

Alternative Performance Measures for Evaluation of Congestion – Congestion Analysis Model Update and Maintenance

FINAL REPORT

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Submitted by

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16. Abstract <p>Traffic congestion has numerous negative effects on the movement of people and goods, economic productivity and the environment. These effects include increased travel times resulting in lost wages and decreased labor productivity, wasted fuel and cost associated with it, deteriorating air quality, and drivers' stress, which can adversely affect safety, health, and labor productivity. In recent years these effects have come to the forefront of the public's concern. In order to quantify traffic congestion and its impacts on New Jersey's motorists, New Jersey Institute of Technology (NJIT) developed the Congestion Analysis Model. This is a computer software tool that estimates congestion costs, congestion related travel delay, and mobility indicators for New Jersey highways. The key advantage of NJIT's model over other computer models developed for the same purpose is that it uses the New Jersey Congestion Management System (NJCMS) database to calculate travel delays and other congestion indicators. This project builds on the accomplishments of the previous work on developing congestion analysis software. Specific objectives of this project are to update the calculation methodology, improve software's user interface, redesign the output tables to meet NJDOT's requirements, update software documentation, and provide limited technical support to NJDOT users.</p>			
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1. SUMMARY

In order to quantify traffic congestion and its impacts on New Jersey's motorists, New Jersey Institute of Technology (NJIT) developed the NJIT Congestion Analysis Model (NJITCAM), a computer software tool that estimates congestion costs, congestion related travel delay, and mobility indicators for New Jersey highways. In 2003 and 2004 the NJITCAM 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 NJITCAM was delivered to the New Jersey Department of Transportation (NJDOT) as part of the deliverables for this study. This research product enabled NJDOT to evaluate congestion in New Jersey and use the measures of effectiveness generated by the model to guide the NJDOT Capital Investment Strategy.

This report summarizes the results of the research project that builds on the accomplishments of previous studies and development of NJITCAM. The main objectives of the project were to further improve the methodology, outputs and user interface of the NJITCAM in order to better assist NJDOT staff in evaluating congestion.

The calculation methodology was modified or re-defined for the following measures:

- Vehicle recurring delay;
- Vehicle non-recurring delay;
- Person-hours of delay (recurring and non-recurring);
- Fuel consumption and cost of wasted fuel;
- Travel Time Index (TTI);
- Unproductive time for the traveling public; and
- Cost of congestion for trucks.

In response to the feedback from NJDOT users of NJITCAM, the user interface was redesigned to enable more user-friendly data-entry and importing of data-tables from the New Jersey Congestion Management System (NJCMS). The new interface also gives users more flexibility with choosing the value of analysis parameters and the types of reports to be generated.

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.

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 users to generate different levels of reports without repeating the calculations.

Revisions of the calculation process and inclusion of additional NJCMS tables in the model database increased complexity of the data flow and application itself. The revised process flow accommodates these revisions, improves users' flexibility in interaction with the model, and eliminates unnecessary steps in the analysis.

The reporting function of the NJITCAM has been completely redesigned. The new report format, exported into Excel spreadsheets or DBF files, provides a more detailed and more readable break down of congestion measures.

A case study was developed to demonstrate the new version of the NJITCAM and revised calculation methodology (for case study see [Chapter 4, page 30](#)). The analysis was conducted for model year 2006, using the corresponding NJCMS outputs, as well as demographic and socio-economic statistics for New Jersey on the county level. The highlights of the case study results are shown in Table 1 (next page). The table summarizes the results of analysis for the three-hour versus four-hour a.m. and p.m. peak periods. In the case study, only delays during the peak periods are analyzed.

The analysis implies that it is reasonable to consider a four-hour, rather than three-hour peak period, since the intensity of travel (as measured by VMTs) remains significant in the fourth hour of the peak periods. The accumulated annual vehicle delay is 14% greater during the 4-hour a.m. and p.m. periods as compared to the 3-hour periods (an increase from 217.4 to 247.4 million vehicle-hours a year). The accumulated person delay increased by 15% (from 266.5 to 307.3 person-hours a year), and the total cost of congestion by 16% (7.4 to 8.6 billion dollars). This test validates the hypothesis that existing travel patterns in effect expanded the 3-hour peak periods to 4 hours, based on the observed VMT and congestion indicators.

The documentation for the NJITCAM has been updated to reflect the changes in calculation methodology, process flow, and user interface. The documentation consists of the project final report, description of the methodology (Appendix A of the final report), and the User Manual (Appendix B of the final report).

Future work and potential extensions of this project should focus on the following:

1. Further refinement of the calculation procedure by providing linkages to NJDOT travel demand models;
2. Further refinement/expansion of the fuel consumption model;
3. Development of a GIS module;

4. Adding corridor or facility level analysis;
5. Integration with NJCMS model;
6. Inclusion of a link level output.

Table 1. Summary of the results for the two case studies: first, assuming 3-hr a.m. and p.m. peak periods; and second, assuming 4-hr a.m. and p.m. peak periods. All results are annual summaries of the peak periods only, for 250 weekdays.

Performance Measures	Case Study with 3-hr Peak Periods (6-9 a.m. and 3-6 p.m.)	Case Study with 4-hr Peak Periods (6-10 a.m. and 3-7 p.m.)
Total annual vehicle delay [million vehicle hours]	217.4	247.4
Total annual person delay [million person-hours]	266.5	307.3
Annual delay per affected person [person-hours]	30	34
Total Annual cost of congestion [billions \$]	\$ 7.4	\$ 8.6
Annual cost of congestion per affected person [\$/person]	\$ 822	\$ 955
Statewide average RCI ³	1.01	1.01
Statewide average TRI ⁴	1.52	1.47
Statewide average TTI ⁵	1.73	1.65
Statewide percent of VMT in congested conditions	43.4	39.3

³ The Roadway Congestion Index (RCI) is a measure of 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.

⁴ 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. A TRI of 1.20, for example, indicates that it will take 20 percent longer to travel to a destination during the peak period than during the off-peak period.

⁵ The Travel Time Index (TTI) is similar to TRI, but it considers both recurring and non-recurring delay.

2. BACKGROUND AND OBJECTIVES

2.1. Background

Traffic congestion has numerous negative effects on the movement of people and goods. It causes significant mobile-source air pollution resulting from engine idle time, wastes fuel, and increases travel time.

In the past, the concerns with traffic congestion often focused on its contribution to poor air quality. Today, congestion relief must focus on quality of life and economic issues in addition to improved air quality. The general public desires livable communities with increased mobility – it wants to travel quickly and easily, with minimal interference. Furthermore, traffic congestion often leads to stress, which can adversely affect quality of life as well as labor productivity.

The negative impacts of congestion on economic productivity have come to the forefront in recent years. Increased travel times can result in lost wages and decreased labor productivity. Congestion translates into higher costs of truck freight operation, and also has a negative impact on the manufacturing industry and the service sector. Congestion decreases productivity of just-in-time manufacturing processes by forcing businesses to keep larger inventories in order to safeguard against variability in delivery schedules.

In order to quantify traffic congestion and its impacts on New Jersey's motorists, the New Jersey Institute of Technology (NJIT) developed the NJIT Congestion Analysis Model (NJITCAM), a computer software tool that estimates congestion costs, congestion related travel delay, and mobility indicators for New Jersey highways. In 2003 and 2004^{6,7}, the NJITCAM 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 via coverage by several newspapers, television, and radio news programs, as well as through the NJIT website <http://www.transportation.njit.edu/>. In addition, the report was distributed to transportation professionals and policymakers. The important task of quantifying road congestion in New Jersey continues with this study.

NJITCAM uses the New Jersey Congestion Management System (NJCMS) database to calculate travel delays and relevant congestion indicators. All the inputs, such as demographics, income statistics, vehicle occupancies, estimates of speeds and accident/incident statistics, are New Jersey specific and are calculated for each of the 21 counties and three facility types: freeways, principal arterials, and other arterials. They can be aggregated to the statewide level. The NJITCAM outputs include a variety

⁶ "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.

⁷ 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.

of congestion indicators, such as: total travel delay due to congestion, total cost of congestion, Travel Rate Index (TRI), and Roadway Congestion Index (RCI).

2.2. Objectives

In 2003, NJITCAM was delivered to the New Jersey Department of Transportation (NJDOT) as part of the final report for the study titled “*Alternative Performance Measures for Evaluating Congestion*”. Software training was also provided. This research product enabled NJDOT to evaluate congestion in New Jersey and to use the measures to guide the NJDOT Capital Investment Strategy.

The current project builds on the accomplishments of the “*Alternative Performance Measures for Evaluating Congestion*” study. The specific objectives of this project are the following:

1. Improve the accuracy of calculations by utilizing direct outputs from NJCMS;
2. Improve the NJITCAM’s user interface and input screens;
3. Provide users with more flexibility in data input and choosing the model parameters;
4. Redesign output tables to meet NJDOT’s requirements; improve readability of the output tables;
5. Provide technical support for installing and running NJITCAM at NJDOT’s Bureau of Systems Development and Analysis;
6. Document revisions in NJITCAM and its calculation methodology.

3. SUMMARY OF REVISIONS TO THE CONGESTION ANALYSIS MODEL

3.1. Changes in Methodology

Changes were made in calculation procedures for the following measures:

- Vehicle recurring delay;
- Non-recurring delay;
- Person-hours of delay (recurring and non-recurring);
- Fuel consumption and cost of wasted fuel;
- Travel Time Index (TTI) [new congestion measure];
- Unproductive time for the traveling public;
- Cost of congestion for trucks.

A review of the complete calculation methodology is given in [Appendix A](#), page 58.

Changes in methodology are addressed in the following sections.

3.1.1. Calculation of Vehicle Recurring Delay

The recurring delay is calculated for each highway link for each hour of the day. It is then aggregated to facility type, county, and statewide level for the final summary outputs. Summary results are provided on an annual or daily basis. The time of aggregations were morning (or a.m.) peak hours, afternoon (or p.m.) peak hours, or entire day. The total vehicle-hours of recurring delay on a link i during an hour h are calculated using the following formula:

$$D_{i,h}^r = \left(\frac{L_i}{S_{i,h}^c} - t_i^0 \right) \cdot Vol_{i,h}, \quad S_{i,h}^c > 0 \quad (1)$$

$$t_i^0 = \frac{t_i^{ff} + t_i^{sc}}{3600}, \quad (2)$$

where:

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

- L_i - Link i length [mi];
- $S_{i,h}^c$ - Estimated average (congested) speed on link i during hour h [mph];
- t_i^{ff} - Zero-volume unconstrained travel time on link i excluding signal cycle delays at intersections [sec/veh];
- t_i^{sc} - Zero-volume signal cycle delay at intersections on link i [sec/veh];
- t_i^0 - Total zero-volume (freeflow) travel time on link i including signal cycle delays [h/veh];
- $Vol_{i,h}$ - Total vehicle volume on link i during hour h [veh].

The link length and estimated average congested speeds on links, freeflow travel time on links, link signal cycle delays, and total hourly vehicle volume are obtained from the NJCMS link file.

3.1.2. Calculation of Non-Recurring Delay

The methodology used by Texas Transportation Institute in preparing the annual urban mobility reports assumes that non-recurring delay is directly proportional to recurring delay.⁸ The amount of non-recurring delay is calculated as a product of the recurring delay in a given area and a non-recurring-to-recurring delay ratio. The ratio is determined based on a detailed examination of the roadway characteristics and volumes for two roadway types – freeways and arterials, and for each metropolitan region in the nation. The ratios for the New York-New Jersey metropolitan area, for example, are 2.5 for freeways and 1.1 for principal arterials. NJITCAM v.2003 methodology used a similar approach, with a difference that the ratios were computed by county and facility type based on data obtained from NJCMS. These ratios were therefore more relevant to New Jersey, and they accounted for specific characteristics of roadways by facility type in each county.

In marked contrast, NJITCAM v.2007 takes the non-recurring delay estimates directly from NJCMS outputs for each link in the network, without the need to calculate aggregated ratios for facility type or county level. The non-recurring delay is calculated in NJCMS for each network link by direction and for each hour of the day. It 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).

NJITCAM summarizes the non-recurring delay both on an annual and daily basis for the morning (a.m.) and afternoon (p.m.) peak periods.

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

The annual summary is a simple sum of the delays over all links. This sum is then further aggregated by facility type, county, and as a statewide summary.

Although 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:

$$S_{i,h}^{n-r} = \frac{L_i}{t_i^o + d_{i,h}^r + d_{i,h}^{n-r}} \quad (3)$$

where:

$$d_{i,h}^r = \frac{D_{i,h}^r}{Vol_{i,h}}, \quad Vol_{i,h} > 0 \quad (4)$$

$$d_{i,h}^{n-r} = \frac{365 \cdot D_{i,h}^{n-r}}{I_{i,h} \cdot Vol_{i,h}}, \quad I_{i,h} > 0, Vol_{i,h} > 0 \quad (5)$$

- $S_{i,h}^{n-r}$ - Estimated average (congested) speed on link i during hour h in incident or accident conditions [mph];
- $d_{i,h}^r$ - Average recurring delay per vehicle on link i during hour h [h/veh];
- $d_{i,h}^{n-r}$ - Average non-recurring delay per vehicle on link i during hour h , in incident or accident conditions [h/veh];
- $D_{i,h}^{n-r}$ - Total vehicle-hours of non-recurring delay on link i during hour h , in incident or accident conditions;
- $I_{i,h}$ - 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.

3.1.3. Calculation of Person-Hours of Delay (Recurring and Non-Recurring)

Recurring and Non-recurring vehicle delay is converted to person delay using vehicle occupancy. The occupancy data is summarized in the NJCMS table OCCUPANT.dbf. It is summarized for passenger vehicles (or autos) by county, facility type, and time period of the day (NJCMS defines four time periods in the analysis of vehicle occupancy: a.m. peak, midday, p.m. peak, and night). NJITCAM calculates the total auto person delay by multiplying the sum of recurring and non-recurring vehicle-delay by occupancy.

3.1.4. Calculation of Fuel Consumption and Wasted Fuel

Fuel consumption is calculated as a function of vehicle speed on a link during each hour of the evaluation. The auto and truck fuel consumption rates are based on CALTRANS's Life-Cycle Benefit-Cost Analysis Model (CAL-B/C)⁹. Figure 1 shows plots of these rates.

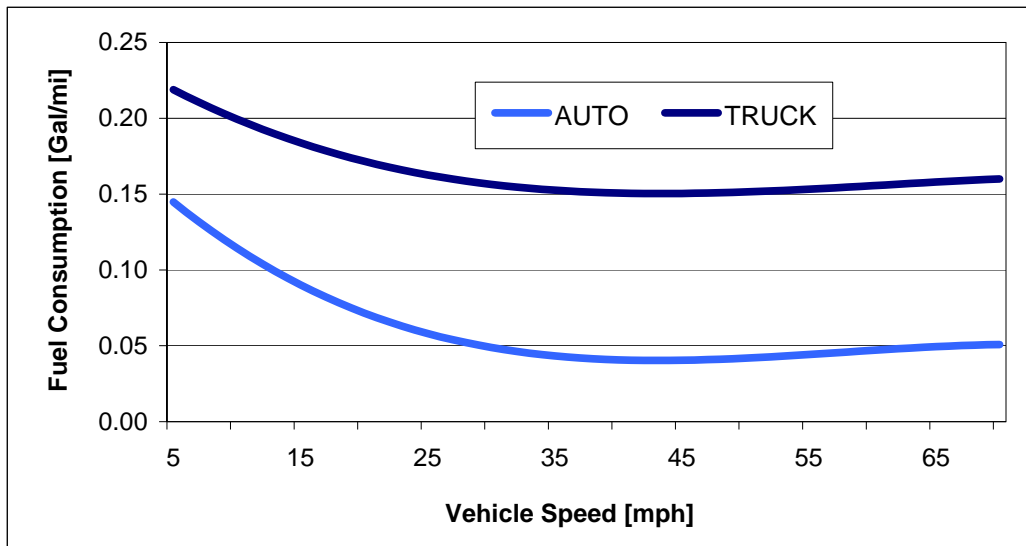


Figure 1. Fuel consumption rates as a function of speed based on CALTRANS Life-Cycle Benefit-Cost Analysis Model (CAL-B/C)

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).

The empirically derived curves are of the following form:

$$g(S) = a_0 + a_1 \cdot S + a_2 \cdot S^2 + a_3 \cdot S^3 \quad (6)$$

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 2 shows the estimated regression coefficients and the coefficient of determination (R^2).

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

Estimators	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. When calculating wasted fuel, there are three speeds that one needs to consider: freeflow (uncongested) speed, congested speed in recurring congestion, and congested speed in non-recurring congestion. With that in mind, wasted fuel on a link and per hour is calculated using the following set of formulas:

Autos:

$$G_{i,h}^{A,r} = \text{Max} \left[g_A(S_{i,h}^c) - g_A\left(\frac{L_i}{t_i^0}\right), 0 \right] \cdot \text{Vol}_{i,h}^A \cdot L_i \quad (7)$$

$$G_{i,h}^{A,n-r} = \text{Max} \left[g_A(S_{i,h}^{n-r}) - g_A(S_{i,h}^c), 0 \right] \cdot \text{Vol}_{i,h}^A \cdot L_i \quad (8)$$

where:

$G_{i,h}^{A,r}$ - Total gallons of fuel wasted by autos due to recurring congestion on link i during hour h ;

$G_{i,h}^{A,n-r}$ - Total gallons of fuel wasted by autos due to non-recurring congestion on link i during hour h ;

g_A - Fuel consumption rate function for autos;

$Vol_{i,h}^A$ - Total hourly auto volume on link i during hour h .

Trucks:

$$G_{i,h}^{T,r} = \text{Max} \left[g_T \left(S_{i,h}^c \right) - g_T \left(\frac{L_i}{t_i^0} \right), 0 \right] \cdot Vol_{i,h}^T \cdot L_i \quad (9)$$

$$G_{i,h}^{T,n-r} = \text{Max} \left[g_T \left(S_{i,h}^{n-r} \right) - g_T \left(S_{i,h}^c \right), 0 \right] \cdot Vol_{i,h}^T \cdot L_i \quad (10)$$

where:

$G_{i,h}^{T,r}$ - Total gallons of fuel wasted by trucks due to recurring congestion on link i during hour h ;

$G_{i,h}^{T,n-r}$ - Total gallons of fuel wasted by trucks due to non-recurring congestion on link i during hour h ;

g_T - Fuel consumption rate function for trucks;

$Vol_{i,h}^T$ - Total hourly truck volume on link i during hour h .

Wasted fuel is summarized by county, facility type, and as a statewide summary on a daily or annual basis.

3.1.5. Calculation of Travel Time Index (TTI) – New Performance Measure

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 as compared to freeflow conditions. A TTI of 1.20, for example, indicates that it will take 20 percent longer to travel to a destination during the peak period.

TTI is calculated based on the following formula developed by the Texas Transportation Institute¹⁰:

$$\text{Travel Time Index} = \frac{\text{All Conditions Travel Rate (minutes/mile)}}{\text{Average Freeflow Travel Rate}} \quad (11)$$

In equation (11) “all conditions” refers to travel conditions considering both recurring and non-recurring travel delay, in addition to freeflow travel time. NJITCAM v.2007 applies the same formula, and the calculation steps are as follows:

$$TTI_{i,a} = \frac{TR'_{i,a}}{TR_i^{ff}} \quad (12)$$

where:

$$TR'_{i,a} = TR_i^{ff} + TR_{i,a}^r + TR_{i,a}^{n-r} \quad (13)$$

$$TR_i^{ff} = \frac{60 \cdot t_i^0}{L_i} \quad (14)$$

$$TR_{i,a}^r = \frac{60 \cdot D_{i,a}^r}{L_i \cdot Vol_{i,a}} \quad (15)$$

$$TR_{i,a}^{n-r} = \frac{60 \cdot D_{i,a}^{n-r}}{L_i \cdot Vol_{i,a}} \quad (16)$$

$TTI_{i,a}$ - Average TTI on link i during analysis period a ;

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

TR_i^{ff} - Average freeflow 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];

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

$Vol_{i,a}$ - Total vehicle volume during analysis period a on link i ;

$TR_{i,a}^{n-r}$ - Average peak period non-recurring delay rate on link i ; [min/mi];

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

¹⁰ Schrank, D. and D. Lomax, “2005 Urban Mobility Report”, Texas Transportation Institute, The Texas A&M University, May 2005.

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):

$$TTI_C = \frac{\sum_{i \in C} TTI_{i,a} \cdot VMT_{i,a}}{\sum_{i \in C} VMT_{i,a}}, \quad (17)$$

where C represents aggregation level (county, or facility type, or entire roadway system).

