“Integration of the Transportation Systems Analysis Model for the Small Aircraft Transportation System”

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ABSTRACT

Standalone computer modules for county to county travel demand forecasting have been integrated. The Trip Generation, Trip Distribution and Mode Choice modules have been unified under one Graphical User Interface (GUI). The outputs are automatically mapped using Geographic Information Systems (GIS) technology to allow immediate and spatial analysis. The integrated model allows for faster running times and quicker analysis of the results. The ability to calculate travel time savings for travelers was also included to the final model. The modeling framework developed is known as the Transportation Systems Analysis Model (TSAM).

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1. INTRODUCTION

1.1 Background

About five years ago, in the year 2000, the National Aeronautics and Space Administration (NASA) started a new program called the Small Aircraft Transportation System [SATS]. The goal of this program was to develop a new form of air transportation that would greatly reduce travel time by using small airplanes and local airports.

Multiple SATS Laboratories were formed to work on different parts of the SATS program. Virginia Tech's Air Transportation Systems Laboratory (ATSL) was a member of the Virginia SATS Lab. The development of a nationwide spatially distributed transportation forecasting model was proposed to predict SATS demand [Trani et al., 2003]. The implementation of this recommendation resulted in the Decision Support Model for SATS.

DSM for SATS is a county level nationwide transportation demand model that estimates the demand, for automobile, commercial airline and SATS across the United States. DSM calculates the demand for three modes, two trip purposes and five household income group brackets between the 3091 counties in the United States.

DSM for SATS is composed of three main modules: Trip Generation [Baik, 2003], Trip Distribution [Baik, 2003] and Mode Choice [Ashiabor, 2003]. The Trip Generation module estimates the number of annual intercity trips produced and attracted by each county in the continental United States. The Trip Distribution module distributes the produced trips to all other counties in the continental United States. Finally, the Mode Choice splits all the trips between automobile, commercial airline and SATS.

1.2 The Problem

1.2.1 Standalone Models

Standalone DSM modules were developed one at the time. Running the DSM required using these individual modules. The task was time consuming and error prone. With the increasing demand for analyses at Virginia Tech and the customer's desire to perform sensitivity analyses quickly a change was in order to decrease running times. A mapping capability was added to the model to inspect results visually.

DSM is built based on the traditional four step model approach. The three key modules of DSM are the Trip Generation, Trip Distribution and Mode Choice. Each of these three modules relies heavily on each other. The Trip Distribution module uses the results of the Trip Generation module. The Mode Choice module requires the Trip Distribution module results.

The standalone modules required the operators to manually transfer input and output files between the modules. This large number of user interactions could result in errors if files were misplaced, overwritten or deleted. Then DSM users had to run the modules in interpreted mode in Mathworks MatLab. The operators had to load, edit and run the actual source code of each module. This required expertise in MatLab by the users of DSM. Additionally, since source code editing was involved for each run, mistakes and bugs could potentially be introduced. Finally, running code in interpreted mode is usually slower than in compiled form and it resulted in higher running times.

Due to the standalone nature of the DSM modules and due to the source code format used it was complicated to package DSM into a redistributable product. There was no easy way to create a setup routine for simple installation of DSM by users. This led to time consuming efforts by users when installing DSM and required the users to be knowledgeable in MatLab in order to setup and use DSM.

1.2.2 Command Line User Interface

The user interface for DSM was command line based and the code was executed in MatLab interpreted mode. Nowadays, users expect a Graphical User Interface (GUI) as it has become the norm in software engineering. Using a command line interface required detailed knowledge of MatLab, which discouraged users of DSM.

The spatial nature of the DSM resulted in about 9 million origin-destination pairs (3091 counties by 3091 counties). The five income group levels and two trip purposes modeled for each of these origin-destination pairs resulted in large quantities of data. The DSM did not contain an automated tool to analyze the large outputs produced by the model.

1.2.3 Sponsor's Reluctance to use DSM

The sponsor was reluctant to use DSM for several reasons. It was complicated to use the three standalone models for the reasons expressed earlier and the run times of the modules were too long. The command line interface was labor intensive and the running of the DSM required knowledge and ownership of MatLab. Finally, it was difficult to receive, install, and configure the standalone modules.

1.2.4 Objective

The objective of the work presented in this thesis is to correct the earlier mentioned problems. The modeling framework developed is known as the Transportation Systems Analysis Model or TSAM instead of DSM.

2. LITERATURE REVIEW

The Transportation Systems Analysis Model (TSAM) for the Small Aircraft Transportation System [SATS] is an integrated four step model that predicts intercity demand in the United States. TSAM's results are automobile, commercial airline and SATS demand between all the counties in the United States. TSAM also fully integrates the simulation models with a GIS framework to display the results visually.

The first section will review intercity demand models. The second section will review Decision Support Systems used in transportation and how they use visualization to illustrate their results. The last section will review the Trip Generation [Baik, 2003], Trip Distribution [Baik, 2003] and Mode Choice [Ashiabor, 2003] modules that are part of TSAM.

2.1 Intercity Transportation Models

The following section reviews two intercity transportation demand models. The first model is the National Transport Model [NTM, 2002] developed by the Department of Transport in the United Kingdom. It was developed to estimate the intercity demand for all ground transportation modes in the United Kingdom. The second model reviewed is an intercity model developed to estimate the demand in the Boston, Massachusetts and Montreal, Quebec, Canada corridor for a new High Speed Rail [BMHSR, 2003].

2.1.1 National Level Model

The National Transport Model [NTM, 2002] is a model developed by the Department of Transport in the United Kingdom. The author describes it as *"an integrated, multi-modal model"* used to *"produce revised forecasts to inform the recent Progress Report on the 10 Year Plan"*.

The NTM *"includes 6 modes of transport – car driver, car passenger, rail, bus, walk and cycle"*. It also uses only nine different region types from Central London to Rural. Its main structure is based around three key modules: the Demand Model, the Road Capacity and Cost Model and the National Rail Model. These three modules are *"applied in iteration to produce key model forecasts"*.

The Demand Model is the center piece of the NTM, because it generates the future demand in person-trips. Inputs to the Demand Model are the local transport policies and a car ownership model. The car ownership model estimates how the number of cars per household will change in the future. The results from the Demand Model are forecasts of the demand by distance bands, trip purpose and mode. It was calibrated to reflect the travel patterns observed in the National Travel Survey in the base year.

The Road Capacity and Costs Model, also called FORGE, generates the road traffic, congestion, emissions and road costs from the generated automobile trips from the Demand Model. The inputs to FORGE are road policies and the outputs of the traffic network model, vehicle market model and multi-modal freight model. The results of FORGE are the cost of road travel. These new costs are then used by the Demand Model for the next iteration.

The National Rail Model (NRM) uses the rail demand produced from the Demand Model to estimate travel costs on the rail network. The NRM takes inputs from the rail growth model and rail policies. These results are then fed back to the Demand Model for the next iteration. These three modules are iterated until steady state is reached.

2.1.2 Corridor Level Model

This section will review the model analysis and ridership estimates of the ridership analysis chapter of the Boston to Montreal High Speed Rail [BMHSR] Planning and Feasibility

Study Phase I. To estimate the potential future demand of the BMHSR an *"integrated discrete choice model was developed"*. The three main modules of this model are: the Trip Frequency Model, the Destination Choice Model and the Mode Choice Models. All of these three modules are integrated to facilitate data communication among them.

The Trip Frequency Model is usually known as the trip generation model. It was developed to estimate the amount of intercity trips in the BMHSR corridor. The American Travel Survey (ATS), Nationwide Personal Transportation Survey (NPTS) and custom surveys were used to develop this model.

The Destination Choice Model estimates where individuals will travel depending on their trip purpose within the BMHSR corridor. This model is based on the traditional gravity model. The results of the Destination Choice Model depend on the relative travel impedance to a destination, the relative size and attraction of a destination and demographics of the traveler or household.

The Mode Choice Model estimates the share of travelers for each available mode between two destinations. This model was calibrated using both revealed-preference and stated-preference data. Revealed-preference data is expected to be more accurate than stated-preference data since it relies on decisions by travelers that have been made in the past. On the other hand stated-preference data was used to asses the potential demand for the new BMHSR since it will be available in the future.

This demand model was run for five different alternatives that include a base case, low and high fares, low frequency and additional stations. Then the results were compared using annual ridership, annual passenger revenue and annual passenger-miles. Additionally, the

BMHSR demand analysis takes in account the induced trips due to the presence of a new and faster mode in the region.

2.2 Decision Support Systems

Decision Support Systems have been developed to help analysts in developing “what if” scenarios. Decision Support Systems have become more popular as they have become easier to use. They have been upgraded with Graphical User Interfaces (GUI), better visualizations and Geographic Information Systems (GIS).

The first paper reviewed [Wang, 2004] illustrates how a Decision Support System is developed. The second paper reviewed [Arampatzis et al., 2002] demonstrates the use of a Decision Support System using a specific case study.

2.2.1 Development of a Decision Support System

The paper entitled *“Integrating GIS, simulation models, and visualization in traffic impact analysis”* [Wang, 2004] presents a traffic impact model that is fully integrated with Geographic Information Systems (GIS), three-dimensional visualizations (3D) and a Graphical User Interface (GUI). According to the author, only a few models have successfully integrated all the technologies above. This paper illustrates how a traffic impact model can be built into a successful decision support tool using the earlier mentioned technologies and third party models. First, the integration between GIS and simulation models is inspected. Then the combination of GIS and visualization is explained. Finally, merging simulation models and visualization is illustrated.

The integration of GIS and simulation models is relatively recent. There are two types of integration. On one hand the *“loose coupling”* requires manual file exchange between the simulation model and GIS. On the other hand the *"deep coupling"* integrates the simulation model and GIS within a common graphical user interface (GUI) and appears as one system to the user. The second alternative is preferred as it eliminates manual intervention from the user.

Similar to the integration of simulation models and GIS, there are four different levels of integration between GIS and visualization. At the *"rudimentary level"* only small amounts of data are shared between the two systems. At the *"operational level"* the integration *"tries to remove data redundancy and achieve data consistency"*. Transparent communication between the two systems is achieved at the *"functional level"*. The *"merged level"* presents a complete integrated package of both technologies. The fundamental or merged integration is the preferred one, as it greatly reduces manual user intervention.

The integration between simulation models and scientific visualization is quite common. However, since it has not been coupled with GIS, planners have been reluctant to use it. Scientific visualization becomes a powerful tool when it is integrated with GIS. Recently, scientific visualization and GIS have been integrated to create impressive 3D visualizations of model results. GIS is used to map out a city and its terrain. Then scientific visualization displays the buildings and other features in a three dimensional view.

The model presented in this paper uses all three integrations discussed above. GIS was used to *"provide a connection to visualization and simulation models"* and to create and visualize the road network accurately in 2D. The scientific visualization was used to display levels of emissions across the network using three-dimensional shapes. The level of service on the network was displayed by 3D traffic flow simulations showing each individual vehicle on the roadway. All these technologies were integrated into one graphical user interface to facilitate its use.

By fully integrating simulation models, GIS and scientific visualization into one comprehensive package and using a graphical user interface a powerful decision support system is created. This kind of approach greatly reduces manual intervention by the user and allows the analyst to better understand the modeling results through the visualizations. Additionally, such visualizations facilitate the communication between decision makers and the public.

2.2.2 Applications of Decision Support Systems

The paper entitled *"A GIS-based decision support system for planning urban transportation policies"* [Arampatzis, 2002] showcases a Decision Support System used in urban transportation planning for the city of Athens, Greece. This model is based on the traditional four step model approach. Additionally, it uses Geographic Information Systems (GIS) and a Graphical User Interface (GUI) to create a user friendly environment. However, the true innovation was that the transportation model, the GIS capabilities and the GUI are tightly integrated to provide *"a user-friendly decision support tool"*.

This decision support system is based around three main parts: a database, a four step model and emission/energy consumption model and the graphical user interface.

The database is GIS driven and stores the spatial data required for the entire model. The transportation network and its attributes are all saved in that database. Additionally, the database stores the results of each of the four sub models and manages the communications between them. The trip generation results are needed for the trip distribution. Then the mode choice requires the trip distribution results. Finally, the traffic assignment model requires the results of the mode choice. The database will also store the results of the emissions and energy model.

The graphical user interface of the model was developed to bring the model closer to the end user. Also, it helps reduce the amount of redundant manual tasks required to run the model.

The GUI presents the model results using *"thematic maps, figures and diagrams"*. A comparison tool helps the analyst compare changes between multiple scenarios. Overall, this fully integrated decision support tool helps the analyst develop key scenarios and compare the alternatives. In turn these key results will help decision makers in taking the correct decisions.

2.3 TSAM's Main Modules

2.3.1 Trip Generation Module

The Trip Generation [Baik, 2003] module in TSAM estimates the annual trips produced and attracted by the 3091 counties in the United States. This module estimates the demand for two trip purposes (business and non-business) and five household income group brackets. The five household income group brackets are as follows:

- Less than $30,000 per year
- Between $30,000 to $60,000 per year
- Between $60,000 to $100,000 per year
- Between $100,000 to $150,000 per year
- Above $150,000 per year

The Trip Generation model uses the American Travel Survey [ATS, 1995] and the Woods & Poole [W&P, 2003] socio-economic data as inputs. The ATS is a nationwide survey that collected travel patterns of American households for one year. It contains information such as mode of transportation, travel time, travel cost and household income group. The ATS is used to derive statewide trip rate tables.

Woods & Poole provides various socio-economic data for all the counties in the United States. The household income and employment data is used to correlate trip production and attractions for each county. Woods & Poole also provides data up to the year 2025 allowing the Trip Generation module to forecast the demand for every year from 1995 to 2025.

Figures 1 and 2 show the results of the Trip Generation module. Figure 1 shows the number of produced business trips in the United States for each county. Figure 2 shows the number of produced non-business trips in the United States for each county.

About 1.2 billion trips are taken by the entire American population in 2005. Approximately one fourth of this amount is for business and three fourth are for leisure. Also, as expected most trips are produced in highly populated areas. The counties with the darker tone are generating the most trips.

