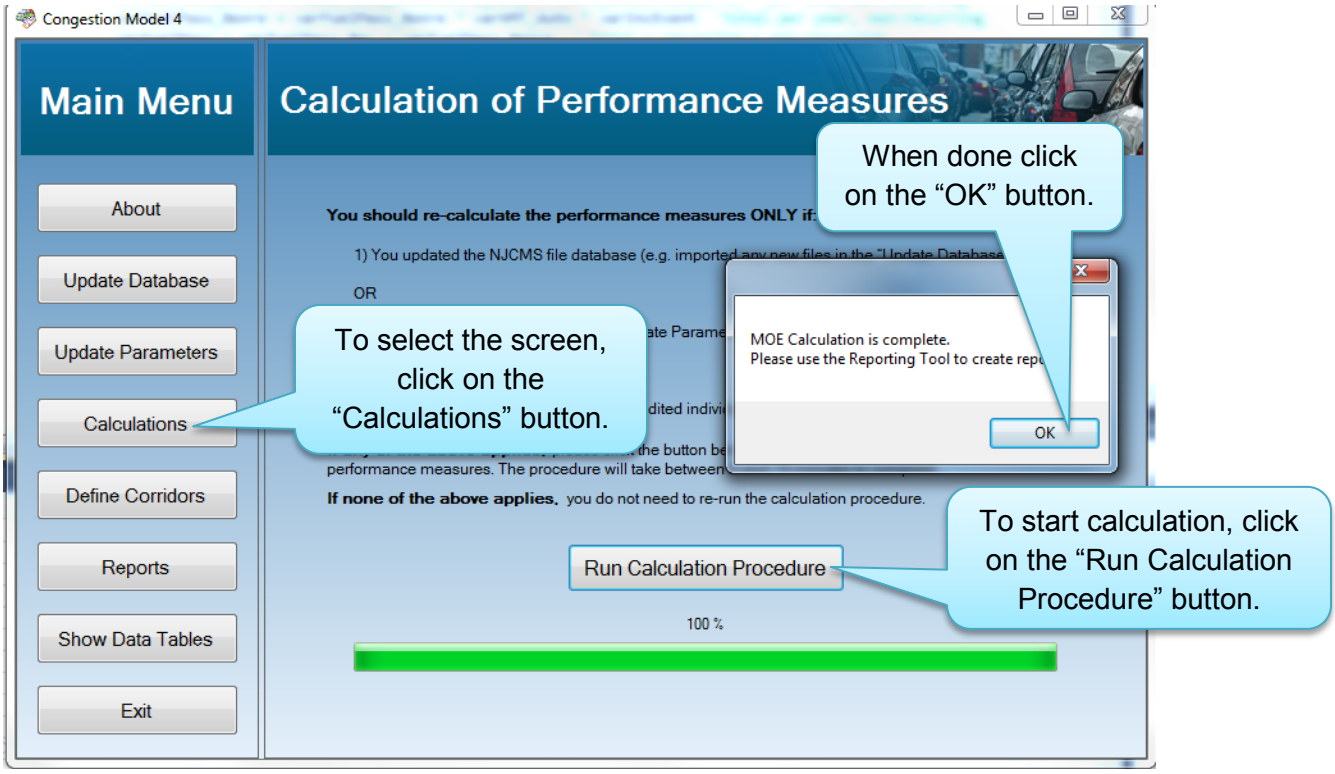

Figure 8 – Progress bar of calculation procedure

Once the calculation is complete and all measures of effectiveness (MOEs) are calculated for the entire network, a dialog box informs the user and directs him/her to the reporting module.

Define Corridors Screen

The user can access the “Define Corridors” screen by clicking on the “Define Corridors” button on the “Navigation Bar”. The “Define Corridors” screen, as shown in Figure 9, gives the user the ability to define custom corridors for analysis.

A dropdown box allows the user to select previously defined corridors and gives the user the ability to edit or update the corridor parameters, or the user can define new corridor by clicking on the “Define New Corridor” button. A more detailed description about editing/updating a previously defined corridor or to define a new corridor is provided in Appendix B User Manual.

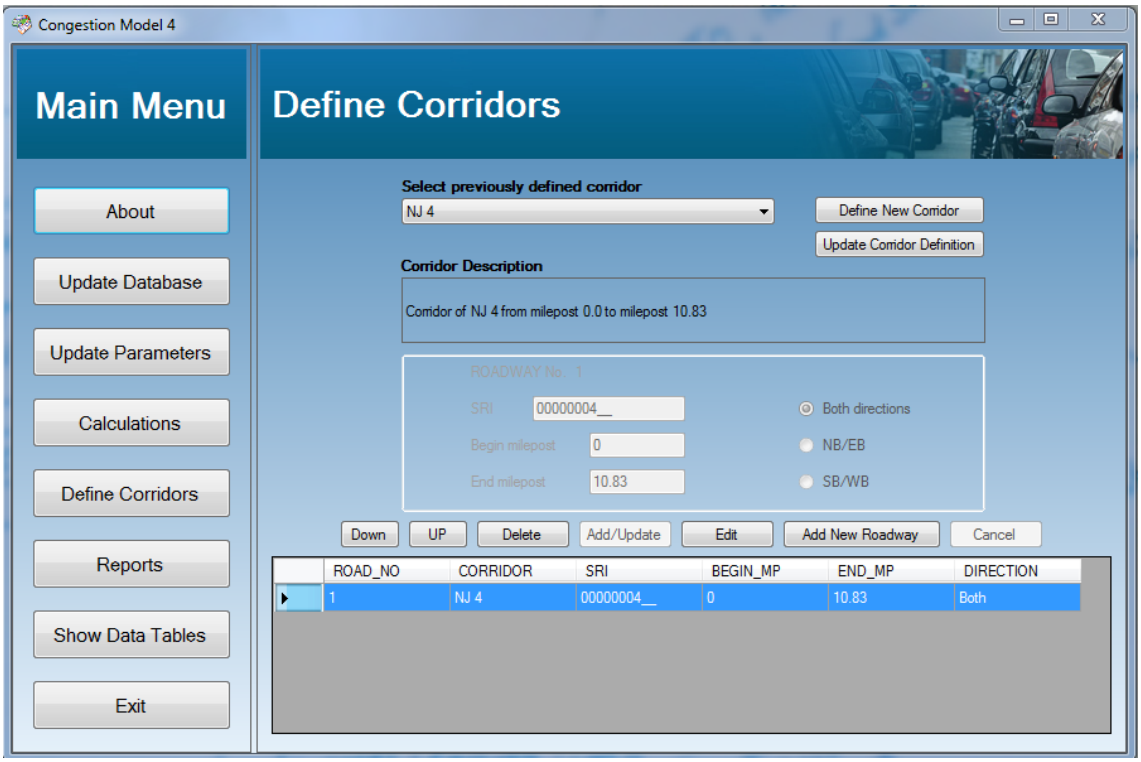

Figure 9 – Define Corridor screen

Report Selection and Generation Screen

The “Generate Reports” screen, shown in Figure 10, can be accessed by clicking on the “Reports” button on the “Navigation Bar”. This screen allows the user to select the report type by:

- Level of aggregation (county or MPO), and summary period (daily or annual summary). The selected summary period option only applies to delays and VMT, whereas costs and wasted fuel are only reported on an annual basis;
- The user can also choose to include a congestion severity sheet in the report, which summarizes congested vs. uncongested VMT and travel delay by county or MPO;
- The user can also choose a one page summary for State by clicking on the “State Summary” button;
- Report for a corridor can be generated by clicking on the “Corridor Summary” button.

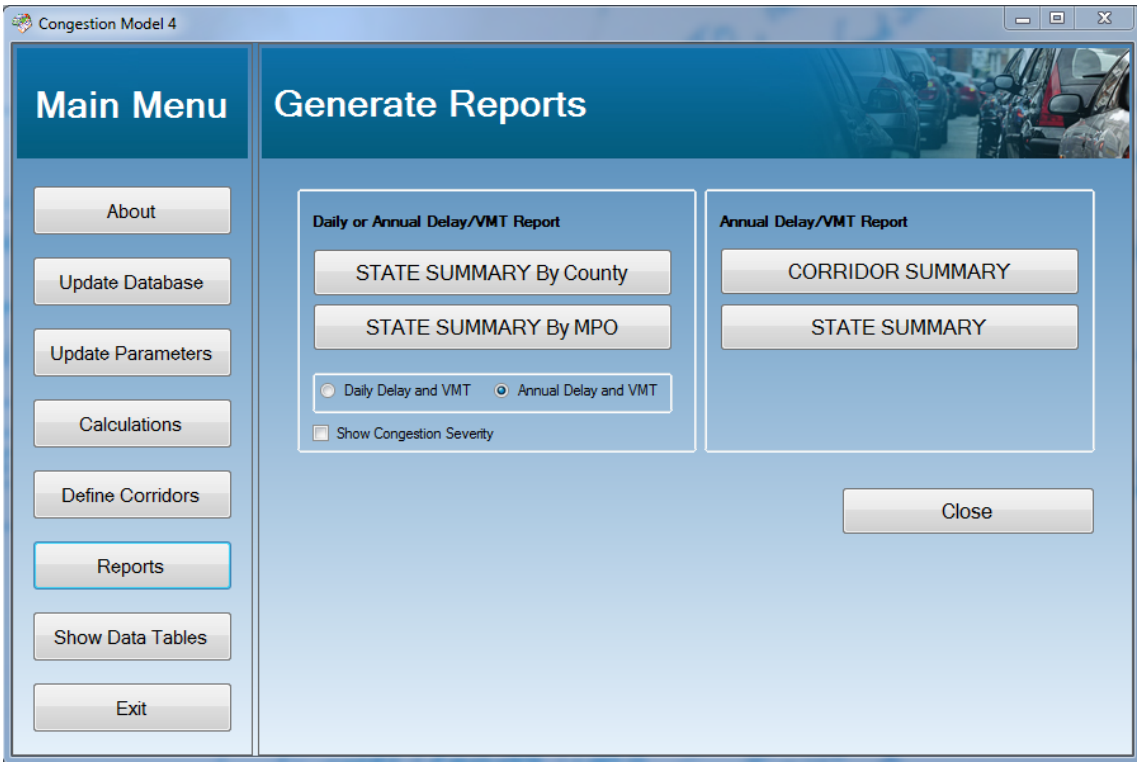

Figure 10 – Report selection screen

After clicking on an appropriate button for the desired report, the user is asked to provide a location for saving the report. After that, the aggregation procedure aggregates the link level MOEs to the user-specified aggregation level and saves the summaries in the report. During the execution of the aggregation procedure, the report generation progress bar screen, shown in Figure 11, provides the user with information about the current status of the aggregation process. An Excel report file gets opened when report generation is complete.

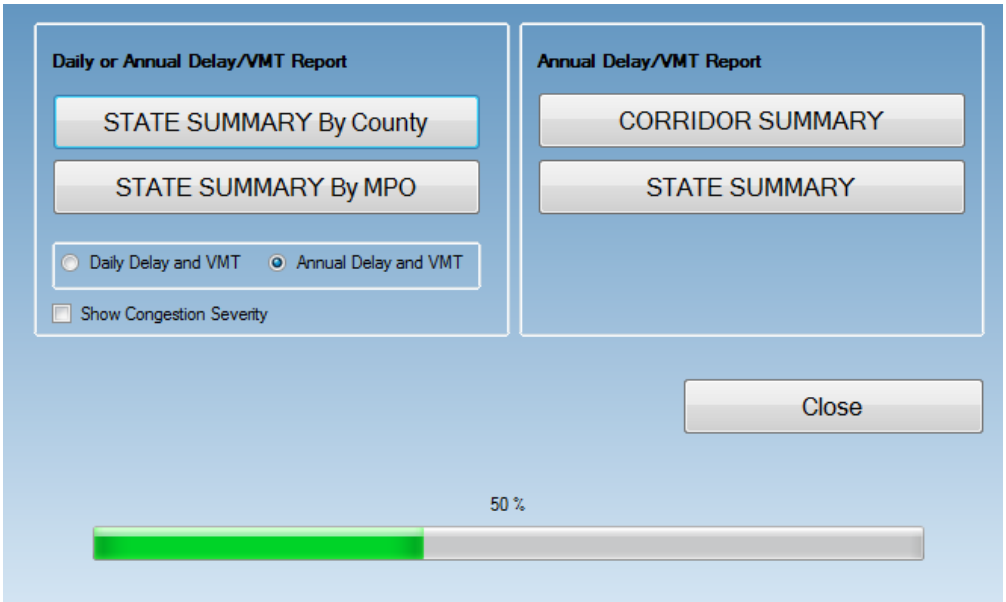

Figure 11 – Progress bar of report generation

Clicking on the “Corridor Summary” button on the Generate Reports screen opens a new window (as shown in Figure 12) giving the user an option to select a corridor from the list of existing corridors, or to add a new corridor. To add a new corridor, the user must click on the “Add New Corridor” button. Clicking on the “Add New Corridor” button will take the user to the module for adding a new corridor. More detail about adding a new corridor is provided in Appendix B: User’s Manual. To generate the report for a previously defined corridor, select it from the dropdown list and click on the “Generate Report” button.

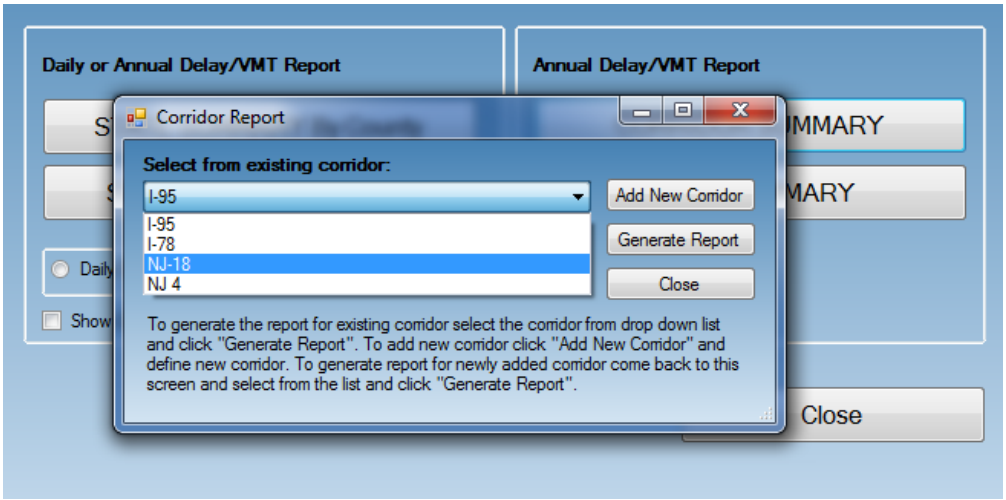

Figure 12 – Corridor selection screen for corridor report

Once the “Generate Report” button is clicked, the “Save File” dialog box will open. Enter the file name of the new report and click “Save”. An Excel report file will get opened when the report generation is completed.

Show Data Tables Screen

The “Show Data Tables” screen, shown in Figure 13, can be accessed by clicking the “Show Data Tables” button on the Navigation Bar. This screen allows the user to view input tables as well as the MOE’s calculation table within the application screen by selecting the table from the drop down list and click on the “Show Table” button.

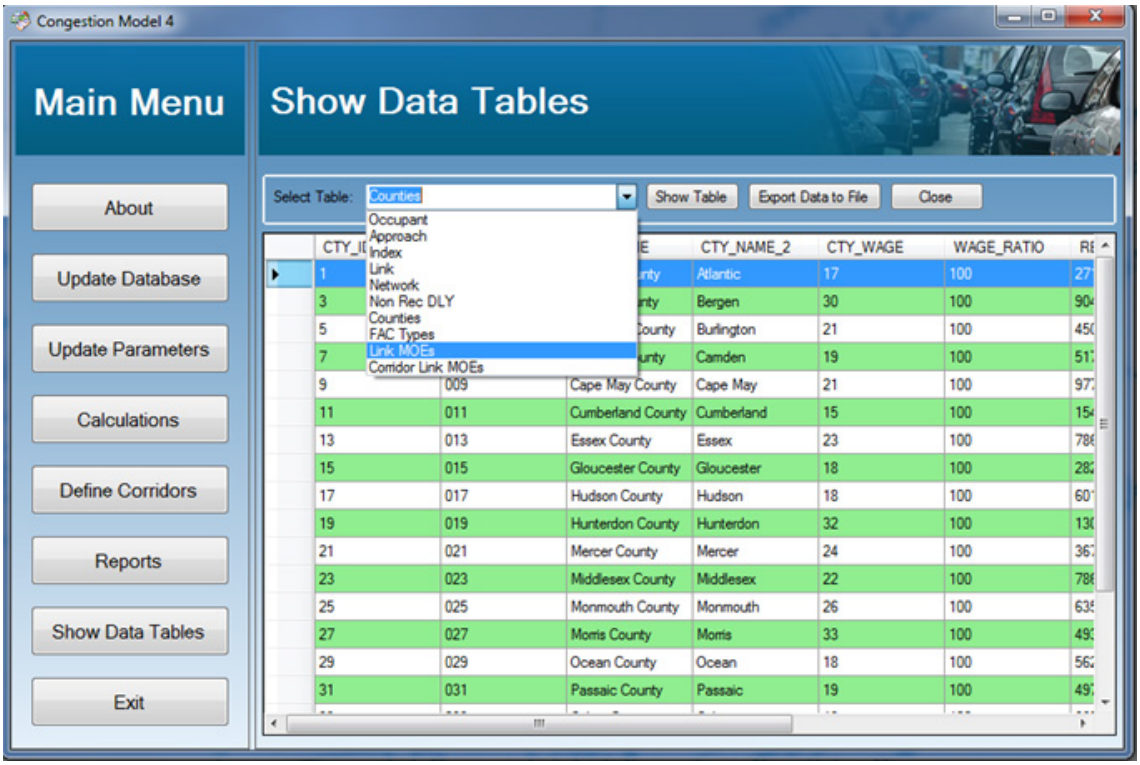

Figure 13 – Show data table screen

The user can also export the selected table into an Excel spreadsheet, DBF file, or CSV file by clicking the “Export Data to File” button. Once the “Export Data to File” button is clicked, the “Save File” dialog box will open, as shown in Figure 14. Enter the file name and select the file type and click on the ”Save” button.

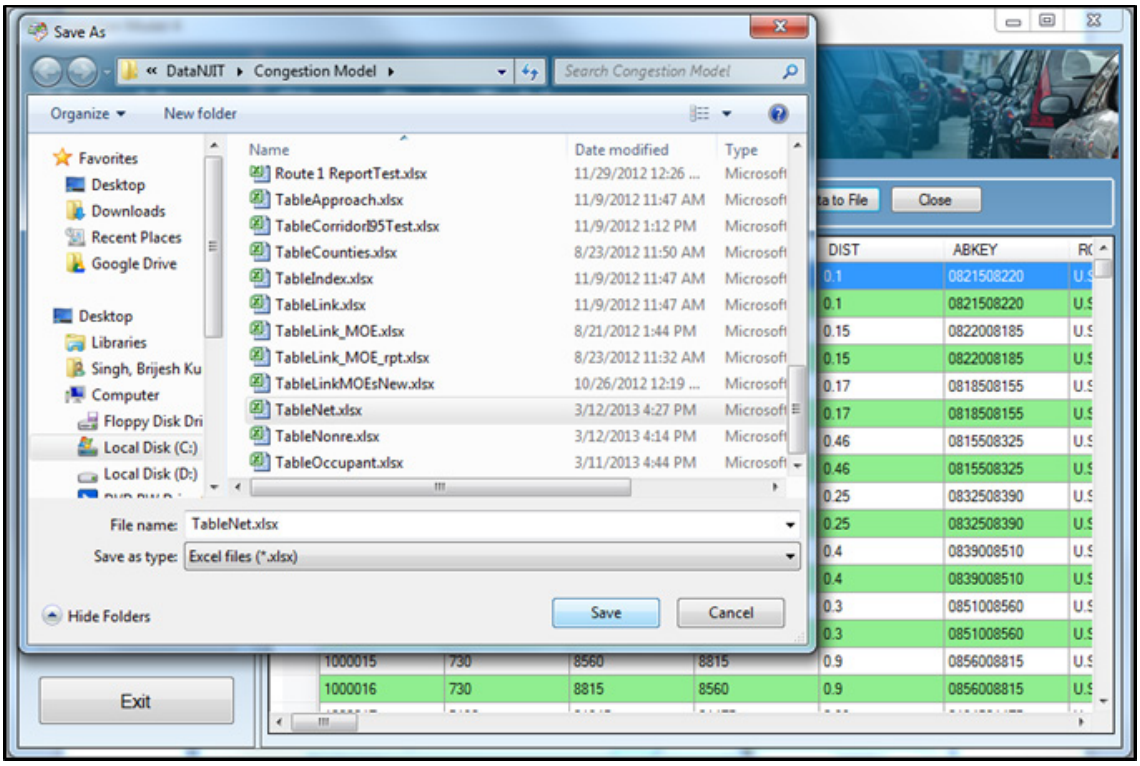

Figure 14 – Export data to file

Redesigned Reporting

The reporting function of the NJCAM has been completely redesigned. The new report format, exported into Excel spreadsheets, provides a more detailed breakdown of congestion measures.

The user can generate the following reports:

- State Summary by County
- State Summary by MPO
- One page State Summary (new report template added)
- Corridor Summary (new report template added).

The first two summary reports provide output data in the form of tables and charts organized in a set of worksheets within a single Excel file. The following worksheets are included:

- Table of Contents
- Input Parameters
- Speeds
- VMT (vehicle-miles traveled)
- RCI, TRI & TTI,6
- Vehicle Delays
- Person Delays
- Costs
- Wasted Fuel
- Congestion Severity (optional)
- Charts (only in “State Summary by County” report).

Table 1 provides a list of tables included in the reports for “Input Parameters” worksheet (for all the reports).

Table 1 - List of Tables in Input Parameters Worksheet in Report

#	Table Name/Description
Worksheet: Input Parameters	
1.	CMS Input Dataset Reference Year
2.	Peak Periods Start and End Times (hh:mm)
3.	Statewide Parameters
4.	Minimum LOS Speeds Relative of Free-flow or Speed Limit
5.	Report Preparation

[6] RCI stands for Roadway Congestion Index; TRI stands for Travel Rate Index; TTI stands for Travel Time Index.

The first worksheet “Table of Contents” provides the complete list of tables in each worksheet. The list is in the form of hyperlink so clicking on the list item will take the user directly to the table.

Tables 2-5 provide a list of tables included in the reports by worksheet. The two reports (county summary and MPO summary) have the same table and worksheet structure, but the aggregation level is different. The former summarizes congestion measures by county and facility type, and the latter provides the same summary by MPO and facility type. Each table also provides statewide average values of corresponding congestion measure by facility type and by statewide total for all roadways.

The congestion severity worksheet is optional and the user decides whether it will be included in the report or not.