3.1.6. Calculation of Cost of Unproductive Time for Traveling Public (Autos)

NJITCAM v.2003 uses as the value of time the average hourly wage in the county where travel delay occurs. The current NJITCAM calculates the value of time as the weighted average of county-specific hourly income and statewide average hourly income per capita. The weight 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:

$$v_k = W_k \cdot p_k + \bar{W} \cdot (1 - p_k) \quad (18)$$

where:

- v_k - Average value of time for travel in county k [\$/hr];
- W_k - Average hourly income per capita 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 income per capita [\$/hr].

The cost of delay to the traveling public on a link, as well as for the aggregation levels of county, state and MPO is then calculated by multiplying the average value of time v_k by person-hours of delay for autos.

3.1.7. Calculation of Cost of Congestion for Trucks

NJCMS furnishes 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). In order to calculate the total cost of congestion for trucks it is necessary to multiply the total accrued truck congestion related 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 cost¹¹ and average speed. The truck congestion cost can be categorized into recurring and non-recurring congestion costs. Link level results are aggregated to facility type, county, and statewide level by summation.

To avoid double-counting, since the cost of fuel is built into the operating cost, the fuel cost for trucks is deducted from the total truck cost to obtain the cost of unproductive time. The fuel cost for trucks is calculated as a product of wasted fuel and gasoline price.

3.2. Changes 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 users more flexibility with choosing the value 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 users 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](#).

3.2.1. Modification of the Process Flow

NJITCAM 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 users' flexibility in interaction with the model, and eliminate unnecessary steps in the analysis.

Figure 2 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 2). After completing data input steps, the user can run the congestion analysis model, which calculates Measures

¹¹ 2001 average per-mile cost of owning and operating a truck is found in the National Transportation Statistics, U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, *National Transportation Statistics 2005*, Washington, DC, Summer 2005, available at http://www.bts.gov/publications/national_transportation_statistics/2005. It includes, among other cost categories, cost of fuel. The data are brought up to 2007 using the consumer price index and producer price index for New Jersey.

of Effectiveness (MOEs) on a link level (MOEs are described in [Appendix A](#)). In the final step, the user selects a type of report (county summaries, MPO summaries, or county summaries in dbf format), and then runs an aggregation procedure. The outputs are saved in an Excel spreadsheet or a DBF file, depending on the user selection.

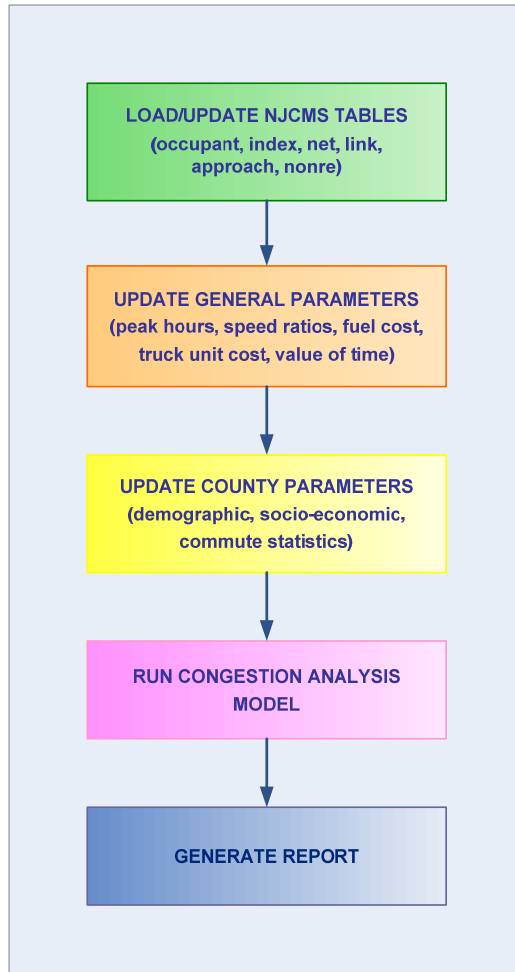


Figure 2. NJITCAM v.2007 general process flow

3.2.2. Modification of the User Interface

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

Main Menu

Figure 3 shows the new design of the “Main Menu” Screen, the opening screen of the application. From this screen, the user can select to update the database (including

roadway network data from NJCMS and analysis parameters), run the analysis, generate reports, or quit the application.

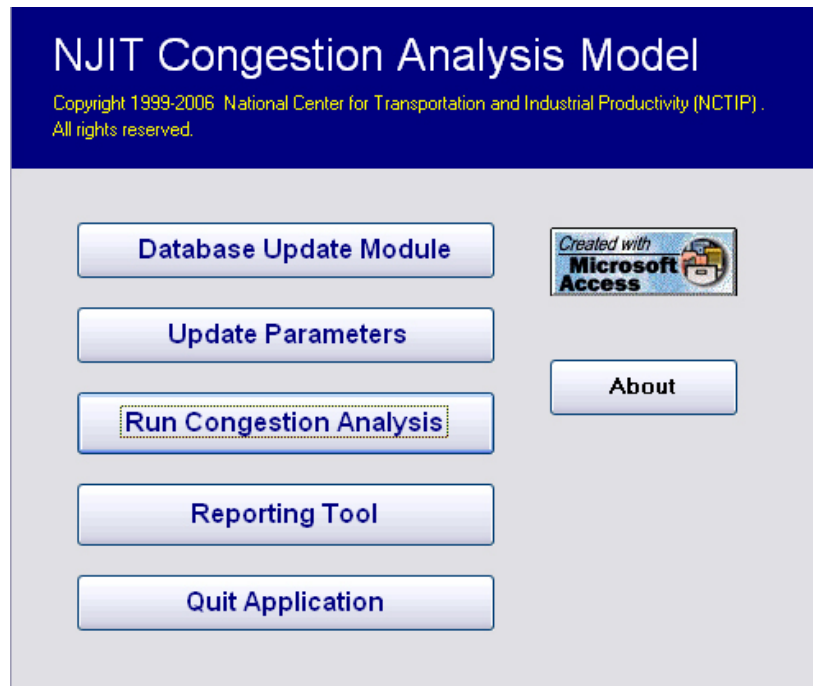


Figure 3. Main screen of the NJIT Congestion Analysis Model

Roadway Network Database Update Screen

Clicking the “Database Update Module” button on the “Main Menu” screen takes the user to the roadway network database update screen shown in Figure 4. This screen allows the user to load NJCMS output files by clicking on the appropriate “Update” button. 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 box next to the file description and “Update” button. These paths serve as a reference to the user indicating locations and file names of the NJCMS tables that are currently loaded in the NJITCAM.

On this screen, the user can reference the model year of the roadway network dataset currently loaded in the database.

In order to prevent the loading of incorrect files, the application checks the file names selected by the users to be loaded. If the file name does not correspond to the common name assigned by NJCMS, it will not be loaded and a warning message will appear.

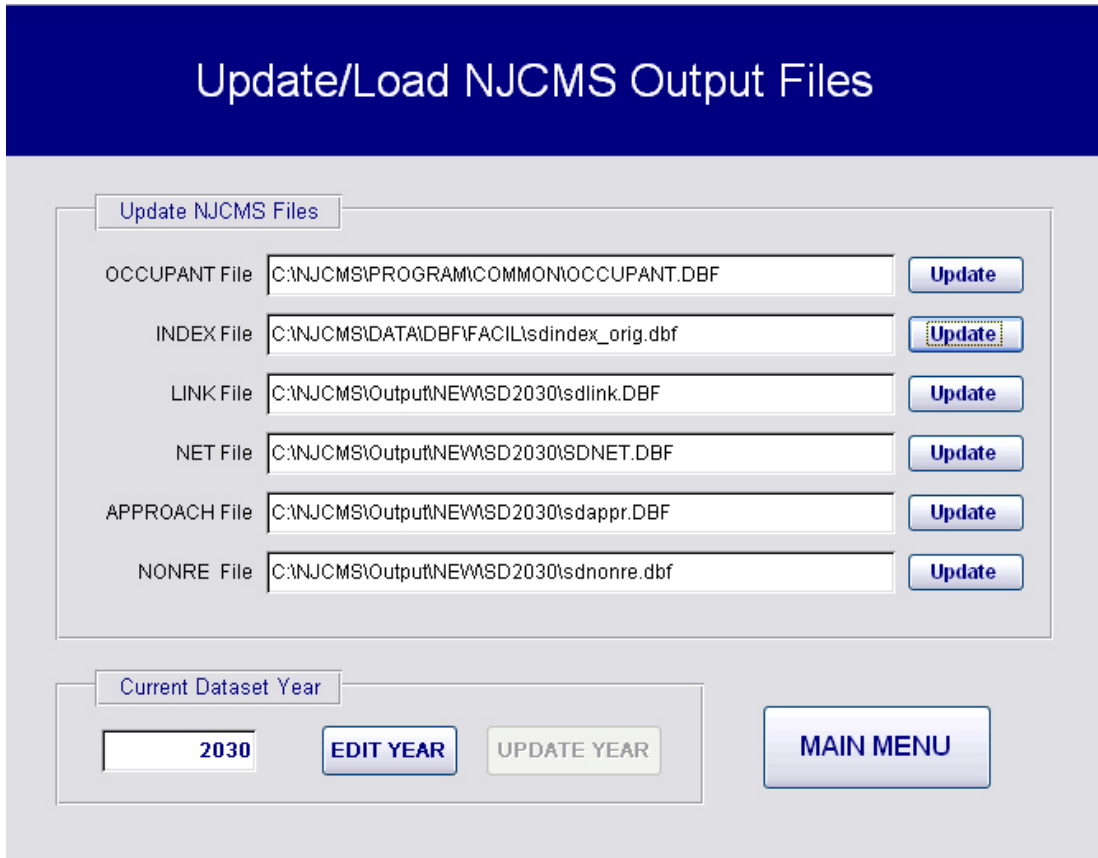


Figure 4. Roadway network database update screen

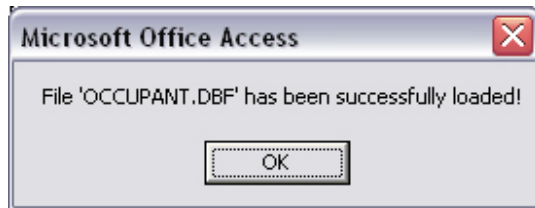


Figure 5. File import confirmation dialog box

Parameter Update Screen

The Parameter Update screen, shown in Figure 6, can be accessed from the main menu by clicking the “Update Parameters” button. Users are 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. Users have flexibility in selecting the actual start and end hours for peak periods.

Users can now specify number of days per year in the analysis, as well as the statewide average fuel costs, per-mile truck operating cost, and statewide average hourly wage.

Update Parameters

Set AM / PM Peak Hours

AM Peak Hours

AM Start ▼

AM End ▼

PM Peak Hours

PM Start ▼

PM End ▼

Speed Ratio [Percent of Normal Operations Speed]

	Freeways	Arterials
Severe Congestion (%)	0.6323	0.4546
Heavy Congestion (%)	0.8608	0.6818
Moderate Congestion (%)	0.9562	0.7727

Days Per Year [days]

Fuel Cost [\$/gallon]

Truck Costs [\$/mile]

Statewide average hourly wage [\$/hour]

UPDATE COUNTY
PARAMETERS

OK

Figure 6. Parameters and analysis settings update screen

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

- Average county hourly wage (income) per capita;
- Wage adjustment factor [%] (% of travel within county attributed to county residents);
- County resident population;
- County employment by place of work; and
- Percent of workers employed in the county who reside outside the county.

County Update Form

Update County Parameters

* Average Hourly Wage is suggested measure of Value of Time for Traveling Public

Atlantic

AVERAGE COUNTY WAGE [\$/person-hour]	<input type="text" value="19.36"/>
WAGE ADJUSTMENT FACTOR [%] *	<input type="text" value="100"/>
COUNTY RESIDENT POPULATION	<input type="text" value="270644"/>
NUMBER OF WORKERS IN THE COUNTY **	<input type="text" value="144416"/>
PERCENT OF WORKERS WHO DO NOT RESIDE IN THE COUNTY	<input type="text" value="25"/>

* Wage adjustment factor represents percentage of travel within county attributed to county residents

** County employment by place of work

Record: of 21

Figure 7. County parameter update form

Executing the Calculation Procedure

After updating the network database, county statistics, and analysis settings, users can execute the calculation procedure by clicking on the “Run Congestion Analysis” button on the main menu in Figure 3. A progress bar appears on the screen, shown in Figure 8, which updates the user about the status of the calculation procedure.

Progress

Calculating Congestion Performance Measures

PLEASE WAIT

20%

Progress:

Figure 8. Progress bar screen

Once the calculation has been completed and all MOEs calculated, a dialog box, shown in Figure 9, informs the user and directs him/her to the reporting tool.



Figure 9. Completion of MOE calculation dialog box

Report Selection and Generation Screen

The Select Report screen, shown in Figure 10, can be accessed from the main menu by clicking on the “Reporting Tool” button. 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. Users can also choose to include a congestion severity sheet in the report, which summarizes congested vs. uncongested VMT and travel delay.

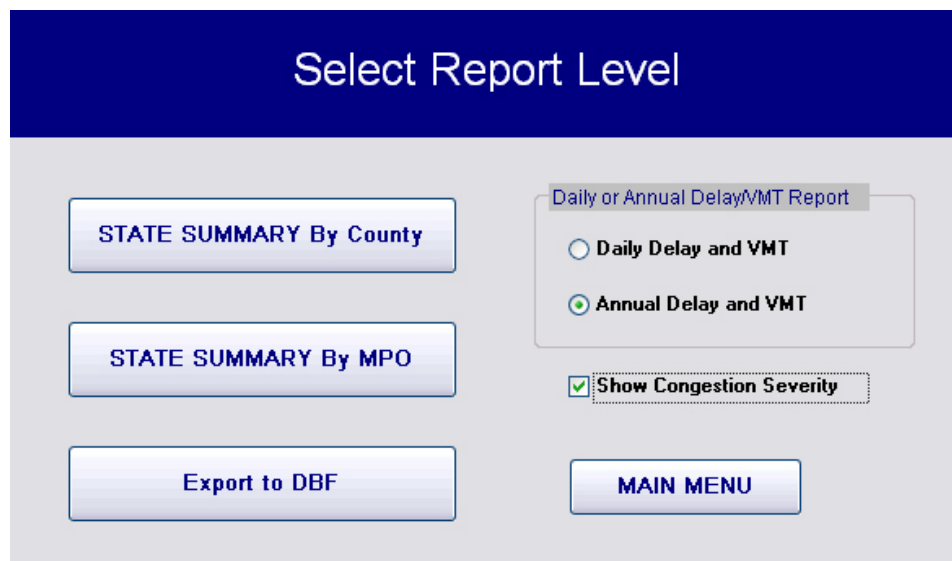


Figure 10. Report selection screen

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. When the report has been generated, a dialog box, shown in Figure 12, appears informing the user.

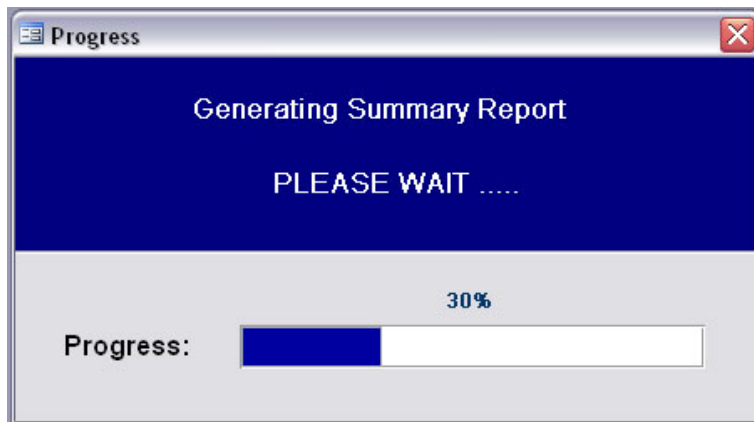


Figure 11. Report generation progress bar screen



Figure 12. Report confirmation dialog box

3.3. Redesigned Reporting

The reporting function of the NJITCAM has been completely redesigned. The new report format, exported into Excel spreadsheets or DBF files, provides a more detailed break down of congestion measures.

The user can generate the following reports:

1. State Summary by County;
2. State Summary by MPO;
3. County Summary table in a DBF format.

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:

1. Speeds;
2. VMT (vehicle-miles traveled);
3. RCI, TRI & TTI¹²;
4. Vehicle Delays;
5. Person Delays;
6. Costs;
7. Wasted Fuel;
8. Congestion Severity (optional);
9. Charts (only in “State Summary by County” report).

Tables 3-7 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 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.

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 is not dependent on the aggregation level of the report (it is always 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 8.

Table 9 provides a list of fields included in the DBF output file. Congestion measures in this report are summarized by county. This output file can be interfaced with GIS software to map out New Jersey counties and display congestion MOEs by county.

¹² RCI stands for Roadway Congestion Index; TRI stands for Travel Rate Index; TTI stands for Travel Time Index

Table 3. List of tables in the summary reports by county or MPO

#	Table Name/Description	Summary Term
Worksheet: Speeds		
1.	Lane miles [mi]	-
2.	Freeflow 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 4. 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.	Recurring Peak Period Delay - Autos [000 vehicle-hours]	Annual or Daily
8.	Recurring Peak Period Delay - Trucks [000 vehicle-hours]	Annual or Daily
9.	Non-Recurring Peak Period Delay - Autos [000 vehicle-hours]	Annual or Daily
10.	Non-Recurring Peak Period Delay - Trucks [000 vehicle-hours]	Annual or Daily
11.	Total Peak Period Delay - Autos [000 vehicle-hours]	Annual or Daily
12.	Total 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 5. 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.	Total Annual Cost of Fuel Wasted Due to Congestion [\$million]	Annual
6.	Total Annual Cost of Congestion for Auto Users/Passengers [\$million]	Annual
7.	Total Annual Cost of Congestion for Truck Operators [\$million]	Annual
8.	Cost of Unproductive Time Due to Recurring Congestion [\$ million]	Annual
9.	Cost of Wasted Fuel Due to Recurring Congestion [\$ million]	Annual
10.	Overall Cost of Recurring Congestion - AUTOS [\$ million]	Annual
11.	Overall Cost of Recurring Congestion - TRUCKS [\$ million]	Annual
12.	Cost of Unproductive Time Due to Recurring Congestion - AUTOS [\$ million]	Annual
13.	Cost of Wasted Fuel Due to Recurring Congestion - AUTOS [\$ million]	Annual
14.	Cost of Unproductive Time Due to Recurring Congestion - TRUCKS [\$ million]	Annual
15.	Cost of Wasted Fuel Due to Recurring Congestion - TRUCKS [\$ million]	Annual
16.	Cost of Unproductive Time Due to Non-Recurring Congestion [\$ million]	Annual
17.	Cost of Wasted Fuel Due to Non-Recurring Congestion [\$ million]	Annual
18.	Overall Cost of Non-Recurring Congestion - AUTOS [\$ million]	Annual
19.	Overall Cost of Non-Recurring Congestion - TRUCKS [\$ million]	Annual
20.	Cost of Unproductive Time Due to Non-Recurring Congestion - AUTOS [\$ million]	Annual

Table 6. List of tables in the summary reports by county or MPO (continued)

#	Table Name/Description	Summary Term
Worksheet: Costs		
21.	Cost of Wasted Fuel Due to Non-Recurring Congestion - AUTOS [\$ million]	Annual
22.	Cost of Unproductive Time Due to Non-Recurring Congestion - TRUCKS [\$ million]	Annual
23.	Cost of Wasted Fuel Due to Non-Recurring Congestion - TRUCKS [\$ million]	Annual
24.	Overall Annual Cost of Unproductive Time - AUTOS [\$ million]	Annual
25.	Overall Annual Cost of Wasted Fuel - AUTOS [\$ million]	Annual
26.	Overall Annual Cost of Unproductive Time - TRUCKS [\$ million]	Annual
27.	Overall Annual Cost of Wasted Fuel - 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

Table 7. 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

Table 8. List of charts and tables in the CHARTS worksheet of the summary report by county

#	Chart 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

Table 9. List of data fields included in the DBF output file

<i>Field Name</i>	<i>Description</i>
CTY_ID	NJCMS county ID
CTY_NAME	County name
VDLYTOTPK	Total annual vehicle delay during peak periods [veh-hours]
VDLYRECPK	Total annual vehicle recurring delay during peak periods [veh-hours]
VDLYNREPK	Total annual vehicle non-recurring delay during peak periods [veh-hours]
VDLYTOT24H	Total annual vehicle delay during 24-hr period [veh-hours]
VDLYREC24H	Total annual vehicle recurring delay during 24-hr period [veh-ours]
VDLYNRE24H	Total annual vehicle non-recurring delay during 24-hr period [veh-s]
PDLYTOTPK	Total annual person delay during peak periods (only autos) [person-hours]
PDLYRECPK	Total annual person recurring delay during peak periods (only autos) [person-hours]
PDLYNREPK	Total annual person non-recurring delay during peak periods (only autos) [person-hours]
COST_TOT	Total annual cost of congestion (recurring and non-recurring) [\$]
COST_REC	Total annual cost of recurring congestion [\$]
COST_NON	Total annual cost of non-recurring congestion [\$]
COST_FUEL	Total annual cost of fuel wasted due to congestion [\$]
COST_PAS	Total annual cost of congestion incurred by traveling public in personal cars [\$]
COST_TRK	Total annual cost of congestion incurred by truck operators [\$]
WASTE_FUEL	Total annual gallons of wasted fuel due to congestion [Gallons]
RCI	Weighted average Roadway Congestion Index (RCI)
TRI	Weighted average Travel Rate Index (RCI)
TTI	Weighted average travel Time Index (RCI)
CON_PER	Percent of peak period VMT that is congested [%]
POP	County population
PRS_AFCT	Number of Affected Persons in County

4. TRAINING AND IMPLEMENTATION

A case study was developed to demonstrate the NJITCAM v.2007. This section outlines the process of obtaining the data necessary for the analysis, and provides a summary and discussion of the model outputs. The same model implementation process should be used by analysts at NJDOT. The case study congestion analysis was conducted for year 2006.