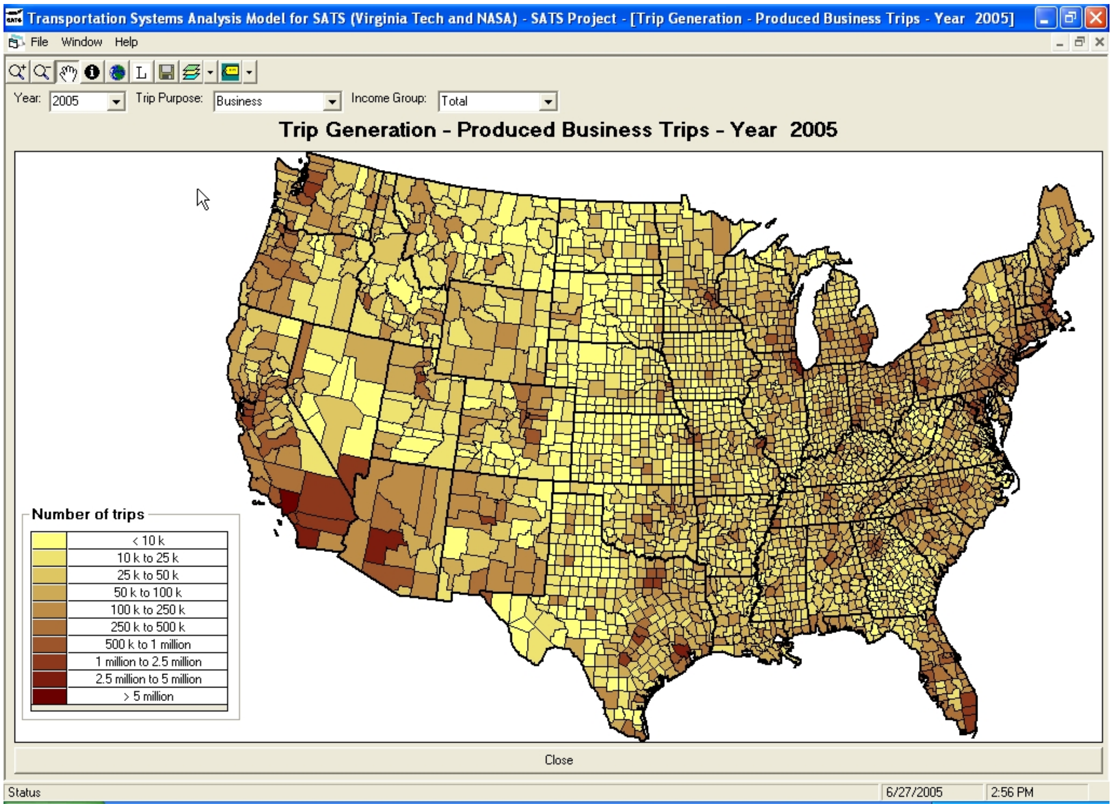


Figure 1: Number of Produced Business Trips in 2005.

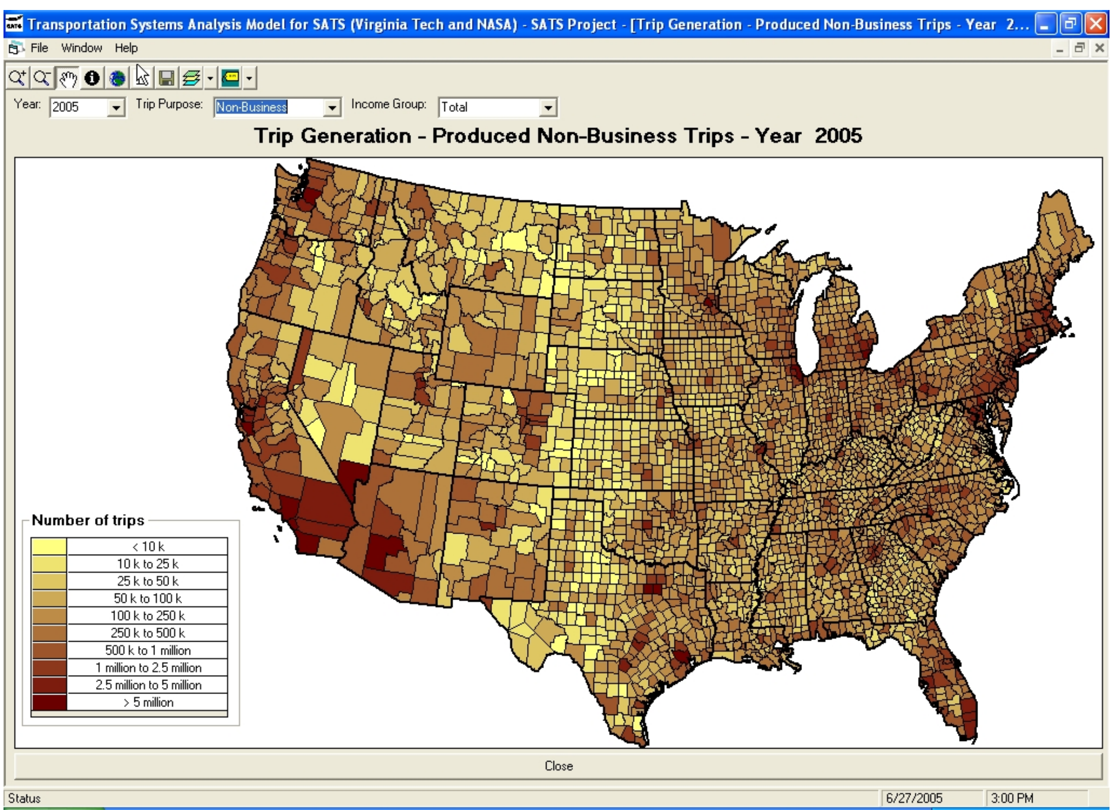


Figure 2: Number of Produced Non-Business Trips in 2005.

2.3.2 Trip Distribution Module

The Trip Distribution [Baik, 2003] module in TSAM distributes the generated trips between the 3091 counties in the United States to all other counties. Again this module distributes the trips by two trip purposes (business and non-business) and five household income group brackets.

The state to state trip rate tables are generated using the American Travel Survey [ATS, 1995]. Next the model distributes the statewide trips at the county level with the Woods and Poole [W&P, 2003] county level data. The Trip Distribution is also able to forecasts demand from 1995 to 2025.

Figures 3 and 4 show the distribution of the generated trips from Fairfax County, Virginia to all other counties for business and non-business purpose respectively. As expected most trips are attracted to large population centers and close counties. The white counties around Fairfax County, Virginia represent the counties that are within 100 miles driving distance from the centroid. No demand is calculated for these counties since TSAM's scope is intercity travel. The ATS does not have any data for trips shorter than 100 miles driving distance.

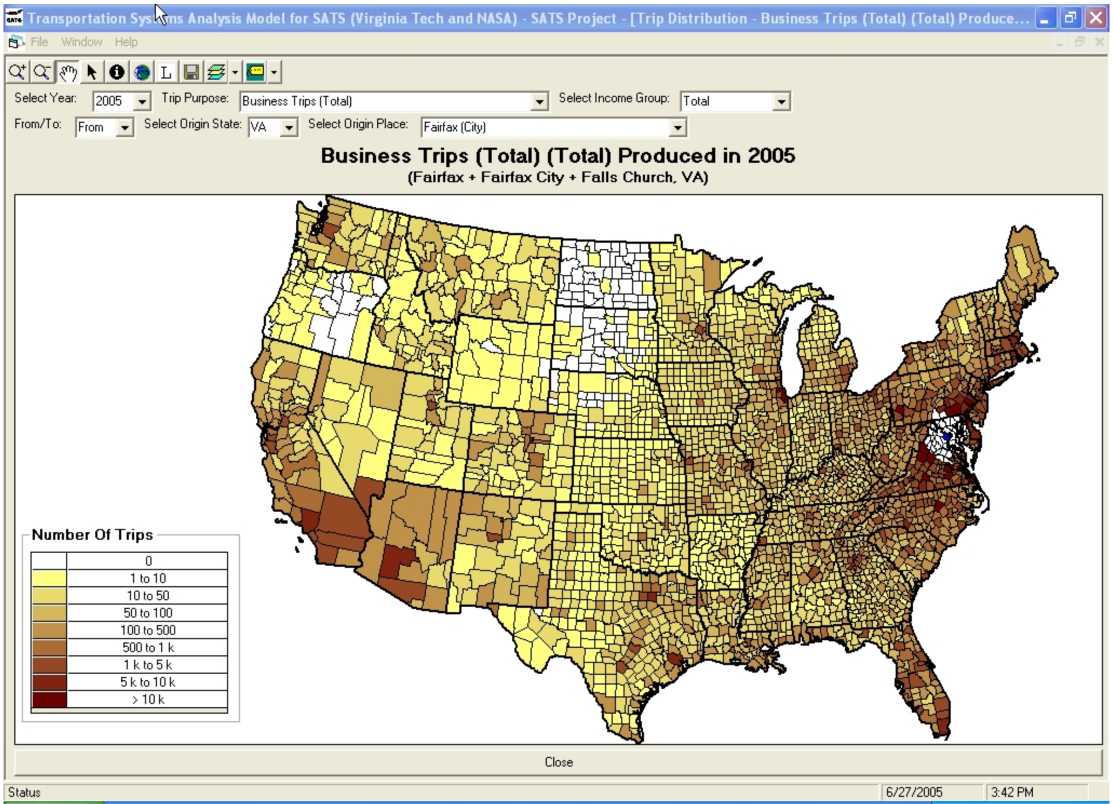


Figure 3: Distribution of the Business Trips Originating from Fairfax County, Virginia.

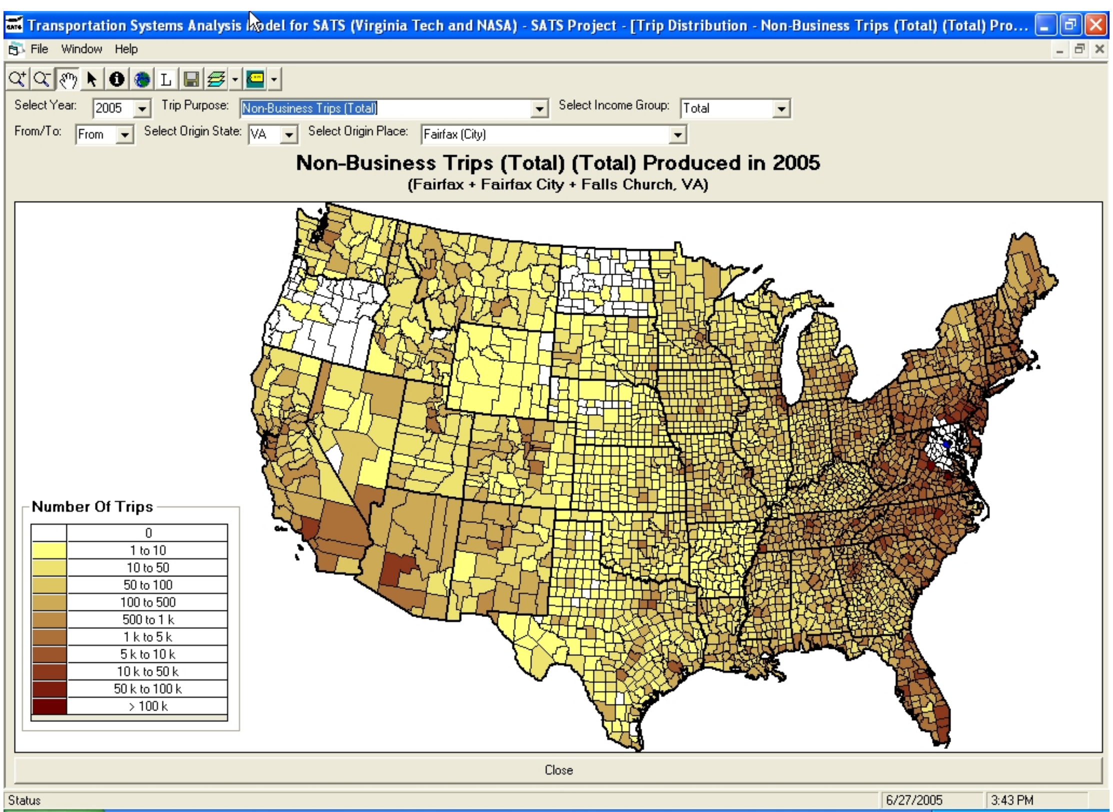


Figure 4: Distribution of the Non-Business Trips Originating from Fairfax County, Virginia.

2.3.3 Mode Choice Module

The Mode Choice [Ashiabor, 2003] module uses the distributed trips to estimate the automobile, commercial airline and SATS demand between the 3091 counties. Again, the demand is also split by two trip purposes and five household income groups. The Mode Choice module is calibrated using the American Travel Survey [ATS, 1995].

The Mode Choice model differentiates between the three available modes by comparing the utility of each route. The utility is based on total travel time and travel cost for each mode. Therefore, the mode choice requires large preprocessed input tables.

Microsoft MapPoint 2004 was used to calculate the automobile driving time and driving distance tables. MapPoint was run between all the counties in the United States, resulting in about 4.5 million one way origin-destination pairs. After automating MapPoint, about one and half month were required to complete the computations. The driving cost was calculated by multiplying the driving distance by the cost per mile of the vehicle.

The commercial airline travel cost was generated using the airline fares [Murthy, 2003] derived using the Department of Transportation Database [DB1B, 2000]. The DB1B records ten percent of the tickets sold in the United States over one year. The commercial airline travel time [Seshadri, 2003] was derived between the 443 commercial airports using the Official Airline Guide [OAG, 2001]. The OAG holds the commercial airline schedule. Additionally, MapPoint was used to calculate the access and egress cost and times between each candidate airport and associated county.

The SATS travel times and travel costs were calculated using the great circle distance between the 3415 airports that could potentially support SATS. A specific cost per seat mile was applied to generate the flying cost of SATS. The flying time was derived using the flying distance and the average flying speed of the proposed SATS plane. The average flying speed was calculated by creating a compliant EUROCONTROL BADA model [BADA] aircraft performance file for the corresponding SATS airplane used in the model. The access and egress times and costs were added to the final travel times and travel costs.