Table 2 – List of Tables in the Summary Report by County or MPO

#	Table Name/Description	Summary Term
Worksheet: Speeds		
1.	Lane Miles [mi]	-
2.	Free-flow Speed [mph]	Daily average weighted by hourly VMT
3.	Peak Period Average Speed [mph]	Daily average weighted by hourly VMT
4.	Average AM Peak Speed [mph]	Daily average weighted by hourly VMT
5.	Average PM Peak Speed [mph]	Daily average weighted by hourly VMT
Worksheet: VMT		
1.	Total 24-Hour VMT (thousands)	Annual or Daily
2.	24-Hour Vehicles Per Lane (thousands)	Annual or Daily
3.	Peak Period VMT (thousands)	Annual or Daily
4.	AM Peak VMT (thousands)	Annual or Daily
5.	PM Peak VMT (thousands)	Annual or Daily
Worksheet: RCI, TRI & TTI		
1.	Average Roadway Congestion Index (RCI)	Daily weighted average
2.	Average Travel Rate Index (TRI)	Daily weighted average
3.	Average Travel Time Index (TTI)	Daily weighted average

Table 3 – List of Tables in the Summary Reports by County or MPO (continued)

#	Table Name/Description	Summary Term
Worksheet: Vehicle Delays		
1.	Total 24-Hour Vehicle Delay [000 vehicle-hours]	Annual or Daily
2.	24-Hour Recurring Vehicle Delay [000 vehicle-hours]	Annual or Daily
3.	24-Hour Non-Recurring Vehicle Delay [000 vehicle-hours]	Annual or Daily
4.	Total Delay During AM and PM Peak Periods [000 vehicle-hours]	Annual or Daily
5.	Recurring Delay During AM and PM Peak Periods [000 vehicle-hours]	Annual or Daily
6.	Non-Recurring Delay During AM and PM Peak Periods [000 vehicle-hours]	Annual or Daily
7.	Total Peak Period Delay - Autos [000 vehicle-hours]	Annual or Daily
8.	Recurring Peak Period Delay - Autos [000 vehicle-hours]	Annual or Daily
9.	Non-Recurring Peak Period Delay - Autos [000 vehicle-hours]	Annual or Daily
10.	Total Peak Period Delay - Trucks [000 vehicle-hours]	Annual or Daily
11.	Recurring Peak Period Delay - Trucks [000 vehicle-hours]	Annual or Daily
12.	Non-Recurring Peak Period Delay - Trucks [000 vehicle-hours]	Annual or Daily
Worksheet: Person Delays		
1.	Total Person-Hours of Delay During Peak Periods - AUTOS ONLY [000 hours]	Annual or Daily
2.	Person-Hours of Recurring Delay During Peak Periods - AUTOS ONLY [000 hours]	Annual or Daily
3.	Person-Hours of Non-Recurring Delay During Peak Periods - AUTOS ONLY [000 hours]	Annual or Daily

Table 4 – List of Tables in the Summary Reports by County or MPO (continued)

#	Table Name/Description	Summary Term
Worksheet: Costs		
1.	Total Annual Cost of Congestion [$ million]	Annual
2.	Total Annual Cost of Recurring Congestion [$ million]	Annual
3.	Total Annual Cost of Non-Recurring Congestion [$ million]	Annual
4.	Total Annual Cost of Lost/Unproductive Time Due to Congestion [$ million]	Annual
5.	Cost of Unproductive Time Due to Recurring Congestion [$ million]	Annual
6.	Cost of Unproductive Time Due to Non-Recurring Congestion [$ million]	Annual
7.	Total Annual Cost of Fuel Wasted Due to Congestion [$million]	Annual
8.	Cost of Wasted Fuel Due to Recurring Congestion [$ million]	Annual
9.	Cost of Wasted Fuel Due to Non-Recurring Congestion [$ million]	Annual
10.	Total Annual Cost of Congestion for Auto Users/Passengers [$million]	Annual
11.	Overall Cost of Recurring Congestion - AUTOS [$ million]	Annual
12.	Overall Cost of Non-Recurring Congestion - AUTOS [$ million]	Annual
13.	Total Annual Cost of Congestion for Truck Operators [$million]	Annual
14.	Overall Cost of Recurring Congestion - TRUCKS [$ million]	Annual
15.	Overall Cost of Non-Recurring Congestion - TRUCKS [$ million]	Annual
16.	Overall Annual Cost of Unproductive Time - AUTOS [$ million]	Annual
17.	Cost of Unproductive Time Due to Recurring Congestion - AUTOS [$ million]	Annual
18.	Cost of Unproductive Time Due to Non-Recurring Congestion - AUTOS [$ million]	Annual
19.	Overall Annual Cost of Unproductive Time - TRUCKS [$ million]	Annual
20.	Cost of Unproductive Time Due to Recurring Congestion - TRUCKS [$ million]	Annual
21.	Cost of Unproductive Time Due to Non-Recurring Congestion - TRUCKS [$ million]	Annual
22.	Overall Annual Cost of Wasted Fuel - AUTOS [$ million]	Annual

#	Table Name/Description	Summary Term
23.	Cost of Wasted Fuel Due to Recurring Congestion - AUTOS [$ million]	Annual
24.	Cost of Wasted Fuel Due to Non-Recurring Congestion - AUTOS [$ million]	Annual
25.	Overall Annual Cost of Wasted Fuel - TRUCKS [$ million]	Annual
26.	Cost of Wasted Fuel Due to Recurring Congestion - TRUCKS [$ million]	Annual
27.	Cost of Wasted Fuel Due to Non-Recurring Congestion - TRUCKS [$ million]	Annual
Worksheet: Wasted Fuel		
1.	Total Annual Wasted Gallons of Fuel Due to Congestion [Gal-millions]	Annual
2.	Wasted Gallons of Fuel Due to Recurring Congestion [Gal-millions]	Annual
3.	Wasted Gallons of Fuel Due to Non-Recurring Congestion [Gal-millions]	Annual
4.	Wasted Gallons of Fuel - Autos [Gal-millions]	Annual
5.	Wasted Gallons of Fuel - Trucks [Gal-millions]	Annual
6.	Wasted Gallons of Fuel - Under Uncongested Condition [Gal-millions]	Annual
7.	Wasted Gallons of Fuel - Under Moderate Congestion [Gal-millions]	Annual
8.	Wasted Gallons of Fuel - Under Heavy Congestion [Gal-millions]	Annual
9.	Wasted Gallons of Fuel - Under Severe Congestion [Gal-millions]	Annual

Table 5 – List of Tables in the Summary Reports by County or MPO (continued)

#	Table Name/Description	Summary Term
Worksheet: Congestion Severity		
1.	Recurring Vehicle Delay on Uncongested Links [000 veh-hours]	Annual or Daily
2.	Recurring Vehicle Delay on Moderately Congested Links [000 veh-hours]	Annual or Daily
3.	Recurring Vehicle Delay on Heavily Congested Links [000 veh-hours]	Annual or Daily
4.	Recurring Vehicle Delay on Severely Congested Links [000 veh-hours]	Annual or Daily
5.	Recurring Person Delay on Uncongested Links [000 person-hours]	Annual or Daily
6.	Recurring Person Delay on Moderately Congested Links [000 person-hours]	Annual or Daily
7.	Recurring Person Delay on Heavily Congested Links [000 person-hours]	Annual or Daily
8.	Recurring Person Delay on Severely Congested Links [000 person-hours]	Annual or Daily
9.	VMT in Uncongested Traffic (thousands)	Annual or Daily
10.	VMT Under Moderate Congestion (thousands)	Annual or Daily
11.	VMT Under Heavy Congestion (thousands)	Annual or Daily
12.	VMT Under Severe Congestion (thousands)	Annual or Daily
13.	Recurring Truck Delay on Uncongested Links [000 veh-hours]	Annual or Daily
14.	Recurring Truck Delay on Moderately Congested Links [000 veh-hours]	Annual or Daily
15.	Recurring Truck Delay on Heavily Congested Links [000 veh-hours]	Annual or Daily
16.	Recurring Truck Delay on Severely Congested Links [000 veh-hours]	Annual or Daily

Charts are included only in the “State Summary by County” report. The reason for this is that they provide a statewide break down of congestion measures which are not dependent on the aggregation level of the report (it is always a statewide summary). Therefore, it is enough to generate charts only once for a given dataset. It was decided to place these charts into the summary report by county as it is expected that this report would be most frequently used. A list of charts provided in the report is given in Table 6.

Table 6 – List of Charts and Tables in the CHARTS Worksheet of the Summary Report by County

#	Table Name/Description	Summary Term
Worksheet: Charts		
1.	Vehicle Delay During AM and PM Peak Hours: Recurring vs. Non-recurring (000 hours)	Annual or Daily
2.	Person Delay During AM and PM Peak Hours: Recurring vs. Non-recurring - ONLY AUTOS (000 hours)	Annual or Daily
3.	Congested vs. Uncongested VMT (000 VMT)	Annual or Daily
4.	Annual Costs of Unproductive Time vs. Wasted Fuel ($ millions)	Annual
5.	Annual Costs of Congestion for Autos vs. Trucks ($ millions)	Annual
6.	Total Annual Cost of Congestion: Recurring vs. Non-recurring ($ millions)	Annual
7.	Hours of Delay per Affected Person	Annual or Daily
8.	Annual Cost of Congestion per Affected Person	Annual
9.	Annual Cost of Wasted Fuel per Affected Person	Annual

If the user generates a “State Summary by County” report, one additional Excel file is created with “_GIS” appended in user supplied name for the report. This output file contains four spreadsheets:

- Costs: provides total cost, recurring cost, and non-recurring cost for each county;
- Person Delays: provides freeway, principal arterials, other arterials, and all roadways person delay for each county;
- VMT: provides VMT for each county; and
- RCI, TRI & TTI: provides RCI, TRI & TTI for each county.

This output file can be interfaced with GIS software to map out New Jersey counties and display congestion information by county.

Tables 7 & 8 provide a list of tables included in the “One page State Summary” and “Corridor Summary” report respectively.

Table 7 – List of Tables in the One Page State Summary Report

#	Table Name/Description	Summary Term
Worksheet: Report		
1.	Vehicle Miles Traveled (thousands)	Annual
2.	RCI, TRI and TTI	Annual
3.	Annual Costs($) and Delay (Hrs) per Affected person	Annual
4.	Vehicle Delay AM & PM Peak Period (thousand vehicle Hrs)	Annual
5.	Person Delay (thousand Hrs)	Annual
6.	AM and PM Peak Period Cost of Congestion ($ Millions)	Annual

Table 8 – List of Tables in the Corridor Summary Report

#	Table Name/Description	Summary Term
Worksheet: Report		
1.	List of Roadways included in corridor	-
2.	Vehicle Miles Traveled (thousands)	Annual
3.	RCI, TRI and TTI	Annual
4.	Vehicle Delay AM & PM Peak Period (thousand vehicle Hrs)	Annual
5.	Person Delay (thousand Hrs)	Annual
6.	AM and PM Peak Period Cost of Congestion ($ Millions)	Annual

CONCLUSIONS AND RECOMMENDATIONS

This research project addressed the need to enhance the New Jersey Congestion Analysis Model (NJCAM), which has been used by the NJDOT's Bureau of Commuter & Mobility Strategies to quantify impacts of traffic congestion on major highways in New Jersey. The enhancements in the modeling methodology and functionalities included development of a corridor-level congestion analysis, updated methodology for calculating congestion performance measures, and revisions in the assumptions and methodology for calculating congestion indicators. In response to the comments from the stakeholders, the Bureau of Commuter & Mobility Strategies decided to consider, as congestion-related delay, the difference between the actual travel time and travel time at Level of Service C. NJCAM was modified so that the reference speed and travel time representing uncongested travel conditions reflect Level of Service C, rather than free-flow conditions as was the case in the previous version of the NJCAM. This should be considered when comparing the congestion indicators calculated using the new (enhanced) version of NJCAM to those produced with previous versions of the calculation tool.

The NJCAM software tool was also redesigned in order to address the software compatibility issues, update the development platform, and improve the work flow and user interface. The application was redesigned in VB.NET and SQL Server Compact Edition (SQL CE) as the database management platforms, replacing Microsoft Access that was used in previous versions. The user interface was redesigned to enable more user-friendly data entry and importing of data tables from NJCMS. The new interface also gives the user more flexibility with choosing the value of analysis parameters and the types of reports to be generated. The redesigned software tool also features more streamlined analysis and reporting functionalities.

The enhanced NJCAM is well suited to be used in conjunction with other analysis tools for evaluating mobility and congestion in New Jersey. NJCAM provides estimates of economic impact of congestion to supplement "Hot Spot" Analysis, such as the Bottleneck Identification and Ranking capabilities of the I-95 Corridor Coalition's Vehicle Probe Project (VPP) Suite, thereby helping to better understand the economic impact of recurring bottlenecks. Additional benefits of the model enhancements include: (a) improved capabilities for identifying needs and analyzing impacts of congestion mitigation improvements on a corridor level; (b) improved capability to effectively present the benefits of specific improvements and express their monetary value; (c) improved ability to provide readily available input to the capital programming and project development process; and (d) extended the useful life of the NJCAM by addressing the

software compatibility issues and migration to a more robust database and analytical software platform.

It is recommended that this version of NJCAM be reviewed periodically to ensure the modeling approach and methodology, as well as outputs, are compatible with the Department's performance monitoring and reporting practices and analytical tools. Once the new version of NJCMS (CMS-21) is completed and implemented, it may be necessary to update NJCAM to ensure compatibility of data models used by these analytical tools. Additional future enhancements may include a more robust GIS module, further enhancements of the corridor analysis methodology and user interface, possible integration with NJCMS (perhaps as an add-on module), as well as making use of probe-vehicle data for estimating vehicle delays.

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APPENDIX A: CALCULATION METHODOLOGY

This section describes the general methodology of calculating congestion measures in the New Jersey Congestion Analysis Model (NJCAM), version 4.0.1.

Roadway Database

The main source of roadway network data for the NJCAM is the New Jersey Congestion Management System (NJCMS). NJCAM is programmed to utilize datasets produced by the NJCMS as inputs.

The NJCMS includes traffic volume, roadway geometry, and roadway operational information for approximately 5,250 roadway segments (including both two-directional and unidirectional) referred to as “links” that make up the interstate, state, and county roadway network in all 21 New Jersey counties. For analysis purposes these links were grouped into three classes: freeways, principal arterials, and other arterials.

Freeways refer to roadways with limited access and egress points, generally at grade-separated interchanges. The capacity of a freeway is generally a function of the number of lanes. Highways that belong to the interstate highway network, the New Jersey Turnpike, the Garden State Parkway, and the Atlantic City Expressway, are all examples of freeways.

Principal arterials refer to major arterial roadways with frequent access and egress points, generally at either at-grade signalized or un-signalized intersections, although some grade-separated interchanges may be present. The capacity of an arterial is generally a function of the number of lanes and the green time allowed by the traffic signals. NJ 4 and NJ 17 in northern New Jersey, and NJ 70 and NJ 73 in southern New Jersey, are examples of principal arterials.

The “other arterials” category refers to the other roadways that are included in the NJCMS database. In general, these roadways were excluded from the Highway Performance Monitoring System (HPMS) database used to produce congestion estimates in the annual Urban Mobility Report by the Texas Transportation Institute. The County 500 series roadway network is generally included in the “other arterials” category. Other minor arterials, collectors, and local streets incorporated in the NJCMS database are also classified as “other arterials”. It should be stated that many minor arterials (including many of the County 600 series roadways) and roadways with a lower functionality are not included in the NJCMS database. Consequently, the congestion

that may exist on these roads was not accounted for in the calculation of congestion related delay and costs.

The NJCMS database has many advantages over other data sources since it contains New Jersey specific traffic information:

- Traffic volumes by direction and by hour of the day: The NJCMS estimates traffic volumes by direction for each hour of the day, instead of just two-directional average daily traffic volumes. Consequently, the detailed information available from the NJCMS provides an opportunity to differentiate between roadway links that have similar average daily traffic volumes, but different peaking characteristics.

- Truck volumes by direction and by hour of the day: The NJCMS estimates truck volumes by direction for each hour of the day. Again, the detailed information available from the NJCMS provides an opportunity to measure the impacts of roadways with heavy truck flows. Heavy truck flows have a significant impact on both roadway capacity and average vehicle operating costs.

- Detailed geometric information by roadway link: NJCMS data includes information such as lane, shoulder, and median widths and the number of traffic signals, so that roadway capacity can be assessed for each link. In addition, the number of traffic signals generally limits the capacity of arterials.

- Speed estimates by hour of the day: NJCMS data contains estimated free-flow speeds for each link in the network. Using Volume-Density Functions (VDF) and based on estimated volumes, geometric characteristics, capacity of the roadway, and free-flow speed, the NJCMS analysis module estimates the actual speed for each hour of the day for each directional link. These speeds are then used to calculate the average travel times for each link in each direction and for each hour of the day.

- Estimated vehicle occupancy: The estimated average vehicle occupancy is calculated as part of the NJCMS. These estimates are based on collected data and are aggregated for each county by facility type and time of day. Vehicle occupancy information is consolidated in the NJCMS input table “OCCUPANT”, which is used as one of the input files in the NJCAM as well. Vehicle occupancies are used in the model to derive total person-hours of delay due to congestion.

- Non-recurring delay: The NJCMS estimates the amount of non-recurring congestion occurring on a facility (link) by using lookup tables of New Jersey historical accident and incident rates and lane blockage and duration rates in

combination with the vehicle volumes and delays experienced on each link. The probability of different incident types occurring and the additional delay that would be experienced are used to determine an annual total of non-recurring delay that can be expected. Estimated non-recurring (or incident) delay is calculated for each link in the NJCMS roadway database and results are provided as NJCMS analysis output in the output table “NONRE”. This table is used as an input for the NJCAM.

Congestion Analysis Model (NJCAM)

NJIT has developed a software package (NJCAM) that provides automated procedures for summarizing vehicle and person delay and calculating costs of congestion and congestion indexes using NJCMS. The new updated version of software (NJCAM version 4.0.1) is developed as a combination of the SQL CE database in the back end, and the VB.NET in the front end. Besides several NJCMS output and input files, NJCAM requires the user to provide additional data in order to perform necessary calculations. User-defined inputs are entered through forms as part of the graphical user interface (GUI).

Input Data

Instead of using national averages as estimates for many congestion related variables (as Texas Transportation Institute does in their annual report on mobility and congestion in metropolitan areas nationwide), NJCAM utilizes New Jersey specific data where appropriate and available. This is done in an effort to make the delay and cost estimates more relevant to New Jersey roadways and drivers.

The main source of roadway network data for NJCAM is NJCMS. The new version of NJCAM (version 4.0.1) is designed to work with table formats used in the NJCMS dataset. NJCMS analysis has to be performed for the model year prior to running NJCAM in order to generate the files necessary for model input. These files include:

- Approach file;
- Link file;
- Network file;
- Nonrecurring delay file.

In addition, files for occupancy and index can also be obtained from NJCMS dataset and used as inputs for the case study. These files can be in the format of .DBF, .XLS, .XLSX or .CSV.

Besides roadway network data, the user needs to supply county statistics and general model parameters, including:

- Statistics by county for the model year, including:
    - Average County Hourly Wage (dollars/worker) and Average State Hourly Wage (dollars/worker);
    - Number of Commuters (by hour of the day, usually considered for the morning and afternoon peak periods);
    - Percent of travel within county by county residents;
- Average statewide fuel cost;
- Average cost of owning and operating a truck in New Jersey in $/veh-mile;
- Definition of peak hours for the a.m. and the p.m. peak;
- Percent of wage used as an estimate of value of time;
- Percent of workers in NJ who do not reside in NJ;
- Speed ratios to determine level of service (LOS). These are ratios of minimum actual speed for each respective level of service and free-flow speed. Ratios are required for LOS D (moderate congestion), E (heavy congestion), and F (severe congestion);
- Number of days per year considered in the analysis.

Calculation Procedure

The calculation procedure is performed in two phases: in Phase One, Measures of Effectiveness (MOEs) and congestion measures are calculated on a link level and saved in a single table in the application database; in Phase Two, the performance measures are aggregated up to a county or an MPO level, and on an annual or daily basis, as specified by the user. Outputs are saved in Excel files.

The following performance measures are calculated and summarized in the first phase of the analysis process:

- Average speed (for each analysis period).
- VMT (for each analysis period). Using the speed ratios, VMT is broken down by congestion severity level (uncongested, moderately congested, heavily congested, and severely congested).
- Vehicle delay (for each analysis period). Total vehicle delay on a link is further broken down by vehicle type (auto and truck), and type of congestion (recurring and non-recurring). In addition, vehicle delay is summarized by congestion level (vehicle hours under moderate, heavy, and severe congestion, or no congestion).
- Person delay (for each analysis period). Person delay is broken down by type of congestion (recurring and non-recurring). It is then summarized by congestion level (vehicle hours under moderate, heavy, and severe congestion, or no congestion).
- RCI, TRI, and TTI.
- Gallons of wasted fuel (annual estimate for each analysis period). Total wasted fuel on each link is broken down by vehicle type (auto and truck), and type of congestion (recurring and non-recurring).
- Costs of congestion. Total cost of congestion on each link is calculated on an annual basis for the a.m. and p.m. peak period combined. It is broken down by vehicle type (auto or truck), type of congestion (recurring or non-recurring), and source of cost (unproductive time or wasted fuel).

The analysis period includes the a.m. and p.m. peak periods combined.

Average Speed

NJCMS link table provides estimates of average vehicle speed and vehicle volume for each link for every hour of the day. The following equation is used to calculate average speed for the analysis period including multiple hours:

$$\overline{S}_{i,a} = \frac{\sum_{h \in a} S_{i,h} \cdot VOL_{i,h}}{\sum_{h \in a} VOL_{i,h}} \quad (5)$$

where:

$\overline{S}_{i,a}$ – (Weighted) average vehicle speed on link i during analysis period a [mph];

$S_{i,h}$ – Estimated average vehicle speed (from NJCMS database) on link i during hour h, where period a includes hour h [mph];

$VOL_{i,h}$ – Total vehicle volume (from NJCMS database) on link i during hour h.

Vehicle Miles Traveled (VMT)

VMT is calculated using the following formula:

$$VMT_{i,a} = \sum_{h \in a} L_i \cdot VOL_{i,h} \tag{6}$$

where:

$VMT_{i,a}$ – Total VMT on link i during analysis period a;

L_i – Length of link i [mi].

$VOL_{i,h}$ – Total vehicle volume (from NJCMS database) on link i during hour h.

VMT is also calculated by vehicle category using the following equations:

$$\text{Truck VMT:} \quad VMT_{i,a}^{tr} = \sum_{h \in a} L_i \cdot VOL_{i,h}^{tr} \tag{7}$$

$$\text{Auto VMT:} \quad VMT_{i,a}^{auto} = \sum_{h \in a} L_i \cdot \left(VOL_{i,h} - VOL_{i,h}^{tr} \right) \tag{8}$$

where:

$VMT_{i,a}^{tr}$ – Vehicle-miles traveled by trucks on link i during analysis period a.

L_i – Length of link i [mi].

$VOL_{i,h}^{tr}$ – Total hourly truck volume on link i during hour h (from NJCMS database).

$VMT_{i,a}^{auto}$ – Vehicle-miles traveled by automobiles on link i during analysis period a.

$VOL_{i,h}$ – Total hourly vehicle volume on link i during hour h (from NJCMS database).

NJCMS link table provides estimates of total vehicle volume and total truck volume for each link for every hour, as well as length for each link in the system.

Vehicle Recurring Delay

In NJCAM, the congestion-related vehicle recurring delay is calculated relative to the maximum travel time at LOS C. The recurring delay is calculated for each highway link, for each hour of the day. If speed and travel time on a link reflect LOS A, B, or C, the recurring delay will be considered to be equal to zero. For this reason, the 'maximum' function is used in the formula for calculating recurring delay as follows:

$$D_{i,h}^{(r)} = \text{Max}\left[\left(\frac{L_i}{S_{i,h}} - t_{i,LOS(C)}\right) \times VOL_{i,h}, 0\right], \quad S_{i,h} > 0 \tag{9}$$

where:

$D_{i,h}^{(r)}$ – Total vehicle-hours of recurring delay on link i during hour h.

L_i – Length of the link i [mi].

$S_{i,h}$ – Estimated average (congested) speed on link i during hour h [mph].

$t_{i,LOS(C)}$ – The maximum travel time on link i that corresponds to LOS C [h/veh].

$VOL_{i,h}$ – Total vehicle volume on link i during hour h [veh].

The link length (L_i), estimated average congested speed ($S_{i,h}$), and total hourly vehicle volume by link and by hour of the day ($VOL_{i,h}$), are obtained from NJCMS database. The maximum travel time corresponding to LOS C $\left(t_{i,LOS(C)}\right)$ on link i is calculated using the following formula:

$$t_{i,LOS(C)} = \frac{t_{i,(f)}}{p_{LOS(C)}} \tag{10}$$

where:

$t_{i,LOS(C)}$ – The maximum travel time on link i that corresponds to LOS C [h/veh].

$t_{i,(f)}$ – Free-flow travel time on link i.

$p_{LOS(C)}$ – User-defined percent of free-flow speed corresponding to LOS C.

It is suggested that the percent of free-flow speed corresponding to LOS C be set to values suggested in the Highway Capacity Manual as follows:

a) For freeways, minimum speed reflecting LOS C is 96% of the free-flow speed

b) For arterials, the minimum speed reflecting LOS C is 77% of the free-flow speed

It should be noted that the signal cycle delay on links with signalized intersections is NOT considered to be congestion-related. It is therefore included in the value of free-flow travel time on link i, $t_{i,(f)}$.