4.1. Case-Study – Assembling the Input Data

The input data consists of the following:

- ❑ New Jersey Congestion Management System (NJCMS) tables. These tables contain data for traffic volumes, 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;
- ❑ Statistics by county for:
 - number of residents;
 - annual income per capita;
 - workers by place of employment;
 - number of workers who reside outside the county of employment;
 - relative proportion of intra-county travel compared to overall travel on county roadways (measured in terms of VMTs);
- ❑ Average statewide fuel cost;
- ❑ Average cost of owning and operating a truck in New Jersey in \$/veh-mile; and
- ❑ Definition of peak hours and speed ratios to determine level of service (LOS).

4.1.1. NJCMS Tables

The main source of roadway network data is NJCMS. The most recent 2005 release of NJCMS, SD Series, was used in the case study.

The 2001 baseline data that feed into the NJCMS analysis was grown (via growth factors) to the estimated 2006 level and the following files were produced

- ❑ Sdlink.dbf;
- ❑ Sdnet.dbf;

- ❑ Sdappr.dbf;
- ❑ Sdnonre.dbf.

In addition,

- ❑ OCCUPANT.dbf; and
- ❑ Sdindex.dbf

were obtained from NJCMS SD dataset.

4.1.2. County Statistics

The county statistics come from New Jersey Department of Labor and Workforce Development and U.S. Census Bureau.

The 2006 statistics on the number of residents by county¹³ is presented in Table 10.

New Jersey’s 2005 income statistics are the most recent data¹⁴. However, U.S. Department of Commerce, Bureau of Economic Analysis provides preliminary estimates of the average personal income by state for 2006¹⁵. These estimates are used to inflate the New Jersey incomes by 5.73%. Average hourly wages were calculated by dividing the 2006 annual income estimate by 2,000 work hours per year. These estimates are shown in Table 10.

Affected Persons

The term “affected persons” is used to describe a subject group impacted by congestion. An affected person is defined as a person who lives and/or works in an analysis region (county) and therefore experiences congestion within that region on a daily basis. The equation for calculating number of affected persons is as follows:

$$\# \text{ Affected Persons} = \text{ResPop} + (\text{OW}\%) \times \text{Workers} \quad (19)$$

where:

Affected Persons = Total number of affected persons in a study region (e.g. county);
ResPop = Total number of residents in a study region;

¹³ <http://www.wnjin.net/OneStopCareerCenter/LaborMarketInformation/Imi02/index.html#county>

¹⁴ <http://www.wnjin.net/OneStopCareerCenter/LaborMarketInformation/Imi10/index.html#perinc>

¹⁵ State Personal Income, U.S. Department of Commerce, Bureau of Economic Analysis, Press Release BEA 07-11, Tuesday, March 27, 2007. Available for download at <http://www.bea.gov/newsreleases/regional/spi/2007/pdf/spi0307.pdf>

OW% = Percentage of workers who work but do not reside in the study region;
Workers = Total number of people who work in the study region.

It is assumed that the number of workers by place of employment is equivalent to estimates of number of jobs by county from the Quarterly Workforce Indicators (QWI)¹⁶. QWI statistics are currently available for the years 1996-2005. Estimates for year 2006 were developed using linear regression. For each county, the number of workers (jobs) and number of affected persons are shown in Table 10.

Table 10. Case study county statistics

<i>County Name</i>	<i>Average Hourly Wage [\$/hour]</i>	<i>Resident Population</i>	<i>Number of Jobs</i>	<i>Percent of Workers with Residence Outside the County/State [%]</i>	<i>Affected Persons</i>
Atlantic	18.14	271,620	141,053	25	306,883
Bergen	29.99	904,037	456,606	44	1,104,944
Burlington	21.43	450,627	207,953	37	527,570
Camden	19.19	517,001	214,433	37	596,341
Cape May	20.92	97,724	41,089	18	105,120
Cumberland	14.89	154,823	59,945	25	169,809
Essex	23.24	786,147	349,678	51	964,483
Gloucester	18.40	282,031	105,103	37	320,919
Hudson	18.24	601,146	234,199	49	715,904
Hunterdon	31.91	130,783	50,704	49	155,628
Mercer	24.28	367,605	208,853	44	459,500
Middlesex	21.71	786,971	409,035	46	975,127
Monmouth	25.65	635,285	247,591	28	704,610
Morris	33.09	493,160	283,800	50	635,060
Ocean	18.25	562,335	147,188	14	582,941
Passaic	18.54	497,093	186,609	45	581,067
Salem	17.53	66,595	22,003	39	75,176
Somerset	32.27	324,186	171,209	60	426,911
Sussex	22.07	153,384	39,630	26	163,688
Union	23.29	531,088	240,774	51	653,883
Warren	19.62	110,919	36,263	44	126,875
New Jersey	23.18	8,724,560	3,853,718	7	8,994,320

¹⁶ The Quarterly Workforce Indicators (QWI) are developed using the Local Employment Dynamics (LED) database of the U.S. Census Bureau <http://lehd.dsd.census.gov/led/datatools/qwiapp.html>.

The percentage of workers who reside outside the county of employment is calculated for each county using the 'Journey to Work and Place of Work' dataset of the 2000 U.S. Census¹⁷. They are summarized in Table 10. The same procedure was applied to estimate the percentage of New Jersey workers who live out-of-state. The statewide number of affected persons (used for calculating statewide statistics) is thus equal to the sum of all New Jersey residents plus people who work in New Jersey but reside outside New Jersey.

Average Value of Time for Travel in County (v_k) (Section 3.1.6, Page 13)

Finally, a relative proportion of intra-county travel compared to the overall travel (in VMTs) on the counties' roadways is needed to determine what portion of travel within a county is performed by county residents and what portion by out-of-county residents. It is assumed that the county residents will have a value of time equivalent to the county average hourly wage, while the out-of-county travelers will have a value of time equivalent to the statewide average hourly wage. In the case study, the value of time for all travel in a given county was based on the average hourly wage for that county only.

4.1.3. Average Statewide Fuel Cost

An average fuel cost of \$2.67 per gallon of regular gasoline was calculated based on the historic gasoline price data obtained from the American Automobile Association's (AAA) *Daily Fuel Gauge Report*¹⁸ for New Jersey. The data covers the June 1, 2006 – December 31, 2006 period.

4.1.4. Truck Cost

A \$3.00 per mile truck cost was estimated using 2006 National Transportation Statistics prepared by the U.S. Bureau of Transportation Statistics¹⁹. The 2001 cost was calculated as a ratio of the total estimated annual expenditures for local and intercity trucks nationwide to the total estimated annual truck miles traveled by single-unit and combination trucks nationwide. The calculated value was then adjusted to 2006 dollars

¹⁷ 2000 Journey To Work and Place Of Work, County-To-County Worker Flow Files; U.S. Census Bureau. Database can be accessed online at: <http://www.census.gov/population/www/cen2000/commuting.html>

¹⁸ American Automobile Association's (AAA) *Daily Fuel Gauge Report* is prepared by the OPIS Energy Group. The summary reports for New Jersey are available to public via AAA website at: <http://www.fuelgauge.com/NJavg.asp>

¹⁹ U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics. *National Transportation Statistics*. http://www.bts.gov/publications/national_transportation_statistics/ as of 04/12/2007.

using the Consumer Price Index (CPI) for the New York-New Jersey-Pennsylvania (NY-NJ-PA) Metropolitan Statistical Area²⁰.

4.1.5. Aggregation Periods

Congestion related delay is first calculated on a link bases for each hour of the day. Amount of delay per day for each link is obtained by summation of delays during the hours included in the analysis period. Analysis period is defined by the user and usually includes only morning and evening peak hours. This approach is applied in the case study and the peak hours are selected to be as follows:

- a.m. peak: 6 – 9;
- p.m. peak: 3 – 6.

Annual amount of congestion delay is obtained by multiplying daily number (as a sum of peak hour delays) by the user specified number of analysis days per year. It was decided to use 250 analysis days in the case study, which is equivalent to the full year excluding weekends and holydays.

All other congestion measures were also aggregated per day and year using the same definitions of daily and annual analysis periods.

4.1.6. Definition of Congested Conditions (Level of Service and Speed Ratios)

The level of service (LOS) concept was used to determine whether a roadway segment is congested or not. The LOS refers to a quality of traffic flow with “A” describing the best operating conditions and “F” representing unsatisfactory operations. According to the 2000 Highway Capacity Manual (HCM), LOS A, B, and C are considered satisfactory operating conditions, while LOS D, E, and F are considered less than satisfactory conditions. In the NJITCAM, a link is considered uncongested if it operates at LOS A, B, or C; it is considered moderately congested if it operates at LOS D, heavily congested at LOS E, and severely congested at LOS F.

The LOS can be determined by comparing the freeflow speed with the actual speed. HCM provides threshold ratios between the two for different roadway types. NJITCAM classifies roadways into three general categories: freeways, principal arterials, and other arterials. Speed ratios are calculated for freeways and as a composite threshold for all arterial roadways. The speed ratios, renamed to match congestion grades used in NJITCAM, are presented in Table 11.

²⁰ Source: U.S. Department of Labor, Bureau of Labor Statistics, Consumer Price Index webpage, <http://www.bls.gov/cpi/> as of 04/08/2007

For each link segment, the travel speed and delays are computed by the NJCMS. NJITCAM analyzes these speeds and assigns the appropriate congestion designation based on the threshold values in Table 11.

Table 11. Speed ratio ranges corresponding to congestion severity levels (ratios of actual to freeflow speed on highway segments)

Congestion Level	Freeways	All Arterials
Moderate Congestion (LOS D)	0.956 – 0.861	0.773 – 0.682
Heavy Congestion (LOS E)	0.861 – 0.632	0.682 – 0.455
Severe Congestion (LOS F)	Less than 0.632	Less than 0.455

4.2. Case Study Results (Year 2006)

4.2.1. Travel Delay

As shown in Table 12, next page, the total annual vehicle delay due to congestion is estimated at **217 million vehicle-hours** statewide. Most delay is recorded in Bergen County (50.2 million vehicle-hours), Middlesex County (24.7 million vehicle-hours), and Passaic County (20.5 million vehicle-hours). Of the total delay, 76% is a result of recurring, while 24% is attributed to non-recurring congestion. The breakdown is shown in Figure 13.

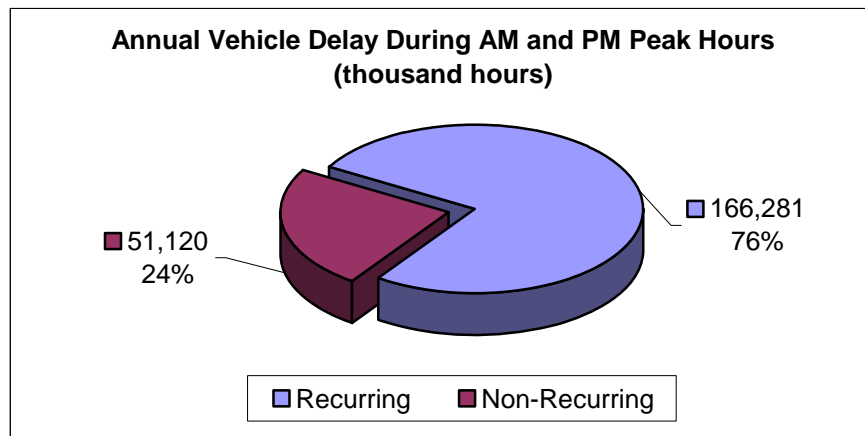


Figure 13. Statewide 2006 recurring vs. non-recurring vehicle delay

Table 12 shows that most of the delay is generated on principal arterials, namely 156.2 million vehicle-hours per year (or approximately 72%). At the same time, principal arterials account for 49% of lane-miles of roadways covered in NJCMS, and 42% of total VMT during peak hours. This means that principal arterials are much more congested than freeways or other arterials. They would be primary candidates for any congestion mitigation actions such as capacity increase and better management of existing capacity. Most problematic are principal arterials in Bergen and Passaic counties. In these counties principal arterials carry 53% and 64% of total VMT during peak hours, while they are responsible for 89% and 93% of delay respectively.

Table 12. Total 2006 annual vehicle delay in New Jersey by county and facility type (3-hr a.m. and p.m. peak periods, 250 weekdays)

County	Total Delay [thousand vehicle-hours]			
	Freeways	Principal Arterials	Other Arterials	All Roadways
Atlantic	18.08	889.64	184.23	1,091.94
Bergen	5,294.25	44,807.09	55.87	50,157.22
Burlington	544.21	4,749.03	120.60	5,413.84
Camden	3,107.41	12,107.20	869.91	16,084.52
Cape May	2.71	53.25	157.26	213.22
Cumberland	1.95	64.76	625.96	692.67
Essex	7,618.18	5,866.62	106.50	13,591.30
Gloucester	791.35	5,194.95	2,710.53	8,696.84
Hudson	4,007.78	9,811.83	964.77	14,784.38
Hunterdon	617.04	1,176.21	374.80	2,168.05
Mercer	604.02	4,230.33	890.39	5,724.73
Middlesex	7,807.10	15,935.37	915.58	24,658.04
Monmouth	2,667.69	9,752.60	743.55	13,163.84
Morris	4,483.60	5,986.65	532.75	11,003.00
Ocean	1,599.37	3,212.31	4,269.10	9,080.77
Passaic	1,510.53	18,999.28	15.29	20,525.10
Salem	173.36	95.05	117.11	385.51
Somerset	749.76	6,655.32	815.23	8,220.31
Sussex	2.06	1,912.49	462.79	2,377.34
Union	4,287.27	3,475.91	63.30	7,826.47
Warren	258.83	1,185.28	97.33	1,541.44
Statewide	46,146.54	156,161.15	15,092.84	217,400.53

The delay can also be classified by vehicle type: 208 million vehicle-hours of delay, or 96% of the total, are attributed to autos. This translates into **266.5 million person-hours** of travel delay as shown in Table 13. Recurring congestion is responsible for 77% of overall person-delay statewide, while the rest, or 23%, can be attributed to non-recurring congestion (Figure 14).

Table 13. Total 2006 annual person delay (3-hr a.m. and 3-hr p.m. peak periods, Autos only, 250 weekdays)

County	Total Person-Hours of Delay During Peak Periods [thousand hours]			
	Freeways	Principal Arterials	Other Arterials	All Roadways
Atlantic	25.38	1,207.29	250.18	1,482.85
Bergen	6,036.58	53,175.81	70.97	59,283.36
Burlington	636.74	5,956.12	161.13	6,753.99
Camden	4,013.06	15,610.25	1,283.74	20,907.05
Cape May	3.98	72.91	208.51	285.41
Cumberland	2.51	92.27	822.03	916.81
Essex	9,053.61	7,342.52	143.41	16,539.54
Gloucester	1,049.20	6,872.94	3,829.91	11,752.06
Hudson	4,249.73	12,395.28	1,214.69	17,859.70
Hunterdon	605.88	1,444.61	474.45	2,524.94
Mercer	657.15	5,284.23	1,199.47	7,140.85
Middlesex	8,532.92	20,221.88	1,168.33	29,923.13
Monmouth	3,512.95	11,913.89	968.32	16,395.16
Morris	4,966.37	7,135.46	674.54	12,776.36
Ocean	2,235.70	4,043.39	5,815.58	12,094.68
Passaic	1,881.99	23,715.65	20.60	25,618.23
Salem	215.48	115.78	141.80	473.06
Somerset	839.01	8,081.37	1,018.85	9,939.23
Sussex	2.29	2,609.81	592.39	3,204.49
Union	4,471.45	4,353.18	81.60	8,906.23
Warren	258.40	1,335.57	125.35	1,719.33
Statewide	53,250.39	192,980.23	20,265.83	266,496.45

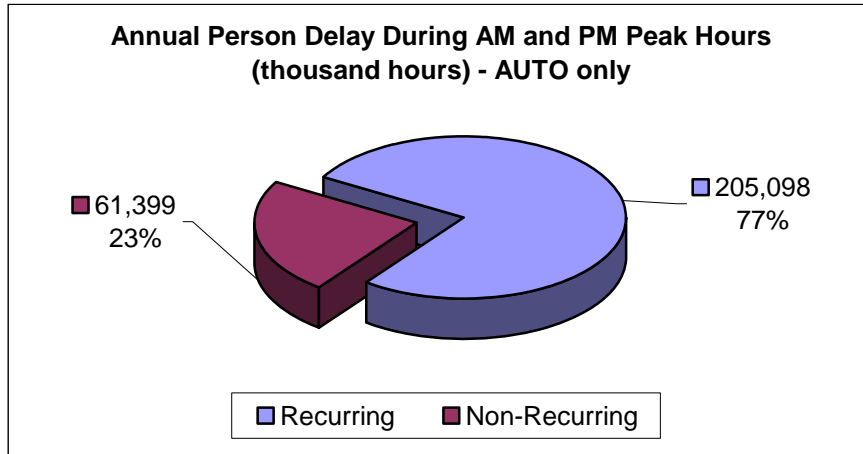


Figure 14. Statewide 2006 recurring vs. non-recurring person delay

Problem areas can also be identified using MOEs such as delay per VMT or delay per affected person. These measures bring the overall congestion into perspective of a local traffic flow and travel demand. Delay per VMT concentrates on vehicle flow, while in case of delay per affected person the focus is on travelers affected by congestion.

Table 14 shows a summary of traffic delay per VMT attributed to congestion presented by county and by facility type. The table shows that the worst conditions are on principal arterials of Bergen, Hudson, and Passaic counties, where congestion adds approximately 225 seconds (3.8 minutes), 199 seconds (3.3 minutes), and 174 seconds (2.9 minutes), respectively to the travel time for every mile traveled. Statewide, travel is least congested on freeways, followed by other arterials. On the average, congestion on principal arterials statewide will cause an increase in travel time of almost 98 seconds (1.6 minutes) for every traveled mile. This is equivalent to a decrease in speed from posted 50 mph to the actual 21 mph, or from posted 40 mph to actual 19 mph, resulting in more than doubling of the travel time.

Table 14. Vehicle delay per VMT, Year 2006

County	Average Vehicle Delay per VMT During Peak Periods [seconds/VMT]			
	Freeways	Principal Arterials	Other Arterials	All Roadways
Atlantic	0.42	16.71	8.72	9.27
Bergen	30.53	225.41	18.48	133.68
Burlington	4.41	44.20	9.57	22.24
Camden	36.92	102.48	67.17	74.72
Cape May	0.19	5.96	9.11	5.26
Cumberland	0.16	9.03	39.53	19.62
Essex	58.15	66.38	20.53	60.52
Gloucester	9.24	101.34	109.90	53.83
Hudson	54.96	198.73	66.54	108.08
Hunterdon	15.16	39.58	18.23	23.83
Mercer	8.37	48.45	63.08	32.98
Middlesex	29.16	89.87	71.82	53.86
Monmouth	17.81	63.50	27.03	39.78
Morris	26.71	62.04	27.58	38.79
Ocean	17.87	53.95	101.76	47.55
Passaic	24.80	174.03	17.72	120.06
Salem	6.35	8.10	12.24	7.93
Somerset	8.63	103.79	58.43	49.84
Sussex	1.60	60.79	25.07	46.43
Union	27.62	52.88	19.90	34.92
Warren	5.63	47.92	13.36	19.76
Statewide	24.21	97.99	47.66	56.97

Figure 15 shows a summary by county of annual hours of delay per affected person. Delay per affected person is the highest in Bergen County – almost 54 hours per year, followed by Passaic County with 44 hours. On the other end, registering relatively low delay per affected person, are Cape May (with 2.7 hours per year), Atlantic (4.8 hours per year), and Cumberland (5.4 hours per year) counties. Average annual delay per affected person statewide is **29.63 hours**.