Figures 5 and 6 show the market share curves for each transportation mode and trip purpose over distance. As expected, automobile is the mode of transportation of choice for shorter trips. However, for long distance trips commercial airline takes over. Also, the market share for commercial airline rises faster for business travelers than for non-business travelers. This is also expected because business travelers are more sensitive to travel time than travel cost. On the other hand non-business travelers are more sensitive to travel cost than travel time.

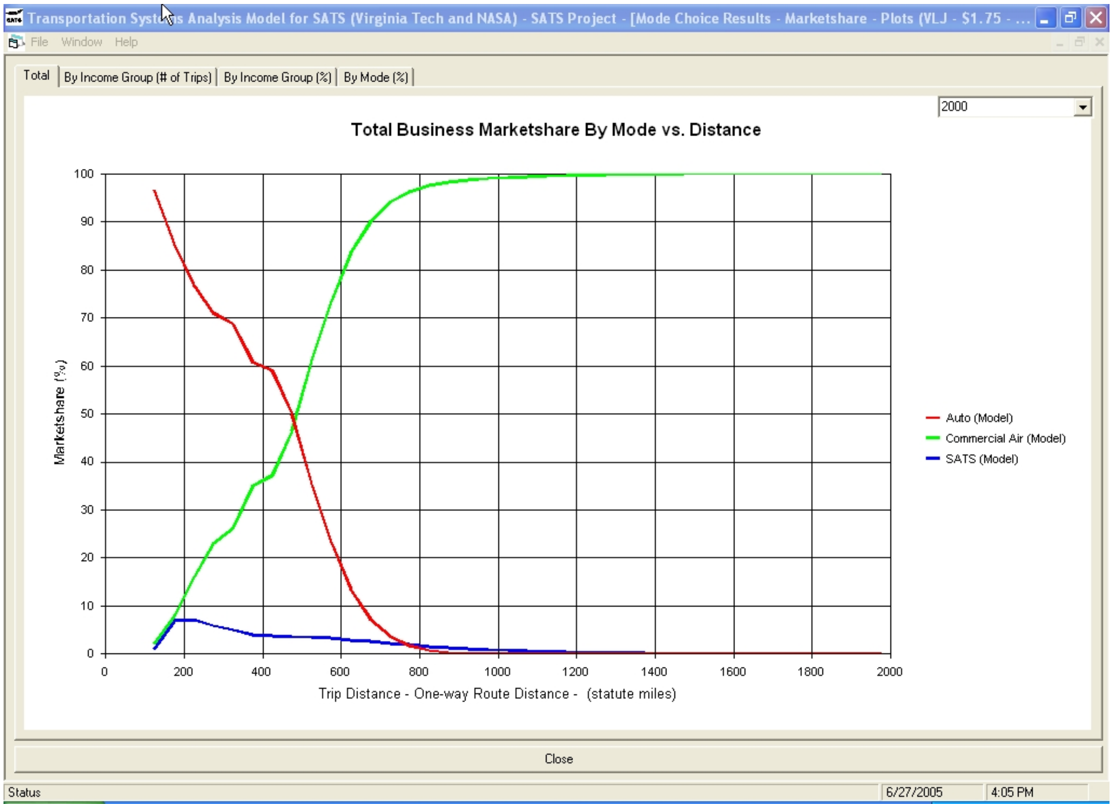


Figure 5: Market Share for Each Transportation Mode for Business Travelers in 2005.

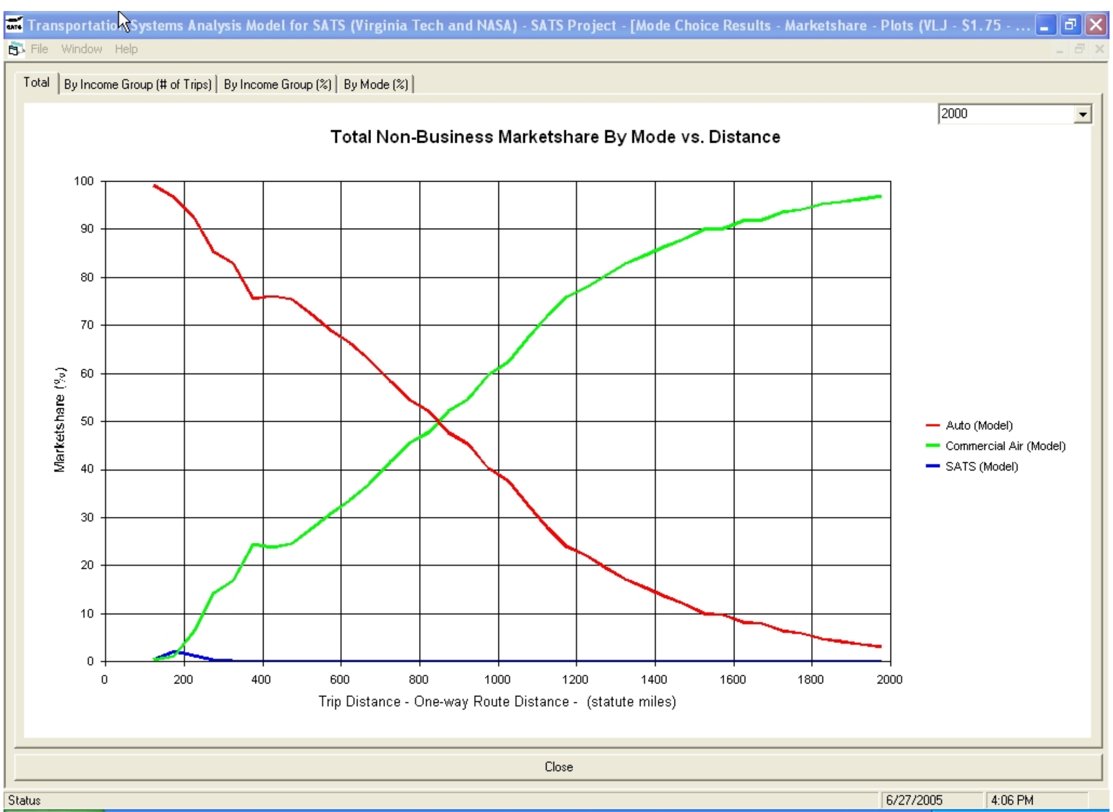


Figure 6: Market Share for Each Transportation Mode for Non-Business Travelers in 2005.

2.4 Literature Review Conclusions

TSAM's integration uses previously used methods of model integration. The standalone modules will be connected so that no manual user intervention will be required. It will have a Graphical User Interface to assist the user in running analysis. Additionally, Geographic Information Systems (GIS) technology will be used to assist the user in the spatial analysis of the outputs.

3. METHODOLOGY

This chapter is divided in two distinct parts. First, the integration of TSAM is explained in detail. Then the procedure used to calculate the travel time savings using SATS is described.

3.1 TSAM Integration

The integration of TSAM was a lengthy and complicated process. First, the different tools used to achieve the integration will be introduced. Next an overview of the GUI developed for TSAM will be given. Then, the structure and organization of TSAM will be provided. Finally, the data structure used in TSAM and the computational workload will be described.

3.1.1 Overview of the Tools

- **Mathworks MatLab:** Mathworks MatLab 7 is the tool used to develop the three large computational modules of TSAM (Trip Generation [Baik, 2003], Trip Distribution [Baik, 2003], and Mode Choice [Ashiabor, 2003]). MatLab is a programming tool for engineers based on the C programming language. It has a large selection of built-in functions, which help the developer by simplifying the programming process.
  MatLab was also chosen because it is a good programming language for the heavy calculations required by TSAM's three modules. MatLab also includes features that accomplish bookkeeping activity required for handling the very large volumes of data inherent in TSAM. These features save the developers a lot of time.
- **Microsoft Visual Basic:** The integration of all three modules of TSAM and the development of the GUI uses Microsoft Visual Basic. Visual Basic is a good tool to develop GUIs, since it almost requires no coding to create interactive applications. Visual

Basic can incorporate third-party objects, allowing inclusion of such important features as GIS capabilities in TSAM with a minimum of effort. The MatLab Dynamic Link Libraries (DLLs), MapObjects, Microsoft Access databases are all linked to the Visual Basic application.

- **ESRI MapObjects:** ESRI, the developer of the popular GIS tool called ArcGIS, distributes a standalone and programmable library of tools to incorporate GIS capabilities into Visual Basic called MapObjects. MapObjects has all the standard capabilities of a GIS software package including loading/saving of maps (shapefiles), map editing and customizing and the usual map controls such as zoom in/ zoom out, panning and display of attributes of map features.
- **Microsoft Access/DAO/SQL:** DAO (Data Access Objects) and SQL convert the saved MatLab outputs into a commonly used data format. The TSAM output database format conforms to the Microsoft Access standard. Visual Basic links MapObjects to the Microsoft Access database to display the data on a map.

3.1.2 TSAM Graphical User Interface Overview

TSAM's Graphical User Interface (GUI) is divided into two sections. The left section is the navigation window. The right section contains the windows opened by the user using the navigation window. The right section can contain windows such as the model option window, output tables and maps displaying results. Figure 7 illustrates the standard TSAM GUI with the traditional navigation window on the left and the introduction window on the right.

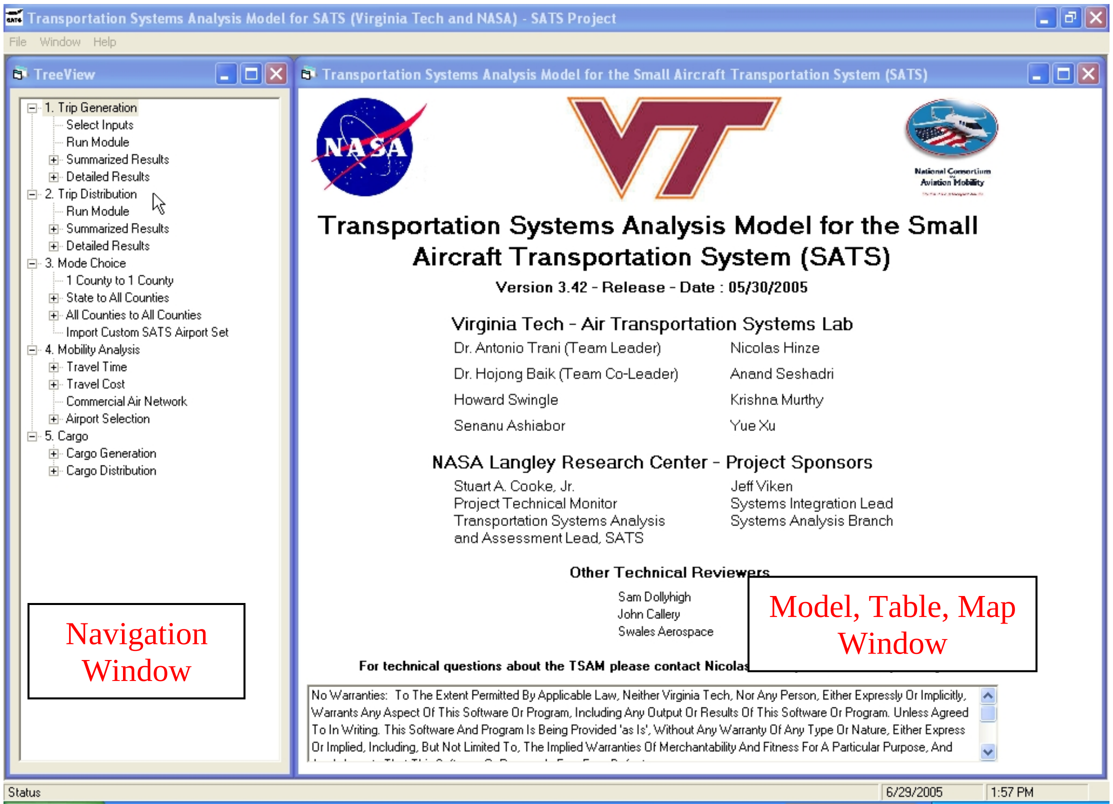


Figure 7: TSAM's GUI Introduction Window.

The navigation window gives the user access to all the features in TSAM. It is organized sequentially following the four step model approach. Figure 8 shows the main structure of the navigation window. Each requested feature in the navigation window is opened into a new window on the right hand side of the main TSAM GUI. For each of the modules the main model can be run and the outputs can be displayed as tables and maps. Additional features such as summarized results are also accessed from the navigation window.