For reporting purposes in NJCAM, recurring delay can be aggregated over a sequence of NJCMS links forming a highway segment or a corridor. The aggregation can also be done for all NJCMS links within a county, MPO, or statewide. The NJCAM reports also provide summaries of recurring delay by facility type and analysis period (e.g. morning peak period and/or afternoon peak period).

Recurring vehicle delay is also summarized by vehicle type: for trucks and autos. Recurring vehicle delay for truck is calculated by multiplying total vehicle delay in Equation 9 ($D_{i,h}^{(r)}$) by percent of trucks on a given link. Recurring delay for autos is obtained by subtracting truck recurring delay on link i from $D_{i,h}^{(r)}$.

Based on hourly speeds, and using speed ratios from HCM, it is possible to determine the level of congestion on each NJCMS link on an hourly basis, and then daily as well as by aggregation. As mentioned before, three levels of congestion are defined: moderate (LOS D), heavy (LOS E), and severe (LOS F). Total vehicle recurring delays for all hours in the analysis period that have the same level of congestion are summed up to provide total vehicle-hours of delay for each of the congestion levels.

Vehicle Non-recurring Delay

The NJCAM (version 4.0.1) takes the non-recurring delay estimates directly from NJCMS outputs. The non-recurring delay is calculated in NJCMS for each network link, by direction and for each hour of the day, and is based on historical data about number, type, and duration of incidents and accidents, as well as volume-to-capacity ratios. The non-recurring delay is reported in NJCMS output table (stored in *NONRE.DBF* file) as total annual vehicle-hours of delay attributed to incidents and accidents (including delays caused by crashes, mechanical, electrical, or tire related vehicle breakdowns, and other causes).

NJCAM summarizes the non-recurring delay both on an annual and daily basis for the morning and afternoon peak periods. The annual summary is a simple sum of the delays over all links, and then further aggregated by facility type, county, and as a statewide summary.

Although non-recurring delays are incurred by the traveling public only when an incident or accident occurs, for the purpose of estimating average daily non-recurring delay it was assumed that the delays are uniformly distributed over the period of 365 days. In order to calculate daily non-recurring delay on a link, annual hourly delays for each link were divided by 365, and then aggregated by facility type, county, and as a statewide summary to obtain appropriate summary values. Non-recurring delay is aggregated to an annual level by multiplying estimates of daily non-recurring delay by the user specified number of analysis days per year (usually 250 weekdays; i.e., a full year excluding weekends and holidays).

In addition to calculating the aggregated non-recurring delays, NJCMS outputs were also used to estimate the impact of non-recurring delay on vehicle speeds. The average incident/accident link speed (with recurring and non-recurring delays) was then used to estimate the amount of wasted fuel. The following formula was used to calculate the estimated average (congested) speed during incident or accident events:

$$S_{i,h}^{(nr)} = \frac{L_i}{t_i^{LOS(C)} + d_{i,h}^{(r)} + d_{i,h}^{(nr)}} \tag{11}$$

where:

$S_{i,h}^{(nr)}$ – Estimated average (congested) speed on link i during hour h, in incident or accident conditions [mph].

L_i – Length of the link i [mi].

$t_i^{LOS(C)}$ – Reference travel time (LOS C) on link i during hour h [h/veh].

$d_{i,h}^{(r)}$ – Average recurring delay per vehicle on link i during hour h [h/veh].

$$d_{i,h}^{(r)} = \frac{D_{i,h}^{(r)}}{VOL_{i,h}}, \quad VOL_{i,h} > 0 \tag{12}$$

$D_{i,h}^{(r)}$ – Total vehicle-hours of recurring delay on link i during hour h.

$VOL_{i,h}$ – Total vehicle volume on link i during hour h [veh].

$d_{i,h}^{(nr)}$ – Average non-recurring delay per vehicle on link i during hour h, in incident or accident conditions [h/veh].

$$d_{i,h}^{(nr)} = \frac{365 \cdot D_{i,h}^{(nr)}}{I_{i,h} \cdot VOL_{i,h}}, \quad I_{i,h} > 0, \quad VOL_{i,h} > 0 \tag{13}$$

$D_{i,h}^{(nr)}$ – Total vehicle-hours of non-recurring delay on link i during hour h.

$I_{i,h}$ – Estimated annual number of incidents and accidents on link i during hour h. If h is in a peak period, then $I_{i,h}$ would be equal to the estimated annual number of incidents/accidents on link i during peak periods; otherwise, $I_{i,h}$ would be equal to the estimated annual number of incidents/accidents on link i during off-peak periods of the day. These values are obtained directly from NJCMS outputs.

Person-Hours of Delay (Recurring and Non-Recurring)

Person-hours of delay are calculated only for autos (i.e. excluding trucks), distinguishing between delays associated with recurring and non-recurring congestion. Previously calculated vehicle-hours of delay are converted to person-hours by multiplying the vehicle hours with the corresponding vehicle occupancy (persons per vehicle). The following is the formula used in this calculation:

$$PD_{i,a} = \sum_{h \in a} \left(d_{i,h}^{(r)} + d_{i,h}^{(nr)} \right) \cdot \left(VOL_{i,h} - VOL_{i,h}^{tr} \right) \cdot OC_{i,h} \tag{14}$$

where:

$PD_{i,a}$ – Total person-hours of delay for autos on link i during analysis period a.

$d_{i,h}^{(r)}$ – Average recurring delay per vehicle on link i during hour h [h/veh].

$d_{i,h}^{(nr)}$ – Average non-recurring delay per vehicle on link i during hour h, in incident or accident conditions [h/veh].

$VOL_{i,h}$ – Total vehicle volume on link i during hour h [veh].

$VOL_{i,h}^{tr}$ – Total hourly truck volume on link i during hour h (from NJCMS database).

$OC_{i,h}$ – Estimated average auto occupancy on link i during hour h [persons/veh].

The vehicle occupancy data is obtained from NJCMS table 'OCCUPANT'. This table provides estimates of average auto occupancy by county and facility type for four time periods of the day: a.m. peak, midday, p.m. peak, and night. In the calculation routine these values are associated with the corresponding hours for each link on the network.

Similar to vehicle-hours of delay, person-hours of delay are calculated for every directional NJCMS link and hour of the day. The delays are then summarized for reporting purposes by time of day, facility type, and by county, and are classified by degree of congestion (i.e., uncongested, moderate, heavy, and severe congestion conditions).

Travel Rate Index (TRI)

The Travel Rate Index (TRI) measures the amount of extra time it takes to travel during the peak period, considering only the effect of recurring congestion. The TRI is calculated as a ratio of travel rate (in minutes per mile) during the peak periods, and the travel rate under free-flow conditions for the same highway segment (e.g., NJCMS link). The following formula, developed by the Texas Transportation Institute[7], is used as a basis for this calculation:

$$\textit{Travel Rate Index} = \frac{\textit{Actual Conditions Travel Rate (minutes / mile)}}{\textit{Average Free - flow Travel Rate}} \qquad (15)$$

[7] Schrank, D. and D. Lomax, "2005 Urban Mobility Report", Texas Transportation Institute, The Texas A&M University, May 2005.

A TRI of 1.20, for example, indicates that it would take 20 percent longer to travel a given highway segment during the peak period than during the off-peak period. However, this estimate does not consider the possibility of encountering non-recurrent events such as traffic incidents.

The actual conditions travel rate is the sum of the free-flow travel rate and the incremental recurring delay rate. Thus, link-level TRI for an analysis period can be calculated using the following formulas:

$$TRI_{i,a} = \frac{TR_{i,a}}{TR_i^{ff}} \tag{16}$$

where:

$$TR_{i,a} = TR_i^{ff} + TR_{i,a}^{r} \tag{17}$$

$$TR_i^{ff} = \frac{60 \times t_{i(f)}}{L_i} \tag{18}$$

$$TR_{i,a}^{r} = \frac{60 \times D_{i,a}^{(r)}}{L_i \times VOL_{i,a}} \tag{19}$$

$TRI_{i,a}$ – Average Travel Rate Index (TRI) on link i during analysis period a.

$TR_{i,a}$ – Average actual-conditions travel rate on link i during analysis period a [min/mi].

TR_i^{ff} – Average free-flow travel rate on link i [min/mi], inclusive of signal cycle delay.

$TR_{i,a}^{r}$ – Average recurring delay rate on link i during analysis period a [min/mi].

$t_{i,(f)}$ – Free-flow travel time on link i [hours].

L_i – Length of the link i [mi].

$D_{i,a}^{(r)}$ – Total vehicle-hours of recurring delay on link i during analysis period a.

$VOL_{i,a}$ – Total vehicle volume on link i during analysis period a.

TRI is then aggregated to a facility type level, by county and statewide, as a link-average weighted by total link-level VMT:

$$TRI_C = \frac{\sum_{i \in C} TRI_{i,a} \cdot VMT_{i,a}}{\sum_{i \in C} VMT_{i,a}} \quad (20)$$

where C denotes the aggregation level (county, or facility type, or entire roadway system) and $VMT_{i,a}$ represents total vehicle-miles traveled on link i during analysis period a.

Travel Time Index (TTI)

Travel Time Index (TTI) measures the amount of extra time it takes to travel during a peak period considering both recurring and non-recurring delay, relative to the free-flow conditions. A TTI of 1.30, for example, indicates that it will take 30 percent longer to travel to a destination during the peak period, considering the possibility of encountering non-recurrent incidents (i.e. traffic accident, inclement weather, work zones, etc.). The following formula, developed by the Texas Transportation Institute[8], is used as a basis for calculation of TTI:

$$Travel\ Time\ Index = \frac{All\ Conditions\ Travel\ Rate\ (minutes\ /\ mile)}{Average\ Free\text{-}flow\ Travel\ Rate} \quad (21)$$

In Equation 21 "all conditions travel rate" is the sum of the free-flow travel rate and incremental travel rates for both recurring and non-recurring congestion delay. In NJCAM model the TTI is calculated as follows:

$$TTI_{i,a} = \frac{TR'_{i,a}}{TR_i^{ff}} \quad (22)$$

where:

$$TR'_{i,a} = TR_i^{ff} + TR_{i,a}^{r} + TR_{i,a}^{nr} \quad (23)$$

[8] Schrank, D. and D. Lomax, "2005 Urban Mobility Report", Texas Transportation Institute, The Texas A&M University, May 2005.

$$TR_{i,a}^{nr} = \frac{60 \times D_{i,a}^{(nr)}}{L_i \times VOL_{i,a}} \quad (24)$$

$TTI_{i,a}$ – Average Travel Time Index (TTI) on link i during analysis period a.

$TR'_{i,a}$ – Average all-conditions travel rate on link i during analysis period a [min/mi].

TR_i^{ff} – Average free-flow travel rate on link i [min/mi], inclusive of signal cycle delay.

$TR_{i,a}^{r}$ – Average recurring delay rate on link i during analysis period a [min/mi].

$TR_{i,a}^{nr}$ – Average peak period non-recurring delay rate on link i [min/mi].

$D_{i,a}^{(nr)}$ – Total vehicle-hours of non-recurring delay on link i during analysis period a.

L_i – Length of the link i [mi].

$VOL_{i,a}$ – Total vehicle volume on link i during analysis period a.

TTI is also aggregated to a facility type level, by county and statewide, as a link-average weighted by total link-level vehicle-miles traveled (VMT):

$$TTI_C = \frac{\sum_{i \in C} TTI_{i,a} \cdot VMT_{i,a}}{\sum_{i \in C} VMT_{i,a}} \quad (25)$$

where C denotes the aggregation level (county, or facility type, or entire roadway system) and $VMT_{i,a}$ represents total vehicle-miles traveled on link i during analysis period a.

Roadway Congestion Index (RCI)

The Roadway Congestion Index (RCI) is a measure of the vehicle travel density on major roadways in urban areas expressed as number of vehicles per vehicle space. A RCI value exceeding 1.0 indicates an undesirable congestion level on the freeways and principal arterial street system during the peak period.

The RCI is a macroscopic measure of congestion and it is calculated for the entire analyzed roadway system by facility type and as a system-wide measure. During the calculation procedure daily vehicle-miles of travel (VMT) are first divided by total lane-miles, including all the links within each facility type to obtain travel densities. Travel densities are then combined in a single RCI index as weighted averages using similar ratios that represent congestion for the same roadway systems. The following equation is used to calculate the RCI:

$$RCI = \frac{\frac{Freeway\,VMT}{lane-mile} \times Freewy\,VMT + \frac{Princ.\,Art.VMT}{lane-mile} \times Princ.\,Art.VMT + \frac{Other\;Art.VMT}{lane-mile} \times Other\;Art.VMT}{14000 \times Freeway\,VMT + 9000 \times Principal\;Arterial\,VMT + 5500 \times Other\;Arterial\,VMT} \quad (26)$$

The resulting index measures conditions on the freeway and arterial street systems. This variable weighting allows comparisons of areas with different intensities of freeway travel.

Calculation of Fuel Consumption and Wasted Fuel

In NJCAM the fuel consumption is calculated as a function of vehicle speed on a link during each hour of the evaluation, and it is estimated for two generic vehicle types: autos and trucks. The auto and truck fuel consumption rates are based on CALTRANS's Life-Cycle Benefit-Cost Analysis Model (CAL-B/C).[9] Figure 15 shows plots of fuel consumption rates in gallons per mile [Gal/mi], as a function of vehicle speed in miles per hour [mph].

[9] Life-Cycle Benefit-Cost Analysis Model (CAL-B/C), CALTRANS, April 2007 (http://www.dot.ca.gov/hq/tpp/offices/ote/benefit_cost.htm) The documentation references "California Air Resources Board, EMFAC2002, V2.2, 2003 & 2023 average estimates" as a data source (http://www.arb.ca.gov/msei/onroad/latest_version.htm).

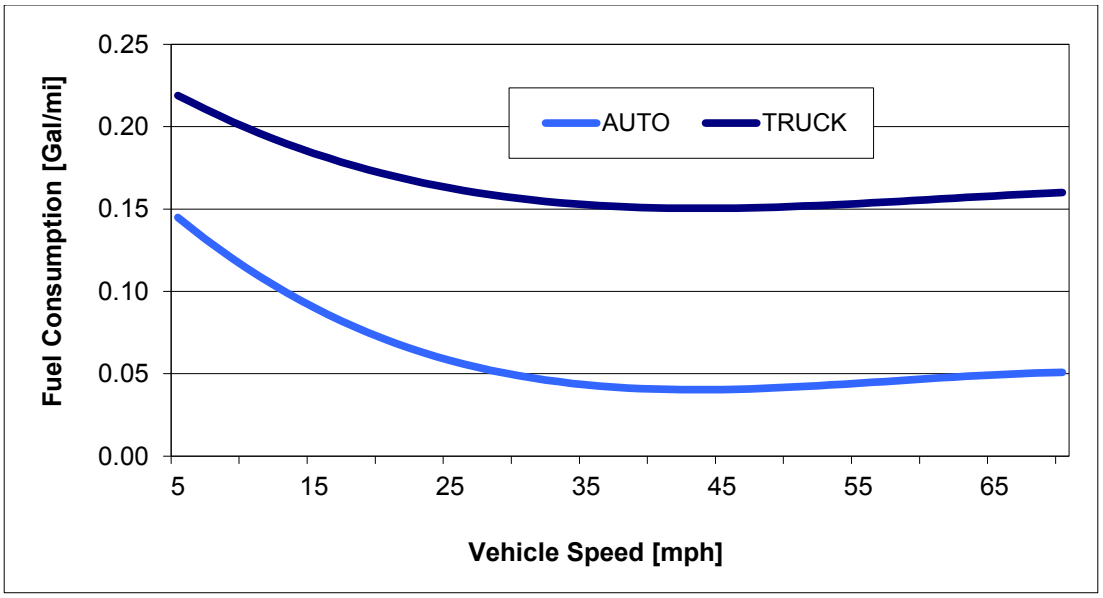


Figure 15 - Fuel consumption rates for autos and trucks as a function of vehicle speed, based on CALTRANS Life-Cycle Benefit-Cost Analysis Model (CAL-B/C)

The empirically derived fuel consumption curves are of the following form:

$$g(S) = a_0 + a_1 \cdot S + a_2 \cdot S^2 + a_3 \cdot S^3 \qquad (27)$$

where:

g – Fuel consumption rate in gallons per mile.

S – Speed in miles per hour.

a_0, a_1, a_2, a_3 – Regression coefficients.

Table 9 shows the estimated regression coefficients and the coefficient of determination (R^2) for auto and truck fuel consumption regression models.

Table 9 - Estimated regression coefficients and R^2 for fuel consumption functions

Regression Coefficients	AUTO	TRUCK
a_0	$1.823381 \cdot 10^{-1}$	$2.42765 \cdot 10^{-1}$
a_1	$-8.2321 \cdot 10^{-3}$	$5.2128514 \cdot 10^{-3}$
a_2	$1.5265 \cdot 10^{-4}$	$9.31 \cdot 10^{-5}$
a_3	$-8.8419 \cdot 10^{-7}$	$-5.072191 \cdot 10^{-7}$
R^2	0.9954	0.9946

Vehicle speed is impacted by recurring and/or non-recurring congestion. It is assumed that reduced speed due to congestion would result in higher fuel consumption. The difference between the fuel consumption when there is no congestion and fuel consumption when traffic is congested is referred to as "wasted fuel due to congestion." As in the case of travel delay, the congested conditions are described by the LOS D, E, and F. The LOS is determined based on the estimated average (prevailing) speed on a link in a given hour of the day obtained from the NJCMS database.

The NJCAM distinguishes between the wasted fuel caused by *recurring congestion*, and that caused by *non-recurring congestion* (e.g. due to traffic incidents such as motor-vehicle crashes, disabled vehicles, blocked roadway, work zones, special events, adverse weather, etc.). With all parameters taken into consideration, the amount of wasted fuel due to recurring congestion is calculated based on the following formula:

$$rG_{v,i,h} = Max\left[\left(g_v(S_{i,h}) - g_v(S_{i,LOS(C)})\right), 0\right] \times VOL_{i,h}^{(v)} \times L_i \qquad (28)$$

where:

$rG_{v,i,h}$ – Total gallons of fuel wasted due to recurring congestion by vehicle type v on link i during hour h.

$g_v(S)$ – Fuel consumption of vehicle type v at speed S.

$S_{i,h}$ – Estimated average (congested) speed on link i during hour h [mph].

$S_{i,LOS(C)}$ – Minimum speed at LOS C on link i.

$VOL_{i,h}^{(v)}$ – Total volume (number of vehicles) of vehicle type v on link i during hour h.

L_i – Length of the link i [mi].

The 'maximum' function is used to ensure that the only 'wasted fuel' considered is that at speeds lower than the minimum speed at LOS C. It is assumed that both the prevailing hourly speed and the speed at the LOS C are sub-optimal in terms of fuel efficiency.

Similarly, the amount of wasted fuel due to non-recurring congestion is calculated based on the following formula:

$$nG_{v,i,h} = Max\left[\left(g_v\left(S_{i,h}^{(nr)}\right) - g_v\left(S_{i,h}\right)\right), 0\right] \times VOL_{i,h}^{(v)} \times L_i \quad (29)$$

where:

$nG_{v,i,h}$ – Total gallons of fuel wasted due to non-recurring congestion by vehicle type v on link i during hour h.

$g_v(S)$ – Fuel consumption of vehicle type v at speed S.

$S_{i,h}^{(nr)}$ – Estimated average (congested) speed on link i during hour h in travel conditions caused by a traffic incident (in mph).

$S_{i,h}$ – Estimated average (congested) speed on link i during hour h [mph].

$VOL_{i,h}^{(v)}$ – Total volume (number of vehicles) of vehicle type v on link i during hour h.

L_i – Length of the link i [mi].

Cost of Congestion – Autos

The cost of congestion for auto users is calculated using the following equation:

$$c_{i,a}^{auto} = v_k \cdot PD_{i,a} + \left(rG_{(auto),i,a} + nG_{(auto),i,a}\right) \cdot c_g \quad (30)$$

where:

$c_{i,a}^{auto}$ – Total cost of congestion for auto users on link i during analysis period a.

v_k – Average value of time for a traveler residing in county *k* (given that link i is located in county *k*).

$PD_{i,a}$ – Total person-hours of delay for autos link i during analysis period a.

$rG_{(auto),i,a}$ – Total gallons of fuel wasted by autos due to recurring congestion on link i during analysis period a.

$nG_{(auto),i,a}$ – Total gallons of fuel wasted by autos due to non-recurring congestion link i during analysis period a.

c_g – Average cost of a gallon of fuel [$/gal];

The first part of Equation 30 is the cost of unproductive time, and the second part is the cost of wasted fuel.

The value of time is calculated as a weighted average of county-specific hourly wage and statewide average hourly wage per worker for all the links within a county. The weighting factors are percentages of trips made by county and out-of-county residents. The formula for calculating the average value of time for travel in county *k* is as follows:

$$v_k = \left(W_k \cdot p_k + \bar{W} \cdot (1 - p_k)\right) \cdot \left(pw / 100\right) \quad (31)$$

where:

v_k – Average value of time for travel in county k [$/hr].

W_k – Average wage per worker in county k [$/hr].

p_k – Portion of travel within county k attributed to county residents ($0 < p_k \leq 1$).

$\bar{W}$ – Statewide average hourly wage per worker [$/hr];

pw – Percent of wage an estimate of value of time, recommend using 50 percent of average wage for drive alone commute and personal driving.[10]

[10] *User and Non-User Benefit Analysis for Highways*, 3rd Edition. American Association of State Highway Transportation Officials (AASHTO), September 2010. Table 5.1, page 5-3.

Calculation of Cost of Congestion for Trucks

NJCMS provides the truck volume data for each link and each hour of the day. The delay accrued by trucks on a link in a given hour is calculated by multiplying total delay (recurring and non-recurring) by corresponding truck percentage (for the same link and hour). The total cost of congestion for trucks is calculated by multiplying the total congestion-related truck delay by the average cost of operating a truck per hour. Truck operating cost per hour is obtained as the product of average per-mile truck cost and average speed. The average per-mile truck cost can be obtained from industry sources, such as American Transportation Research Institute (ATRI). ATRI publishes *An Analysis of the Operational Costs of Trucking*, which provides a detailed analysis and breakdown of truck operating costs in the U.S.[11] These costs include driver wages, fuel cost, vehicle depreciation, wear and tear and vehicle maintenance, vehicle registration, insurance, and other administrative costs, as well as other costs associated with owning and operating a truck. The ATRI report provides these costs as national averages. The following is the formula for calculating cost of congestion for trucks:

$$c_{i,a}^{tr} = \left(d_{i,h}^{(r)} + d_{i,h}^{(nr)}\right) \cdot VOL_{i,h}^{tr} \cdot S_{i,h} \cdot tC(mi) \qquad (32)$$

where:

$c_{i,a}^{tr}$ – Total cost of congestion pertaining to trucks, accrued on link i during hour h, including both recurring and non-recurring delay [$].

$d_{i,h}^{(r)}$ – Average recurring delay per vehicle on link i during hour h [h/veh].

$d_{i,h}^{(nr)}$ – Average non-recurring delay per vehicle on link i during hour h [h/veh].

$VOL_{i,h}^{tr}$ – Truck vehicle volume on link i during hour h [veh/h].

$S_{i,h}$ – Average vehicle speed on link i during hour h [mph].

$tC(mi)$ – Average truck operating cost per mile [$/veh-mi].

Link level results are aggregated to facility type, county, and statewide level by summation.

[11] The most recent issue of this publication is An Analysis of the Operational Costs of Trucking: A 2013 Update, and can be obtained from ATRI through their website, at http://atri-online.org

It should be noted that the truck operating cost already includes cost of fuel. Therefore, the cost of unproductive time for trucks is calculated by deducting the cost of fuel wasted by trucks from the total truck cost, $c_{i,a}^{tr}$. The cost of wasted fuel for trucks is calculated as a product of gallons of fuel wasted by trucks due to congestion and user-defined average fuel cost per gallon, c_g.

Aggregation

In the second phase of the calculation process, performed as part of the report generation, performance measures and congestion measures summarized on the link-level are aggregated to a county and facility type level. In NJCAM (version 4.0.1) two new types of aggregation were added: statewide and user defined custom corridor. This is done using link identification codes (to determine in which county or corridor each link is located and what facility type each represents).

These are either simple sums (including VMT, delays, costs, and wasted fuel) or weighted averages by VMT (including speeds, RCI, TRI, and TTI).