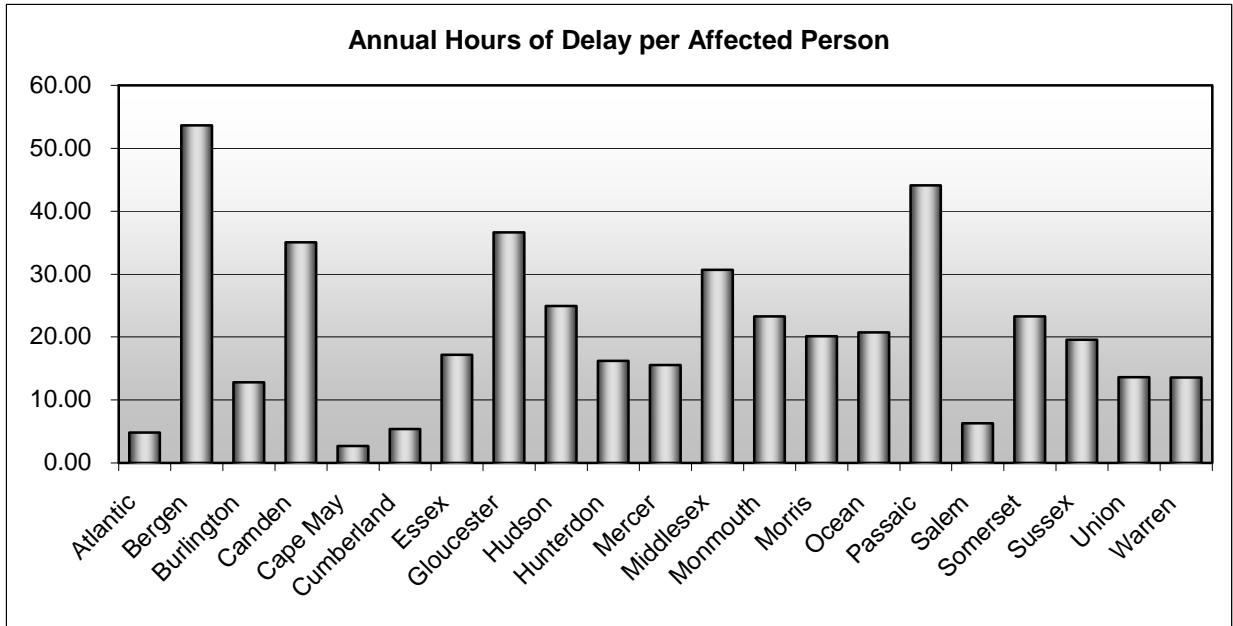


Figure 15. Annual 2006 hours of delay per affected person

4.2.2. Cost of Congestion (3-hr a.m. and p.m. peak periods)

The estimated annual cost of congestion in New Jersey was approximately \$7.4 billion. Bergen County incurred the highest cost of congestion of \$2 billion, or 28% of the statewide total. In general, the northern New Jersey counties experienced higher congestion costs than the southern counties, but all counties suffered some costs of weekday peak period congestion throughout the year. The total annual costs of congestion by facility type and county are summarized in Table 15. It is worth mentioning that the counties along the New Jersey shore experience significantly more congestion during summer weekend periods; this analysis, however, does not account for these seasonal variations, hence underestimating overall impact of congestion in these counties.

The cost of congestion for auto users is \$6.7 billion (or 91%), while truck operators lost an estimated \$691 million (or 9% of the total) as a result of traffic congestion. This breakdown is shown in Figure 16, Page 42.

The estimated amount of wasted fuel due to congestion was approximately 129 million gallons, which at the average cost of \$2.67 per gallon results in a cost of \$345 million. Compared to the total congestion costs statewide, the fuel cost makes up 5% of the total. Figure 17 shows a breakdown of total statewide cost of congestion between fuel cost and cost of lost productivity.

Table 15. Total 2006 annual costs of congestion by county and facility type

County	Total Annual Cost of Congestion [\$ million]			
	Freeways	Principal Arterials	Other Arterials	All Roadways
Atlantic	\$0.52	\$27.73	\$5.62	\$33.87
Bergen	\$234.09	\$1,808.33	\$2.33	\$2,044.74
Burlington	\$15.40	\$154.56	\$3.79	\$173.75
Camden	\$86.08	\$353.56	\$26.71	\$466.35
Cape May	\$0.09	\$1.81	\$5.25	\$7.14
Cumberland	\$0.04	\$1.87	\$15.13	\$17.05
Essex	\$236.63	\$189.95	\$3.82	\$430.39
Gloucester	\$22.36	\$148.81	\$75.72	\$246.89
Hudson	\$97.49	\$259.76	\$25.59	\$382.84
Hunterdon	\$45.15	\$52.10	\$16.42	\$113.67
Mercer	\$17.83	\$153.05	\$31.15	\$202.02
Middlesex	\$242.96	\$482.61	\$27.45	\$753.02
Monmouth	\$96.47	\$345.78	\$28.91	\$471.16
Morris	\$219.69	\$259.07	\$24.16	\$502.91
Ocean	\$43.61	\$86.96	\$117.88	\$248.45
Passaic	\$43.66	\$510.74	\$0.45	\$554.86
Salem	\$6.51	\$3.17	\$3.25	\$12.93
Somerset	\$33.96	\$283.86	\$35.96	\$353.77
Sussex	\$0.15	\$68.02	\$16.21	\$84.38
Union	\$131.14	\$115.16	\$2.13	\$248.43
Warren	\$14.15	\$40.63	\$2.95	\$57.74
Statewide	\$1,587.98	\$5,347.53	\$470.87	\$7,406.39

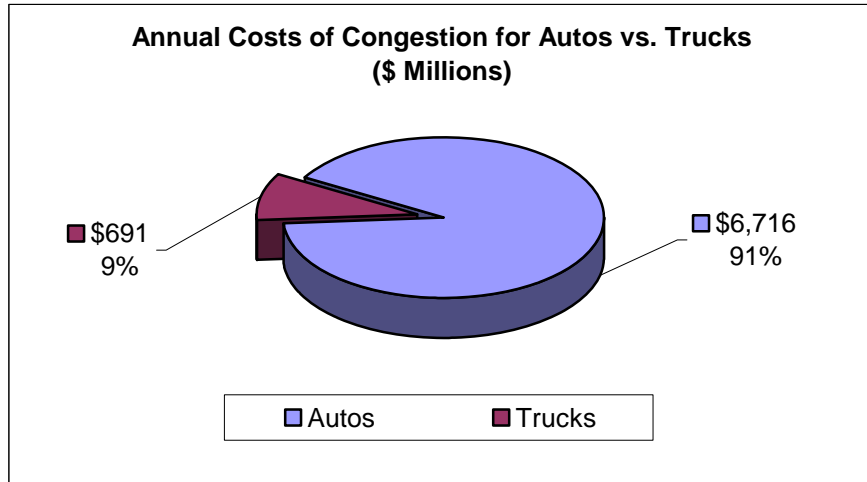


Figure 16. Annual 2006 costs of congestion: autos vs. trucks

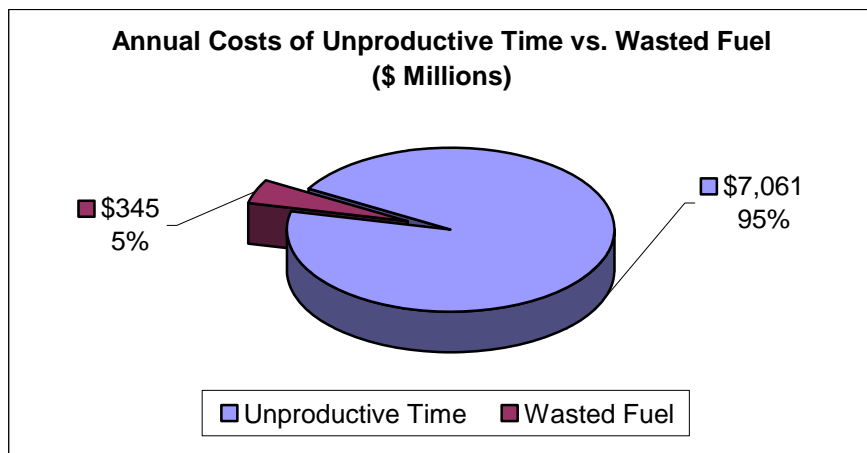


Figure 17. Annual 2006 costs of congestion: unproductive time vs. wasted fuel

Finally, Figure 18 summarizes costs of congestion per affected person by county. The most congested county, Bergen, also records the highest cost of congestion per affected person – about \$1,850 annually. This is almost twice as much as the cost per affected person in Passaic County, the second highest, at \$955 per year. The average annual cost of congestion per affected person statewide is **\$823.45²¹**.

²¹ Workers residing in one county and working in another county are counted as affected persons in each county, but counted as affected persons only once statewide. As a result, the cost per affected person statewide is higher than the simple average cost per affected person for all counties.

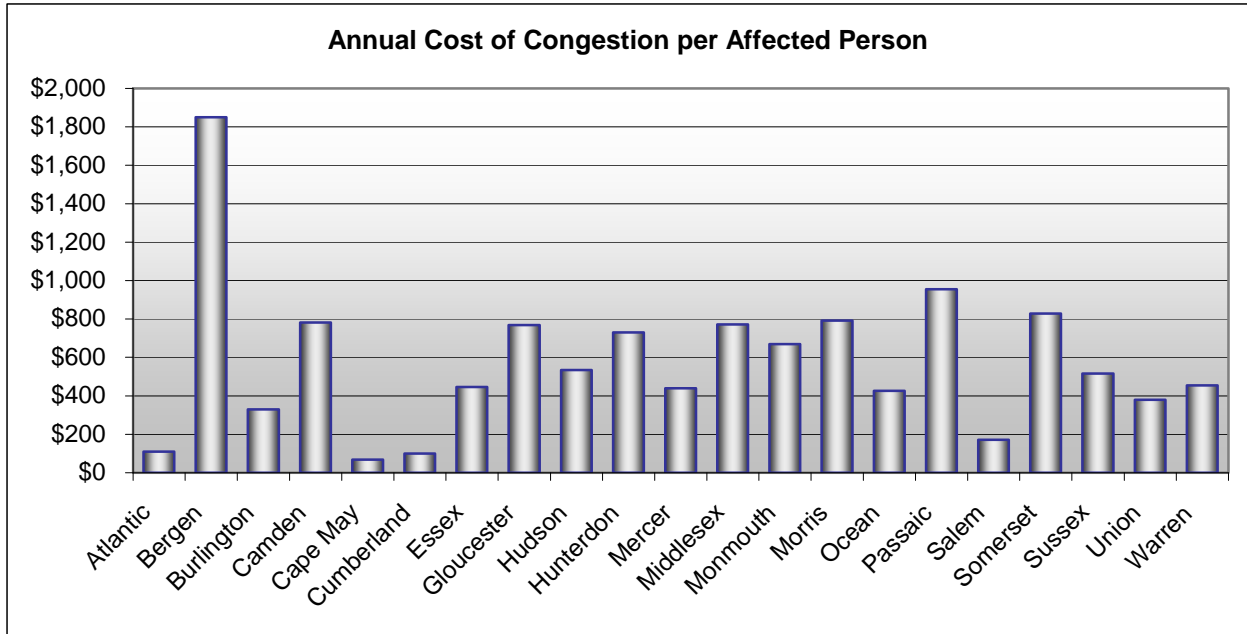


Figure 18. Annual cost of congestion per affected person by county (2006)

4.2.3. Congested Travel (3-hr a.m. and p.m. peak periods)

The percentage of vehicle miles traveled (VMT) in congested conditions during the peak periods gauges the overall quality of traffic flow. Figure 19 shows that 43% of peak period travel in New Jersey takes place under congested conditions, meaning under LOS D, E, or F.

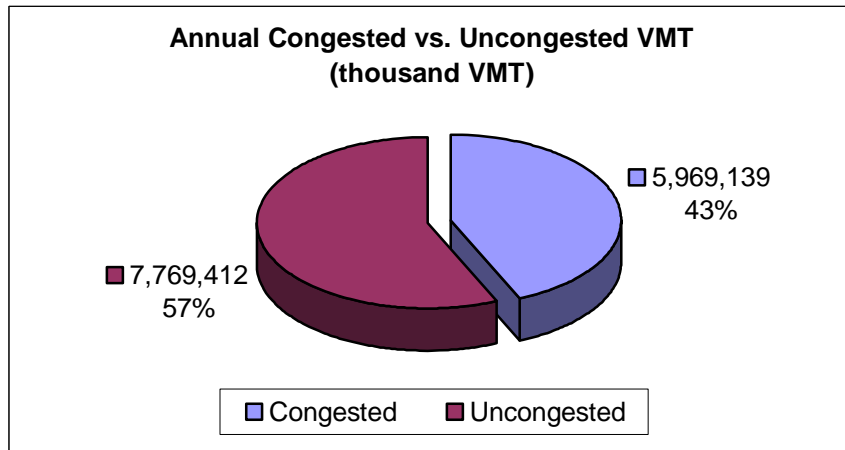


Figure 19. Annual 2006 congested vs. uncongested travel

4.2.4. Congestion Indexes: RCI, TRI, and TTI

The Roadway Congestion Index (RCI), the Travel Rate Index (TRI), and the Travel Time Index (TTI) are determined for each roadway link for the peak periods and aggregated for each facility type and county.

The Roadway Congestion Index (RCI) is a measure of cars per road space; i.e. a measure of vehicle travel density on major roadways in urban areas. An RCI value exceeding 1.0 indicates an undesirable congestion level on the freeways and principal arterial street system during the peak period.

The Travel Rate Index (TRI) is a measure of the amount of extra time it takes to travel during the peak period considering only recurring delay. A TRI of 1.20, for example, indicates that it will take 20 percent longer to travel to a destination during the peak period than during the off-peak period due to recurring congestion.

The Travel Time Index (TTI) is similar to TRI, but it considers both recurring and non-recurring delay.

Summaries of RCI, TRI, and TTI by facility type and county are presented in Tables 16 – 18, respectively.

The average RCI in New Jersey is 1.01. The average TRI is 1.52 and the average TTI is 1.73. These results show that New Jersey roadways are highly congested. This is especially true for principal arterials: the statewide average RCI is 1.0, TRI 1.91, and TTI 2.17. It is interesting to note that the statewide RCI is highest for facility type “other arterials” with a value of 1.05 (Table 16).

Bergen County again has the worst overall performance measures: RCI of 1.36, TRI of 2.30, and TTI of 2.85. Overall, 10 counties (or almost half the state) have an RCI greater than 1, and 18 counties (or 86% of the state) have a TRI greater than 1.10. When the TRI exceeds 1.10, there starts to be some locations with severely congested traffic conditions. In Bergen County (TRI=2.30), there is a very high percentage of the highway network with severe congestion. If one adds the effects of non-recurring congestion into the equation and calculates TTI, the picture becomes even worse (Table 18).

It is indicative that almost all counties are affected by congestion. Some are under severe congestion during the peak hours, and others are struggling with their roadway capacity generally not satisfying travel demand during the commuter a.m. and p.m. peaks. The counties in the south are generally in better shape in this respect, where Camden, as most congested, has an RCI of 0.99, TRI of 1.66, and TTI of 1.84.

Figures 20 – 22, which show the plots of RCI, TRI, and TTI on the map of New Jersey, offer a geographic perspective of congestion.

Table 16. Roadway congestion index (RCI) by facility type and county (2006)

County	Average Roadway Congestion Index (RCI)			
	Freeways	Principal Arterials	Other Arterials	All Roadways
Atlantic	0.60	0.69	0.74	0.65
Bergen	1.28	1.47	1.07	1.36
Burlington	0.93	0.83	0.95	0.90
Camden	1.03	0.92	1.33	0.99
Cape May	0.39	0.48	0.83	0.49
Cumberland	0.41	0.55	0.88	0.56
Essex	1.36	0.84	0.91	1.19
Gloucester	0.86	0.85	1.21	0.88
Hudson	1.01	1.31	1.33	1.12
Hunterdon	0.86	0.79	0.80	0.83
Mercer	0.91	0.92	1.04	0.92
Middlesex	1.19	1.28	1.08	1.22
Monmouth	1.16	1.02	1.28	1.11
Morris	1.10	0.97	1.20	1.07
Ocean	1.05	0.83	1.35	1.02
Passaic	1.35	1.19	0.79	1.26
Salem	0.79	0.56	0.73	0.73
Somerset	0.81	1.30	2.11	1.03
Sussex	0.61	0.70	0.90	0.74
Union	1.22	1.14	1.12	1.20
Warren	0.62	0.73	0.64	0.65
Statewide	1.02	1.00	1.05	1.01

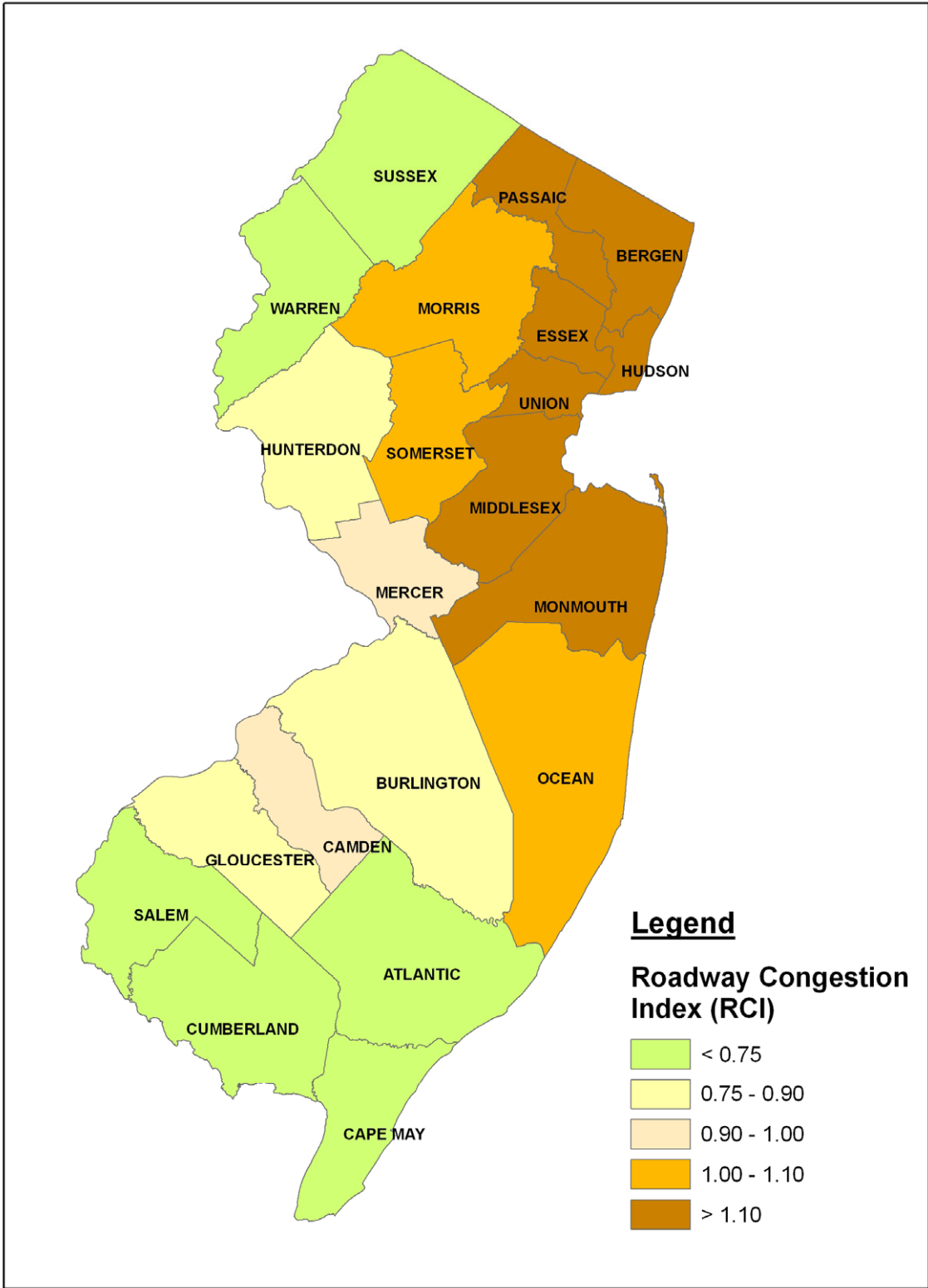


Figure 20. Roadway Congestion Index (RCI)

Table 17. Travel rate index (TRI) by facility type and county (2006)