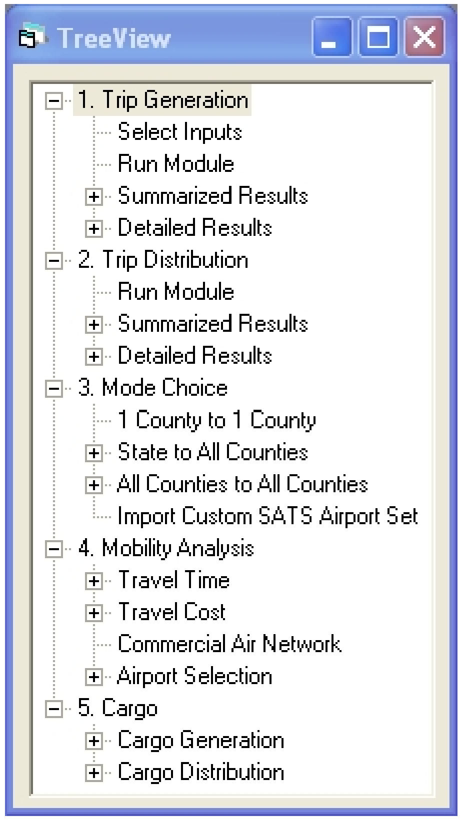
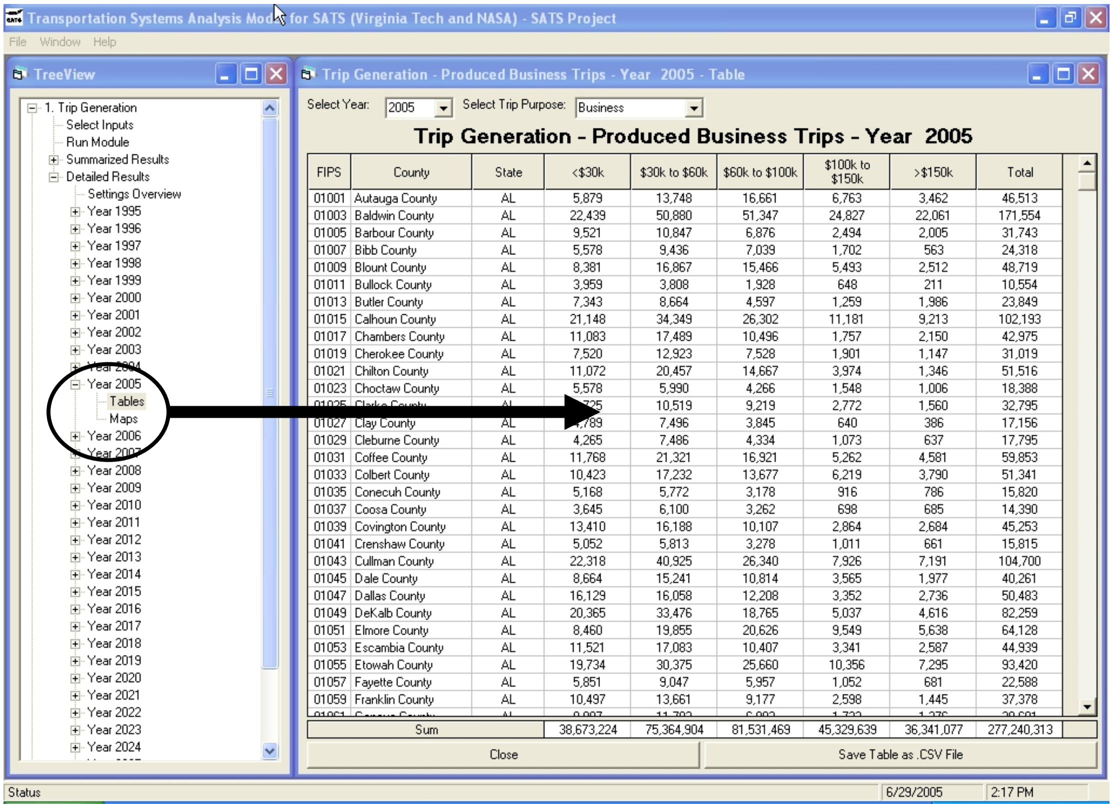


Figure 8: TSAM's Navigation Window showing the Sequential Order of the Three Key Modules.

The table window in TSAM displays very detailed information in tabular form. For example, Figure 9 displays the produced business trips in the 2005. The table has nine columns and 3091 rows. The first three rows contain the county information. The FIPS number is similar to a serial number and is unique for each county. The next columns display the county and state names respectively. The last six columns display the number of trips produced in the year 2005 for each of the five income groups and the summation of them. The number of trips per income group is displayed at the bottom of the table.

At the top of the window, drop down boxes are provided to select the specific data to be displayed. For trip generation, the user can select the year and trip purpose (business or non-business) for which to display the data.

This tabular format is similar for all other outputs in TSAM when the unit of analysis is a county. The first three columns change when the unit of analysis is commercial airline or SATS airports. However, the layout and design are very similar.



FIPS	County	State	<$30k	$30k to $60k	$60k to $100k	$100k to $150k	>$150k	Total
01001	Autauga County	AL	5,879	13,748	16,661	6,763	3,462	46,513
01003	Baldwin County	AL	22,439	50,880	51,347	24,827	22,061	171,554
01005	Barbour County	AL	9,521	10,847	6,876	2,494	2,005	31,743
01007	Bibb County	AL	5,578	9,436	7,039	1,702	563	24,318
01009	Blount County	AL	8,381	16,867	15,466	5,493	2,512	48,719
01011	Bullock County	AL	3,959	3,808	1,928	648	211	10,554
01013	Butler County	AL	7,343	8,664	4,597	1,259	1,986	23,849
01015	Calhoun County	AL	21,148	34,349	26,302	11,181	9,213	102,193
01017	Chambers County	AL	11,083	17,489	10,496	1,757	2,150	42,975
01019	Cherokee County	AL	7,520	12,923	7,528	1,901	1,147	31,019
01021	Chilton County	AL	11,072	20,457	14,667	3,974	1,346	51,516
01023	Choctaw County	AL	5,578	5,990	4,266	1,548	1,006	18,388
01025	Clarke County	AL	[illegible]	10,519	9,219	2,772	1,560	32,795
01027	Clay County	AL	[illegible]	7,496	3,845	640	386	17,156
01029	Cleburne County	AL	4,265	7,486	4,334	1,073	637	17,795
01031	Coffee County	AL	11,768	21,321	16,921	5,262	4,581	59,853
01033	Colbert County	AL	10,423	17,232	13,677	6,219	3,790	51,341
01035	Conecuh County	AL	5,168	5,772	3,178	916	786	15,820
01037	Coosa County	AL	3,645	6,100	3,262	698	685	14,390
01039	Covington County	AL	13,410	16,188	10,107	2,864	2,684	45,253
01041	Crenshaw County	AL	5,052	5,813	3,278	1,011	661	15,815
01043	Cullman County	AL	22,318	40,925	26,340	7,926	7,191	104,700
01045	Dale County	AL	8,664	15,241	10,814	3,565	1,977	40,261
01047	Dallas County	AL	16,129	16,058	12,208	3,352	2,736	50,483
01049	DeKalb County	AL	20,365	33,476	18,765	5,037	4,616	82,259
01051	Elmore County	AL	8,460	19,855	20,626	9,549	5,638	64,128
01053	Escambia County	AL	11,521	17,083	10,407	3,341	2,587	44,939
01055	Etowah County	AL	19,734	30,375	25,660	10,356	7,295	93,420
01057	Fayette County	AL	5,851	9,047	5,957	1,052	681	22,588
01059	Franklin County	AL	10,497	13,661	9,177	2,598	1,445	37,378
Sum			38,673,224	75,364,904	81,531,469	45,329,639	36,341,077	277,240,313

Figure 9: Results of the Trip Generation Module Displayed as a Table.

The map window in TSAM spatially displays the tabular information as a map. Also, it will only be able to display one column at the same time on each map. Features helpful to users are included in the map window. At the top of the window a toolbar controls the map appearance allowing users to:

- zoom in
- zoom out
- panning
- extend the view to the entire map
- display specific information about a feature
- turn on/off the legend
- save the map
- display additional layers (airports, interstates, etc…)
- label the displayed features/layers

A second toolbar allows the user to adjust the information that is displayed. Figure 10 shows the business trips generated for the year 2005. Here again, the user can select the year and trip purpose (business and non-business) for which to display the data. In addition the user can select among five income groups for display. The design and features of the map window are similar throughout TSAM. Some map windows will look a bit different reflecting the preferred way to display different types of information.

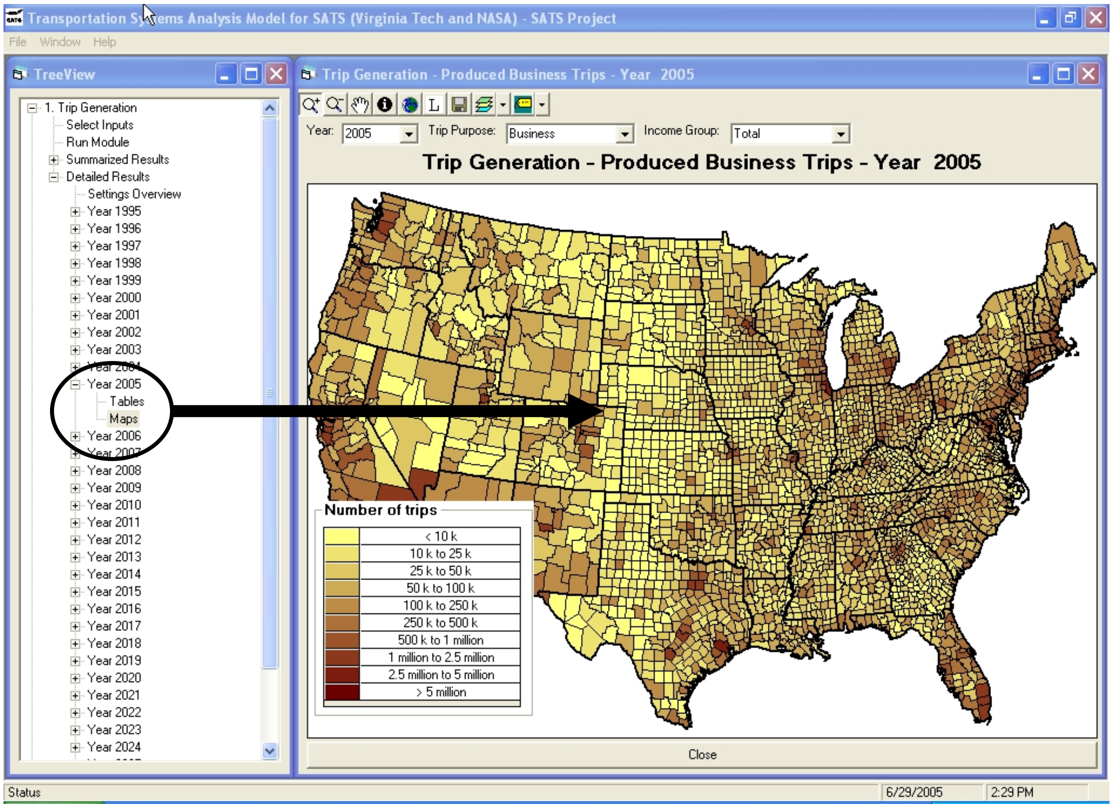


Figure 10: Results of the Trip Generation Module Displayed as a Map.

TSAM has three model windows: one for Trip Generation [Baik, 2003], Trip Distribution [Baik, 2003] and Mode Choice [Ashiabor, 2003]. The model window assists the user in selecting the correct options for each scenario and manages the model runs. Figure 11 illustrates the model window for the Mode Choice model. A case name can be typed in by the user in order to save a description of the specific analysis being performed. Options, such as automobile and SATS cost for the current scenario, can be set. In order to save the user time, a batch process feature is available to allow the user to run multiple scenarios back to back.

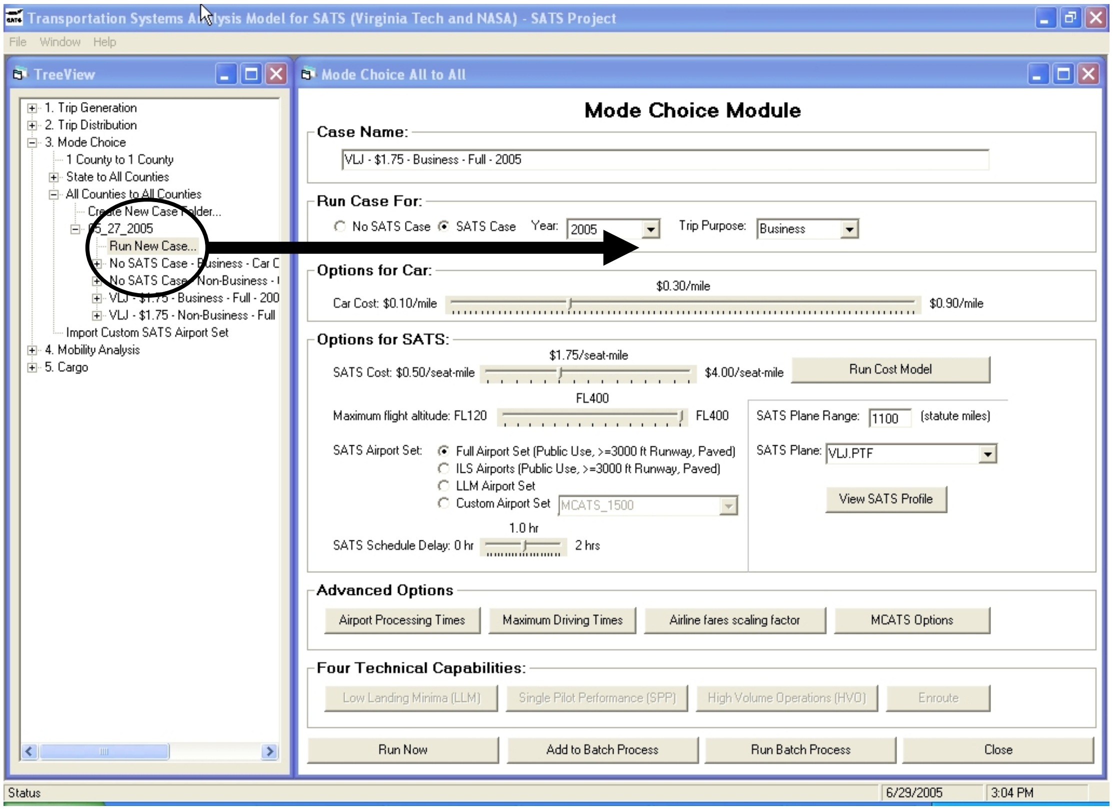


Figure 11: Mode Choice Model Option Screen.

3.1.3 TSAM Configuration

The previously mentioned four step model approach is the basis of TSAM's structure. The three modules are arranged in logical sequential order: Trip Generation, Trip Distribution and Mode Choice. Each of the three modules needs specific and shared input databases. As shown in the flowchart in Figure 12, the Trip Distribution module depends on the Trip Generation results and the Mode Choice module depends on the Trip Distribution results. Also, the Trip Generation and Trip Distribution are relying on the American Travel Survey [ATS, 1995] and Woods & Poole [W&P, 2003] databases. The Mode Choice needs three large databases that store the travel time and travel cost for different modes. The commercial airline flying cost and time, the driving time and distance of automobile and the SATS airport set and network are all preprocessed.