Subject Group

Total delay and congestion costs are difficult to relate to until they are averaged for a subject group, such as per capita, per driver, or per trip. Since the NJCMS is a link-based database and contains no origin-destination information, it cannot be used to generate subject group totals. Based on the review of the current congestion reporting practices at NJDOT and nationwide, and discussing the alternatives with the NJDOT Bureau of Commuter & Mobility Strategies, it was concluded that the most meaningful subject group affected by congestion would be ***commuters***. Commuters are defined in NJCAM as workers who travel during morning peak hours or afternoon peak hours.

NJCAM requires the following inputs in order to calculate performance measures for an average commuter:

- Total number of commuters by county, for each county in New Jersey; and
- Percent of travel within county by county residents, for each county in New Jersey.

Number of commuters in each county and percent of travel within county by county residents can be calculated using the data provided in the National Household Travel Survey (NHTS) database, or from the Journey to Work (5 year) data included in the

U.S. Census Transportation Planning Products Program (CTPP). The aforementioned data sources provide estimated number of commuter trips by the hour of day (looking at either departure or arrival times). It should be noted that the estimate of the number of commuters used in the analysis should be consistent with peak hours (both morning and afternoon) selected as the analysis period for calculation purposes in NJCAM. It should also be noted that when calculating statewide averages per commuter, each commuter trip is counted 50% in the county of residence and 50% in the county of work to avoid double-counting. If the worker lives and works in the same county, he or she is counted once in that county.

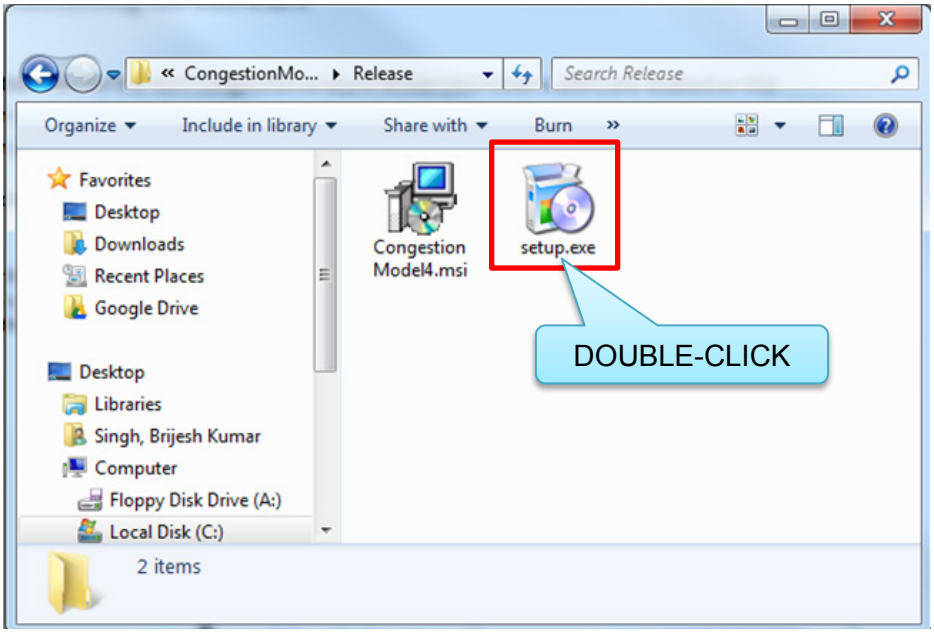
APPENDIX B: USER'S MANUAL

Step 1: Installing the Software

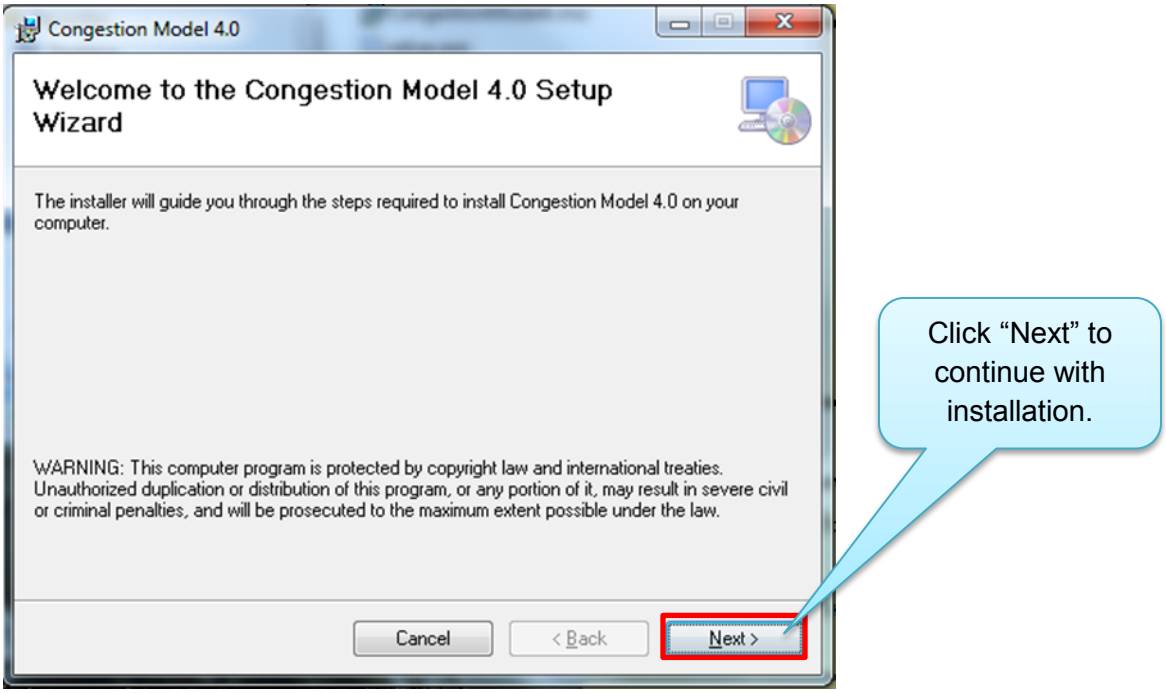
All installation files for the New Jersey Congestion Analysis Model (NJCAM ver. 4.0) are located on the installation CD. Installation can be executed either from the CD, or the user can copy the entire installation directory to the local drive and execute the installation from there.

Please follow the following steps to install the model application:

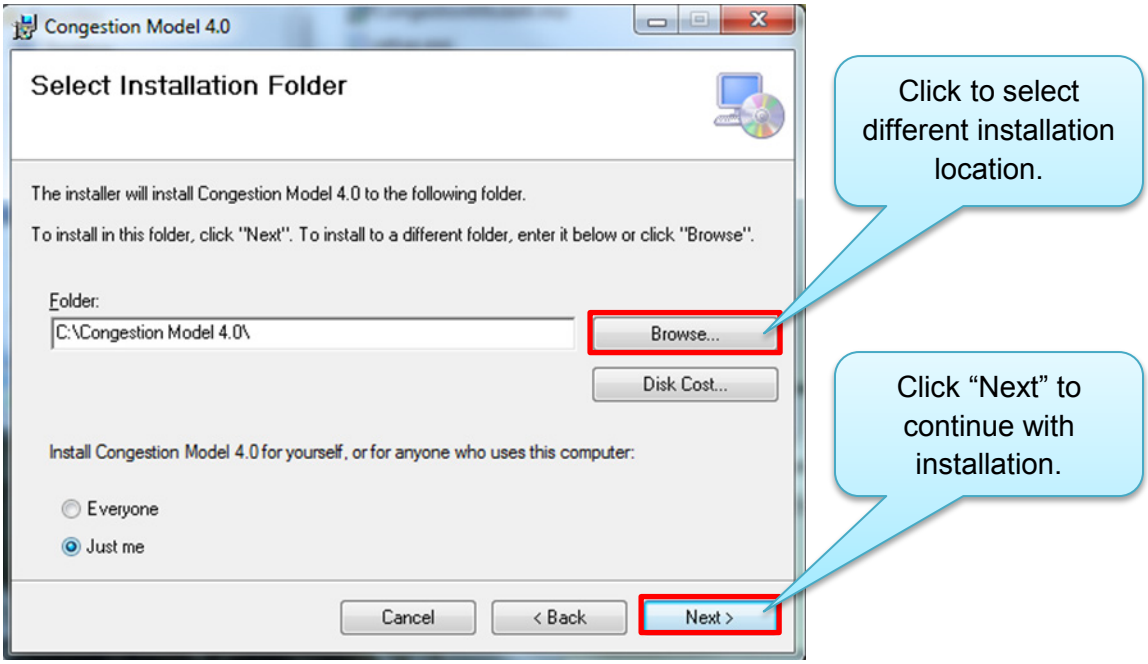
1. Locate the installation directory and double-click on the file setup.exe.



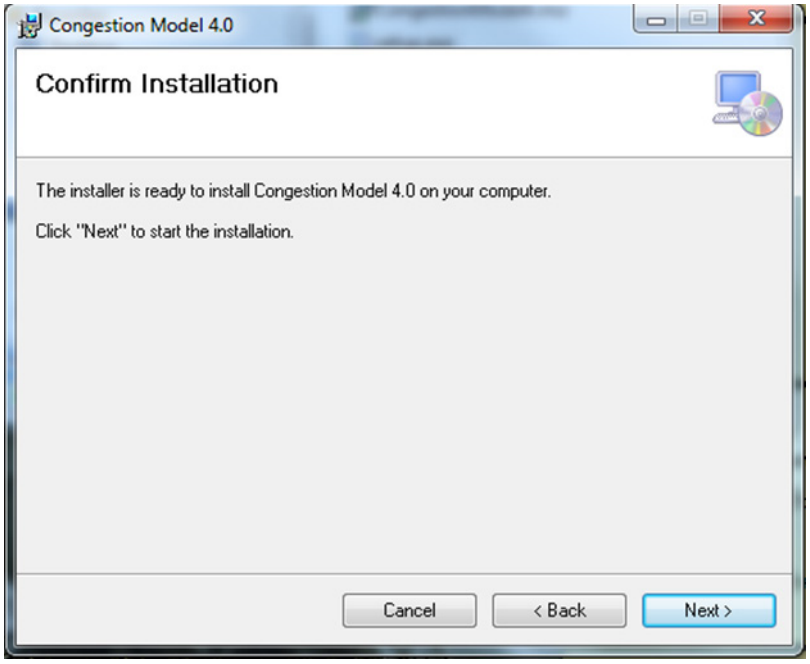
2. Click on the ”Next” button on the installation welcome screen



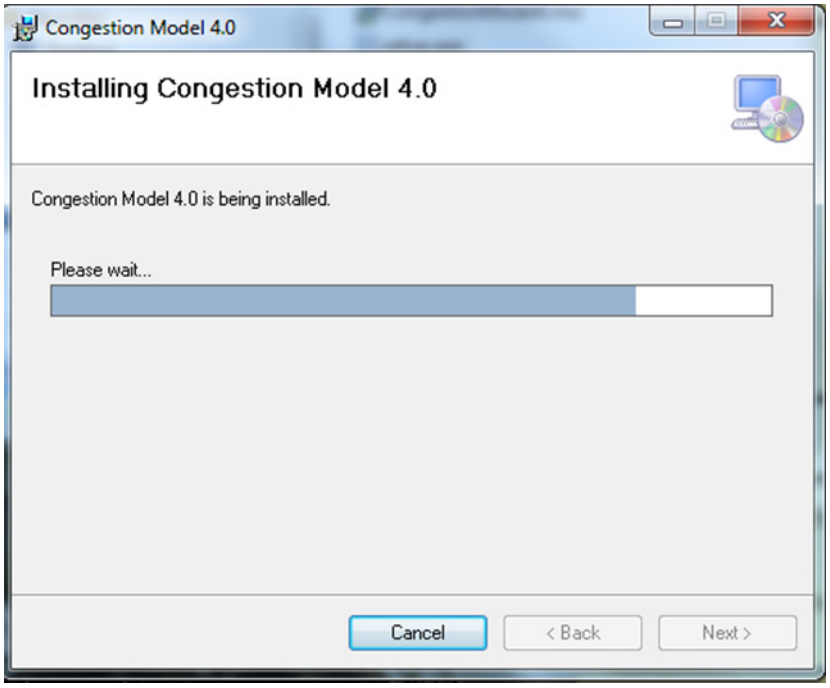
3. If you want to install the application in default directory then click on the “Next” button. If you want to install it in another location, click on the “Browse…” button, select the installation location, and then click on the “Next” button.



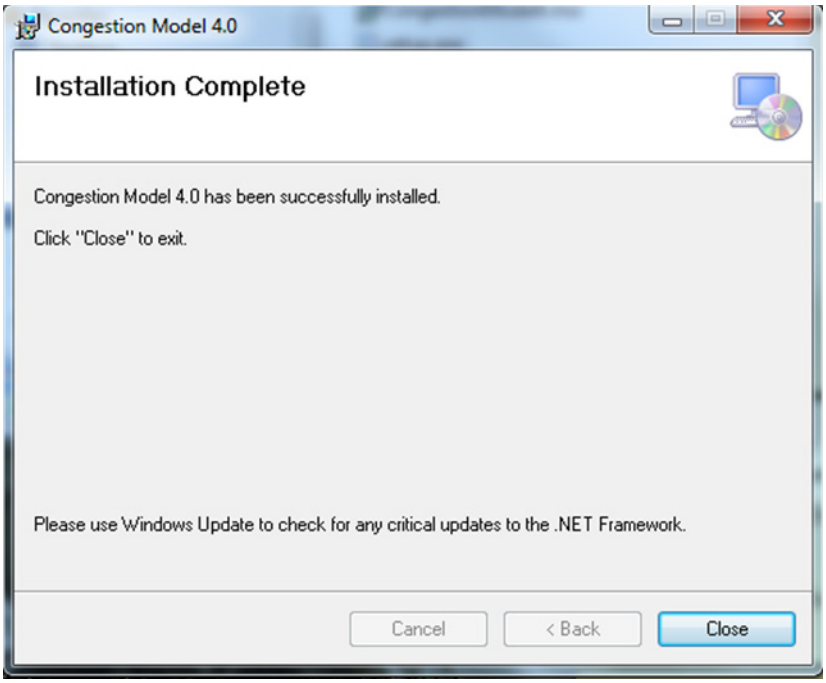
4. Click on the ”Next” button to confirm installation.



5. Installation will begin and all necessary files will be installed on your local drive.



6. Installation complete window will appear informing you that the installation was successfully completed. Click on the ”Close” button to conclude the installation.



Step 2: Prepare Model Inputs

Input parameters can be classified into two groups:

- Parameters derived from NJCMS;
- Other parameters and statistics collected by the user.

In order to run the congestion model the user has to prepare six tables that are part of NJCMS. They consist of NJCMS input and output tables:

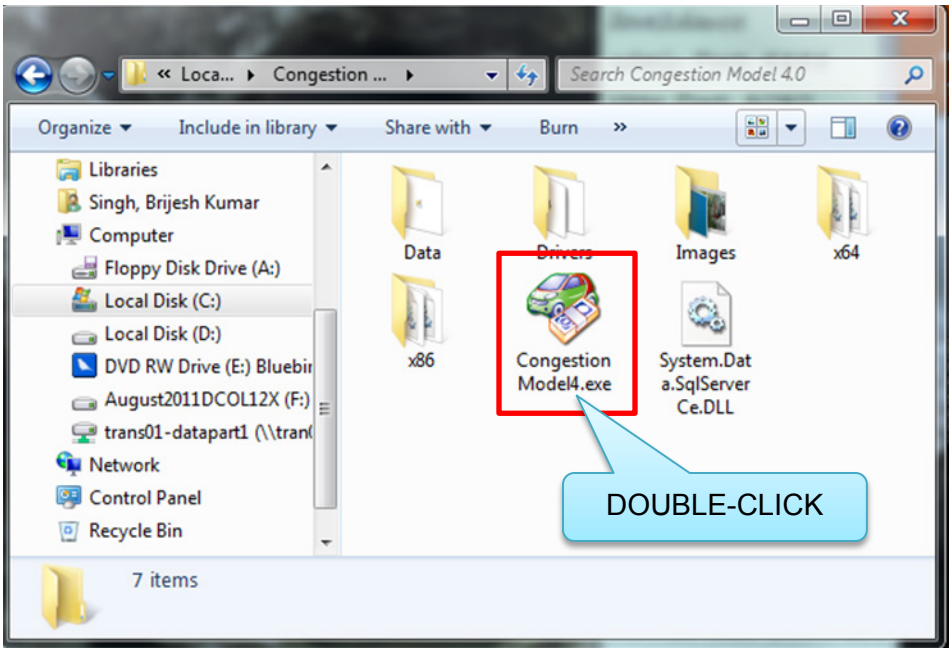
- Index table (input)
- Occupant table (input)
- Approach table (output)
- Link table (output)
- Network table (output)
- Nonrecurring delay file (output)

Other parameters and statistics necessary for the model analysis include:

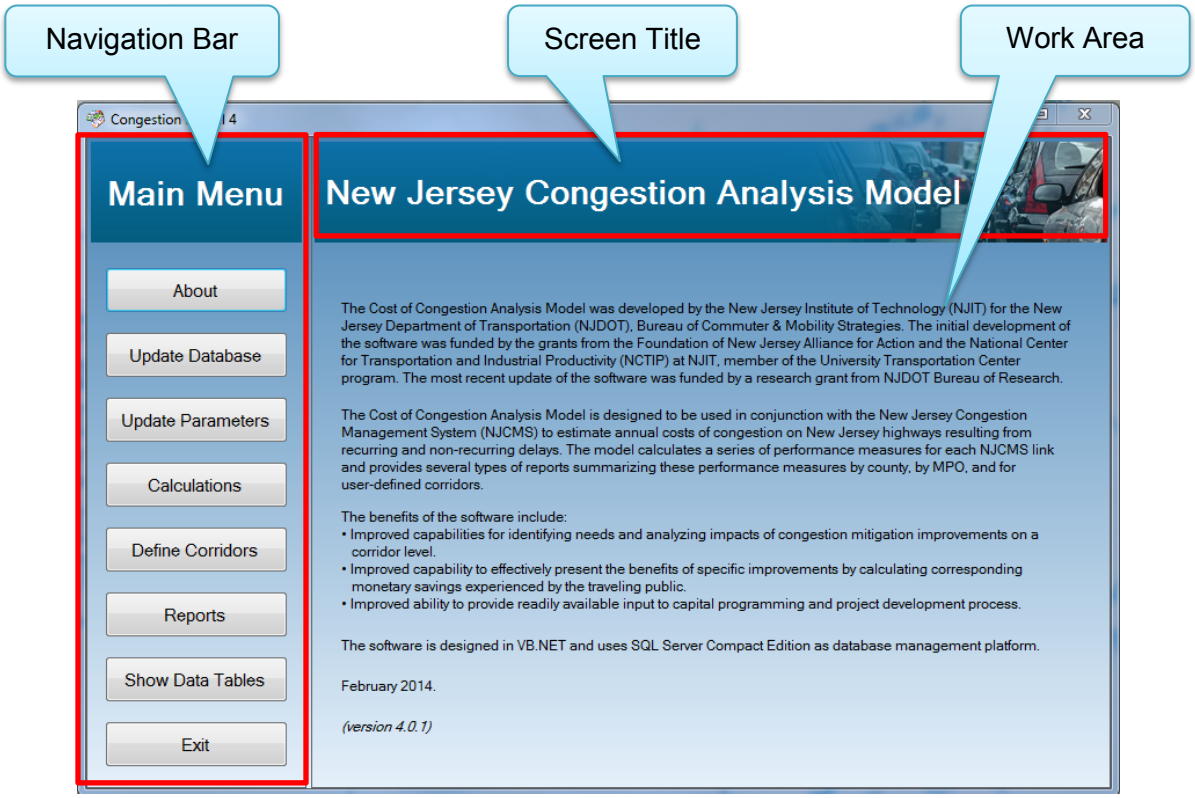
- Statistics by county for the model year, including:
    - Average County Hourly Wage (dollars/worker) and Average State Hourly Wage (dollars/worker);
    - Number of Commuters (by hour of the day, usually considered for the morning and afternoon peak periods);
    - Percent of travel within a county by county residents;
- Average statewide fuel cost;
- Average cost of owning and operating a truck in New Jersey in $/veh-mile;
- Definition of peak hours for the a.m. and the p.m. peak;
- Percent of wage used as an estimate of value of time;
- Percent of workers in NJ who do not reside in NJ;
- Speed ratios to determine the LOS. These are ratios of minimum actual speed for each respective level of service and free-flow speed. Ratios are required for LOS D (moderate congestion), E (heavy congestion), and F (severe congestion);
- Number of days per year considered in the analysis.

Step 3: Starting the Application

The NJCAM application is started by double-clicking the application shortcut on the computer desktop screen or in the application directory. The default location of the application directory is **"C:\Congestion Model 4.0\"**.

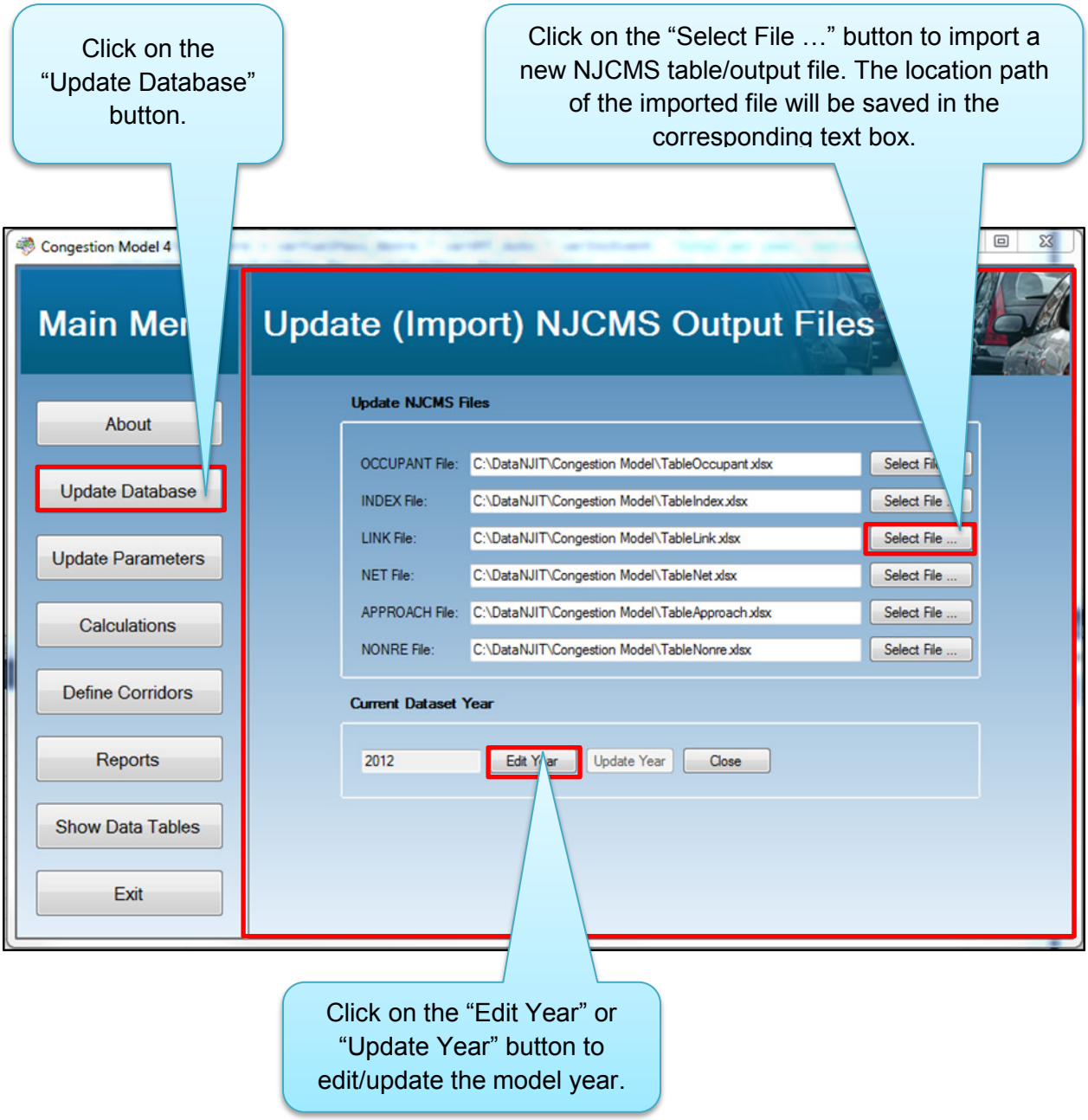


The figure below shows the opening screen of the application. The screen is divided in two parts, “Navigation Bar” on the left part of the screen gives user the ability to navigate through the different modules of the application, and “Work Area” on the right part of the screen will load the module as per the selection in the “Navigation Bar”. From this screen, a user can navigate to all other application modules. The default selection is the “About” Screen.