County	Average Travel Rate Index (TRI)			
	Freeways	Principal Arterials	Other Arterials	All Roadways
Atlantic	1.00	1.17	1.10	1.10
Bergen	1.31	3.18	1.14	2.30
Burlington	1.05	1.46	1.10	1.23
Camden	1.37	1.89	1.53	1.66
Cape May	1.00	1.06	1.10	1.06
Cumberland	1.00	1.08	1.39	1.19
Essex	1.47	1.49	1.14	1.47
Gloucester	1.10	1.94	2.17	1.53
Hudson	1.47	2.62	1.37	1.88
Hunterdon	1.21	1.48	1.19	1.29
Mercer	1.03	1.46	1.50	1.28
Middlesex	1.23	1.74	1.60	1.44
Monmouth	1.14	1.66	1.26	1.39
Morris	1.25	1.62	1.26	1.37
Ocean	1.17	1.52	1.91	1.44
Passaic	1.16	2.75	1.15	2.18
Salem	1.06	1.08	1.12	1.08
Somerset	1.12	1.87	1.55	1.45
Sussex	1.03	1.51	1.28	1.42
Union	1.28	1.41	1.17	1.32
Warren	1.08	1.44	1.10	1.19
Statewide	1.22	1.91	1.44	1.52

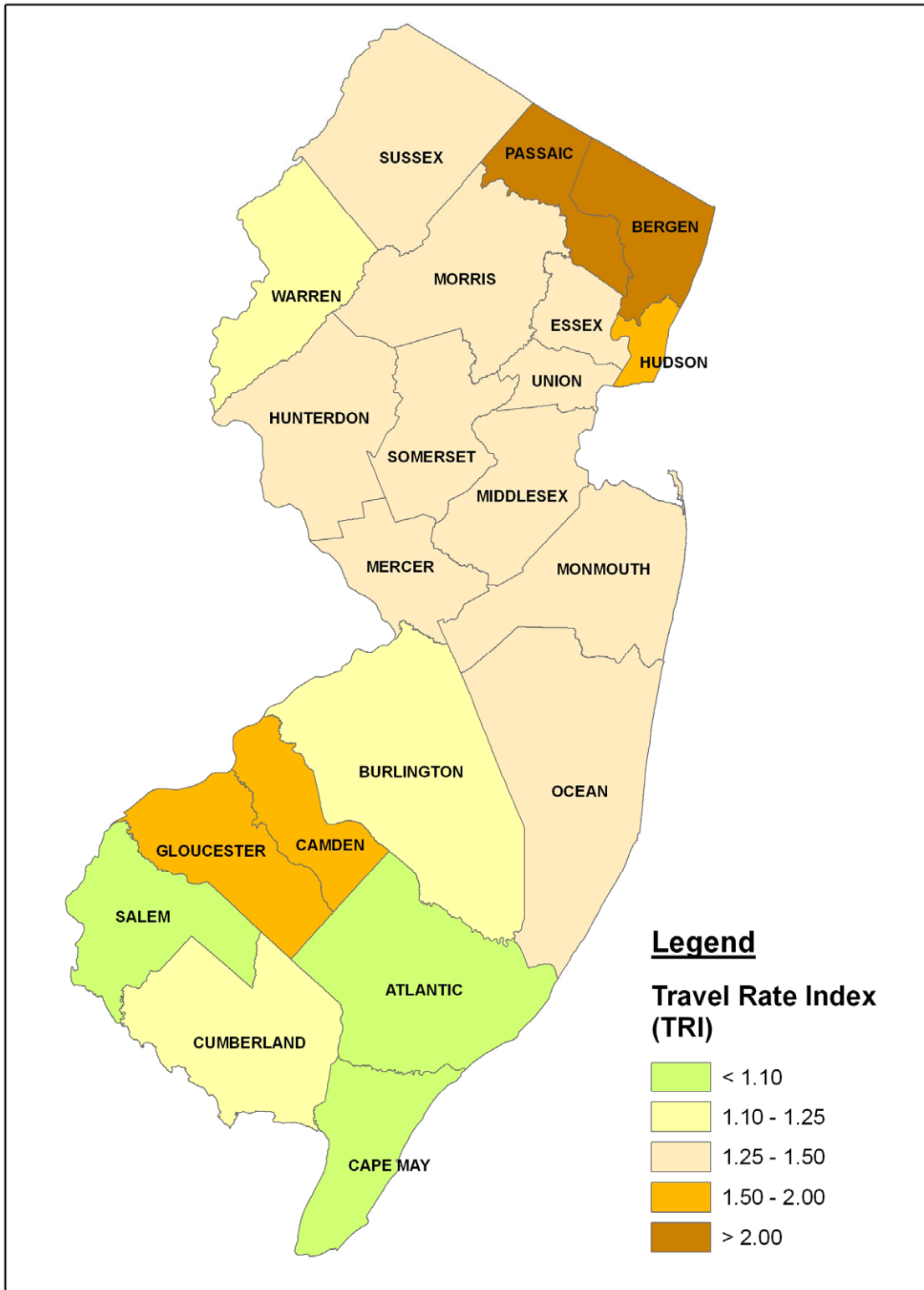


Figure 21. Travel Rate Index (TRI)

Table 18. Travel time index (TTI) by facility type and county (2006)

County	Average Travel Time Index (TTI)			
	Freeways	Principal Arterials	Other Arterials	All Roadways
Atlantic	1.01	1.20	1.12	1.11
Bergen	1.51	4.05	1.16	2.85
Burlington	1.09	1.52	1.11	1.28
Camden	1.54	2.07	1.61	1.84
Cape May	1.00	1.07	1.11	1.06
Cumberland	1.00	1.10	1.43	1.21
Essex	1.98	1.55	1.16	1.79
Gloucester	1.18	2.14	2.24	1.65
Hudson	1.69	3.17	1.46	2.20
Hunterdon	1.29	1.53	1.22	1.35
Mercer	1.16	1.54	1.56	1.39
Middlesex	1.49	1.94	1.67	1.67
Monmouth	1.32	1.75	1.29	1.52
Morris	1.51	1.71	1.29	1.56
Ocean	1.34	1.59	2.09	1.58
Passaic	1.41	3.41	1.16	2.69
Salem	1.10	1.10	1.14	1.11
Somerset	1.17	2.05	1.77	1.56
Sussex	1.03	1.57	1.32	1.46
Union	1.49	1.61	1.21	1.52
Warren	1.10	1.48	1.11	1.22
Statewide	1.41	2.17	1.50	1.73

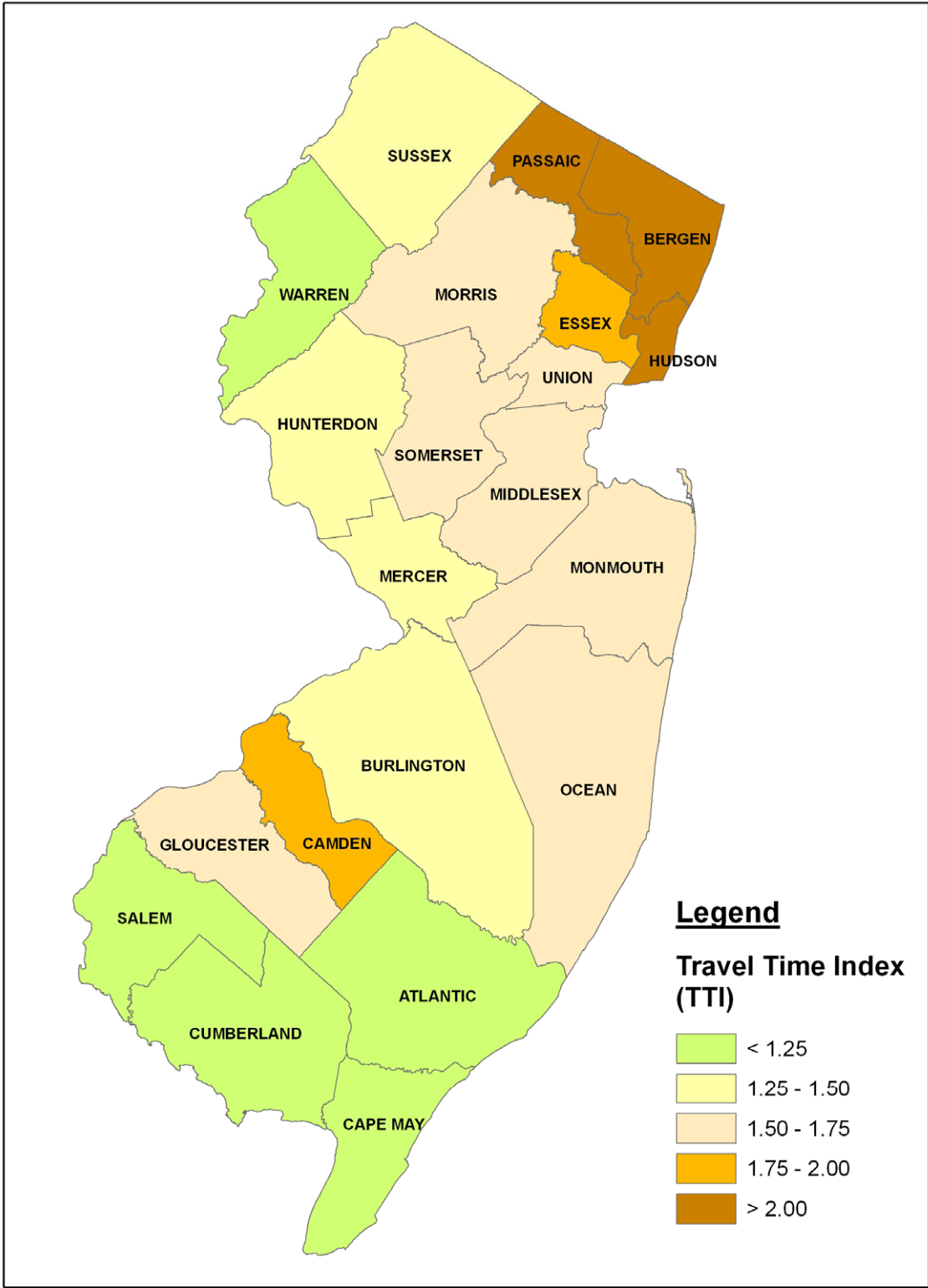


Figure 22. Travel Time Index (TTI)

4.2.5. Impacts of Increasing the Duration of A.M. and P.M. Peak Periods from Three to Four Hours

The section presents the changes in MOEs and the cost of congestion resulting from prolonging the duration of peak periods from three to four hours. This means that the 9 - 10 am hour is included in the morning peak and the 6-7 pm is included in the afternoon peak. The impetus for extending the peak period duration was an early finding indicating that the intensity of travel (as measured by VMTs) remains significant in the fourth hour of the peak periods.²²

Table 19 summarizes the results of the comparison of congestion analysis for the three-hour and four-hour a.m. and p.m. peak periods.

Table 19. Summary of results* for two case studies: first, assuming 3-hr a.m. and p.m. peak periods; and second, assuming 4-hr a.m. and p.m. peak periods.

Performance Measures	Case Study with 3-hr Peak Periods (6-9 a.m. and 3-6 p.m.)	Case Study with 4-hr Peak Periods (6-10 a.m. and 3-7 p.m.)
Total annual vehicle delay [million vehicle hours]	217.4	247.4
Total annual person delay [million person-hours]	266.5	307.3
Annual delay per affected person [person-hours]	29.6	34.2
Total Annual cost of congestion [billion \$]	\$ 7.4	\$ 8.6
Annual cost of congestion per affected person [\$/person]	\$ 823.5	\$ 950.7
Statewide average RCI	1.01	1.01
Statewide average TRI	1.52	1.47
Statewide average TTI	1.73	1.65
Statewide percent of VMT in congested conditions	43.4	39.3

*All results are annual summaries of the peak periods only, for 250 weekdays.

²² The average hourly statewide VMT during the 6 - 9 a.m. period was 8.5 million. For the 6 - 10 a.m. peak, the average hourly statewide VMT was 8.2 million. This meant that the traffic was still quite heavy between 9 - 10 a.m., and that the analysis of the four hour period was warranted. The same holds for the p.m. peak period. For the three-hour peak (3-6 p.m.) the average hourly statewide VMT was 9.8 million; for the extended peak period 3-7 p.m. the average hourly statewide VMT was 9.3 million.

The accumulated annual vehicle delay is 14% greater during the 4-hour a.m. and p.m. periods as compared to the 3-hour periods (an increase from 217.4 to 247.4 million vehicle-hours a year). The accumulated person delay increased by 15% (from 266.5 to 307.3 person-hours a year), and the total cost of congestion by 16% (7.4 to 8.6 billion dollars).

4.3. Implementation Notes

Two issues were identified during the model development and testing that are important for the model implementation. They pertain to changes and anomalies in the input datasets and changes in the calculation methodology. Both influence comparability of the results reported herein and the results of the studies that utilized NJITCAM v.2003 and the older NJCMS dataset.

4.3.1. Impact of Anomalies and Changes in NJCMS Input Data

There have been several changes in NJCMS since the NJITCAM v.2003. First, the table structure has been modified by adding new fields and/or renaming existing ones. This was addressed in the NJITCAM v.2007, but this means that NJITCAM v.2007 is not backwards compatible (with the NJCMS datasets preceding the SB Series). In addition, if the field structure in any of the NJCMS tables used by NJITCAM v.2007 is modified, the NJITCAM v.2007 will not run.

Second, it was noted that the NJITCAM v.2007 truck costs and truck VMTs are significantly lower when compared to the NJITCAM v.2003. This is due to a change in the definition of “truck” vehicle types in NJCMS. In the RA and RB dataset series, the truck vehicle type included the following four vehicle categories: category 3 (light-duty gasoline trucks), category 4 (heavy-duty gasoline vehicles), category 6 (light-duty diesel trucks), and category 7 (heavy-duty diesel vehicles). In the SD release, only categories 4 and 7 are considered trucks. Furthermore, changes have been made in the pattern file revising volume percentages of each vehicle type for each county and facility type.

Revisions of truck-type definition and changes in the pattern file pertaining to truck volumes effectively resulted in a significant decrease in total truck VMT reported in NJCMS outputs for the 8-hour peak period (including periods 6-10 a.m. and 3-7 p.m.). The RA dataset estimated a daily truck VMT at 7,019,555, compared to the SD dataset’s daily truck VMT of 3,074,660 (roughly a 50% decrease)! This decrease has a directly proportional impact on the cost of truck delay, causing it to drop by nearly 50%. It also causes a decrease in wasted fuel cost, which is proportional to the total vehicle delay under congestion.

During the test it was noticed that NJITCAM produces slightly higher sums of lane-miles and VMT. It was found that this is due to an error in coding nodes in the INDEX.DBF file for the link with CMSNUM=4458. This link has the same ANODE and BNODE

identification. This anomaly causes multiple double-counting of this link in both directions in the series of calculations performed by the NJITCAM based on the assumption of uniqueness of the combination of the CMSNUM, ANODE, and BNODE fields for each link in the NJCMS database. It is suggested that this anomaly be corrected in an appropriate NJCMS file.

4.3.2. Impact of Changes in Methodology

The main consequence of the changes in the methodology is a lower estimate of the congestion cost. This is due to the following modifications in the calculation procedures:

1. *Calculation of cost of unproductive time.* Cost of unproductive time in the new procedure is calculated separately for auto users and truck operators. For truck operators this cost is part of the overall cost per mile, and for auto users it is equal to the product of person-hours of delay and the corresponding value of time (depending on the county where delay is generated). In NJITCAM v.2003 all vehicle delay was multiplied by the average occupancy by vehicle type to get person-hours of delay, and then this product was multiplied by the value of time. Truck cost was added to this cost. Therefore, as expected, new estimates are lower than before, especially when it comes to the costs incurred by truck operators.
2. *Calculation of the amount of wasted fuel.* NJITCAM v.2003 assumed that gasoline consumption was directly proportional to speed (a linear functional relationship) and had the same parameters for all vehicles (autos and trucks). Instead, the NJITCAM v.2007 uses a polynomial function of the 3rd degree. In addition, trucks and autos have their unique functions. It was found that the new estimates of gasoline consumption are lower than reported in 2003²³.
3. *Calculation of recurring delay.* In NJITCAM v.2007 the recurring delay does not include the signal cycle delay. In NJITCAM v.2003 the recurring delay did include the signal cycle delay. On the other hand, in NJITCAM v.2007 all delay generated in addition to a freeflow time is considered as congestion, while in NJITCAM v.2003 only delays on links with LOS D or worse were counted as congestion. These changes had the opposite impact on overall estimates: excluding the signal cycle delay caused the total delay to decrease, while considering all delay as congestion increased the impact of congestion. Tests of the model show that combining these changes do not produce significantly different estimates of recurring delay compared to results of the analysis using NJITCAM v.2003.

²³ *Mobility and the Costs of Congestion in New Jersey – 2003 Update.* Report to New Jersey Governor McGreevey's Blue Ribbon Commission on Transportation, New Jersey Institute of Technology, September 2003.

4. *NJITCAM v.2003 assumed an 8-hour daily peak period (6-10 a.m. and 3-7 p.m.). It also considered adjusted traffic volumes on roadways connecting points along the New Jersey shore on summer Fridays (between Memorial and Labor Day). All this needs to be considered when comparing NJITCAM v.2007 with v.2003.*

4.4. Documentation

This final report includes an updated description of the calculation methodology ([Appendix A](#)) and a revised User Manual ([Appendix B](#)). They are an integral part of the project's final report.

5. CONCLUSIONS

The NJIT Congestion Analysis Model is significantly improved making more direct use of outputs from the NJCMS. This was one of the main requests from NJDOT's Bureau of Systems Development and Analysis, which is the primary user of the model. In addition, the user interface has been completely redesigned to meet the requirements of NJDOT staff, mainly pertaining to the parameter setting and selection of reports.

Reports have been completely redesigned to provide a more detailed break-down of calculated congestion measures and better readability of results with visual appeal. Tables and graphs generated in output spreadsheets can be pasted directly into Microsoft Office documents without alterations and without reformatting. Select measures can also be saved in the DBF format for easier data manipulation and interface with geographic information systems (GIS).

A case study was developed to demonstrate the new version of NJITCAM and the revised calculation methodology. The analysis was conducted for model year 2006, using the corresponding NJCMS outputs, as well as corresponding demographic and socio-economic statistics for New Jersey on the county level.

The impact of the peak hour duration on congestion analysis results was analyzed as part of the case study. The analysis implies that it is reasonable to consider a four-hour, rather than three-hour peak period, since the intensity of travel (as measured by VMTs) remains significant in the fourth hour of the peak periods. The accumulated annual vehicle delay is 14% greater during the 4-hour a.m. and p.m. periods as compared to the 3-hour periods (an increase from 217.4 to 247.4 million vehicle-hours a year). The accumulated person delay increased by 15% (from 266.5 to 307.3 person-hours a year), and the total cost of congestion by 16% (7.4 to 8.6 billion dollars). This test validates the hypothesis that existing travel patterns in effect expanded the 3-hour peak periods to 4 hours, based on the observed VMT and congestion indicators.

Finally, the documentation has been updated to reflect the changes in the calculation methodology, process flow, and user interface. The documentation consists of the project final report, description of the methodology, and the User Manual.

6. RECOMMENDATIONS AND FUTURE WORK

Future work and potential extensions of this project should focus on the following:

1. *Further refinement of the calculation procedure by providing linkages to NJDOT travel demand models.* Potential linkages to, and data produced by, the travel demand models should be explored. This data may provide information about number of trips and their distribution on the roadway network, which in turn can be used to better estimate impacts of congestion on the traveling public. For example, the model can estimate delay or cost per trip or person-trip, rather than per affected person.
2. *Further refinement/expansion of the fuel consumption model.* Although the current polynomial model is more realistic than the linear model used in the past, it would be beneficial to conduct research or review the state of practice in estimating gasoline consumption in congested traffic. Existing routines in NJCMS program can be utilized in this respect in conjunction with the research findings. In addition, valuation of negative effects of fuel emissions could be added to the cost estimation procedure.
3. *Development of a GIS module.* The ability to directly generate maps displaying MOEs would greatly improve visualization of the results and presentation capabilities by putting everything in geographic context. This can be accomplished by writing a script that would utilize existing GIS software on the user's computer, or as a built-in GIS mapping application with basic viewing functionality.
4. *Adding corridor or facility level analysis.* The same methodology used for the county and statewide analysis would be employed to calculate congestion measures for predefined corridors or user-specified facilities. This would allow users to analyze congestion impacts on a corridor and facility level.
5. *Integration with the NJCMS model.* The Congestion Analysis Model could potentially be integrated with NJCMS and serve as a post-processing tool for the calculation of specific congestion measures.
6. *Inclusion of link level output.* This would enable the model to report link-level congestion measures including a link-level priority score.

7. REFERENCES

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Appendix A: Calculation Methodology

This section describes the general methodology of calculating congestion measures in the NJIT Congestion Analysis Model (NJITCAM).

Roadway Database

The main source of roadway network data for the NJITCAM is New Jersey Congestion Management System (NJCMS). NJITCAM is programmed to utilize SD series dataset produced by the most recent release of NJCMS.