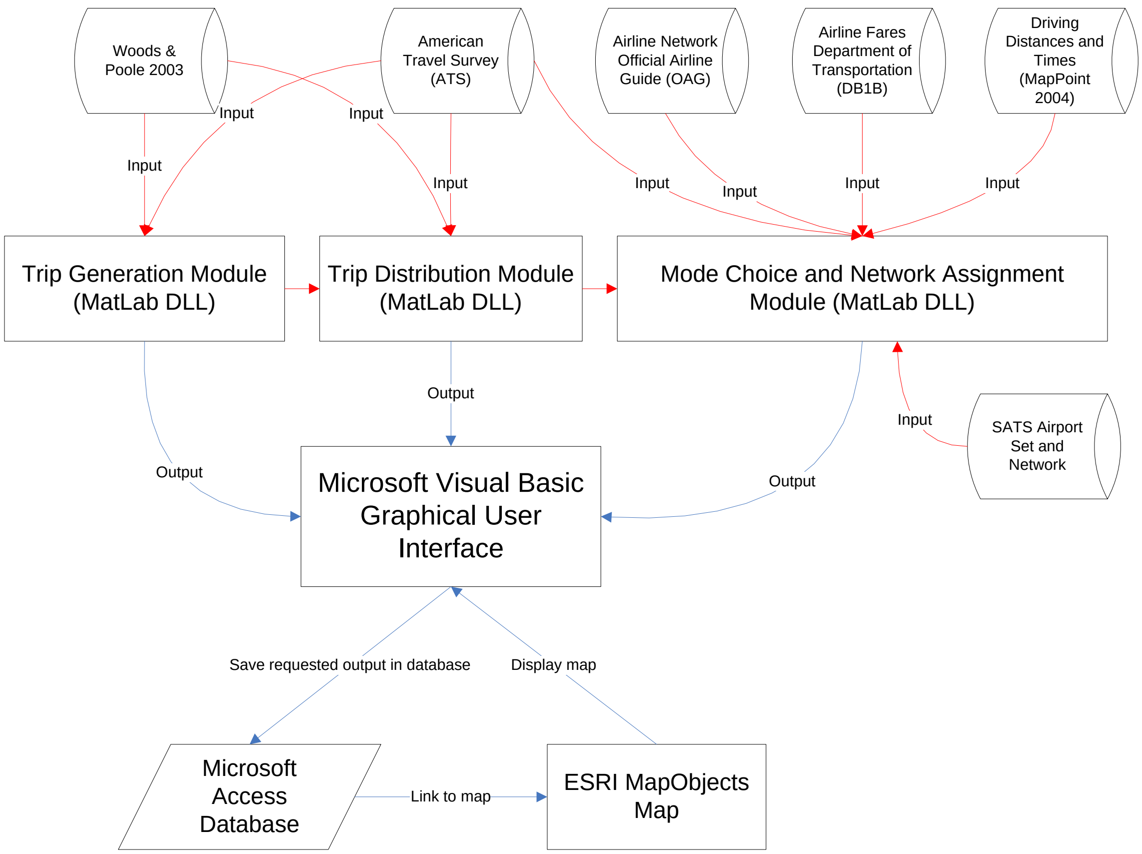


Figure 12: Flowchart Explaining the Structure of TSAM.

The Visual Basic GUI manages all three modules, the databases and the output maps and tables. To display the outputs from one of the three modules, the Visual Basic GUI will retrieve the results from the module. It will save the data in a Microsoft Access database and finally it will link it to the MapObjects map for graphic display.

3.1.4 Integration of MatLab Code into VB

The three standalone modules of TSAM were coded in MatLab. To shorten the runtime of the overall TSAM model as well as any of the three individual modules, compilation of the modules was required. Integration of these modules within the GUI also required they be compiled. MatLab's Compiler Toolbox was used to compile the source code into a Dynamic Link Libraries (DLLs). These DLLs were integrated into TSAM by referencing them to the GUI.

A few modifications to the code were required before compiling the three TSAM modules into DLLs using the MatLab COMBuilder. Converting each MatLab main file of the TSAM modules into a function was a necessity, since DLLs are similar to functions called from within a program. The conversion to a function requires creating a function definition listing the different inputs and outputs for the specific module. Placing this function definition at the top of the main file of the module completes the process. The MatLab help provides a complete example on how to compile MatLab code into standalone DLLs.

It is also important to know that to create a standalone executable of MatLab code, any compatible C++ compiler is acceptable. However, the Microsoft Visual C++ compiler is specifically required to compile the MatLab code into a DLL.

After completing the compilation, the TSAM modules were integrated into the Visual Basic GUI using a reference to their COMObject. Finally, a few specific lines of code take care of loading and calling the DLLs. This procedure allows the complete integration of MatLab source code into a Visual Basic GUI.

Another advantage of this method of compilation and integration is that it created a standalone application. This allows the user to install and use TSAM without owning a copy of MatLab. (Running TSAM on a computer where MatLab is not loaded does require the installation of the free MatLab Runtimes.)

3.1.5 Converting the MatLab Output Data from the Binary Files for use in Visual Basic

MatLab binary files are only readable by MatLab. As a part of the integration, it was critical to find a way to import the output data into a more commonly used standard. The data format needed to allow easy integration into Visual Basic and MapObjects. The format chosen is the Microsoft Access database.

The solution chosen was to create small functions in MatLab that would read in the requested data. For example, reading the row number 2892 from the automobile output matrix will retrieve the number of automobile trips starting from Montgomery County, VA (Index: 2892). This is a relatively easy task in MatLab.

To accomplish this task the function takes as input the origin county index and then outputs the correct row. This function was compiled into a DLL as described previously and integrated into Visual Basic. Then the DLL is called by Visual Basic with the requested index. The DLL will then load the MatLab binary file and retrieve the requested row. The retrieved output is an array of 1 x 3091 in Visual Basic. The GUI stores the retrieved data in a Microsoft Access database. Visual Basic links the database to the corresponding MapObjects control for spatial display of the results.

3.1.6 Integration of GIS and Visual Basic

MatLab produces large amounts of data that are difficult to analyze as tables. To aid in analysis GIS tools that create simple maps to display the complex output spatially were incorporated in TSAM.

ESRI MapObjects was selected for handling the GIS tasks in the TSAM GUI. MapObjects also allows a seamless integration into a Visual Basic GUI as a custom COMObject. Another advantage of MapObjects is that it provides free runtimes for third party users of TSAM avoiding users to acquire a MapObjects license.

3.1.7 TSAM Data Structure

Model Inputs

The TSAM modules require large amounts of input data to function properly. For example, the Mode Choice module compares the travel time and travel cost between different modes of transportation between all the counties in the United States. The three main modes of transportation used in TSAM are automobile, commercial airline and SATS.

The automobile driving time and driving distance is necessary to calculate the travel time and travel cost. Microsoft MapPoint 2004 was used to compute the driving distance and driving time between all the counties in the United States. However, as mentioned previously, there are about 4.5 million different one way origin-destination pairs considered in TSAM. Therefore, this task was automated by calling MapPoint from Visual Basic to automate the calculation. The origin and destination of the automobile trips are the county population centroids defined by their longitude and latitude. The results were then converted into a MatLab matrix of size 3091 x 3091 cells.

The commercial airline travel time was derived by reconstructing the commercial airline network [Seshadri, 2003] using the Official Airline Guide [OAG, 2001]. The OAG contains the commercial airline schedule for one year. The commercial airline travel cost was calculated using the commercial airline fares [Murthy, 2003] derived from the Department of Transportation database [DB1B, 2000]. DB1B holds a ten percent sample of all the tickets sold in the United States over one year. Two separate input matrixes store the travel time and travel cost by commercial airline.

The American Travel Survey [ATS, 1995] is used by the Trip Generation, Trip Distribution and Mode Choice modules. The ATS is a nationwide travel behavior survey that surveyed the travel pattern of households across the United State for one year. It contains information such as income group, travel purpose, party size, travel time, travel cost and mode of transportation. The ATS was used to derive trip rate tables for the Trip Generation [Baik, 2003] and Trip Distribution [Baik, 2003] models. The ATS was also used to calibrate the Mode Choice [Ashiabor, 2003] module.

The Woods and Poole [W&P, 2003] socio-economic model is used by the Trip Generation and Trip Distribution modules. The Woods and Poole dataset provides socio-economic data at the county level up to the year 2025. The data used by the modules are the population, household income and employment characteristics of each county.

Model Outputs

The main outputs of TSAM are the estimated round trips between each county pair. MatLab files (.mat) of the size 3091 x 3091 cells store the results in a binary format. Each row is the origin county index and each column is the destination county index. The basis of the county index is on the ascending order of the county's FIPS number, which uniquely identifies a county. These FIPS number were retrieved from the Woods and Poole socio-economic model.

The Trip Generation module estimates the total number of intercity round trips in the United States. It estimates the demand from each county to all other counties in the continental United States. The results are split by five income groups and between a business and non-business trip. Therefore, the Trip Generation module output tables are 3091 counties x 5 income groups x 2 trip purposes (business and non-business).

The Trip Distribution module distributes the generated trips from one county to all other counties. It considers two trip purposes and five household income groups. The outputs of the Trip Distribution module are ten tables of size 3091 x 3091 counties.

The Mode Choice module splits the number of distributed trips between different modes of transportation. TSAM's Mode Choice module considers three different modes of transportation: automobile, commercial airline and SATS. Therefore, it has many of these large (3091 x 3091) output tables. For example, there are output tables for each trip purpose, household income group and mode of transportation. This yields to thirty tables of 3091 x 3091 cells. Additionally, there are airport-to-airport trip demand tables for commercial airline and SATS modes, which add another ten tables of output data.

3.1.8 TSAM's Computational Volume

As explained previously, TSAM calculates travel demand between the 3091 counties in the Untied States. The Trip Generation module is the simplest and fastest module to run since it estimates the produced trips for all the counties. Therefore, it only executes the Trip Generation code 3091 times for each trip purpose and household income group. On a Pentium 4 with a 3.0 GHz clock rate the Trip Generation module takes only a few minutes to complete.

The Trip Distribution module is more complex since it has to run the code for each county origin and destination pair. Therefore, the Trip Distribution code runs 9.55 million times for each trip purpose and household income group. Using a Pentium 4 with a 3.0 GHz clock rate the Trip Distribution module takes about 30 minutes to complete.

The Mode Choice module is the most complex and time consuming module in TSAM. It has to retrieve and compare the travel times and travel costs for each mode between all the county origin and destination pairs. Additionally, it needs to estimate the market share for each trip purpose and income group level to calculate the demand. The 9.55 million county to county calculations required to complete the Mode Choice module take about 6 hours using the computing power described previously.

3.2 Travel Time Savings Calculations

One of the main purposes of TSAM is to estimate the Small Aircraft Transportation System [SATS] demand and its benefits on the mobility in the United States. One key measure of improved mobility are the travel time savings SATS users could enjoy when using the new mode of transportation. This next section will describe how the travel time savings are calculated.

3.2.1 Calculation of Total Travel Time

Before travel time savings can be calculated, the actual total time spent by each traveler needs to be calculated. The following paragraphs will describe how the travel time is calculated for each of the three modes of transportation.

Automobile

The travel time by automobile is essentially the driving time plus the additional overnight stays if required. The driving time was calculated using Microsoft MapPoint and is based on the speed limit on the road network. TSAM requires business travelers to have an overnight stay every 7.5 hours of driving. Non-business travelers are allowed to drive up to 9.0 hours before stopping for an overnight stay.

The total travel time by automobile is simply derived by multiplying the number of automobile travelers by the automobile travel time.

Commercial Airline

The travel time by commercial airline depends on multiple factors. The commercial airline travel time has the following components:

- Access time from the origin to the origin airport
- Processing time at the origin airport
- Schedule delay at the origin airport
- Flight time to the destination airport including stopovers
- Processing time at the destination airport
- Egress time from the destination airport to the final destination

The access and egress time are calculated using Microsoft MapPoint 2004 and are the actual driving times to the airports. The processing times at the origin and destination airports depend on the airport type and are displayed in Table 1. The schedule delay [Teorodovic, 1988] is calculated based on the frequency of schedules between the origin and destination airports. The more frequently flights occur between two airports, the lower the schedule delay. The flight time [Seshadri, 2003] was calculated using the Official Airline Guide [OAG, 2001] as explained previously.

Table 1: Processing Times at Origin and Destination Airports in TSAM

	Origin Airport	Destination Airports
Large Hub	1.50 hrs	0.75 hrs
Medium Hub	1.25 hrs	0.75 hrs
Small Hub	1.00 hrs	0.50 hrs
Non-Hub	0.75 hrs	0.50 hrs

The total travel time spent on commercial airline is calculated similarly to automobile. The total commercial airline travel time between each county origin-destination pair is multiplied by the number of travelers using commercial airline.

SATS

The travel time by SATS also depends on multiple factors. The SATS travel time has the same components as commercial airline:

- Access time from the origin to the origin airport
- Processing time at the origin airport
- Schedule delay at the origin airport
- Flight time to the destination airport including stopovers
- Processing time at the destination airport
- Egress time from the destination airport to the final destination

The total travel time spent on SATS is calculated the same way as for commercial airline. The travel time by SATS between the origin and destination counties is multiplied by the demand for SATS.

3.2.2 Calculation of Travel Time Savings

After calculating the total time spent on each transportation mode by each traveler the actual travel time savings can be calculated before and after the introduction of SATS. First, a scenario without SATS is run and the total travel times are determined. Then a scenario with SATS is run and again the total travel times are determined.

The total travel time savings are calculated by subtracting the total travel time for the No SATS scenario with the total travel time of the SATS scenario. This results in nationwide travel time savings due to the presence of SATS. If the nationwide travel time savings are divided by the total SATS demand, then the average travel time savings per SATS traveler can be found. The results of this analysis are presented in Chapter 4.

4. RESULTS

In this section the results of the integration will be reviewed, the features of TSAM will be demonstrated and the results of the travel time savings calculations will be presented.