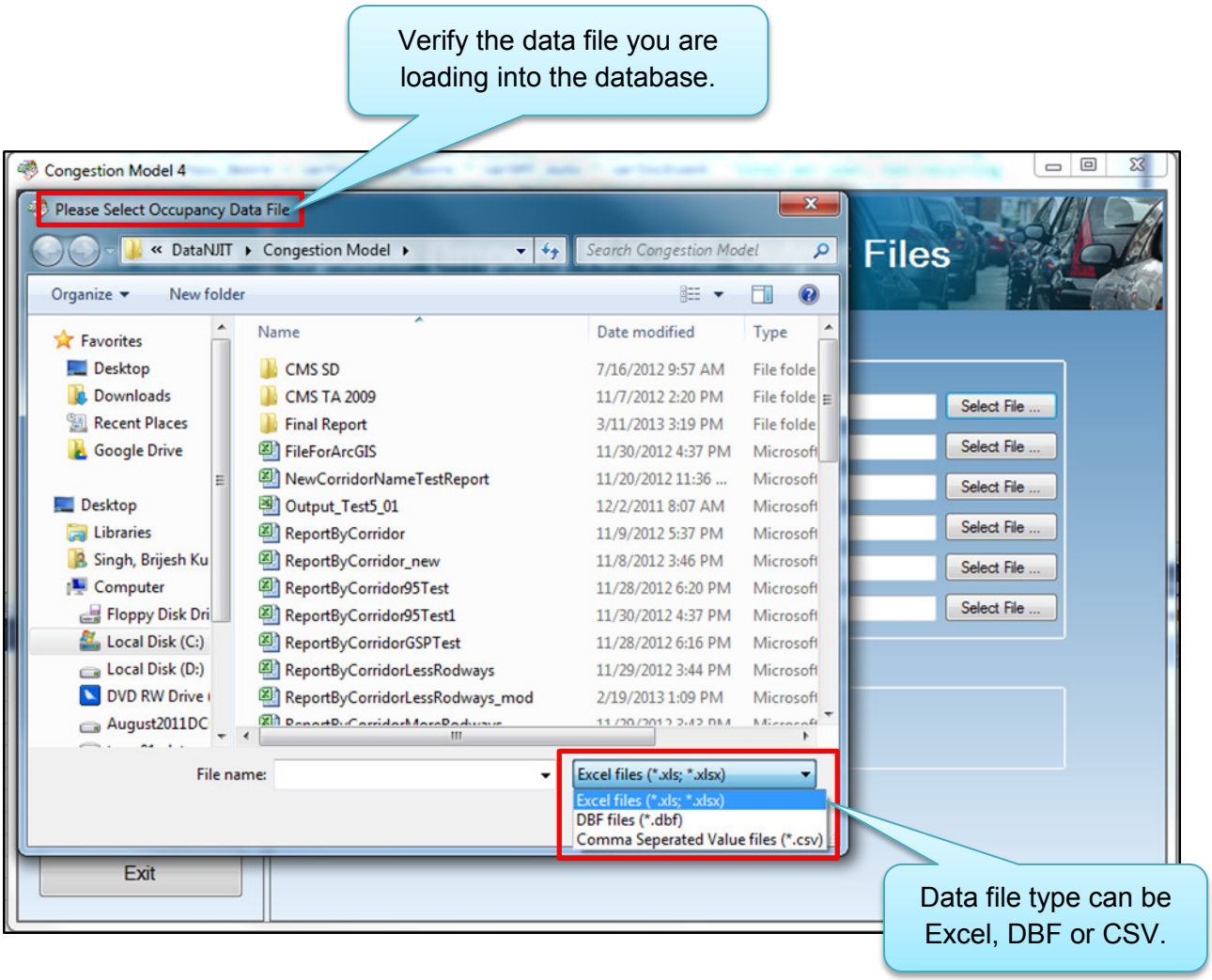


Step 4: Updating the NJCMS Tables in the Database

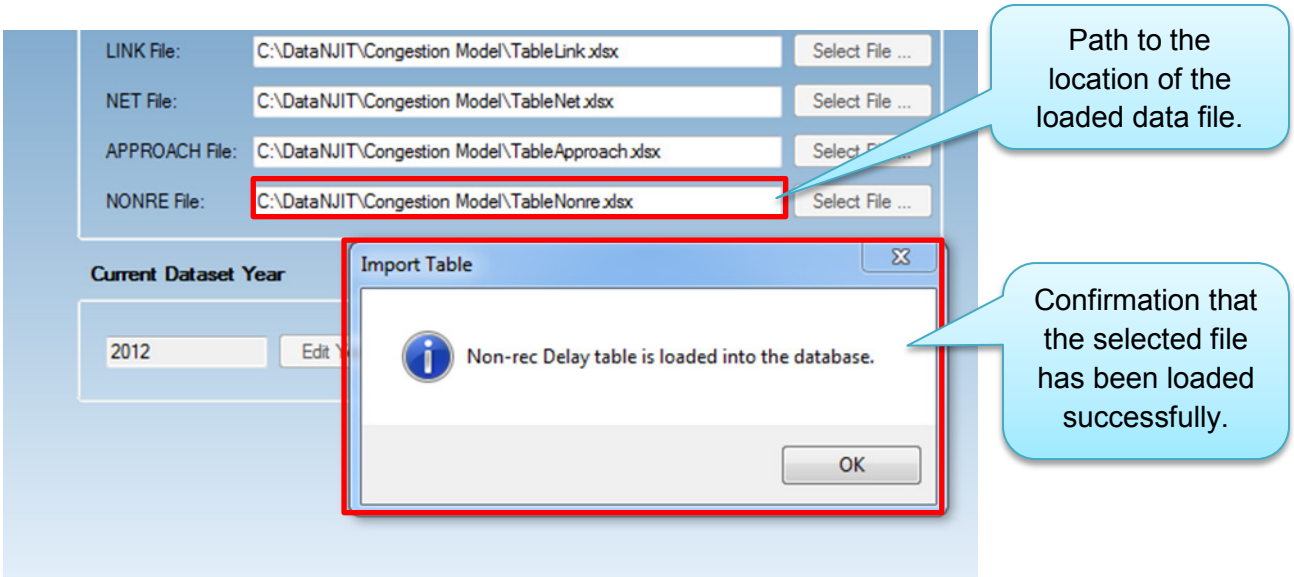
Clicking on the “Database Update” button in the “Navigation Bar” takes the user to the roadway network database update screen. This screen allows the user to load NJCMS output files by clicking on the appropriate “Select File …” button.



The "Open File…" dialog box appears to allow the user to select the appropriate file. In order to prevent loading wrong files, please verify the title of the "Open File…" Dialog box and select the correct file.

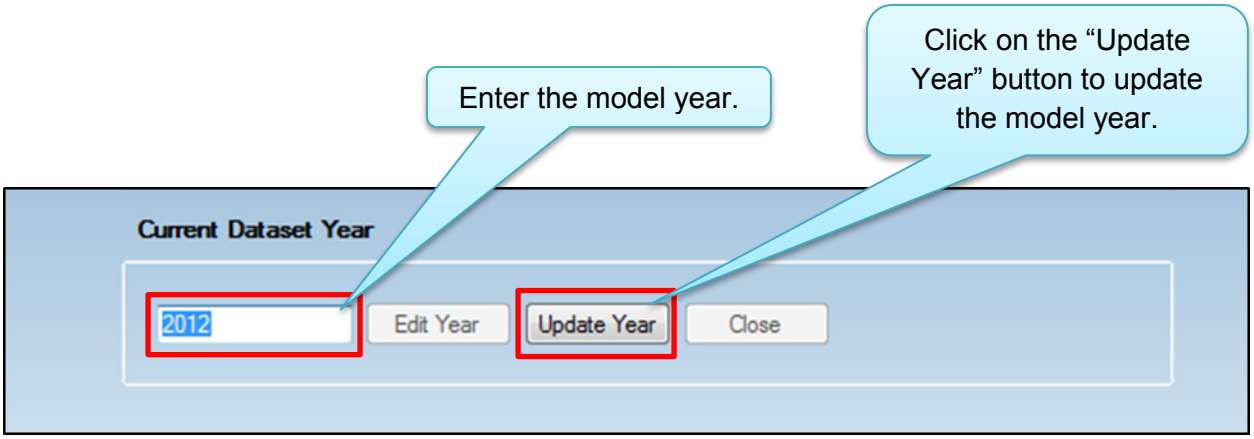


The user can load data from DBF, Excel and CSV file type. After selecting the file, the table is loaded into the database. A dialog box displays a message that the table is created.



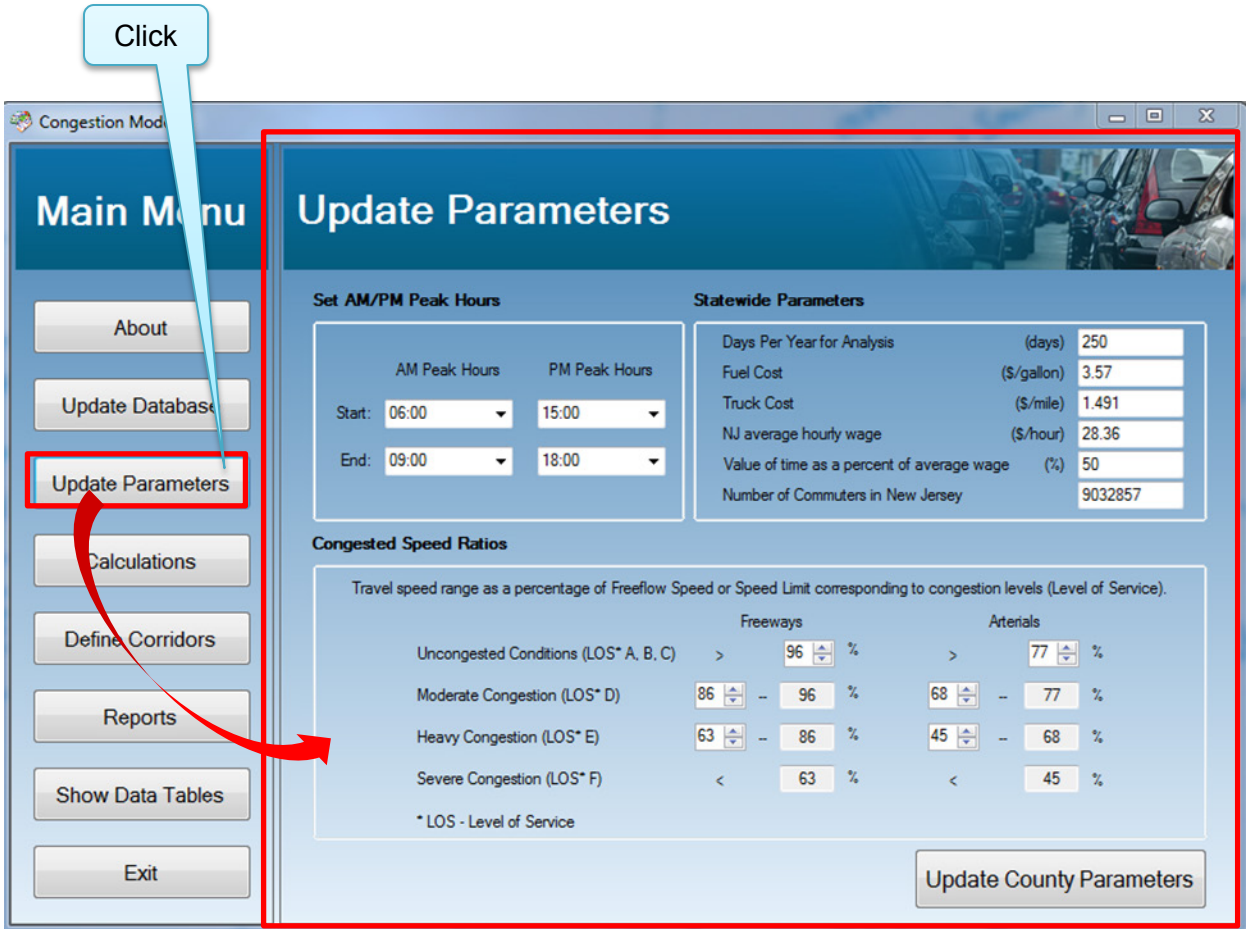
A path to the location of the loaded file is also saved and displayed in a box next to the file description and the “Select File…” button. Although NJCMS tables are actually imported in the application database, these paths serve as a reference for the files that are currently loaded in the database.

On the “Update (Import) NJCMS Output Files” screen the user can also modify the model year of the loaded roadway network once the files are updated (as shown below). Clicking on the “Close” button on the “Update (Import) NJCMS Output Files” screen takes the user back to the “About” screen.

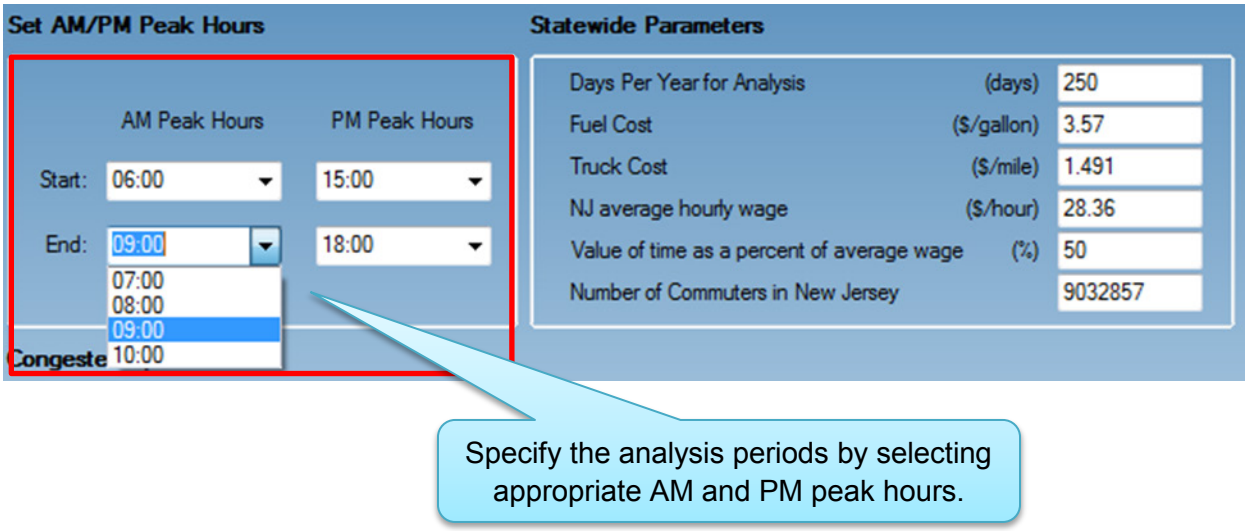


Step 5: Updating General Model Parameters

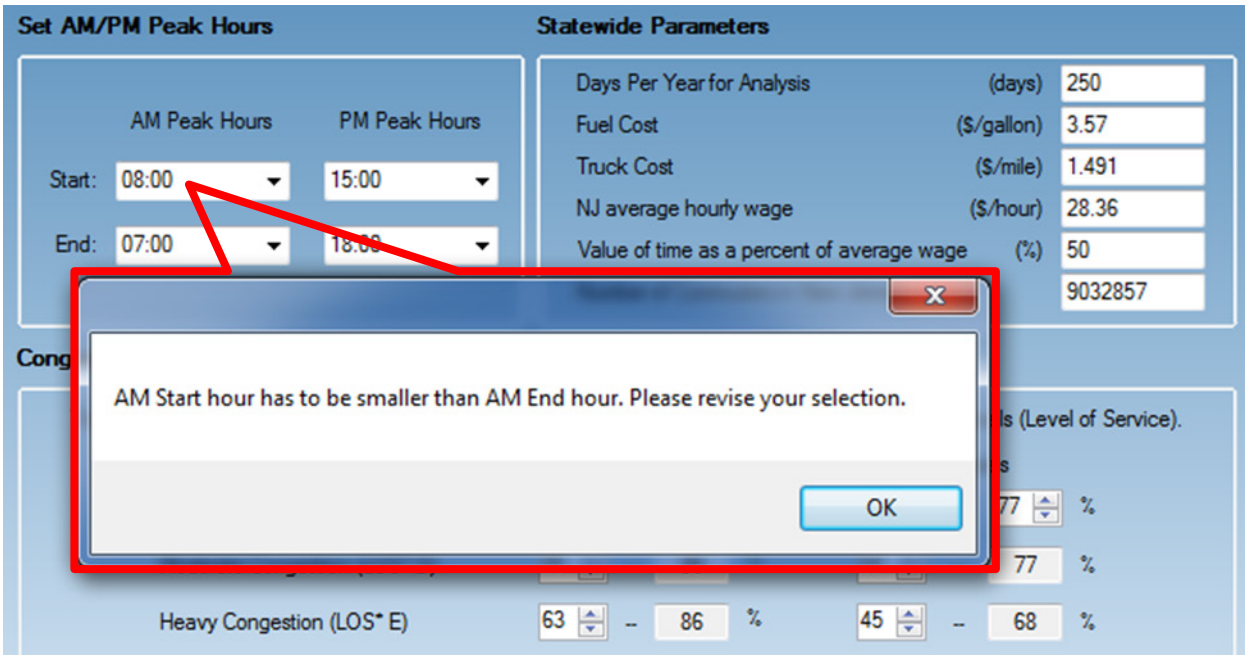
Parameters are updated on the “Update Parameters” screen, accessed by clicking on the “Update Parameters” button on “Navigation Panel”. On this screen, the user can: update values for the speed percentages used to determine LOS on network links, select a.m. and p.m. peak hours, and specify the number of days per year for analysis purposes, statewide average fuel costs, per-mile truck cost, statewide average hourly wage used to estimate value of time for the traveling public, value of time as a percent of average wage and number of commuters in New Jersey.



Peak hours are selected by specifying the a.m. and p.m. peak starting and ending hours. For example, to select a 3-hour a.m. peak from 6:00 to 9:00, the user would select 6:00 from the “AM Start” and 9:00 from the “AM End” menu. This menu allows the user to specify any combination of a.m. and p.m. periods to be analyzed in the model.



Built-in verification logic does not allow infeasible selections, e.g. AM Start at 8:00 and AM End at 7:00 (see below).

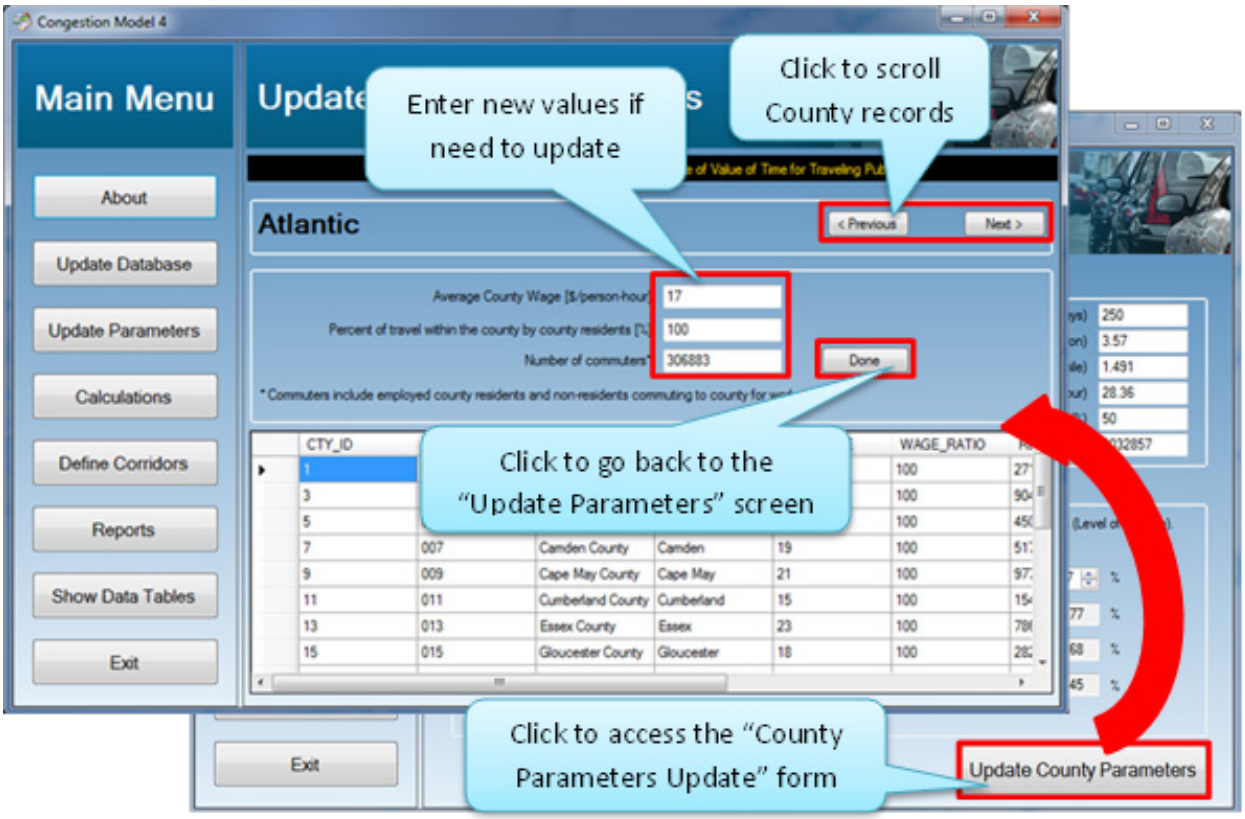


Other parameter values on the “Update Parameters” screen can be edited manually. The values are immediately updated in the model database.

Step 6: Updating County Parameters

From the “Update Parameters” screen the user can open the “Update County Parameters” form by clicking on the “Update County Parameters” button. In this form the user can browse through and update parameters for each county. The parameters include:

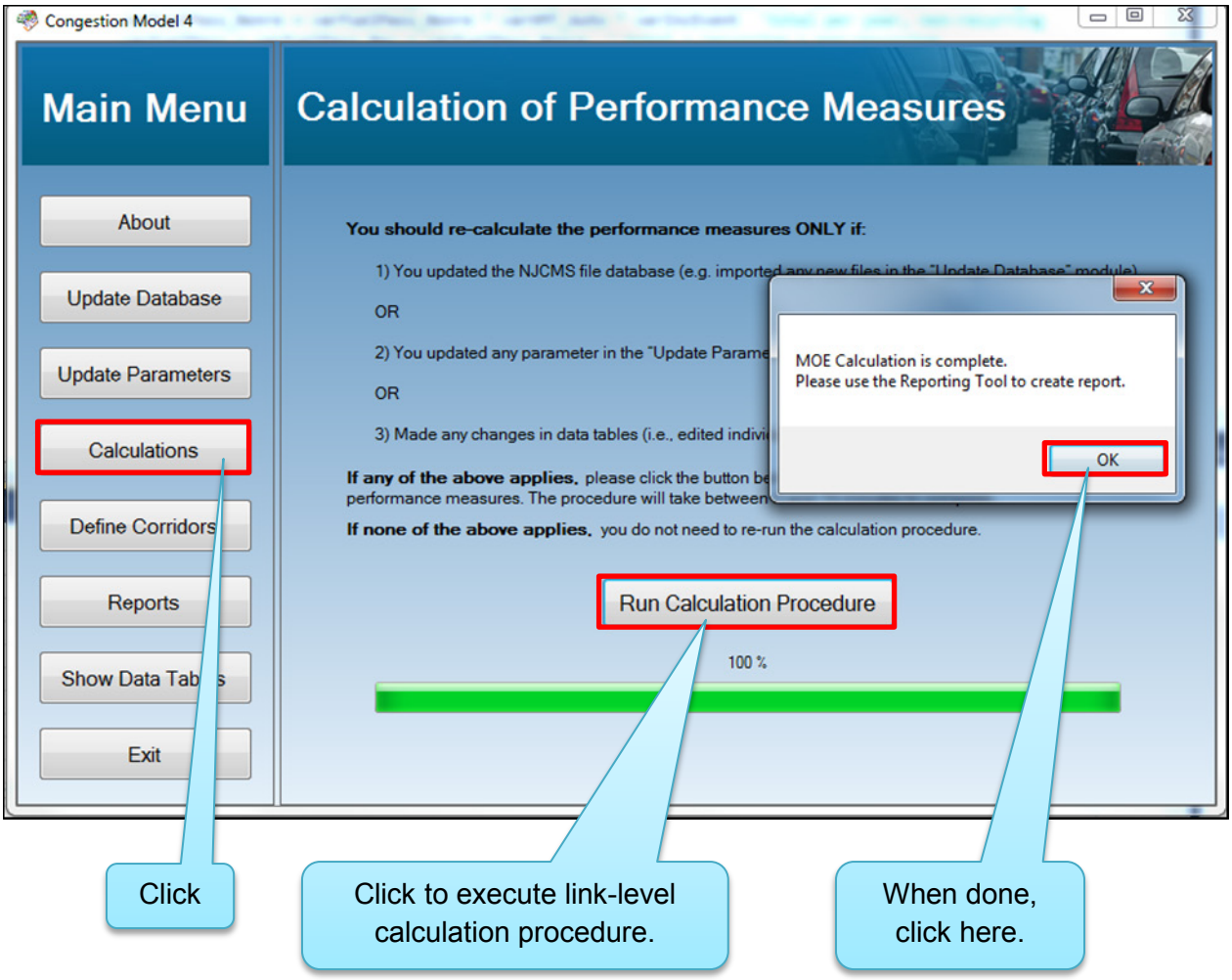
- Average county hourly wage per worker [dollars per hour];
- Percent of travel within the county by county residents [%] ;
- Number of commuters.