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 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 some minor arterials (including some 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 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, instead of assuming an average value across all links. 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 a unique roadway capacity can be assessed for each link, instead of assuming an average capacity value for each facility type. Many freeways and expressways in New Jersey were built to older design standards with narrow lanes and shoulders and, as a result, have lower capacity. In addition, the number of traffic signals generally limits the capacity of arterials.
- ❑ *Speed estimates by hour of the day:* NJCMS data contains estimated freeflow speeds for each link in the network. Using Volume-Density Functions (VDF) and based on estimated volumes, geometric characteristics, capacity of the roadway, and freeflow 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 for 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 field data and are aggregated for each county by facility type and time of day. Vehicle occupancy information is consolidated in the NJCMS input file OCCUPANT.dbf, which is used as one of the input files in the Congestion Analysis Model 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 the 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 file *XXnonre.dbf*²⁴. This file is used as an input for the Congestion Analysis Model.

Congestion Analysis Model (NJITCAM)

NJIT has developed a software package (NJITCAM) that provides automated procedures for summarizing vehicle and person delay and calculating costs of congestion and congestion indexes using NJCMS. The software is developed as a combination of the Microsoft Access database in the back end, and the VisualBasic application in the front end. Besides several NJCMS output and input files, NJITCAM requires users 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), NJITCAM 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 NJITCAM is NJCMS. The new version of NJITCAM (v.2007) is designed to work with table formats used in the NJCMS SD series dataset. NJCMS analysis has to be performed for the model year prior to running NJITCAM in order to generate the files necessary for model input. These files include:

- ❑ Approach table. Naming convention: *xxappr.dbf*²⁵;
- ❑ Link table. Naming convention: *xxlink.dbf*;
- ❑ Network table. Naming convention: *xxnet.dbf*;
- ❑ Nonrecurring delay file. Naming convention: *xxnonre.dbf*.

In addition, files *OCCUPANT.dbf* and *sdindex.dbf* were also obtained from NJCMS SD dataset and used as inputs for the case study.

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

²⁴ XX in the file name denotes dataset series index. For example, if SD series dataset is used, the name of this file would be "sdnonre.dbf".

²⁵ XX in the file name denotes dataset series index (e.g. sdappr.dbf in SD Series dataset).

- ❑ Statistics by county for the model year, including:
 - number of residents;
 - annual/hourly income per capita;
 - number of workers by place of employment or number of jobs;
 - number of workers who reside outside the county of employment;
 - relative proportion of intra-county travel compared to overall travel on county roadways (measured in terms of vehicle-miles-traveled (VMT));
- ❑ 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;
- ❑ Speed ratios to determine level of service (LOS). These are ratios of minimum actual speed for each respective level of service and freeflow speed. Ratios are required for LOS D (moderate congestion), E (heavy congestion), and F (severe congestion).

Calculation Procedure

The calculation procedure is performed in two phases: in the first phase Measures of Effectiveness (MOEs) and congestion measures are calculated on a link level and saved in a single table in the application database; in the second phase, performed during the report generation process, performance measures are aggregated up to a county or an MPO level, and on an annual or daily basis, depending on the user's report selection. Outputs are saved in an Excel spreadsheet or DBF file, depending on the selected output type.

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 VMT).
- ❑ Vehicle delay (for each analysis period). Total vehicle delay on a link is further broken down by vehicle type (auto and truck), and character 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 character of congestion (recurring and non-recurring). Person delay is 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 character 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), character of congestion (recurring or non-recurring), and source of cost (unproductive time or wasted fuel).

The analysis period can be the whole day (24 hours), the a.m. peak period, the p.m. peak period, or 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:

$$\bar{S}_{i,a} = \frac{\sum_{h \in a} S_{i,h}^c \cdot Vol_{i,h}}{\sum_{h \in a} Vol_{i,h}} \quad (20)$$

where:

- $\bar{S}_{i,a}$ - (Weighted) average vehicle speed on link i during analysis period a [mph];
- $S_{i,h}^c$ - Estimated average (congested) vehicle speed on link i during hour h , where period a includes hour h [mph];
- $Vol_{i,h}$ - Total vehicle volume on link i during hour h .

Vehicle Miles Traveled (VMT)

VMT is calculated using the following formula:

$$VMT_{i,a} = \sum_{h \in a} L_i \cdot Vol_{i,h} \quad (21)$$

where:

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

L_i - Link i length [mi].

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

$$\text{Truck VMT: } VMT_{i,a}^{tr} = \sum_{h \in a} L_i \cdot Vol_{i,h}^{tr} \quad (22)$$

$$\text{Auto VMT: } VMT_{i,a}^{auto} = \sum_{h \in a} L_i \cdot (Vol_{i,h} - Vol_{i,h}^{tr}) \quad (23)$$

where:

$Vol_{i,h}^{tr}$ - Total hourly truck volume on link i during hour h .

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

Vehicle Recurring Delay

The recurring delay is calculated for each highway link for each hour of the day. It is then aggregated to facility type, county, and statewide level for the final summary outputs. Summary results are provided on an annual or daily basis. The time of aggregations were morning (or a.m.) peak hours, afternoon (or p.m.) peak hours, or entire day. The total vehicle-hours of recurring delay on a link i during an hour h is calculated using the following formula:

$$D_{i,h}^r = \left(\frac{L_i}{S_{i,h}^c} - t_i^0 \right) \cdot Vol_{i,h}, \quad S_{i,h}^c > 0 \quad (24)$$

$$t_i^0 = \frac{t_i^{ff} + t_i^{sc}}{3600}, \quad (25)$$

where:

- $D_{i,h}^r$ - Total vehicle-hours of recurring delay on link i during hour h ;
- L_i - Link i length [mi];
- $S_{i,h}^c$ - Estimated average (congested) speed on link i during hour h [mph];
- t_i^{ff} - Zero-volume unconstrained travel time on link i excluding signal cycle delays at intersections [sec/veh];
- t_i^{sc} - Zero-volume signal cycle delay at intersections on link i [sec/veh];
- t_i^0 - Total zero-volume (freeflow) travel time on link i including signal cycle delays [h/veh];
- $Vol_{i,h}$ - Total vehicle volume on link i during hour h [veh].

The link length and estimated congested speeds on links, freeflow travel time on links, link signal cycle delays, and total hourly vehicle volume is obtained from the NJCMS link file.

The variable $D_{i,h}^r$, total vehicle-hours of recurring delay, does not include signal cycle delay. Signal cycle delay is subtracted out along with the freeflow time (Equations 24 and 25).

Vehicle delay is summarized for the analysis period a by the following equation:

$$D_{i,a}^r = \sum_{h \in a} D_{i,h}^r \quad (26)$$

where:

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

Recurring vehicle delay is also summarized for trucks and autos. This is done by multiplying the vehicle delay in Equation 24 ($D_{i,h}^r$) by the truck volume divided by the total vehicle volume to obtain truck recurring delay, and then subtracting that number from $D_{i,h}^r$ to obtain auto recurring delay.

Based on hourly speeds, and using speed ratios from HCM, it is possible to determine the level of congestion on each particular link for each hour of the day. 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 those congestion levels (moderate, heavy, severe congestion, or no congestion).

Vehicle Non-recurring Delay

The methodology used by Texas Transportation Institute in preparing the annual urban mobility reports assumes that non-recurring delay is directly proportional to recurring delay.²⁶ The amount of non-recurring delay is calculated as a product of the recurring delay in a given area and a non-recurring-to-recurring delay ratio. The ratio is determined based on a detailed examination of the roadway characteristics and volumes for two roadway types – freeways and arterials, and for each metropolitan region in the nation. The ratios for the New York-New Jersey metropolitan area, for example, are 2.5 for freeways and 1.1 for principal arterials. NJITCAM v.2003 methodology used a similar approach, with a difference that the ratios were computed by county and facility type based on data obtained from NJCMS. These ratios were therefore more relevant to New Jersey, and they accounted for specific characteristics of roadways by facility type in each county.

In marked contrast, NJITCAM v.2007 takes the non-recurring delay estimates directly from NJCMS outputs for each link in the network, without the need to calculate aggregated ratios by facility type or county. The non-recurring delay is calculated in NJCMS for each network link by direction and for each hour of the day. It 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).

NJITCAM summarizes the non-recurring delay both on an annual and daily basis for the morning (a.m.) and afternoon (p.m.) peak periods.

The annual summary is a simple sum of the delays over all links. This sum is then further aggregated by facility type, county, and as a statewide summary.

Although 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

²⁶ Schrank, D. and D. Lomax, "2005 Urban Mobility Report", Texas Transportation Institute, The Texas A&M University, May 2005.

estimate the amount of wasted fuel. The following formula was used to calculate the estimated average (congested) speed during incident or accident events:

$$S_{i,h}^{n-r} = \frac{L_i}{t_i^0 + d_{i,h}^r + d_{i,h}^{n-r}} \quad (27)$$

where:

$$d_{i,h}^r = \frac{D_{i,h}^r}{Vol_{i,h}}, \quad Vol_{i,h} > 0 \quad (28)$$

$$d_{i,h}^{n-r} = \frac{365 \cdot D_{i,h}^{n-r}}{I_{i,h} \cdot Vol_{i,h}}, \quad I_{i,h} > 0, Vol_{i,h} > 0 \quad (29)$$

- $S_{i,h}^{n-r}$ - Estimated average (congested) speed on link i during hour h , in incident or accident conditions [mph];
- $d_{i,h}^r$ - Average recurring delay per vehicle on link i during hour h [h/veh];
- $d_{i,h}^{n-r}$ - Average non-recurring delay per vehicle on link i during hour h , in incident or accident conditions [h/veh];
- $D_{i,h}^{n-r}$ - 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.

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

For autos, recurring and non-recurring vehicle delay is converted to person delay using vehicle occupancy. The occupancy data is summarized in the NJCMS table OCCUPANT.dbf. It is summarized for passenger vehicles (or autos) by county, facility type, and time period of the day (NJCMS defines four time periods in the analysis of vehicle occupancy: a.m. peak, midday, p.m. peak, and night). NJITCAM calculates the total person delay for autos by multiplying the sum of recurring and non-recurring vehicle-delay by occupancy:

$$PD_{i,a} = \sum_{h \in a} (d_{i,h}^r + d_{i,h}^{n-r}) \cdot (Vol_{i,h} - Vol_{i,h}^{tr}) \cdot OC_{i,h} \quad (30)$$

Where:

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

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

NJCMS provides estimates for 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.

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 travel rate (in minutes per mile) during the peak period was compared to the travel rate under freeflow speeds to calculate the TRI. A TRI of 1.20, for example, indicates that it will take 20 percent longer to travel to a destination during the peak period than during the off-peak period. On a link level, TRI is calculated using the following formula developed by the Texas Transportation Institute²⁷:

$$\text{Travel Rate Index} = \frac{\text{Actual Conditions Travel Rate (minutes/mile)}}{\text{Average Freeflow Travel Rate}} \quad (31)$$

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

$$TRI_{i,a} = \frac{TR_{i,a}}{TR_i^{ff}} \quad (32)$$

where:

$$TR_{i,a} = TR_i^{ff} + TR_{i,a}^r \quad (33)$$

$$TR_i^{ff} = \frac{60 \cdot t_i^0}{L_i} \quad (34)$$

$$TR_{i,a}^r = \frac{60 \cdot D_{i,a}^r}{L_i \cdot Vol_{i,a}} \quad (35)$$

²⁷ Schrank, D. and D. Lomax, "2005 Urban Mobility Report", Texas Transportation Institute, The Texas A&M University, May 2005.

- TR_i^{ff} - Average freeflow 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];
- $D_{i,a}^r$ - Total vehicle-hours of recurring delay during analysis period a on link i ;
- $Vol_{i,a}$ - Total vehicle volume during analysis period a on link i ;
- $TR_{i,a}$ - Average actual-conditions travel rate during analysis period a on link i [min/mi];
- $TRI_{i,a}$ - Average TRI 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:

$$TRI_C = \frac{\sum_{i \in C} TRI_{i,a} \cdot VMT_{i,a}}{\sum_{i \in C} VMT_{i,a}}, \quad (36)$$

where C represents the aggregation level (county, or facility type, or entire roadway system).

Calculation of 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 as compared to the freeflow conditions. A TTI of 1.20, for example, indicates that it will take 20 percent longer to travel to a destination during the peak period.

TTI is calculated based on the following formula developed by the Texas Transportation Institute²⁸:

$$\text{Travel Time Index} = \frac{\text{All Conditions Travel Rate (minutes/mile)}}{\text{Average Freeflow Travel Rate}} \quad (37)$$

In Equation 37 “all conditions travel rate” is the sum of the freeflow travel rate and incremental travel rates for both recurring and non-recurring congestion delay. NJITCAM v.2007 applies this formula, and the calculation steps are as follows:

²⁸ Schrank, D. and D. Lomax, “2005 Urban Mobility Report”, Texas Transportation Institute, The Texas A&M University, May 2005.

$$TTI_{i,a} = \frac{TR'_{i,a}}{TR_i^{ff}} \quad (38)$$

where:

$$TR'_{i,a} = TR_i^{ff} + TR_{i,a}^r + TR_{i,a}^{n-r} \quad (39)$$

$$TR_{i,a}^{n-r} = \frac{60 \cdot D_{i,a}^{n-r}}{L_i \cdot Vol_{i,a}} \quad (40)$$

$TTI_{i,a}$ - Average TTI on link i during analysis period a ;

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

$TR_{i,a}^{n-r}$ - Average peak period non-recurring delay rate on link i ; [min/mi];

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

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):

$$TTI_C = \frac{\sum_{i \in C} TTI_{i,a} \cdot VMT_{i,a}}{\sum_{i \in C} VMT_{i,a}}, \quad (41)$$

where C represents the aggregation level (county, or facility type, or entire roadway system).

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:

$$RCI = \frac{\frac{Freeway\ VMT}{lane-mile} \times Freewy\ VMT + \frac{Princ.\ Art.\ VMT}{lane-mile} \times Princ.\ Art.\ VMT + \frac{Other\ Art.\ VMT}{lane-mile} \times Other\ Art.\ VMT}{14000 \times Freeway\ VMT + 9000 \times Principal\ Arterial\ VMT + 5500 \times Other\ Arterial\ VMT} \quad (42)$$

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

Fuel consumption is calculated as a function of vehicle speed on a link during each hour of the evaluation. The auto and truck fuel consumption rates are based on CALTRANS's Life-Cycle Benefit-Cost Analysis Model (CAL-B/C)²⁹. Figure 23 shows plots of these rates.

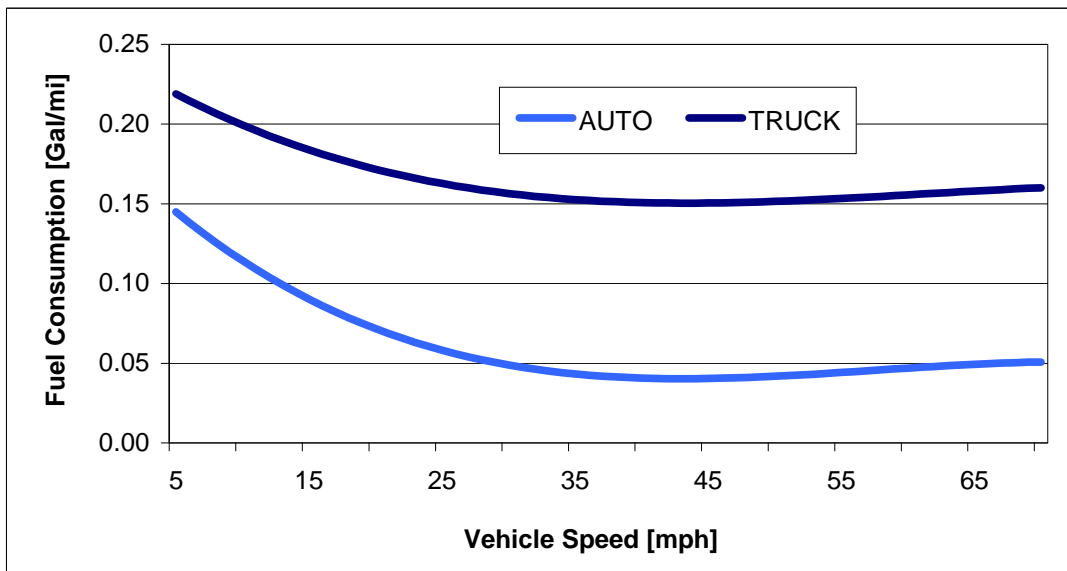


Figure 23. Fuel consumption rates as a function of speed based on CALTRANS Life-Cycle Benefit-Cost Analysis Model (CAL-B/C)

²⁹ 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).

The empirically derived curves are of the following form:

$$g(S) = a_0 + a_1 \cdot S + a_2 \cdot S^2 + a_3 \cdot S^3 \quad (43)$$

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 20 shows the estimated regression coefficients and the coefficient of determination (R^2).

Table 20. Estimated regression coefficients and R^2 for fuel consumption functions

Estimators	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. When calculating wasted fuel, there are three speeds that one needs to consider: freeflow (uncongested) speed, congested speed in recurring congestion, and congested speed in non-recurring congestion. With that in mind, wasted fuel on a link and per hour is calculated using the following set of formulas:

Autos:

$$G_{i,h}^{A,r} = \text{Max} \left[g_A(S_{i,h}^c) - g_A \left(\frac{L_i}{t_i^0} \right), 0 \right] \cdot \text{Vol}_{i,h}^A \cdot L_i \quad (44)$$

$$G_{i,h}^{A,n-r} = \text{Max} \left[g_A \left(S_{i,h}^{n-r} \right) - g_A \left(S_{i,h}^c \right), 0 \right] \cdot \text{Vol}_{i,h}^A \cdot L_i \quad (45)$$

where:

$G_{i,h}^{A,r}$ - Total gallons of fuel wasted by autos due to recurring congestion on link i during hour h ;

$G_{i,h}^{A,n-r}$ - Total gallons of fuel wasted by autos due to non-recurring congestion on link i during hour h ;

g_A - Fuel consumption rate function for autos [gal/mi];

$\text{Vol}_{i,h}^A$ - Total auto volume on link i during hour h ;

Trucks:

$$G_{i,h}^{T,r} = \text{Max} \left[g_T \left(S_{i,h}^c \right) - g_T \left(\frac{L_i}{t_i^0} \right), 0 \right] \cdot \text{Vol}_{i,h}^T \cdot L_i \quad (46)$$

$$G_{i,h}^{T,n-r} = \text{Max} \left[g_T \left(S_{i,h}^{n-r} \right) - g_T \left(S_{i,h}^c \right), 0 \right] \cdot \text{Vol}_{i,h}^T \cdot L_i \quad (47)$$

where:

$G_{i,h}^{T,r}$ - Total gallons of fuel wasted by trucks due to recurring congestion on link i during hour h ;

$G_{i,h}^{T,n-r}$ - Total gallons of fuel wasted by trucks due to non-recurring congestion on link i during hour h ;

g_T - Fuel consumption rate function for trucks [gal/mi];

$\text{Vol}_{i,h}^T$ - Total truck volume on link i during hour h .

Wasted fuel is summarized by county, facility type, and as a statewide summary on a daily or annual basis.

Cost of Congestion - Autos

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

$$c_{i,a}^{auto} = v_k \cdot PD_{i,a} + \left(G_{i,a}^{A,r} + G_{i,a}^{A,n-r} \right) \cdot c_g \quad (48)$$

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 on link i ;
- $PD_{i,a}$ - Total person-hours of delay for autos on link i during analysis period a ;
- c_g - Average cost of a gallon of fuel [\$/gal].

The first part of Equation 48 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 income and statewide average hourly income per capita for all the links within a county. The weight 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:

$$v_k = W_k \cdot p_k + \bar{W} \cdot (1 - p_k) \quad (49)$$

where:

- W_k - Average hourly income per capita 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 income per capita [\$/hr];

Calculation of Cost of Congestion for Trucks

NJCMS furnishes 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). In order to calculate the total cost of congestion for trucks it is necessary to multiply the total accrued truck congestion related 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 cost³⁰ and average speed. The truck congestion cost can be categorized into recurring and non-recurring congestion costs. Link level results are aggregated to facility type, county, and statewide level by summation.

³⁰ 2001 average per-mile cost of owning and operating a truck is found in the National Transportation Statistics, U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, *National Transportation Statistics 2005*, Washington, DC, Summer 2005, available at http://www.bts.gov/publications/national_transportation_statistics/2005. It includes, among other cost categories, cost of fuel. The data are brought up to 2007 using the consumer price index and producer price index for New Jersey.

To avoid double-counting, since the cost of fuel is built into the operating cost, the fuel cost for trucks is deducted from the total truck cost to obtain the cost of unproductive time. The fuel cost is calculated as a product of wasted fuel and gasoline price.