4.1 Results of Integration

The integration of TSAM drastically changed the way results were analyzed and the way the model was improved. With the compilation, the code runs much faster. With the integration the time required to perform an analysis is greatly reduced. It requires much less manual intervention and multiple scenarios can be run overnight without user intervention. It also offers immediate automated spatial analysis of the results. Finally, TSAM is now a standalone and redistributable product that can be easily packaged and shipped to the sponsor and easily installed and used by the sponsor.

4.1.1 Faster Runtimes due to the Integration

The integration of TSAM resulted in much faster runtimes and reduced tedious manual intervention by the user. The faster runtimes were achieved by compiling the TSAM source code. This allowed TSAM to run in native mode instead of the slower interpreted mode in MatLab. The compiled code is running about twice as fast as the interpreted code when developed with MatLab Version 7.

TSAM's integration also allowed the automation of tedious tasks that the user was subjected to previously while running the model. Previously, the user had to transfer the output files between the modules manually. The user also had to manually manage the file structure for each scenario for each module. This was due to the input and output directories being hard coded in each of the standalone modules.

Now TSAM manages the entire process and handles the directory structure automatically using its Graphical User Interface (GUI). This provides seamless communication between the different modules. The manual output file transfer and directory structure management has been completely eliminated. The user can now concentrate on running the models and performing better analysis.

The last time savings feature added to TSAM is the ability to run multiple scenarios automatically. This feature is called “Batch Process”. The user can run multiple years for the Trip Generation [Baik, 2003] and Trip Distribution [Baik, 2003] modules in a row. For the Mode Choice [Ashiabor, 2003] module, the user can run multiple scenarios back to back. This allows for faster sensitivity analysis since all these scenarios can be run automatically overnight or during weekends without user intervention. The user simply prepares different scenarios and saves them into a queue before starting the module.

4.1.2 Faster Analysis due to GIS

The integration of TSAM also allowed faster analysis of the results due to its mapping abilities. These Mapping abilities were added using Geographic Information Systems (GIS) technology.

Previously the user would have to extract the outputs from the model and convert them into a standard database format before importing them into professional GIS software. This process can be rather lengthy and error prone. After importing the results into professional GIS software, the user would need to connect the data to the corresponding map. Finally, the user will have to select the correct map format and legend type for the corresponding data. This process is involved for users unfamiliar with the data and with the GIS software.

TSAM's integration takes care of the extraction and conversion of the model outputs automatically. It also creates maps of all the results automatically with the correct map format and legend type. This allows a novice user to analyze the results quickly. The automatic mapping abilities also saved the development team a lot of time since they could display and analyze outputs much faster than before. This feature greatly helped the debugging process.

4.1.3 Standalone and Redistributable Product

The integration of TSAM allowed the creation of a standalone and redistributable product. This was critical since it facilitated the packaging and shipment of TSAM to the sponsor, which in turn helped the sponsor installing TSAM. Additionally, the installation of TSAM is now part of an automatic setup feature, which assists the user in installing TSAM on a new computer.

4.2 TSAM's Features and Applications

This section will showcase the selected outputs feature of TSAM and their applications. It is divided into four parts following the structure of the model. The features are mainly the different outputs presented by TSAM. Each different output will be described in a paragraph accompanied by a map. All the maps will be based on the data of Fairfax County, Virginia.

4.2.1 Trip Generation

The Trip Generation module generates the number of trips produced and attracted to all the 3091 counties in the United States. The results are for business and non-business travelers and are divided in five different income group levels.

Figures 13 and 14 show the total amount of produced trips in the year 2005 for business and non-business travelers respectively. With these maps an analyst can identify the amount of produced trips from each county in the United States. It can easily be identified that most of the trips are generated in highly populated areas such as the East and West Coast. TSAM can also display a map for each income group level when selecting it in the “Income Group” drop down menu box.

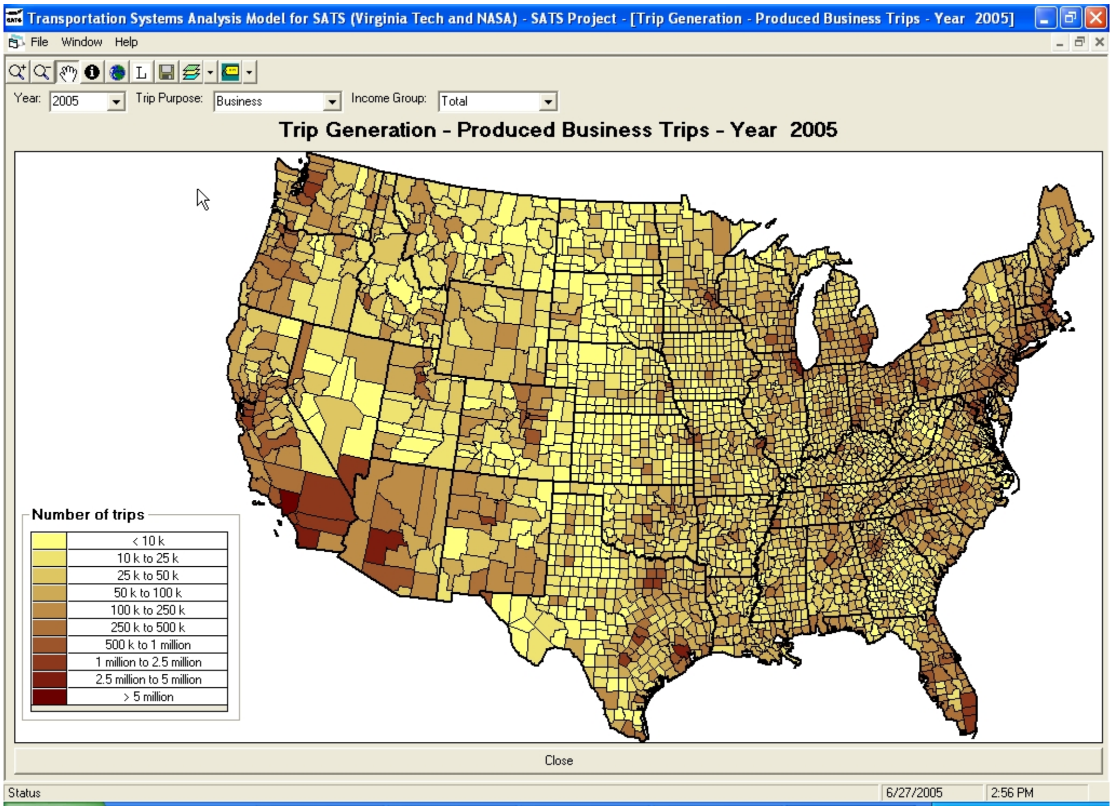


Figure 13: Total Amount of Produced Business Trips in 2005 Estimated by TSAM.

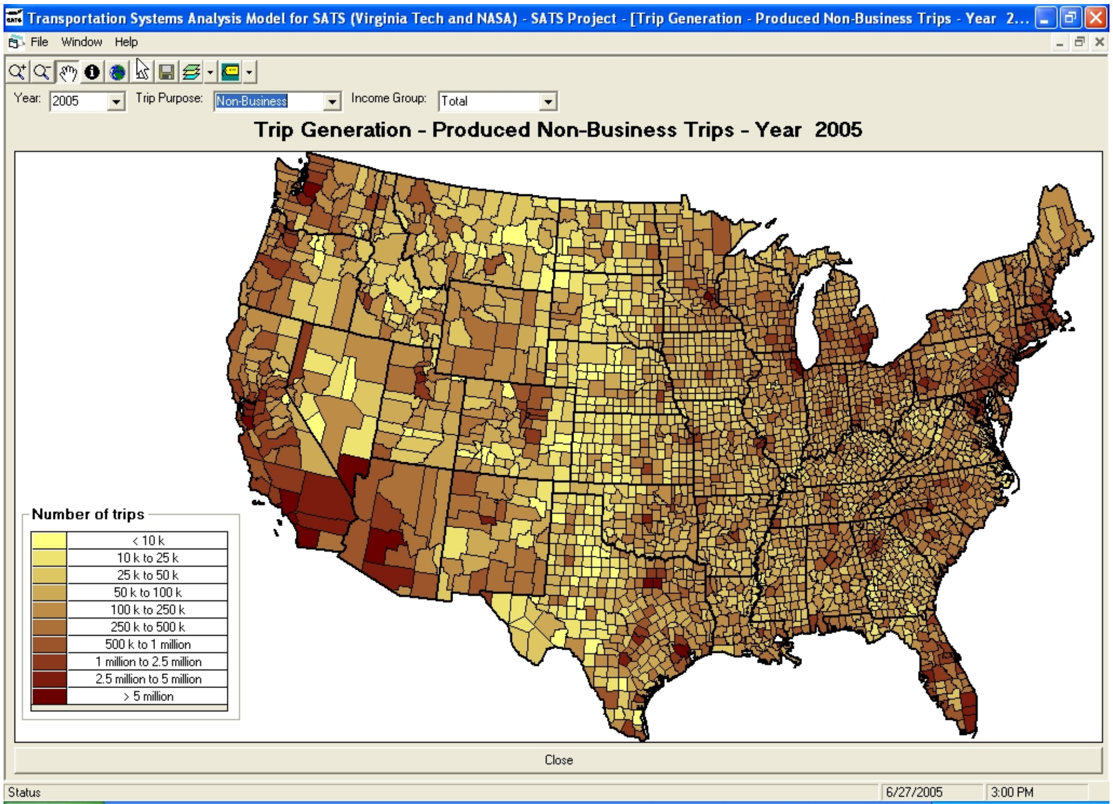


Figure 14: Total Amount of Produced Non-Business Trips in 2005 Estimated by TSAM.

4.2.2 Trip Distribution

The Trip Distribution maps can be used to analyze travel behavior across the United States. TSAM can display the Trip Distribution for all the counties in the United States. Planners can use such output to plan future transportation capacity improvements or to develop local and national travel behavior studies that fit their needs.

The Trip Distribution module distributes all the generated trips to all other counties in the continental United States. The results are for business and non-business travelers and are divided in five different income group levels.

Figures 15 and 16 show the Trip Distribution results from Fairfax County, Virginia to all other counties for business and non-business respectively. As expected, the closer counties and the major metropolitan areas attract most of the trips. This shows that people usually travel short distances more often and are more attracted to large population centers. The travel patterns between business and non-business travelers are similar. However, non-business travelers are more numerous that business travelers.

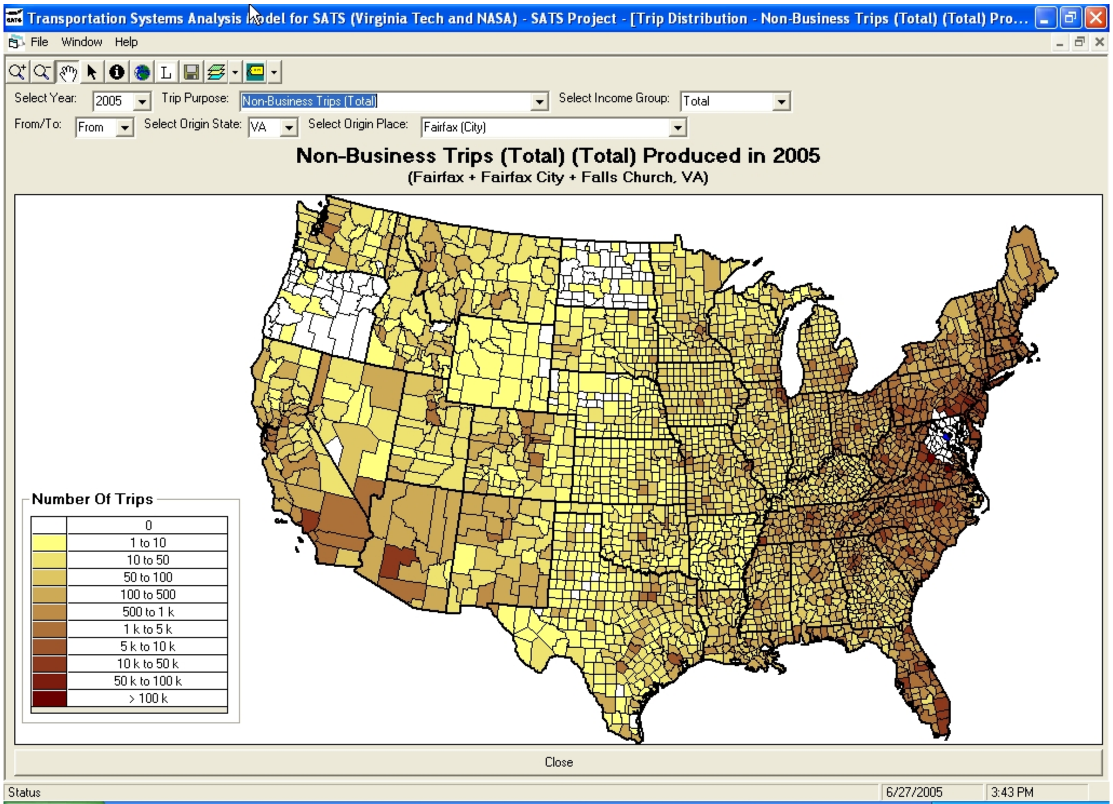


Figure 15: Distribution of all the Business Trips from Fairfax County, Virginia in 2005.