When finished updating county parameters, the user should click on the “DONE” button on the “County Parameter Update” form to go back to the “Parameter Update” screen.

Step 7: Running the Analysis (Executing Calculation Procedure)

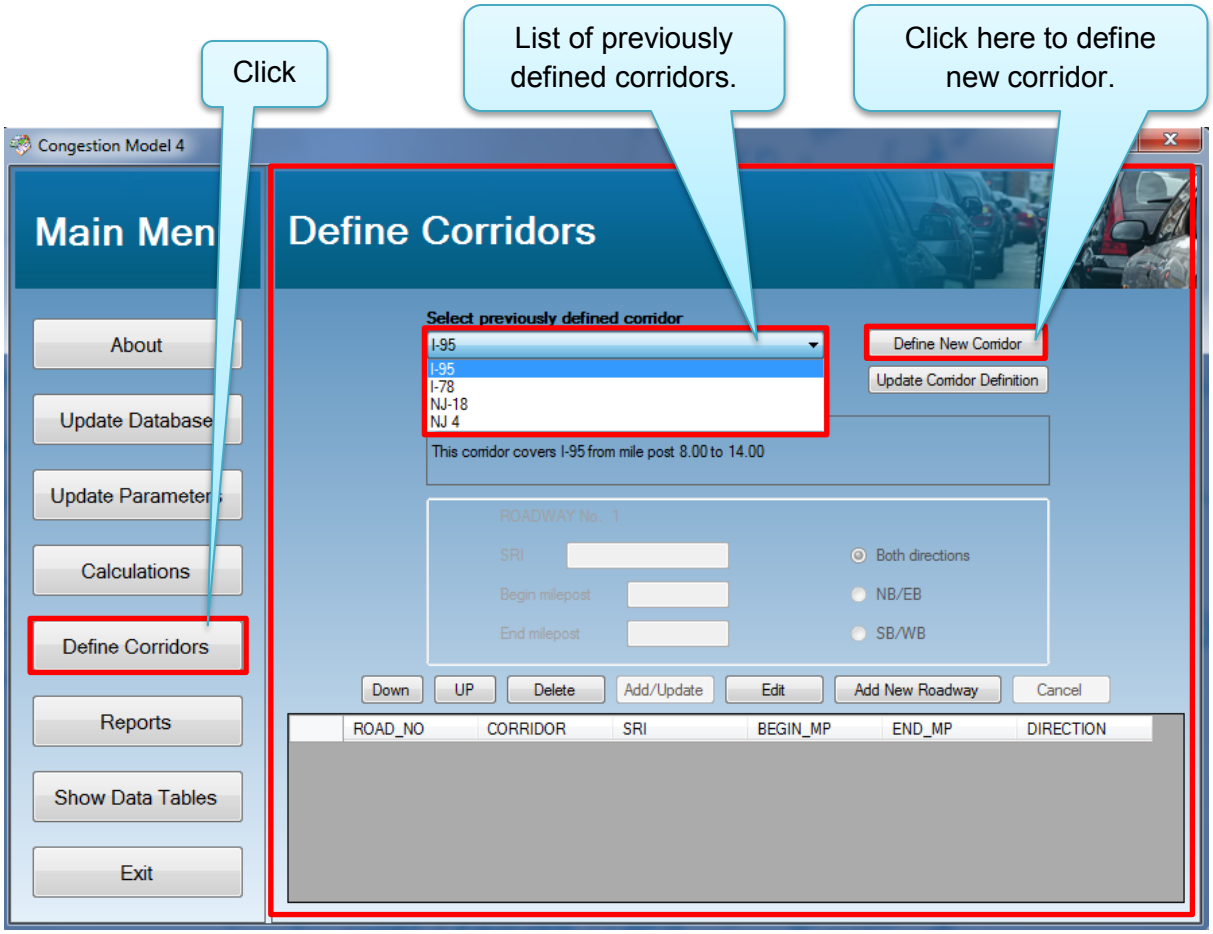
After updating the network database, county statistics, and analysis settings, the user can access the “Calculation of Performance Measures” screen by clicking on the “Calculations” button on the “Navigation Bar”. The user can execute the calculation procedure by clicking on the “Run Congestion Analysis” button on the “Calculation of Performance Measures” screen. The progress bar appears on the screen which updates the user about the status of the calculation procedure. During this process all performance and congestion measures are calculated on the link level and saved in the model database.



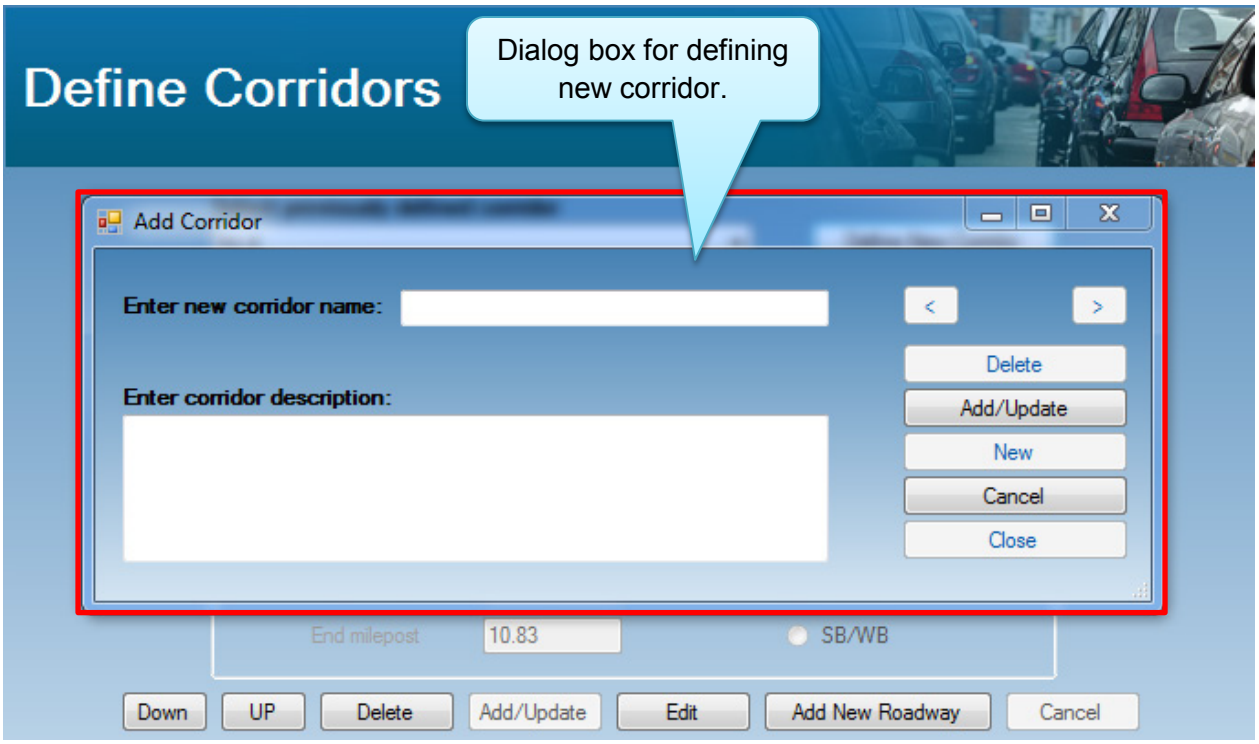
Once the calculation is complete and all measures of effectiveness (MOEs) are calculated for the entire network, a dialog box informs the user and directs him/her to the reporting module.

Step 8: Define Corridors

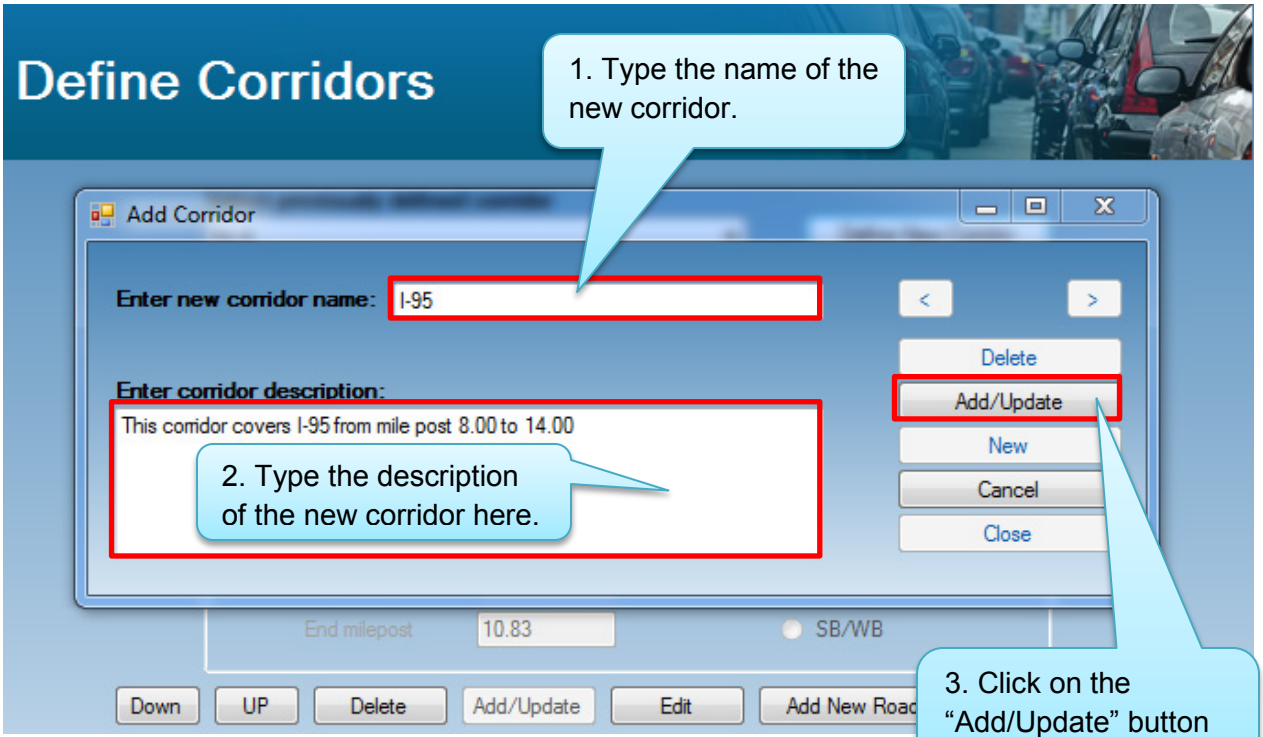
The user can access the “Define Corridors” screen by clicking on the “Define Corridors” button on the “Navigation Bar”. Define Corridors gives the user the ability to define custom corridors for analysis. A dropdown box allows the user to select previously defined corridors and gives the user the ability to edit or update the corridor parameters (explained later).



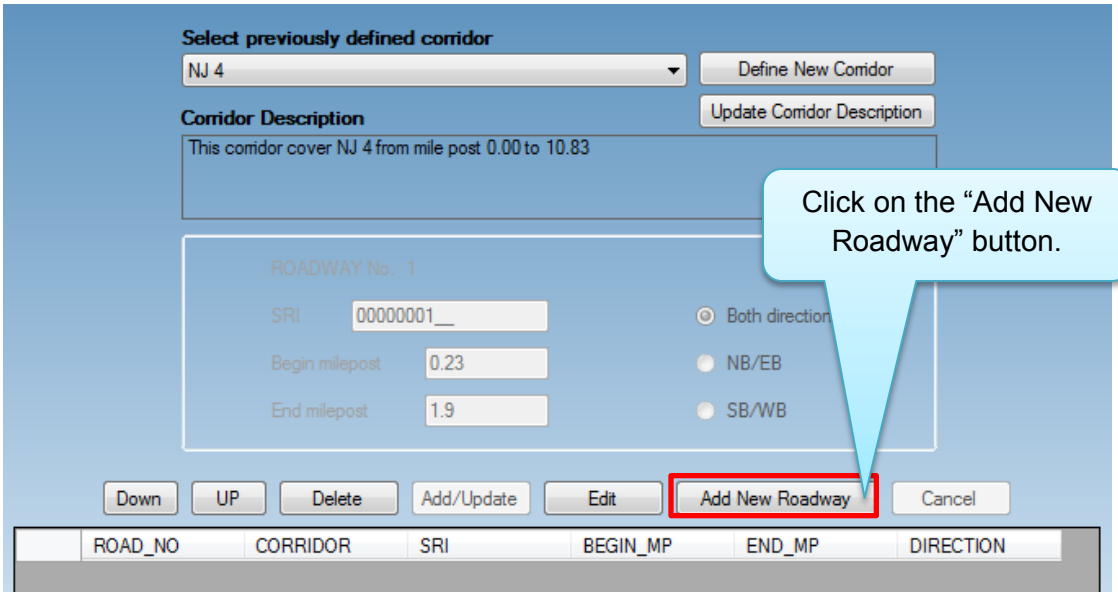
A new corridor can be defined by clicking on the “Define New Corridor” button in the work area, which pops up a new window with blank form to define a new corridor as shown in the figure below.



To add a new corridor, type in the name of the corridor, number of the commuters for the corridor and description of the corridor and click on the “Add/Update” button.

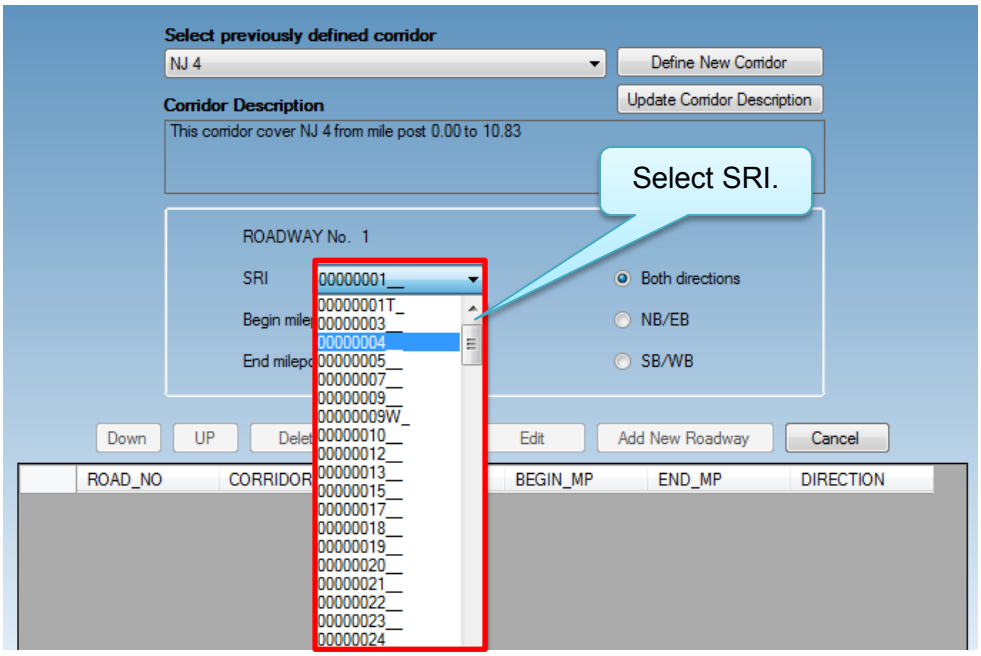


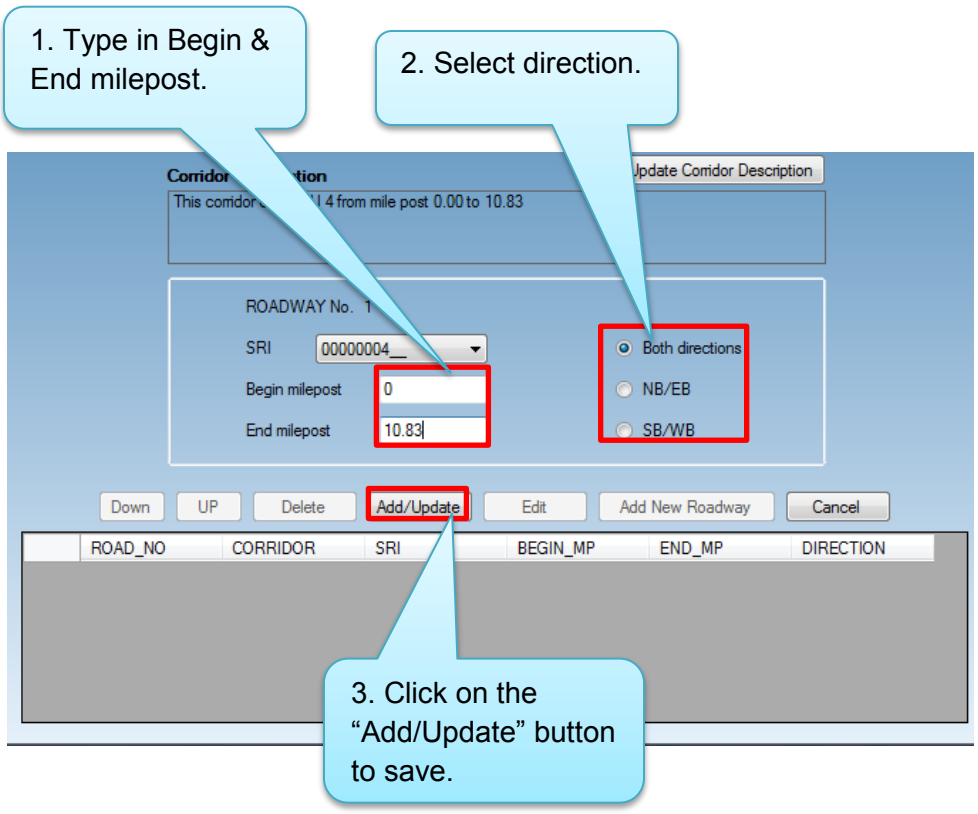
By clicking on the “Add/Update” button, the application brings the user back to the “Define Corridors” screen and automatically selected the new added corridor in the dropdown box. On this screen, the user can add roadways to the newly added corridor.



To add a new roadway, click on the “Add New Roadway” button, clicking on the “Add New Roadway” button enables the parameter input box.

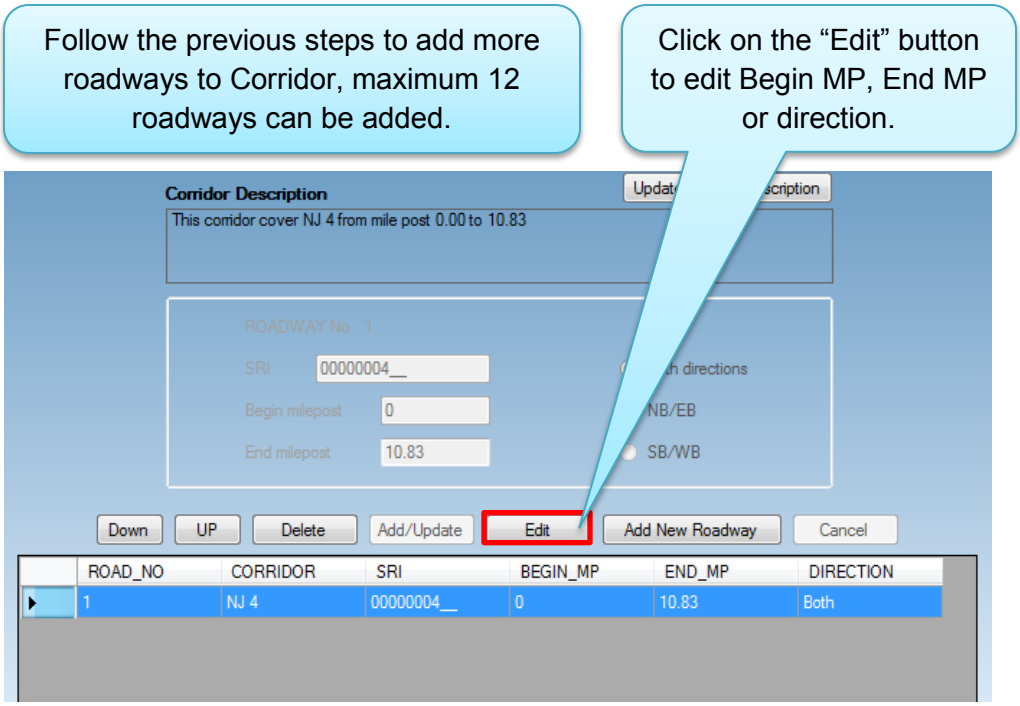
- Select SRI from the dropdown list of SRI’s;
- Select direction of the roadway (e.g. NB/SB);
- Enter start milepost and end milepost values in the corresponding text box;
- Click on the “Add/Update” button to add and save this new roadway to the corridor;
- A maximum of 12 roadways can be added to one single corridor.