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. This is done using link identification codes (to determine in which county each link is located and to what facility type each belongs).

These are either simple sums (VMT, delays, costs, wasted fuel) or weighted averages by VMT (speeds, RCI, TRI, 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. The only subject group defined in the model is called “affected persons”.

The term “affected persons” is used to describe a subject group impacted by congestion. An affected person is defined as a person who lives and/or works in an analysis region (county) and therefore experiences congestion within that region on a daily basis. The equation for calculating number of affected persons is as follows:

$$\# \text{ Affected Persons} = \text{ResPop} + (\text{OW}\%) \times \text{Workers} \quad (50)$$

where:

Affected Persons = Total number of affected persons in a study region (e.g. county);

ResPop = Total number of residents in a study region;

OW% = Percentage of workers who work but do not reside in the study region;

Workers = Total number of people who work in the study region.

It is assumed that the number of workers by place of employment is equivalent to estimates of the number of jobs by county from the Quarterly Workforce Indicators (QWI)³¹. QWI statistics are currently available for years 1996-2005. Estimates for year 2006 were developed using linear regression.

³¹ The Quarterly Workforce Indicators (QWI) are developed using the Local Employment Dynamics (LED) database of the U.S. Census Bureau <http://lehd.dsd.census.gov/led/datatools/qwiapp.html>.

The percentage of workers who reside outside the county of employment is calculated for each county using the Journey To Work and Place Of Work dataset of the 2000 U.S. Census³². The same procedure was applied to estimate the percentage of New Jersey workers who live out-of-state. The statewide number of affected persons (used for calculating statewide statistics) is thus equal to the sum of all New Jersey residents plus people who work in New Jersey but reside outside New Jersey.

³² 2000 Journey To Work and Place Of Work, County-To-County Worker Flow Files; U.S. Census Bureau. Database can be accessed online at: <http://www.census.gov/population/www/cen2000/commuting.html>

Appendix B: User Manual

Table of Contents

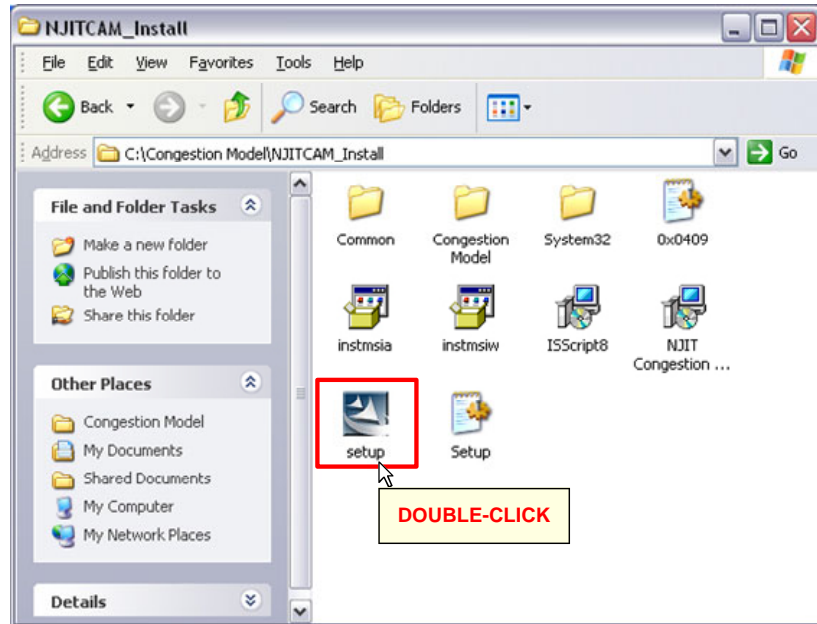
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STEP 1: Installing the software

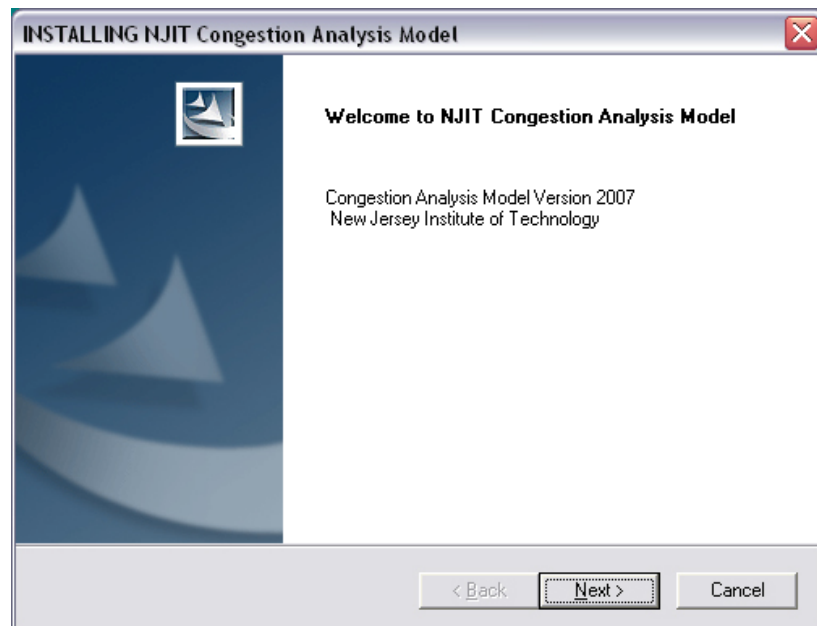
All installation files for the NJIT Congestion Analysis Model (NJITCAM v.2007) are located on the installation CD. Installation can be executed either from the CD, or the user can copy the entire installation directory to the local drive and execute the installation from there.

Please follow the following steps to install the model application:

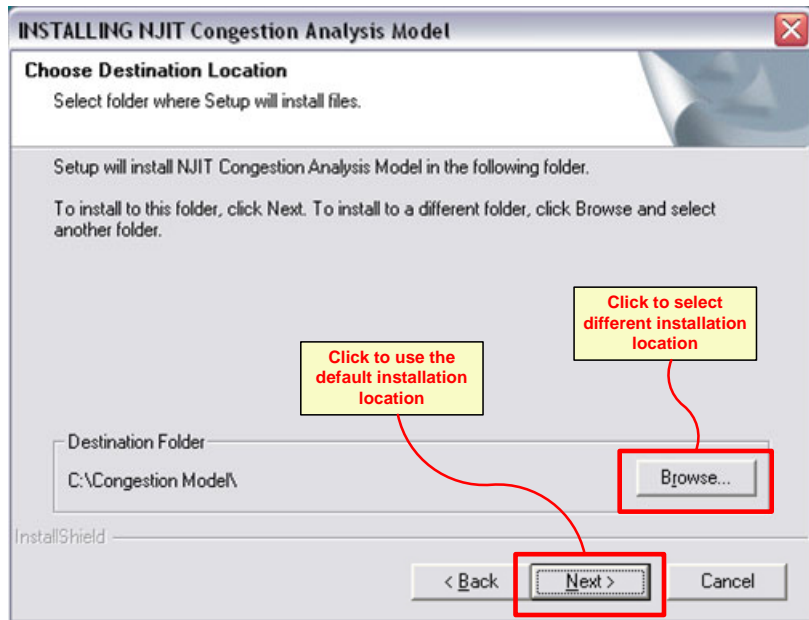
1. Locate the installation directory and double-click on the file *setup.exe*



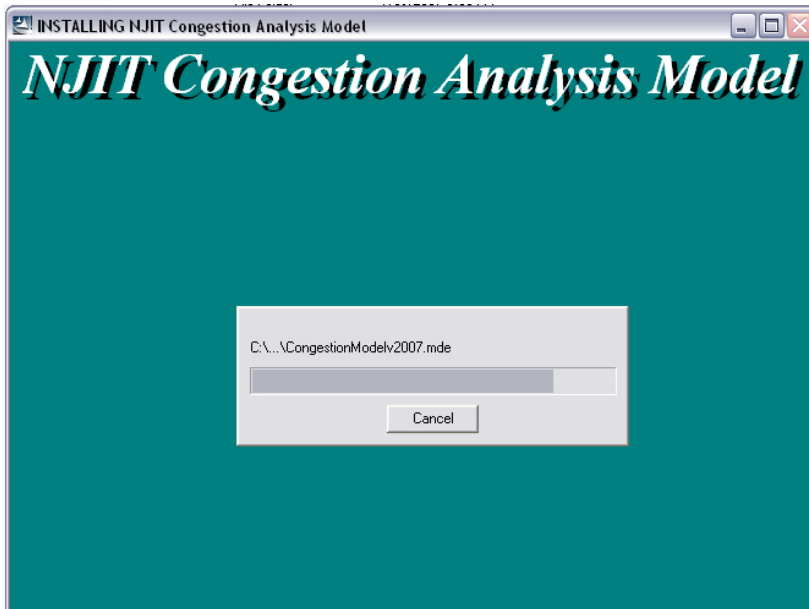
2. Click "Next" on the installation welcome screen.



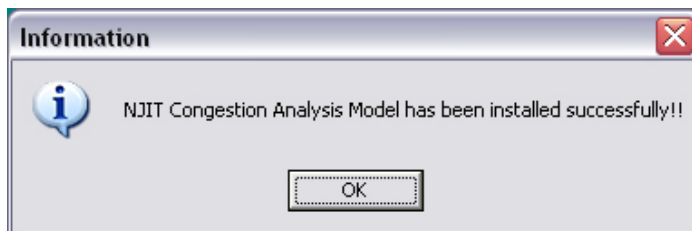
3. If you want to install the application in the default directory click "Next". If you want to install it in another location, click "Browse" and select the installation location. Then click "Next".



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



5. Upon installation a dialog box will appear informing you that the installation was successfully completed. Click "OK". This concludes 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). Naming convention: *xxindex.dbf*, where 'xx' denotes data series; e.g. in SD series dataset this file would be called *sdindex.dbf*.
- Occupant table (input). File name: OCCUPANT.dbf
- Approach table (output). Naming convention: *xxappr.dbf*.
- Link table (output). Naming convention: *xxlink.dbf*.
- Network table (output). Naming convention: *xxnet.dbf*.
- Nonrecurring delay file (output). Naming convention: *xxnonre.dbf*.

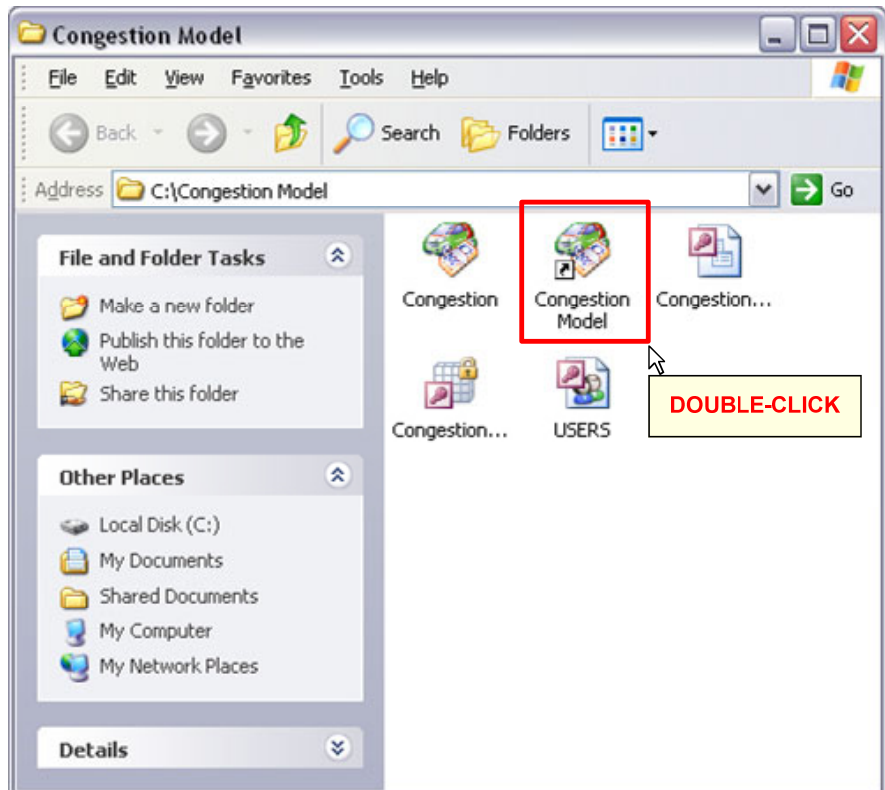
Other parameters and statistics necessary for the model analysis include:

- Statistics by county for the model year, including:
 - number of residents;
 - annual/hourly income per capita;
 - number of workers by place of employment or number of jobs;
 - number of workers who reside outside the county of employment;
 - relative proportion of intra-county travel compared to overall travel on county roadways (measured in terms of vehicle-miles-traveled (VMT)).
- 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;
- Speed ratios to determine the LOS. These are ratios of minimum actual speed for each respective level of service and freeflow speed. Ratios are required for

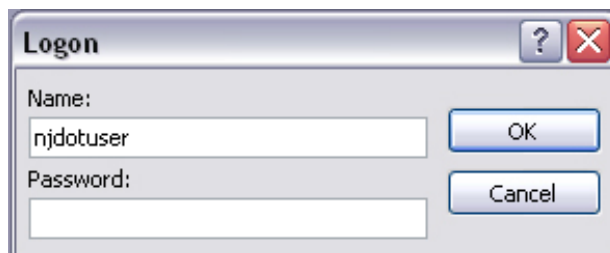
LOS D (moderate congestion), E (heavy congestion), and F (severe congestion).

STEP 3: Starting the application

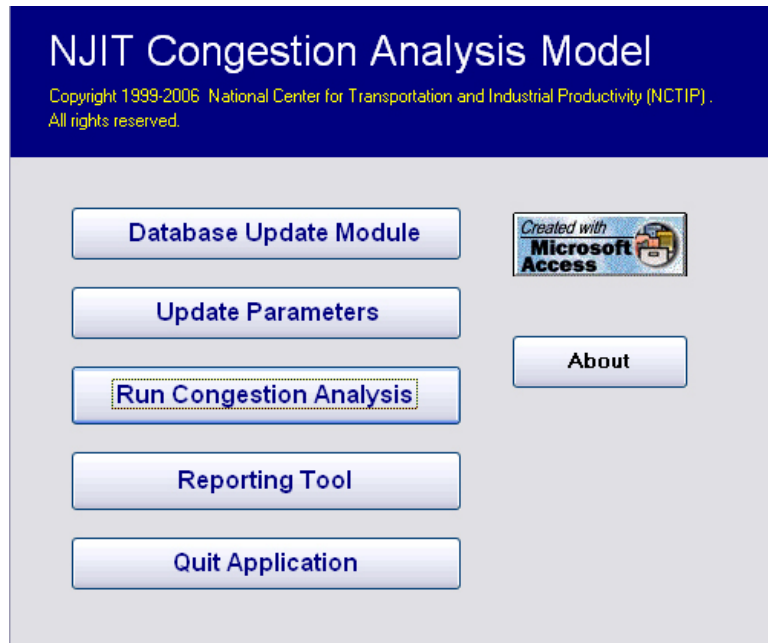
The NJITCAM application is started by double-clicking the application shortcut on the computer desktop screen or in the application directory. The default location of the application directory is "C:\Congestion Model".



At the login screen please type "*njdotuser*" as your login name and leave the password field empty (there is no password). Click "OK" to load the application.

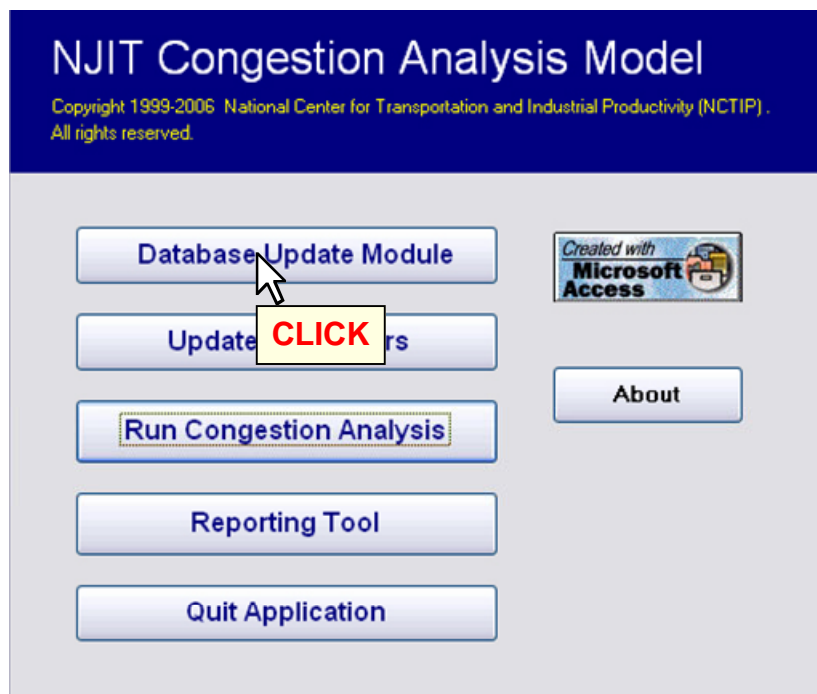


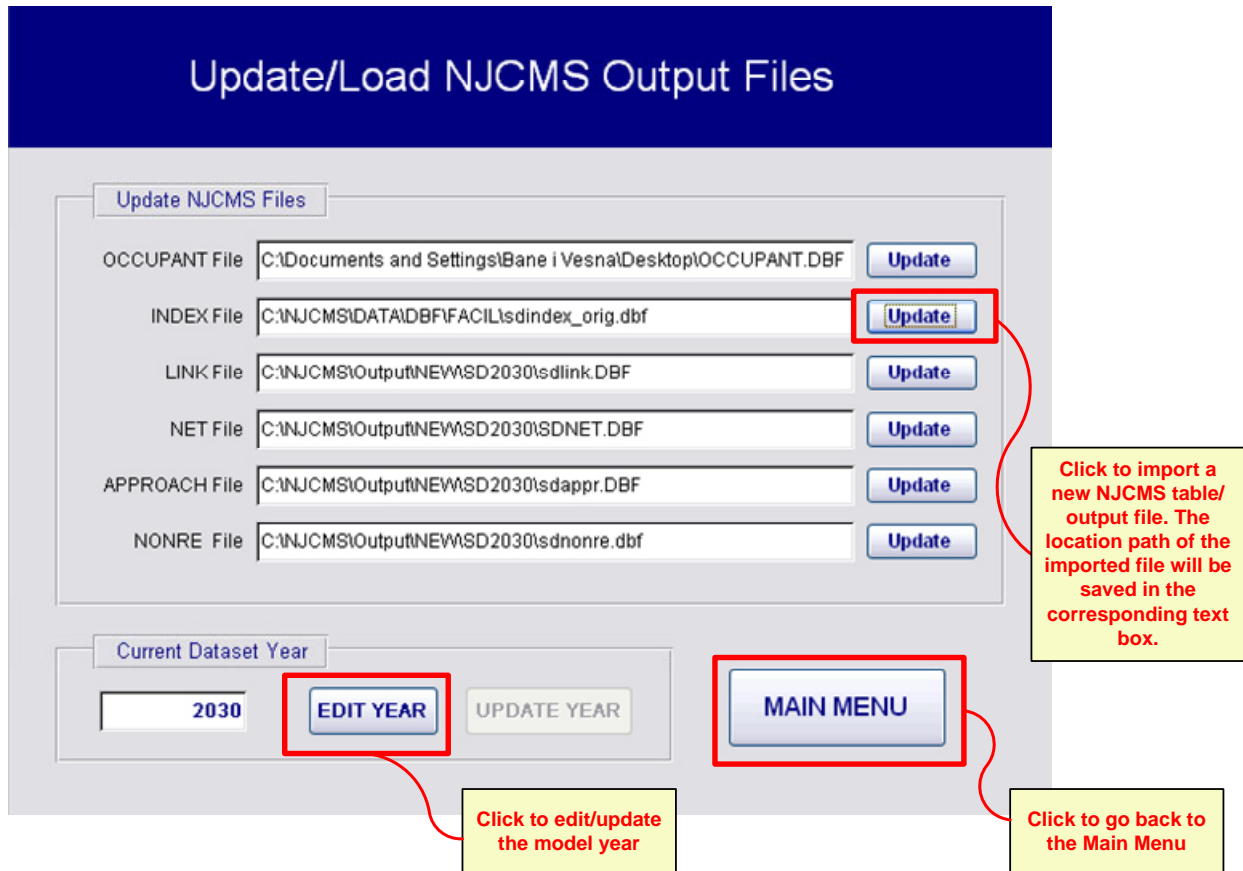
The “Main Menu” screen is the opening screen of the application. From this screen you can navigate to all other application modules.