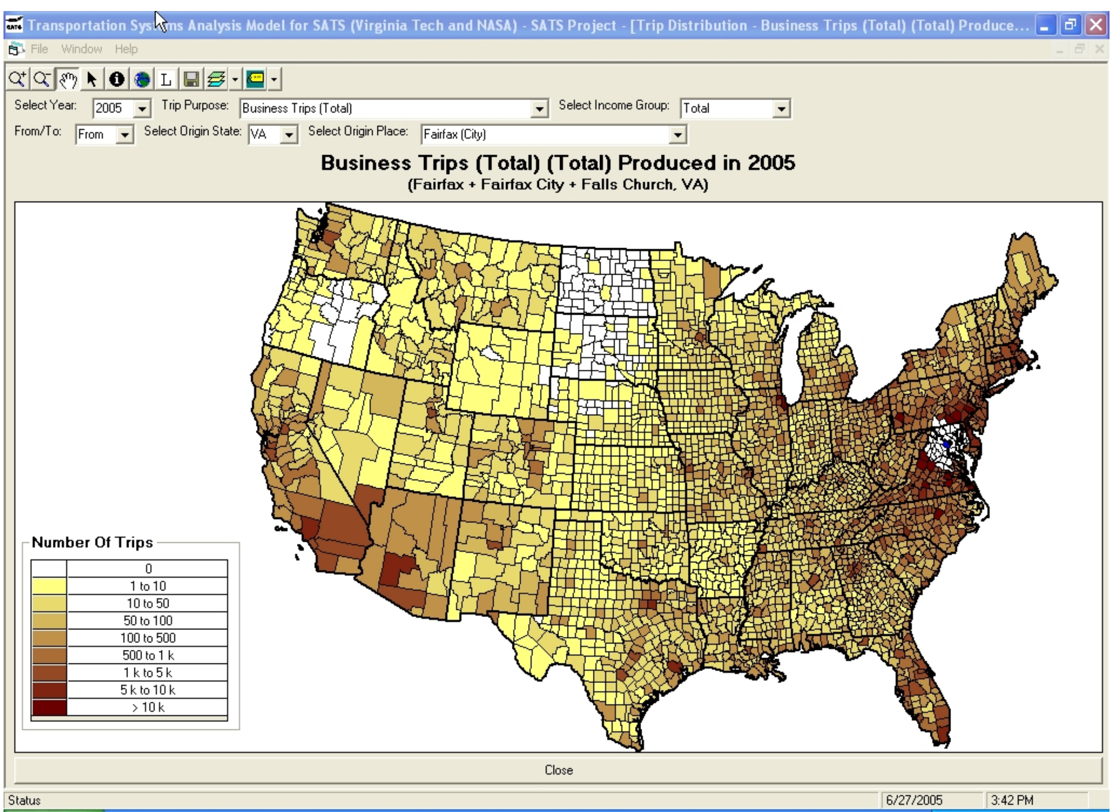


Figure 16: Distribution of all the Non-Business Trips from Fairfax County, Virginia in 2005.

4.2.3 Mode Choice

The Mode Choice module splits the distributed trips between three different transportation modes. The different modes are automobile, commercial airline and SATS. The outputs produced by the Mode Choice module are much larger and detailed than the previous two modules. This section will present the travel demand, market share, travel time and travel cost outputs generated by the module.

Travel Demand

The travel demand maps can be used by transportation analysts to analyze traveler's behavior in transportation mode choice. The demand for each of the transportation modes can be analyzed for the entire country. From this data, the impact on the interstate, commercial airline and SATS network can be assessed and changes planned.

Figures 17, 18 and 19 show number of business trips from Fairfax County, Virginia for automobile, commercial airline and SATS respectively. As expected the distribution of the trips across the United States between the different transportation modes is quite different. The automobile trips are of short to medium length and are more numerous close to the origin. Commercial airline trips are of medium to long range and are spread across the entire United States. SATS trips are sparser and are of short to medium length nature.

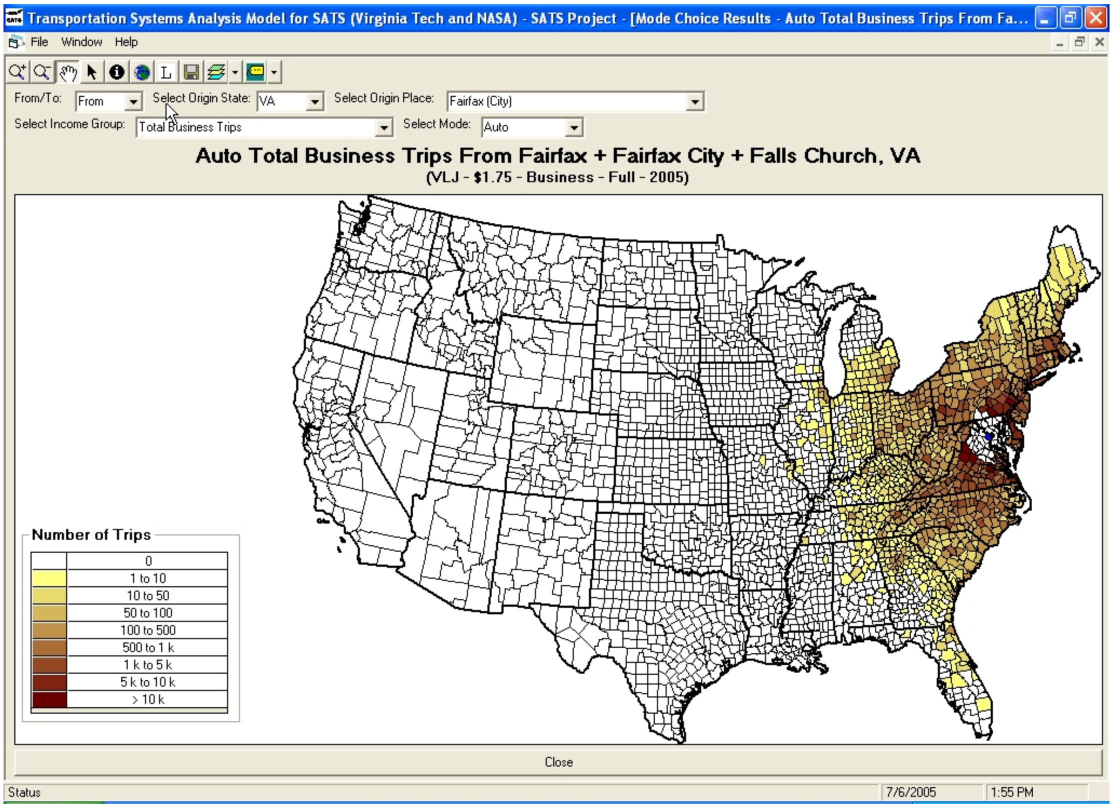


Figure 17: Distribution of the Automobile Business Trips from Fairfax County, Virginia.

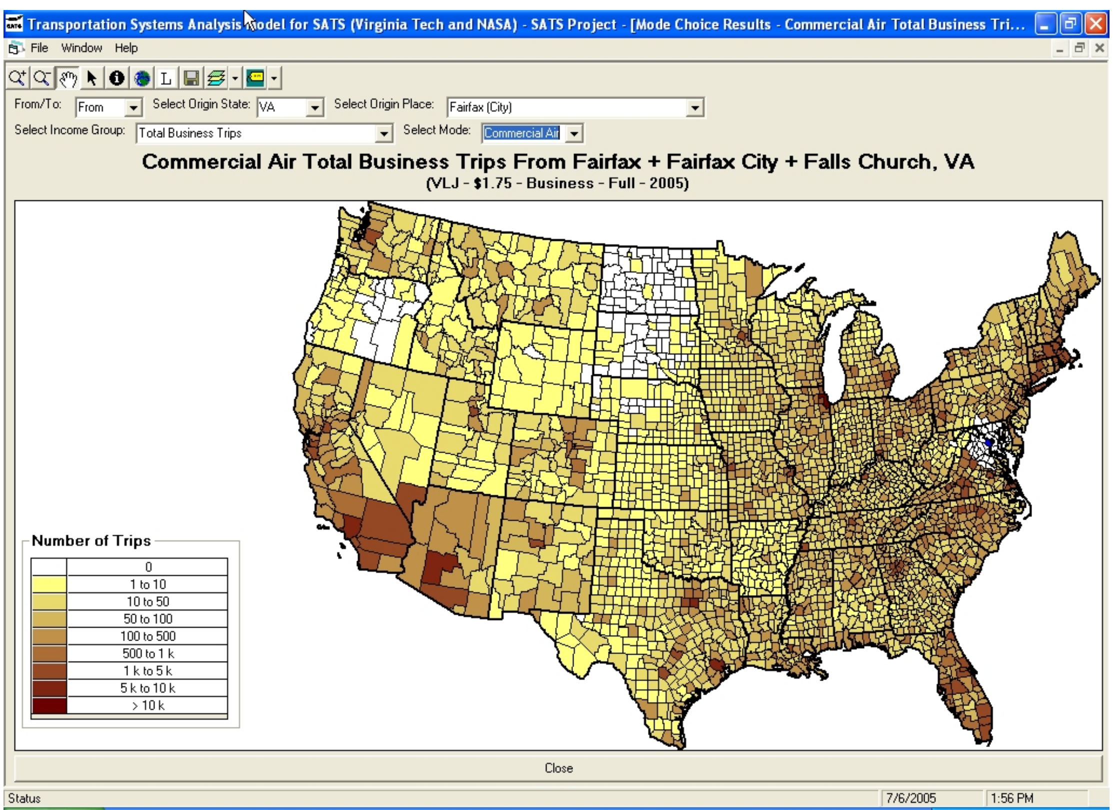


Figure 18: Distribution of the Commercial Airline Business Trips from Fairfax County, Virginia.

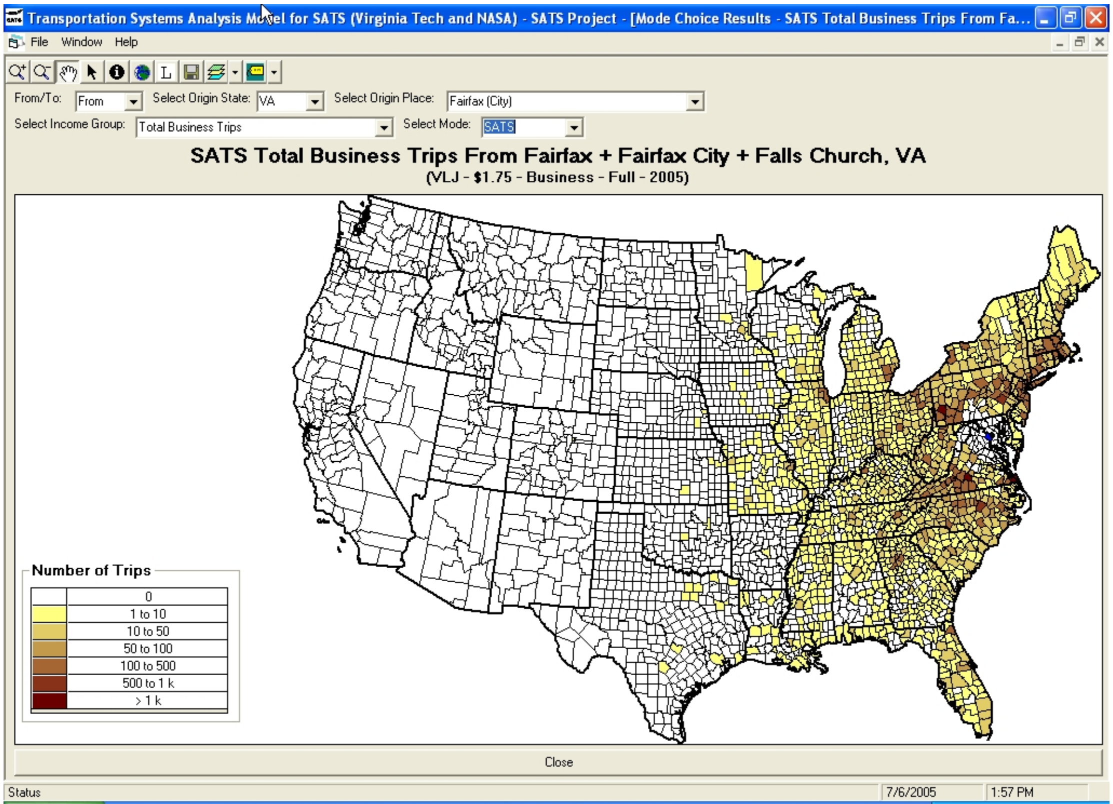


Figure 19: Distribution of the SATS Business Trips from Fairfax County, Virginia.

Market Share

The market share maps can be used by analysts to identify where a certain mode is more attractive than another. Such maps can also help in identifying trouble spots where the expected market share for a mode is not reached. This could be from the travel cost being too high or the travel time being too low.

Figures 20, 21 and 22 display the market share results for automobile, commercial airline and SATS respectively. As expected the market share for automobile is the highest for short trips and it reduces the longer the trip is. The commercial airline market share is the opposite of the automobile market share and is the highest for medium to long trips. Finally, the SATS market share is low for any origin-destination pair due to its high travel cost at this time compared to the other modes.

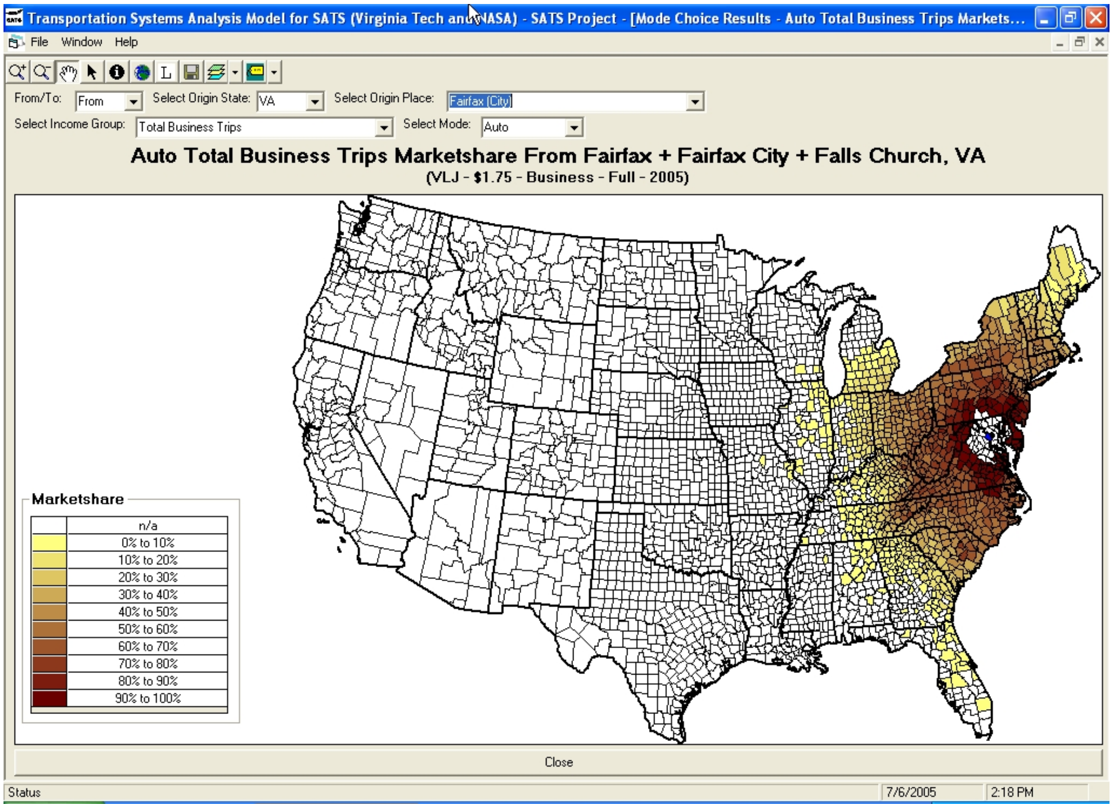


Figure 20: Market Share for Automobile Business Trips from Fairfax County, Virginia.