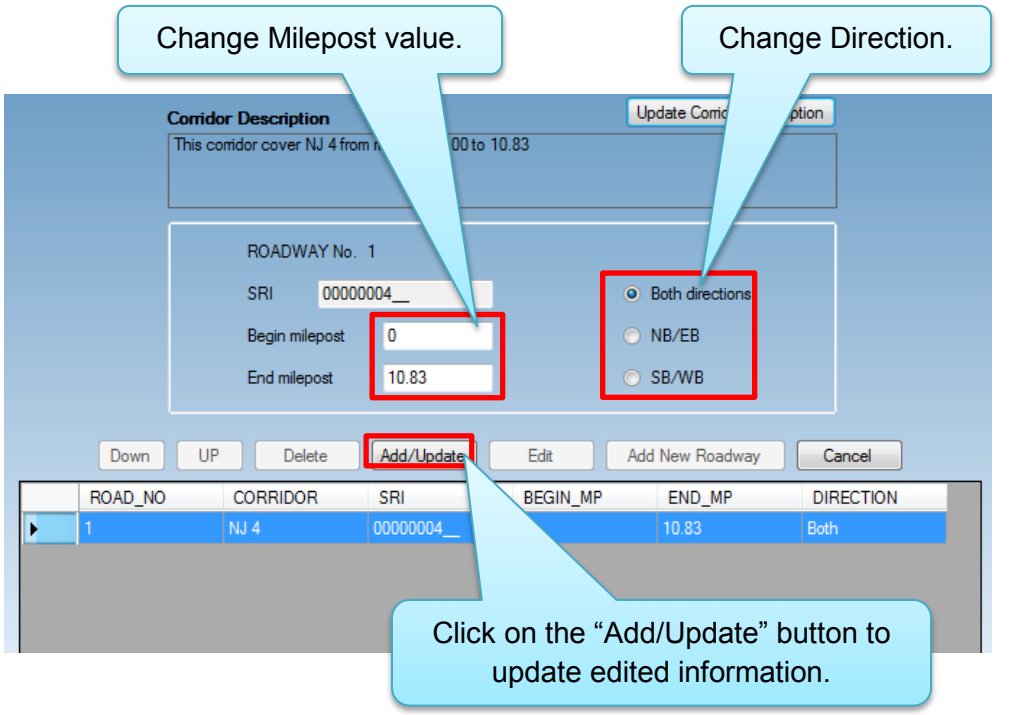




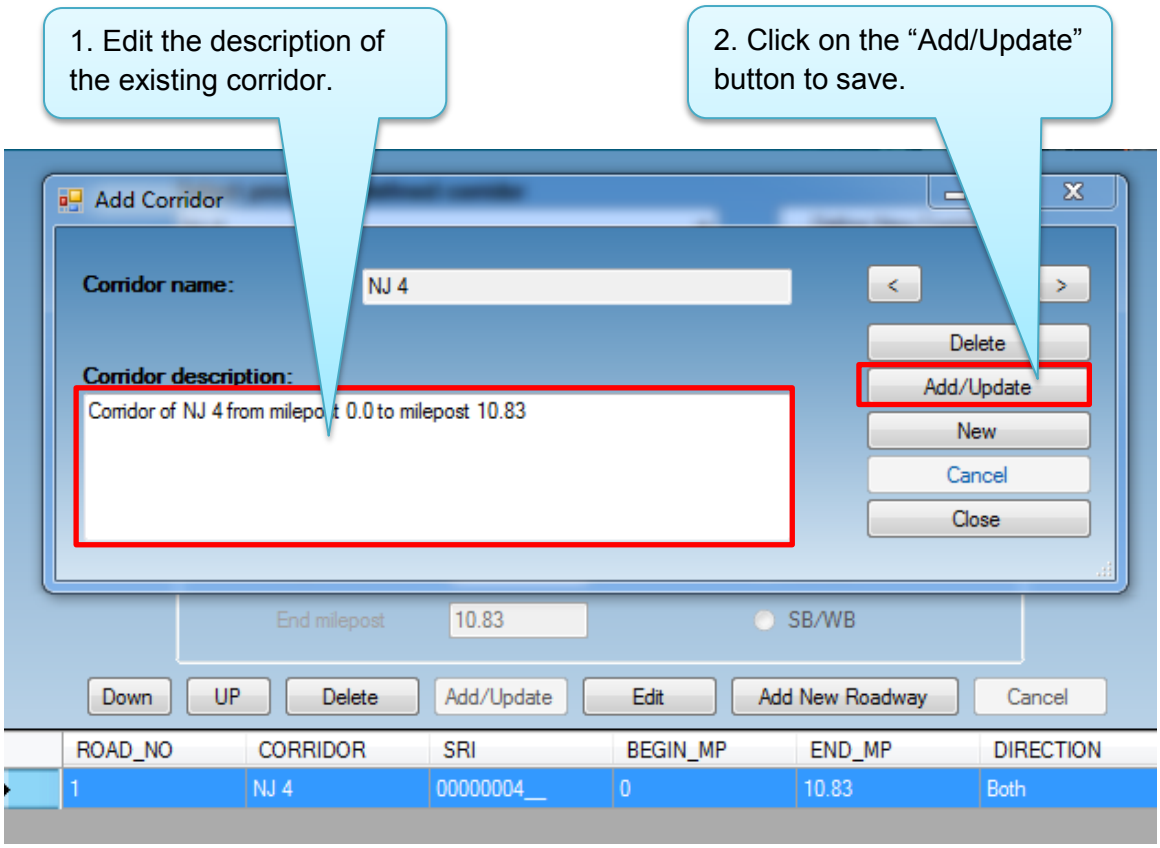
Clicking on the "Edit" button allows the user to edit the existing roadway information of the corridor, after clicking on the "Edit" button, select the desired roadway from the table and make changes to begin milepost, end milepost or direction of the roadway as

required and click on the “Add/Update” button to save the changes. The user cannot modify the SRI of the roadway. If the SRI needs to be changed, the user should delete the existing roadway with that SRI and add a new roadway with desired SRI to the corridor.





To update the corridor description click on the “Update Corridor Definition” button. This action opens a pop up window with information of the selected corridor. The user can edit the number of commuters in the corridor or the corridor description and click on the “Add/Update” button to save the changes. Clicking on the “Add/Update” button will bring the user back to the “Define Corridors” screen with updated information.

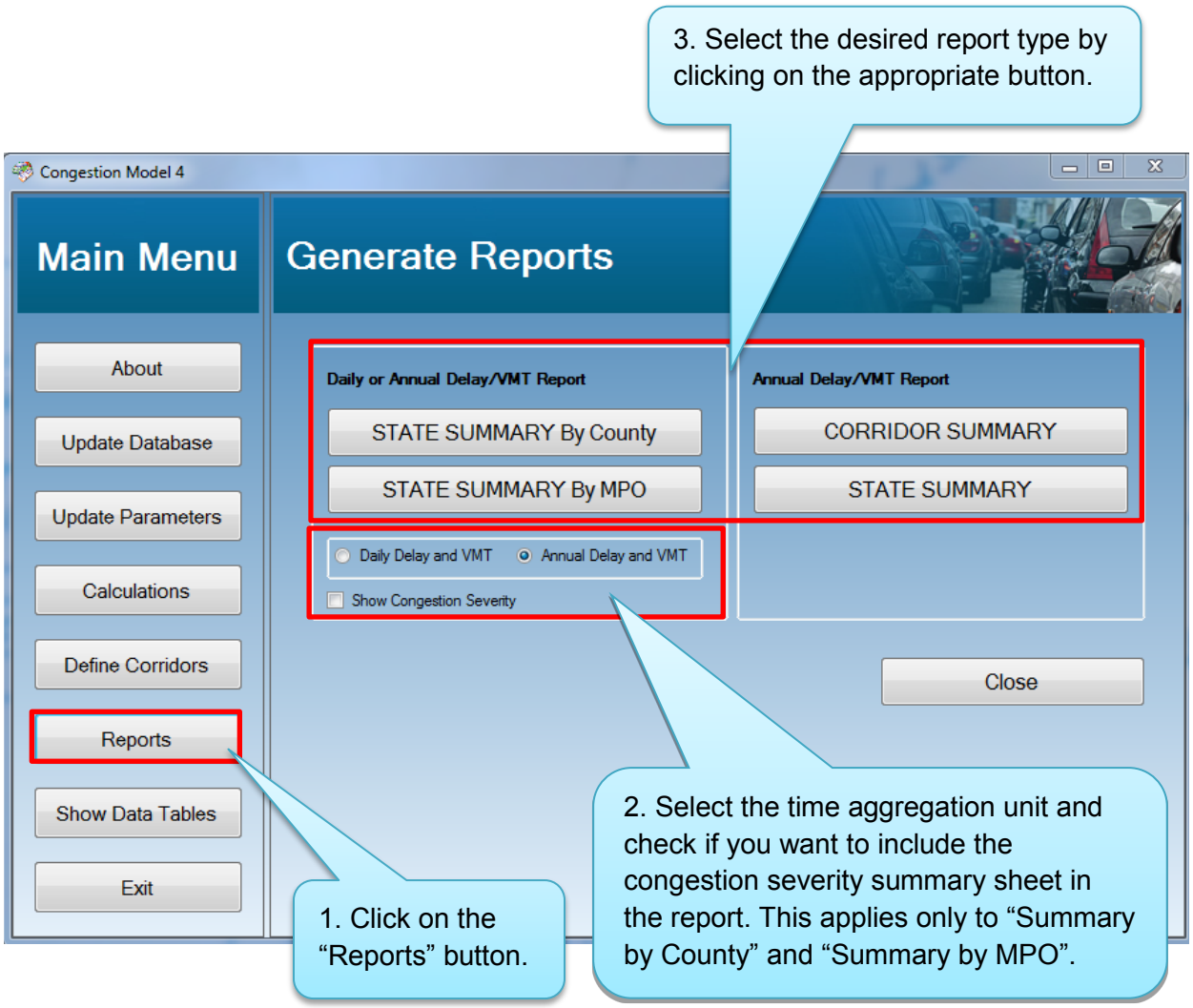


Step 9: Generating Reports

The “Generate Reports” screen can be accessed by clicking on the “Reports” button on “Navigation Bar”. This screen allows the user to select the report type.

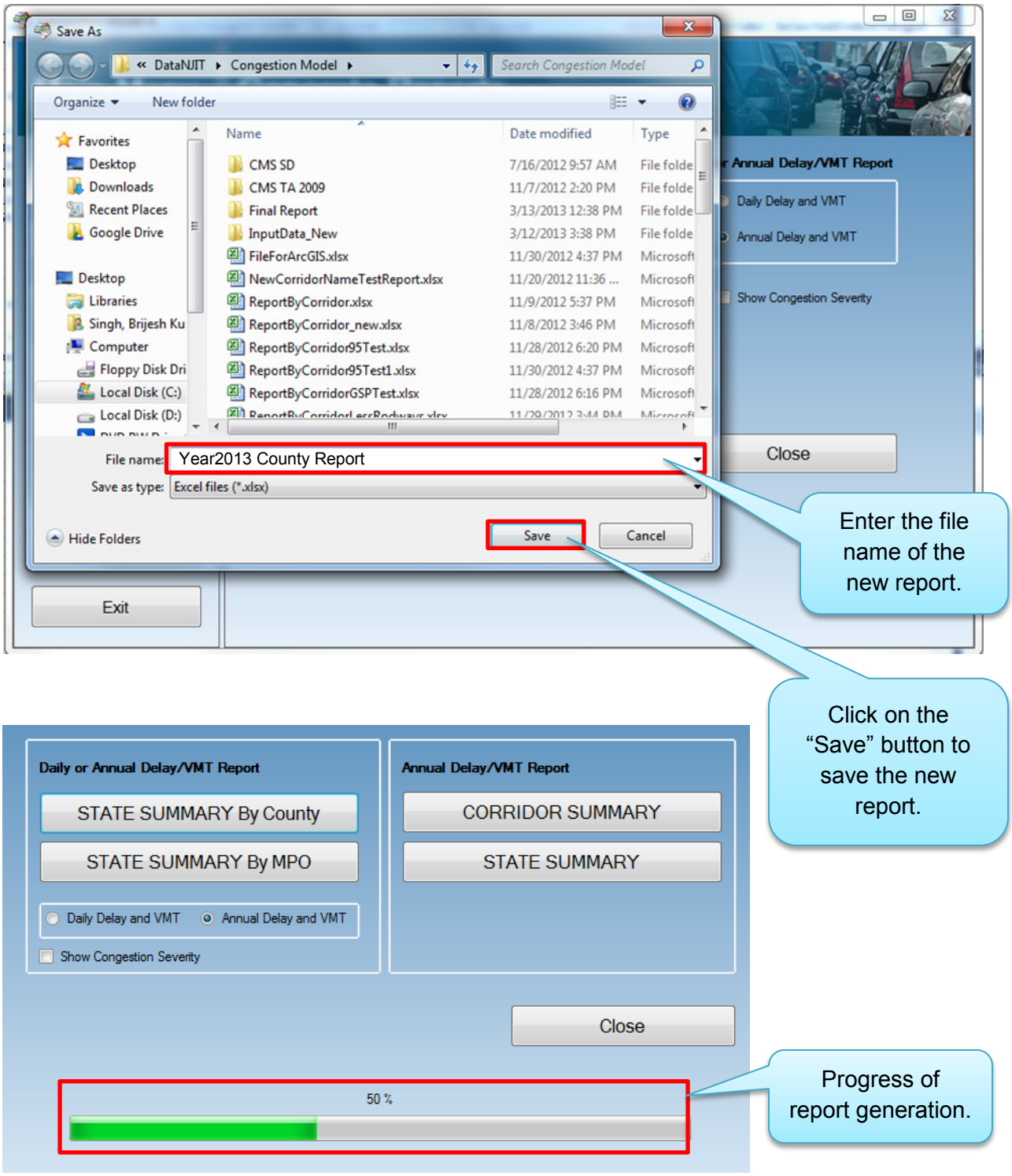
- The user can select the report by level of aggregation (county or MPO), and summary period (daily or annual summary). The selected summary period option only applies to delays and VMT, whereas costs and wasted fuel are only reported on an annual basis.

- The user can also choose to include a congestion severity sheet in the report, which summarizes congested vs. uncongested VMT and travel delay by county or MPO.
- The user can also choose a one page summary for State by clicking on the “State Summary” button.
- A Report for the corridor can be generated by clicking on the “Corridor Summary” button (complete process explained later in the section).



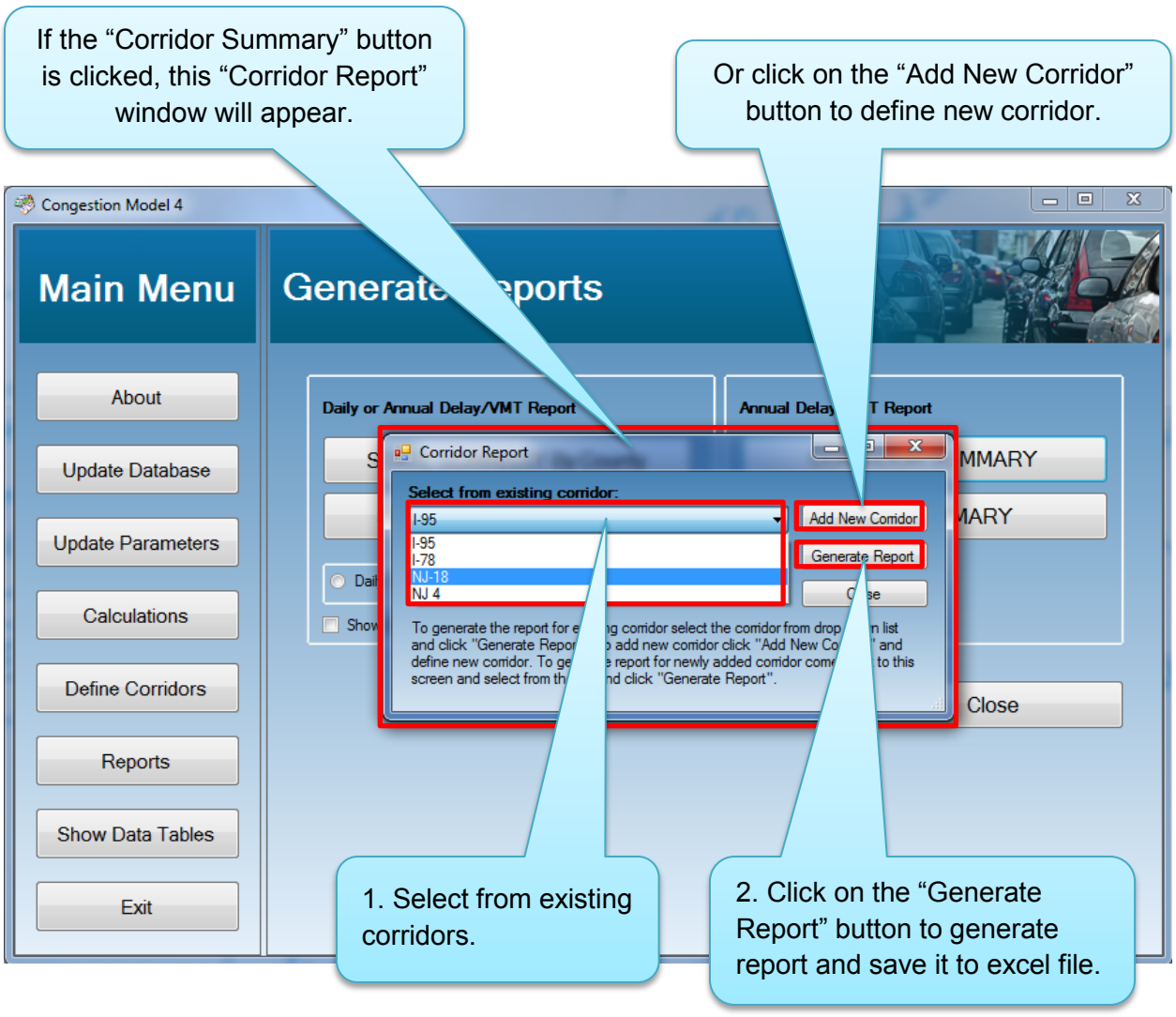
After clicking on the appropriate button for the desired report, the user is asked to provide a location to save the report (see the next page). After that the aggregation procedure aggregates the link level MOEs to the user-specified aggregation level and saves the summaries in the report. During the execution of the aggregation procedure,

the report generation progress bar screen provides the user with the information about the current status of the aggregation process. An Excel report file gets opened when the report generation is complete.



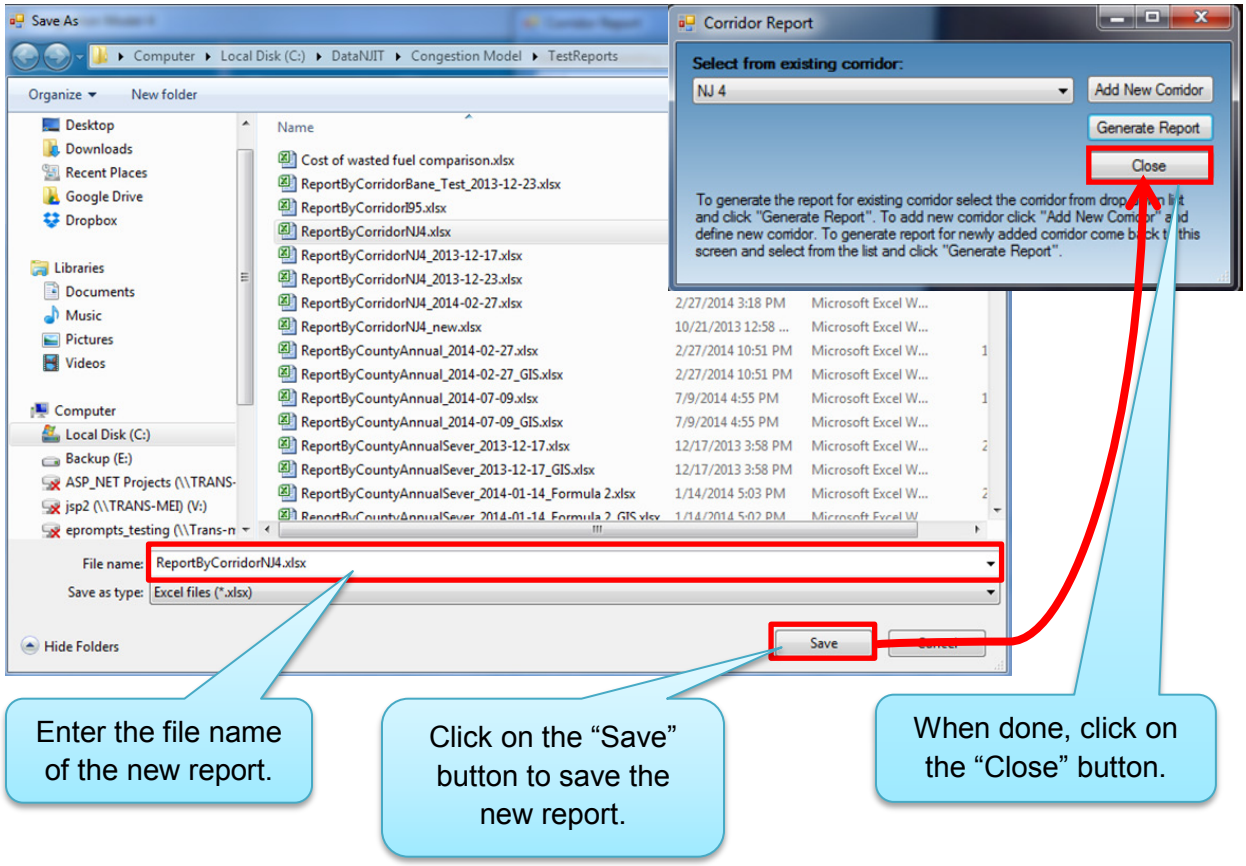
If the user clicks on the “Corridor Summary” button on the “Generate Reports” screen, then a new window opens giving the user the option to select the corridor from existing corridors or the user can add a new corridor. To add a new corridor, click on the “Add New Corridor” button. Clicking on the “Add New Corridor” button will take the user to the module of adding new corridor and adding new roadways to the corridor.

To generate the report for a newly added corridor, the user can go back to the “Generate Reports” screen and select “Corridor Summary”, which opens the “Corridor report” window. Now the user can select the newly added corridor from the dropdown list and click on the “Generate Report” button.



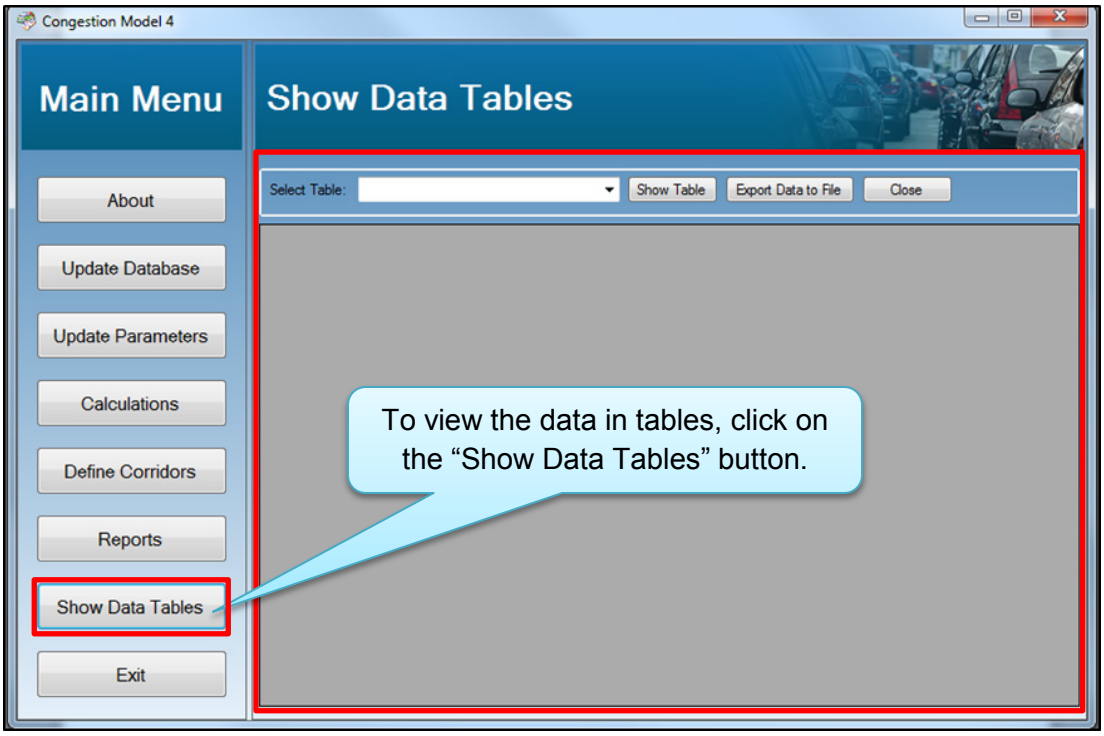
Once the “Generate Report” button is clicked, the “Save File” dialog box will open. Enter the file name of the new report and then click on the “Save” button. An Excel report file will get opened when report generation is completed.

After the corridor summary report generation is completed, the application will bring the user back to the “Corridor Report” window. The user can select another corridor to generate the report if needed or click on the “Close” button to exit from the “Corridor Report” window.