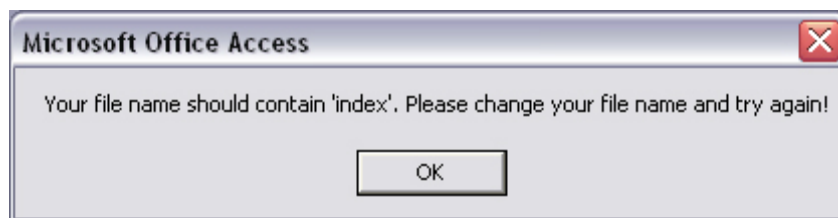
STEP 4: Updating the NJCMS tables in the database

Clicking the “Database Update Module” button on the “Main Menu” screen takes the user to the roadway network database update screen. This screen allows the user to load NJCMS output files in DBF format by clicking the appropriate “Update” button.





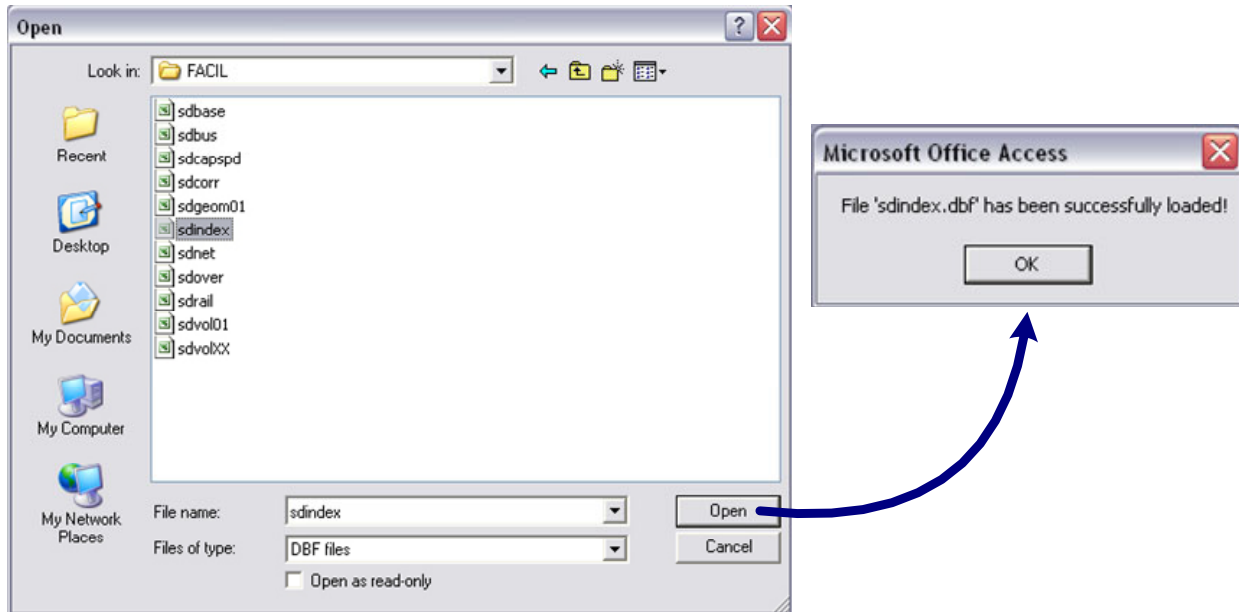
The “Save...” dialog box appears to allow the user to select the appropriate file. In order to prevent loading wrong files, the application checks the file names selected by the user to be loaded. If the file name does not correspond to the common name assigned by NJCMS, it will not be loaded and the user will be informed by a message on the screen.



After verifying the file name, the table is loaded into the database. A dialog box displays a message that the file has been successfully loaded (see next page).

A path to the location of the loaded file is also saved and displayed in a box next to the file description and “Update” 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.

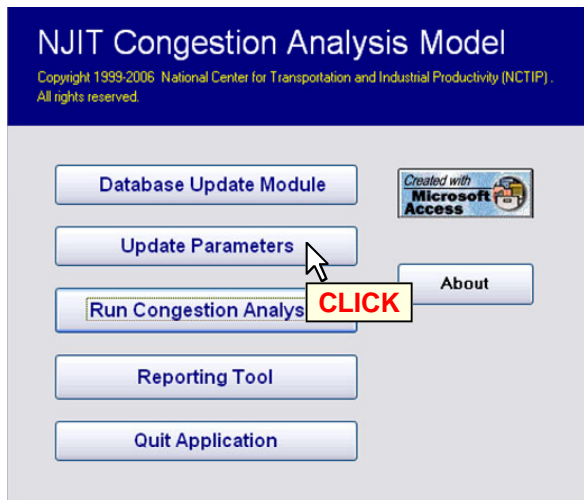


On the “Update/Load NJCMS Output Files” screen the user can also modify the model year of the loaded roadway network once the files are updated (as shown below). Clicking the “Main Menu” button on the “Update/Load NJCMS Output Files” screen takes the user back to the “Main Menu” screen.



STEP 5: Updating general model parameters

Parameters are updated on the “Parameter Update” screen, which can be accessed from the main menu by clicking the “Update Parameters” button. On this screen users can: update values for the speed ratios 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, and statewide average hourly wage used to estimate value of time for the traveling public.



Update Parameters

Set AM / PM Peak Hours

<p style="margin: 0;">AM Peak Hours</p> <p>AM Start <input style="width: 50px;" type="text" value="6"/></p> <p>AM End <input style="width: 50px;" type="text" value="9"/></p>	<p style="margin: 0;">PM Peak Hours</p> <p>PM Start <input style="width: 50px;" type="text" value="15"/></p> <p>PM End <input style="width: 50px;" type="text" value="18"/></p>
--	--

Speed Ratio [Percent of Normal Operations Speed]

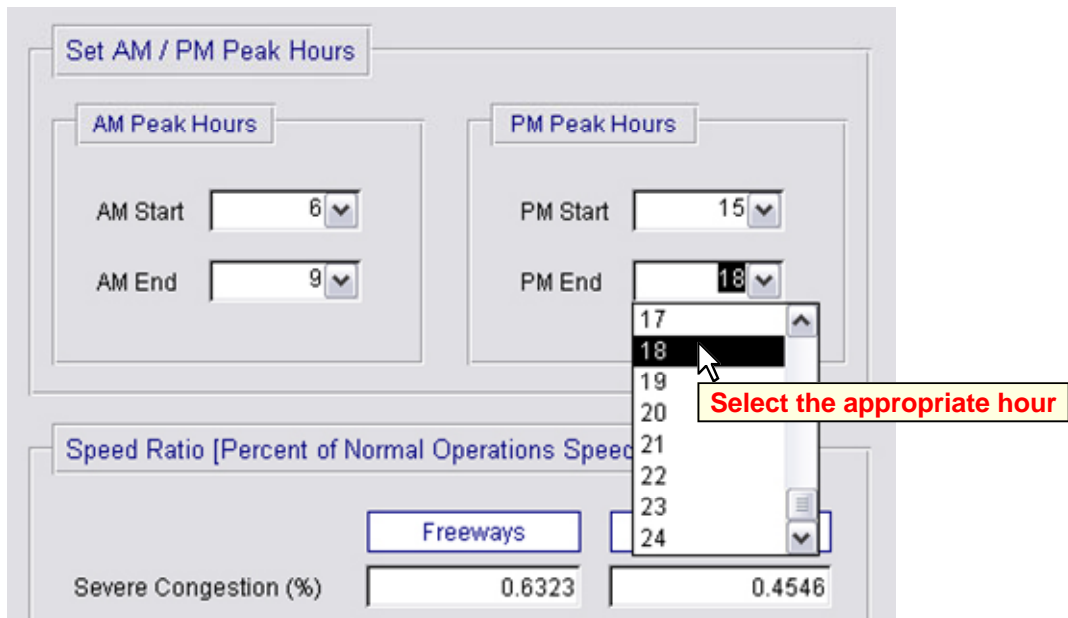
	Freeways	Arterials
Severe Congestion (%)	0.6323	0.4546
Heavy Congestion (%)	0.8608	0.6818
Moderate Congestion (%)	0.9562	0.7727

Days Per Year [days]	250
Fuel Cost [\$/gallon]	\$2.79
Truck Costs [\$/mile]	\$3.52
Satewide average hourly wage [\$/hour]	\$24.73

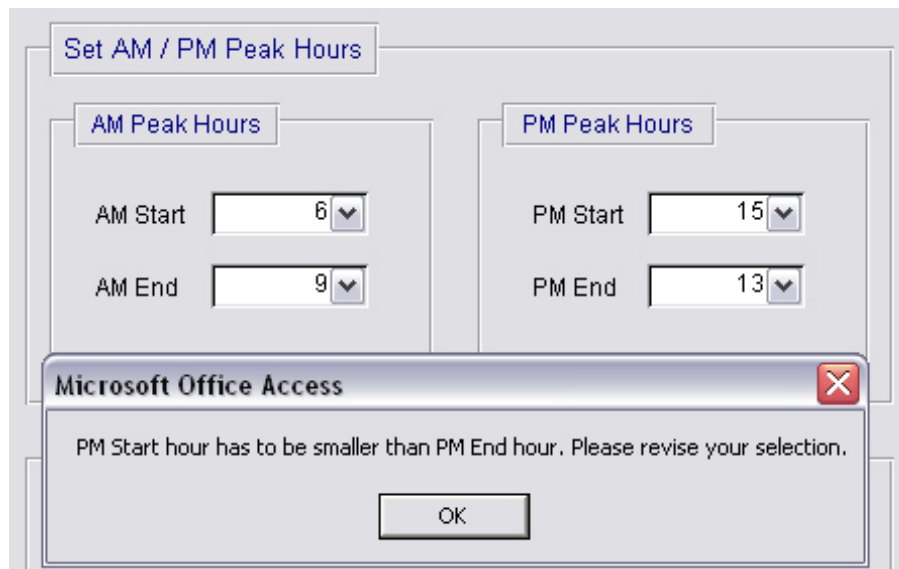
UPDATE COUNTY PARAMETERS

OK

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 to 9, the user would select 6 from the “AM Start” and 9 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. PM Start at 19:00 and PM End at 15:00 (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 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 (income) per capita;
- ❑ Wage adjustment factor [%] (see the definition of p_k on Page 73);
- ❑ County resident population;
- ❑ County employment by place of work; and
- ❑ Percent of workers employed in the county who reside outside the county.

The screenshot shows the "Update Parameters" interface. A modal window titled "County Update Form" is open, displaying the "Update County Parameters" form for the "Atlantic" county. The form includes the following fields and values:

Parameter	Value
AVERAGE COUNTY WAGE [\$/person-hour]	19.36
WAGE ADJUSTMENT FACTOR [%]	100
COUNTY RESIDENT POPULATION	270644
NUMBER OF WORKERS IN THE COUNTY ***	144416
PERCENT OF WORKERS WHO DO NOT RESIDE IN THE COUNTY	25

Below the form, there are two callout boxes:

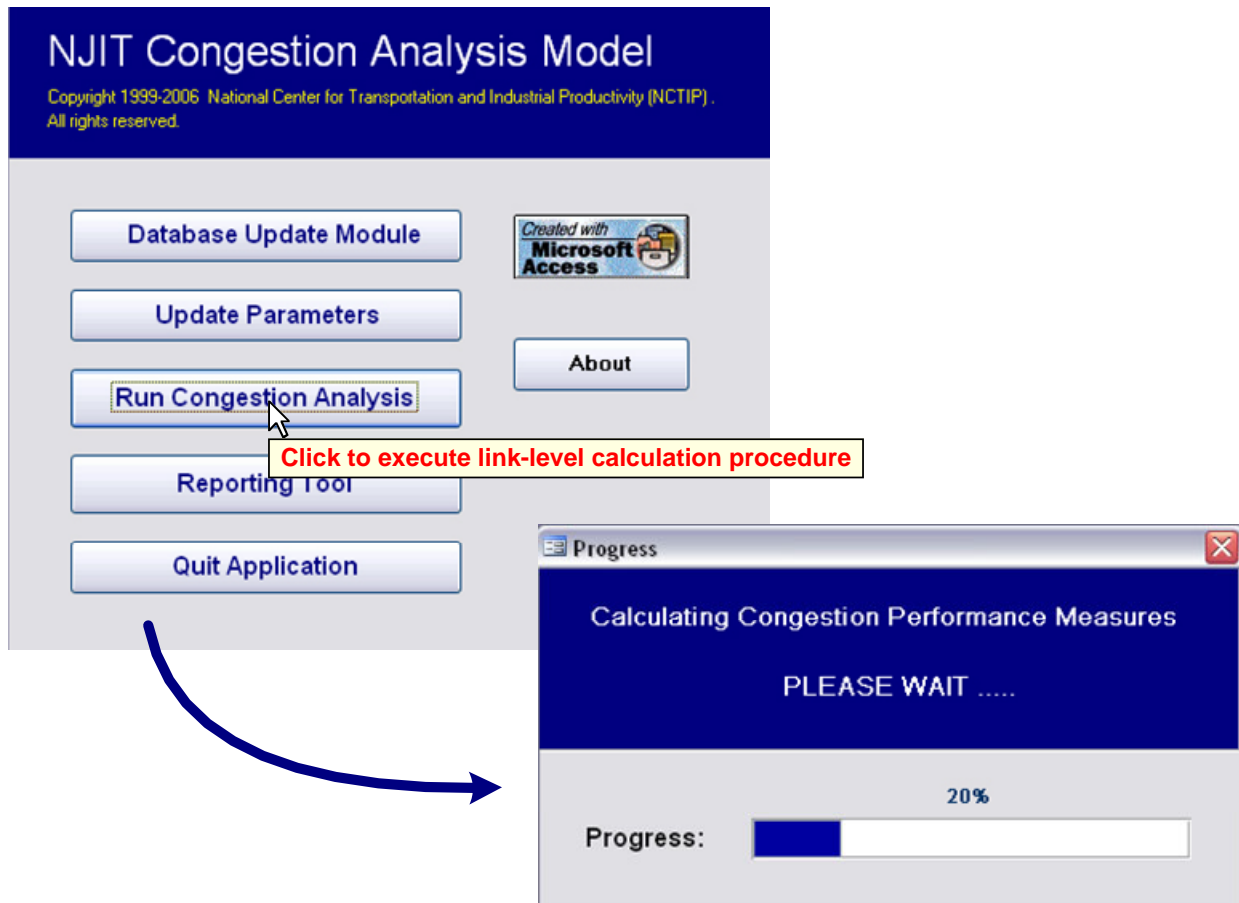
- A red box highlights the "UPDATE COUNTY PARAMETERS" button on the main screen, with a blue arrow pointing to the "County Update Form". A yellow callout box contains the text: "Click to access the 'County Parameter Update' form".
- A yellow callout box points to the "DONE" button on the "County Update Form" with the text: "Click to go back to the 'Parameter Update' screen".

At the bottom of the "County Update Form", there is a "Record:" indicator showing "1 of 21".

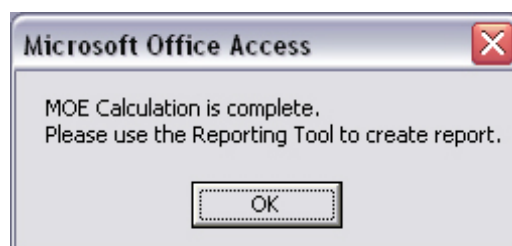
When finished updating county parameters, the user should click “DONE” on the “County Parameter Update” form to go back to the “Parameter Update” screen and then “OK” to go back to the Main Menu.

STEP 7: Running the analysis (executing calculation procedure)

After updating the network database, county statistics, and analysis settings, the user can execute the calculation procedure by clicking on the “Run Congestion Analysis” button on the Main Menu. 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: Generating reports

The report selection screen can be accessed from the main menu by clicking on the “Reporting Tool” button. 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. Users 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.

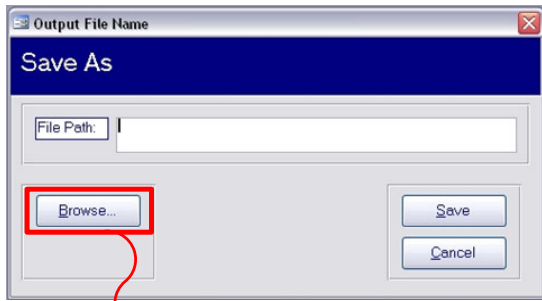
The screenshot displays the 'NJIT Congestion Analysis Model' interface. The top left panel contains several buttons: 'Database Update Module', 'Update Parameters', 'Run Congestion Analysis', 'Reporting Tool', and 'CLICK' (with a mouse cursor over it). A blue arrow points from the 'Reporting Tool' button to the 'Select Report Level' screen. The 'Select Report Level' screen features three main buttons: 'STATE SUMMARY By County', 'STATE SUMMARY By MPO', and 'Export to DBF'. On the right side, there is a section for 'Daily or Annual Delay/VMT Report' with radio buttons for 'Daily Delay and VMT' and 'Annual Delay and VMT', and a checked checkbox for 'Show Congestion Severity'. A 'MAIN MENU' button is located at the bottom right. Three red callout boxes provide instructions: one points to the 'Reporting Tool' button, another points to the 'Daily or Annual Delay/VMT Report' section, and a third points to the 'MAIN MENU' button.

Select the time aggregation unit and check if you want to include the congestion severity summary sheet in the report.

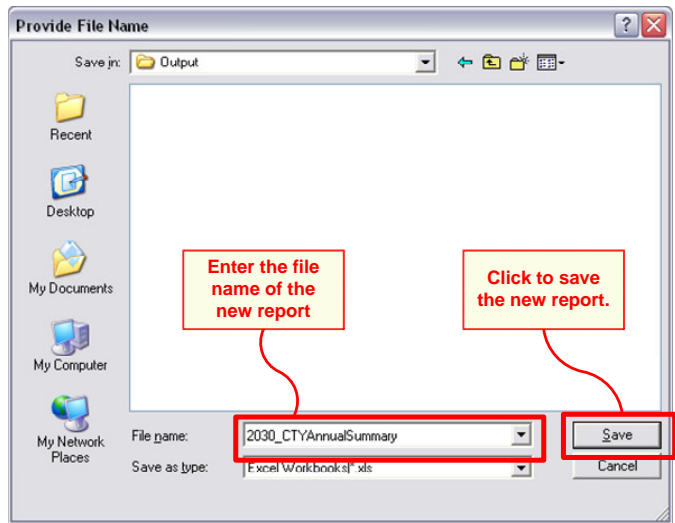
Select the desired report type by clicking the appropriate button. Then select the location to save the report.

Click to go to the Main Menu

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. When the report is ready a dialog box appears informing the user that the report has been created. Click the “Main Menu” button on the “Select Report Level” screen to return to the Main Menu.

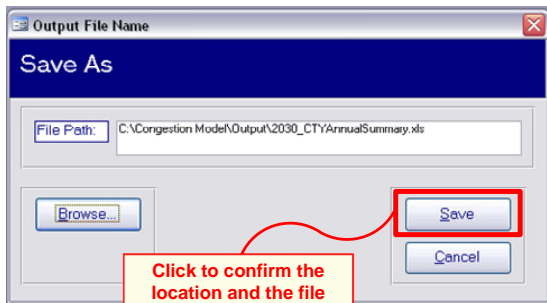


Click to browse to the location and specify the file name of the new report

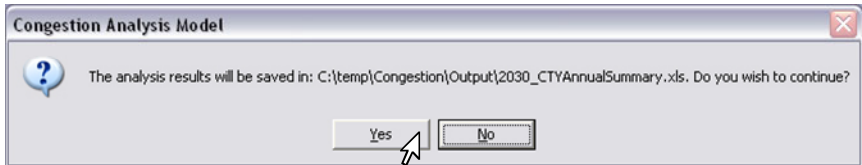


Enter the file name of the new report

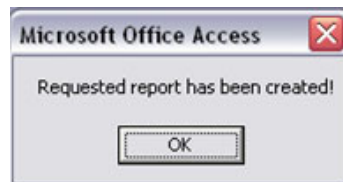
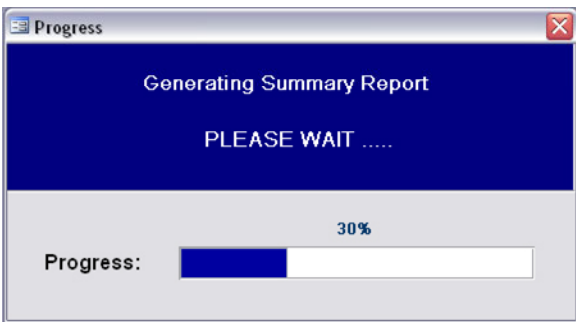
Click to save the new report.



Click to confirm the location and the file name of the new report



CLICK



STEP 9: Exiting the application

The user exits the application by clicking on the “Quit Application” button on the Main Menu. Before shutting down, the application backs up data and compacts the database, which may take several seconds to more than a minute, depending on the computer configuration.