Step 10: Show Data Tables

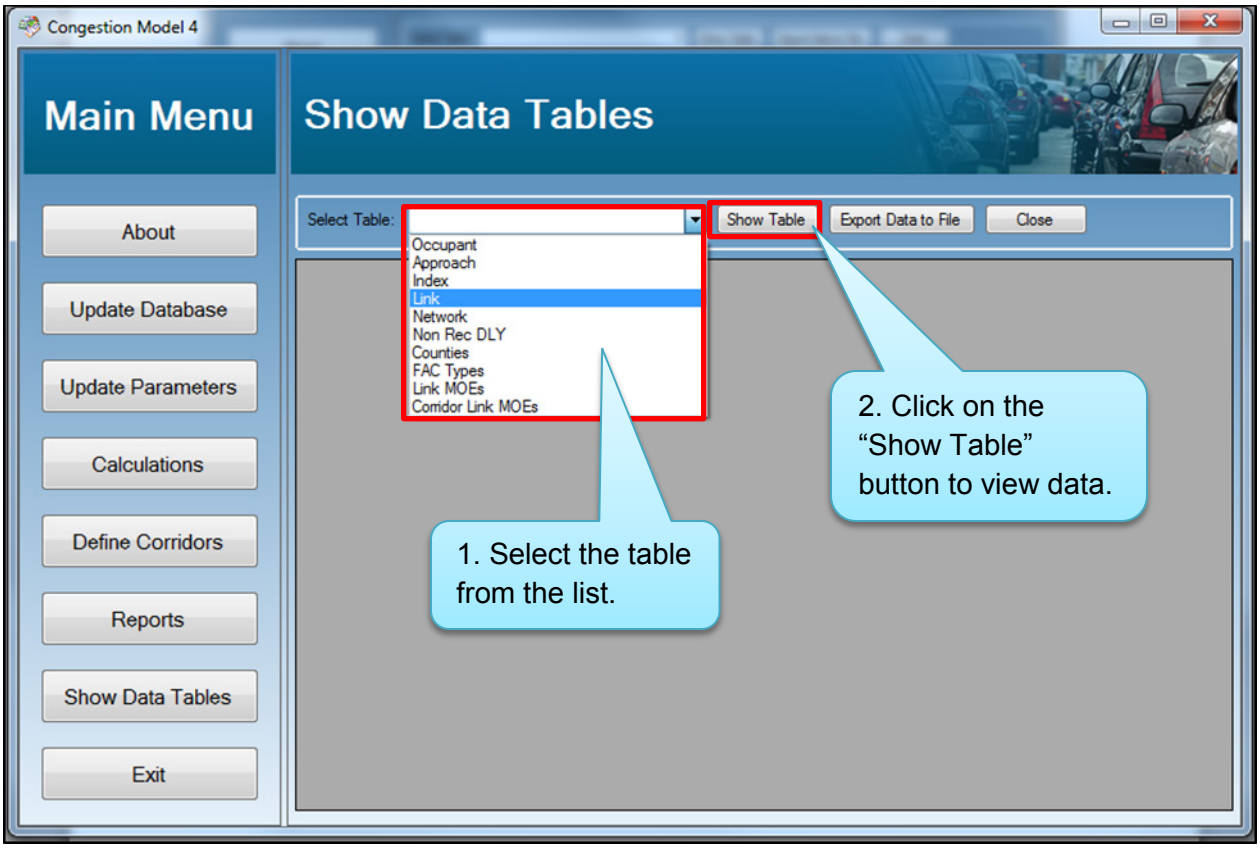
From the “Show Data Tables” screen which can be accessed by clicking on the “Show Data Tables” button on the “Navigation Bar”, the user can view the table data loaded in to the application database.



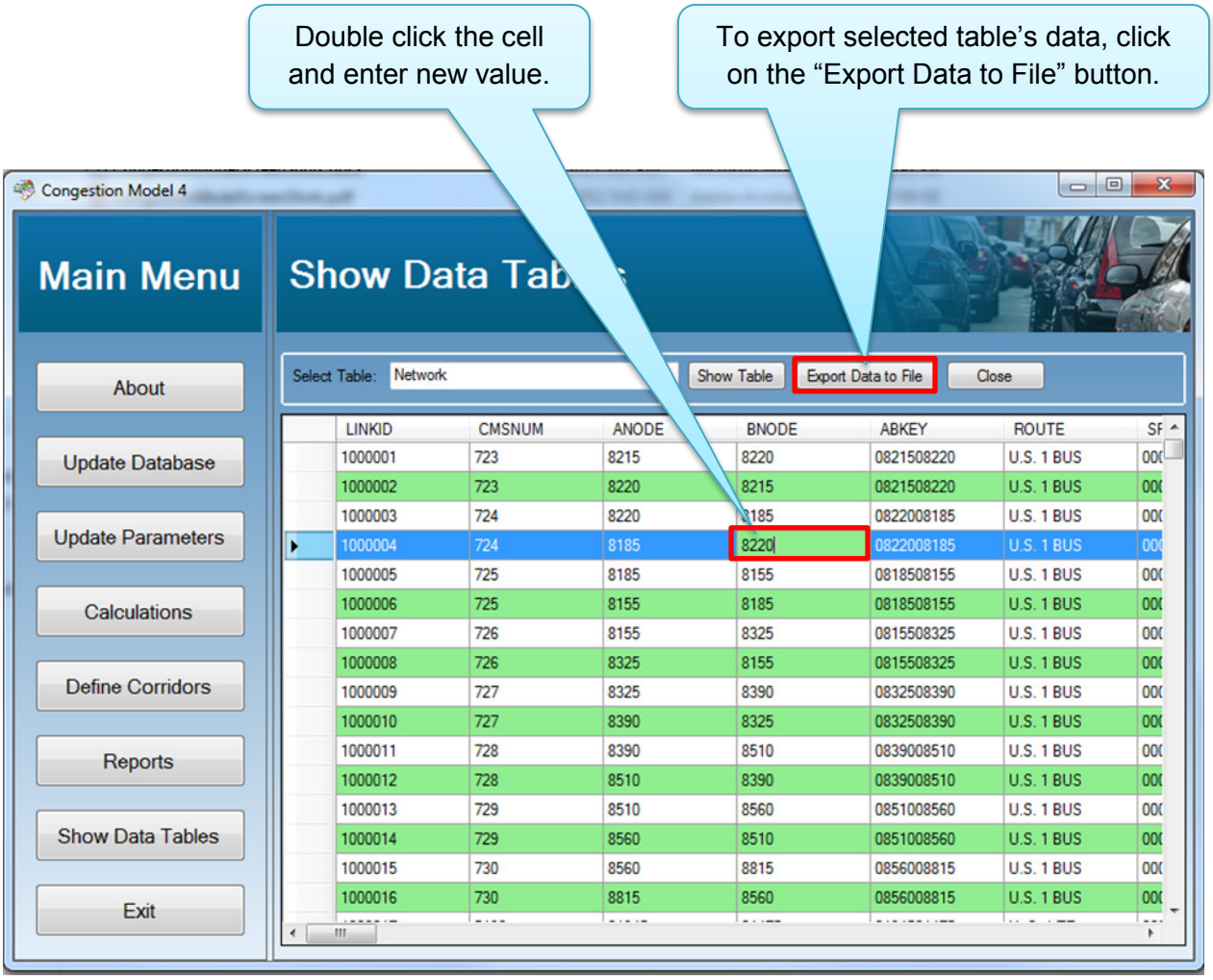
The user can select the desired data table from the dropdown list. The following is the list of tables which can be viewed:

1. Occupant
2. Approach
3. Index
4. Link
5. Network
6. Non-Recurring Delay
7. Counties
8. Facility Types
9. Link Measures of Effectiveness (MOEs)
10. Corridor Link MOEs (only for the corridor for which last report was generated)

Once the table is selected, table data can be viewed by clicking on the "Show Table" button, this action will populate the data of the table on the screen.

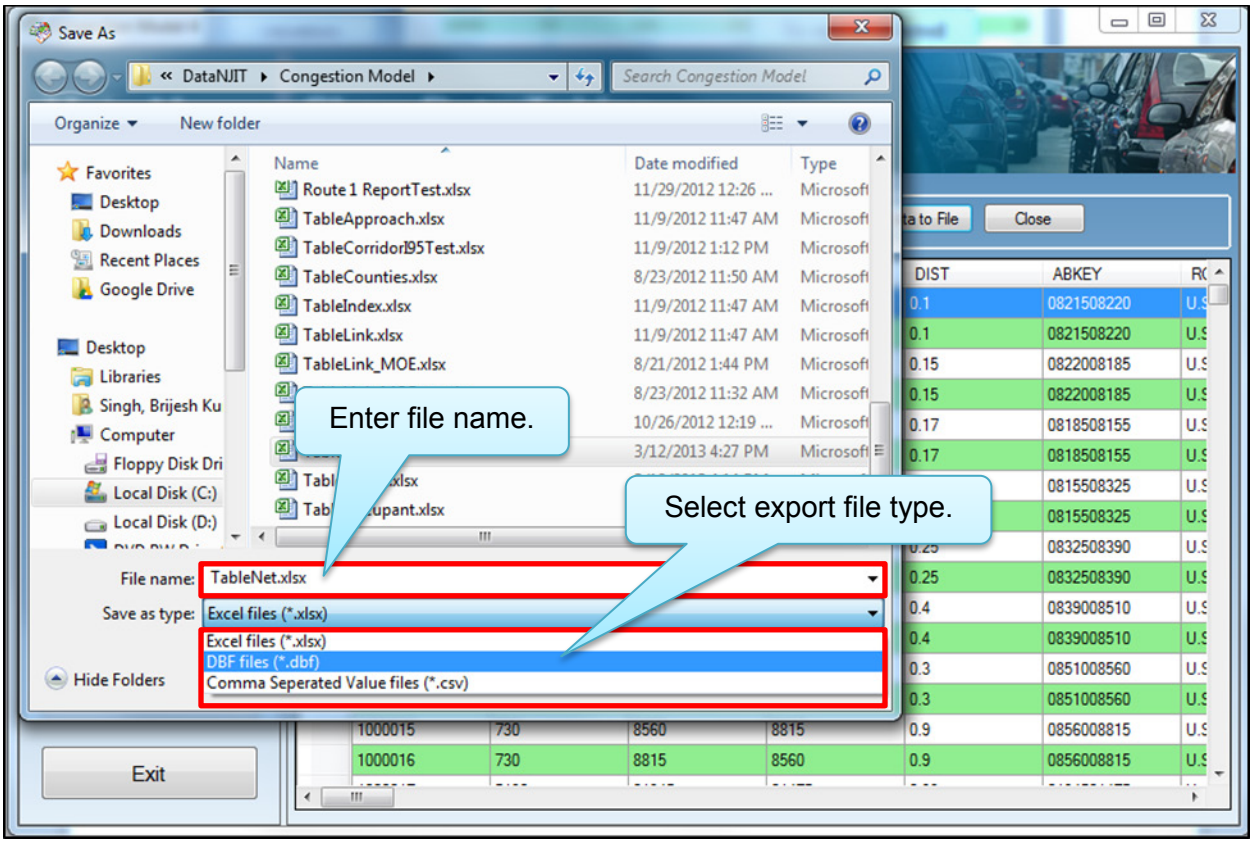


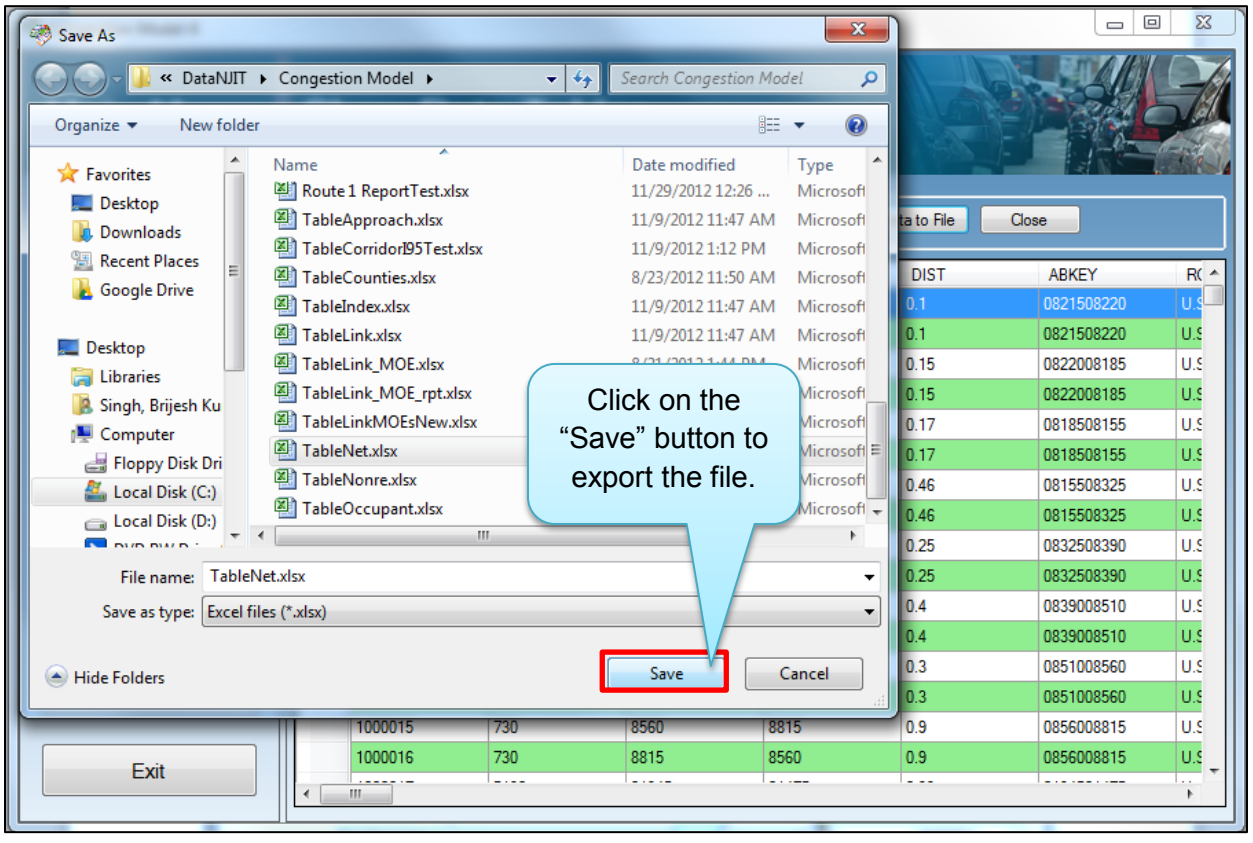
Once the data of the table is populated, the user has the ability to change the values in the table by double clicking (this action will change the cell to edit mode) the desired cell. Now, the user can enter the new value in the cell, and then click anywhere else on the screen, and the new value will be updated into the database.

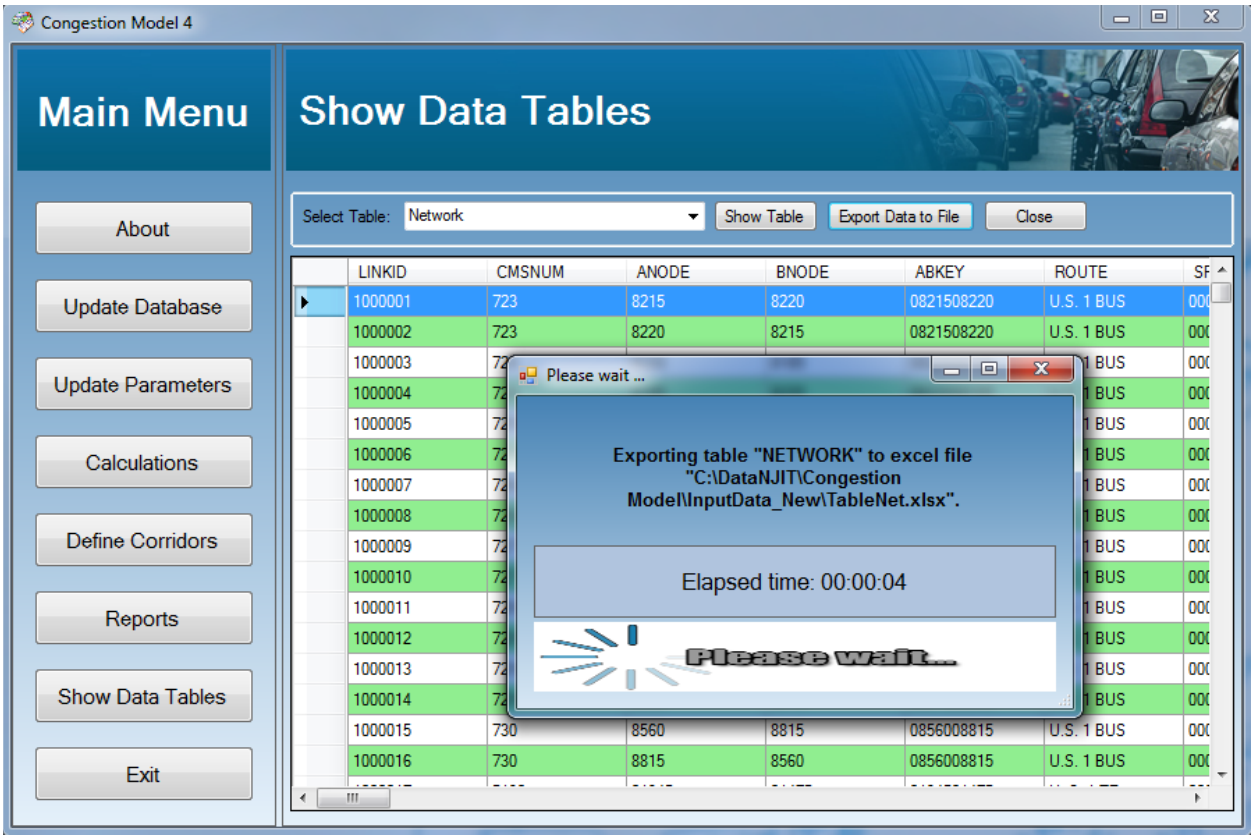


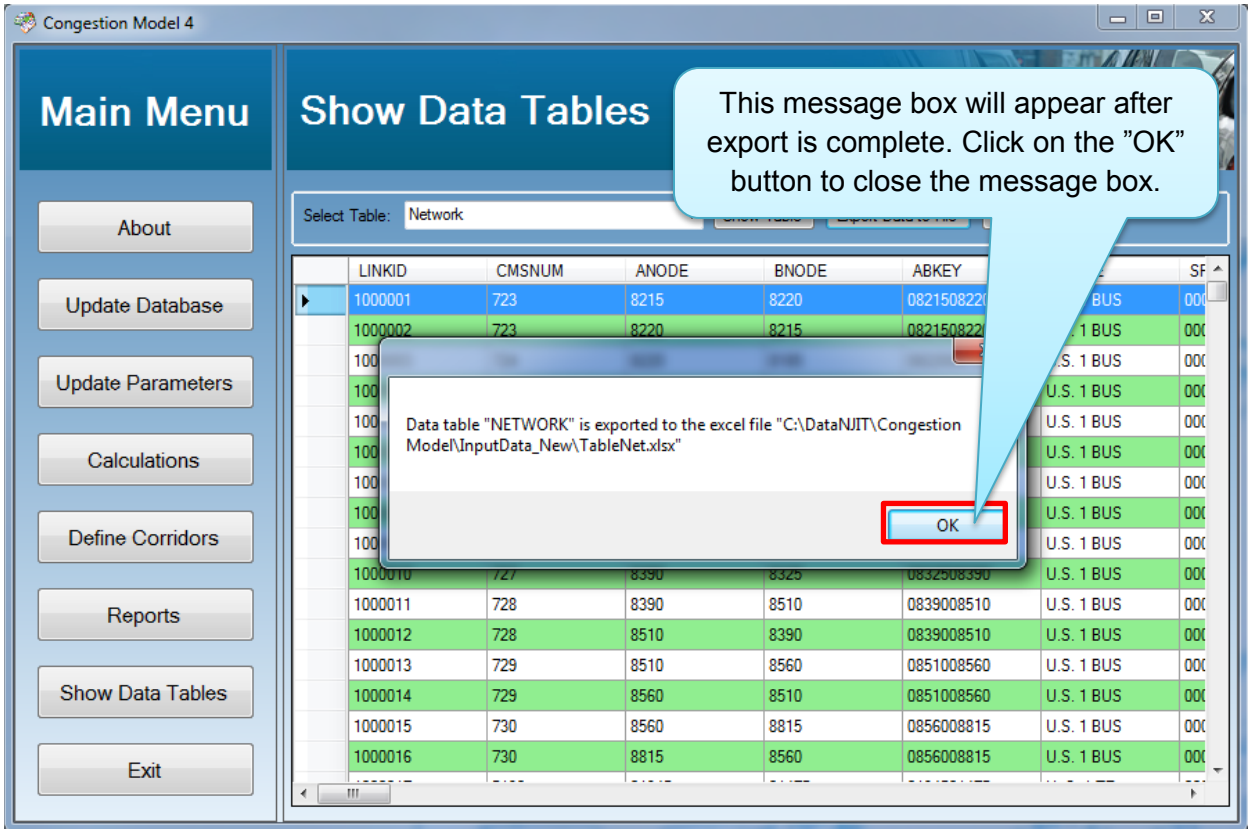
The user has the ability to export the selected table data in Excel, DBF or CSV file type. The user can export data by clicking on the "Export Data to File" button, this action will open the "Save File" dialog box, and the user can enter the name of the file and select the file type as shown in the figure, click on the "Save" button to export the data.

The next couple of figures show the process of exporting the table data in sequence as it appears after clicking on the "Export Data to File" button.


Save As
DataNJIT ▸ Congestion Model ▸
Search Congestion Model
Organize
New folder
Favorites
Desktop
Downloads
Recent Places
Google Drive
Desktop
Libraries
Singh, Brijesh Ku
Computer
Floppy Disk Dri
Local Disk (C:)
Local Disk (D:)
Name
Date modified
Type
Route 1 ReportTest.xlsx
TableApproach.xlsx
TableCorridorI95Test.xlsx
TableCounties.xlsx
TableIndex.xlsx
TableLink.xlsx
TableLink_MOE.xlsx
Enter file name.
Select export file type.
File name: TableNet.xlsx
Save as type: Excel files (*.xlsx)
Excel files (*.xlsx)
DBF files (*.dbf)
Comma Seperated Value files (*.csv)
Hide Folders
Exit
Close
DIST
ABKEY


Save As
DataNJIT ▸ Congestion Model ▸
Search Congestion Model
Organize
New folder
Favorites
Desktop
Downloads
Recent Places
Google Drive
Desktop
Libraries
Singh, Brijesh Ku
Computer
Floppy Disk Dri
Local Disk (C:)
Local Disk (D:)
Name
Date modified
Type
Route 1 ReportTest.xlsx
TableApproach.xlsx
TableCorridorI95Test.xlsx
TableCounties.xlsx
TableIndex.xlsx
TableLink.xlsx
TableLink_MOE.xlsx
TableLink_MOE_rpt.xlsx
TableLinkMOEsNew.xlsx
TableNet.xlsx
TableNonre.xlsx
TableOccupant.xlsx
Click on the "Save" button to export the file.
File name: TableNet.xlsx
Save as type: Excel files (*.xlsx)
Hide Folders
Save
Cancel
Exit
Close
DIST
ABKEY


Congestion Model 4
Main Menu
About
Update Database
Update Parameters
Calculations
Define Corridors
Reports
Show Data Tables
Exit
Show Data Tables
Select Table: Network
Show Table
Export Data to File
Close
LINKID CMSNUM ANODE BNODE ABKEY ROUTE
1000001 723 8215 8220 0821508220 U.S. 1 BUS
1000002 723 8220 8215 0821508220 U.S. 1 BUS
1000015 730 8560 8815 0856008815 U.S. 1 BUS
1000016 730 8815 8560 0856008815 U.S. 1 BUS
Please wait ...
Exporting table "NETWORK" to excel file "C:\DataNJIT\Congestion Model\InputData_New\TableNet.xlsx".
Elapsed time: 00:00:04
Please wait...


Congestion Model 4
Main Menu
About
Update Database
Update Parameters
Calculations
Define Corridors
Reports
Show Data Tables
Exit
Show Data Tables
Select Table: Network
This message box will appear after export is complete. Click on the ”OK” button to close the message box.
Data table "NETWORK" is exported to the excel file "C:\DataNJIT\Congestion Model\InputData_New\TableNet.xlsx"
OK
1000001 723 8215 8220
1000011 728 8390 8510 0839008510 U.S. 1 BUS
1000012 728 8510 8390 0839008510 U.S. 1 BUS
1000013 729 8510 8560 0851008560 U.S. 1 BUS
1000014 729 8560 8510 0851008560 U.S. 1 BUS
1000015 730 8560 8815 0856008815 U.S. 1 BUS
1000016 730 8815 8560 0856008815 U.S. 1 BUS

Step 11: Exiting (closing) the Application

The user exits the application by clicking on the “EXIT” button on the “Navigation Bar”.