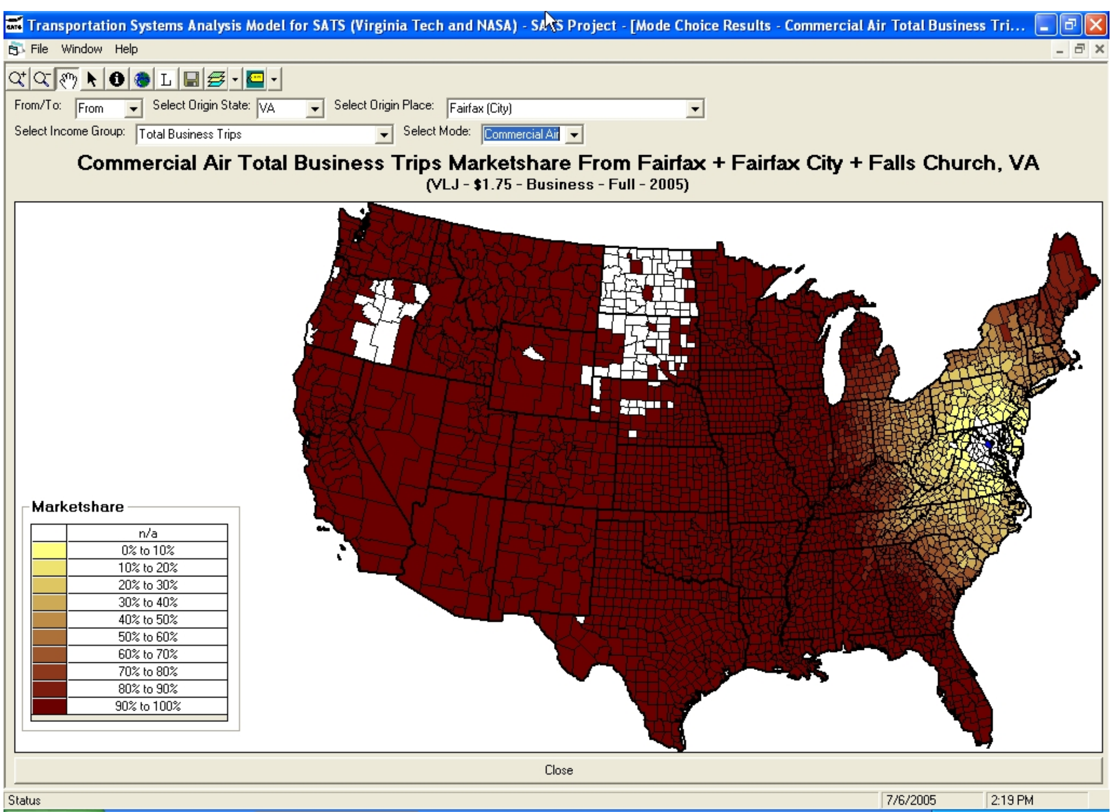


Figure 21: Market Share for Commercial Airline Business Trips from Fairfax County, Virginia.

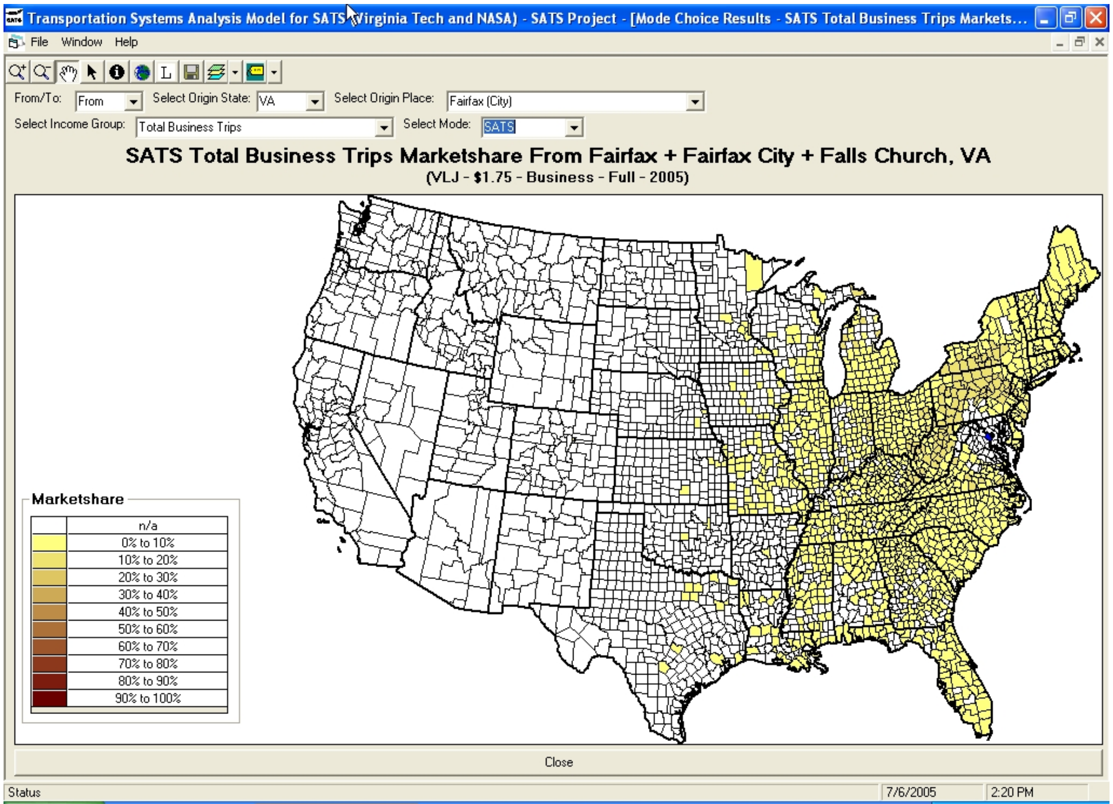


Figure 22: Market Share for SATS Business Trips from Fairfax County, Virginia.

Travel Time For Each Mode of Transportation

The travel time by mode of transportation maps can be used by analysts to identify bottlenecks or disconnected areas in their transportation networks. Additionally, the travel time competitiveness between modes can be analyzed. These maps are also used to validate the travel time calculations of the model.

Figures 23, 24 and 25 show the one way door-to-door travel time for business travelers from Fairfax County, Virginia to all other counties for automobile, commercial airline and SATS respectively.

The automobile travel time takes in account the actual driving time and the required overnight stays. As a rule, business travelers have an overnight stay for every 7.5 hours of driving time. As expected, Figure 23 shows that automobile travel time along the interstate system is faster than in poorly connected areas of the country.

The commercial airline travel time takes in account the access time, processing time and schedule delay [Teodorovic, 1988] at the origin airport, the flight time and finally the processing time and egress time from the destination airport. Figure 24 shows that commercial airline travel time is faster between large hub airports than between small airports.

The SATS travel time has the same components as the commercial airline travel time. However, access/egress times and processing times are unusually much lower for SATS. Also, the SATS flight is planned to be straight to the destination. Figure 25 shows that the further the destination is, the longer the SATS trip travel times.

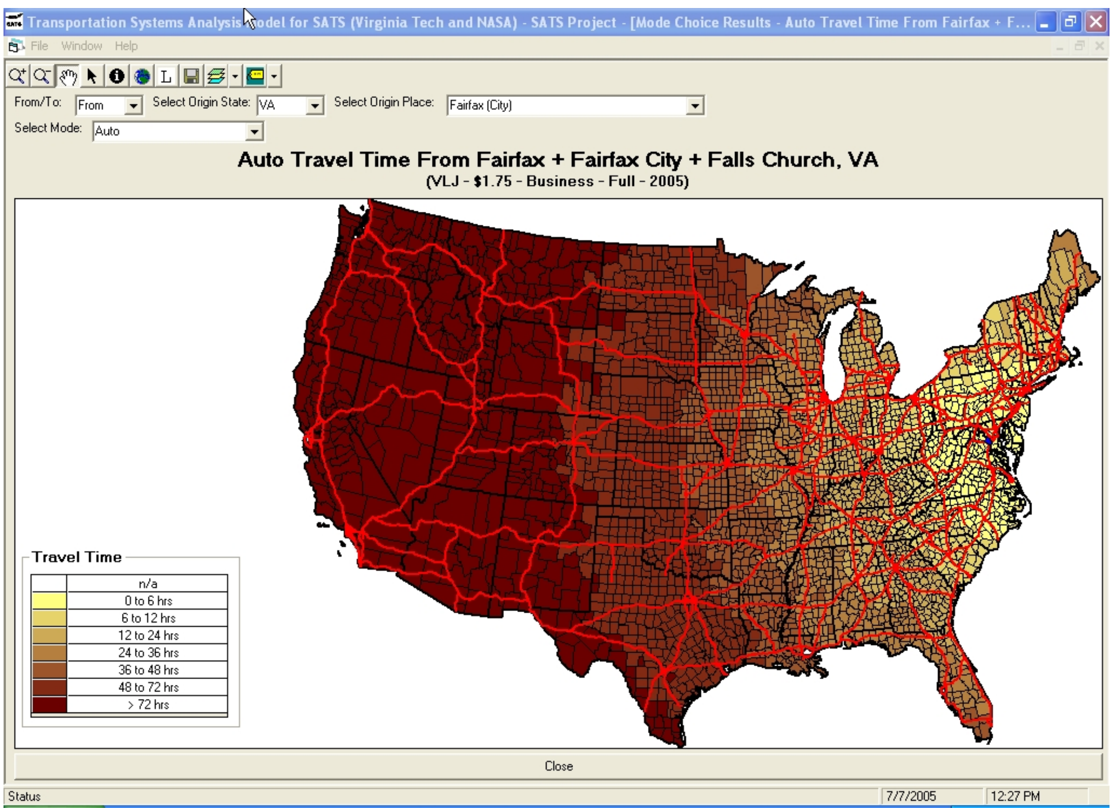


Figure 23: Automobile Travel Time for a Business Trip from Fairfax County, Virginia.

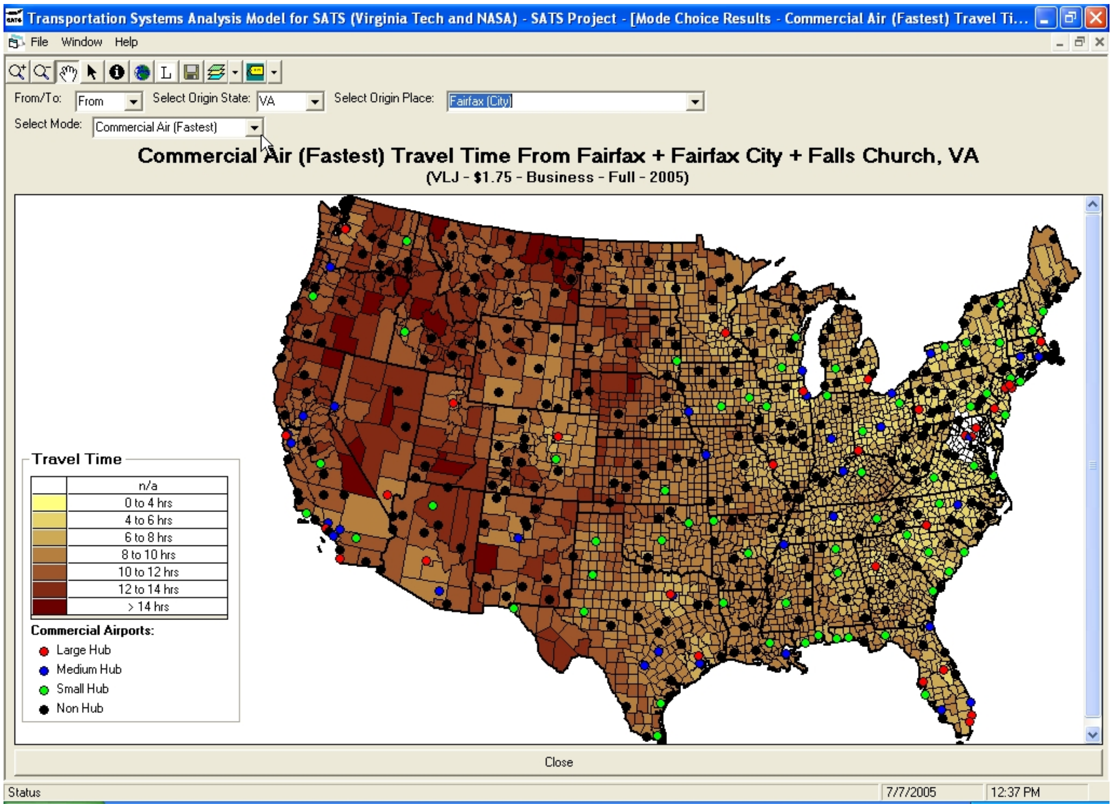


Figure 24: Commercial Airline Travel Time for a Business Trip from Fairfax County, Virginia.

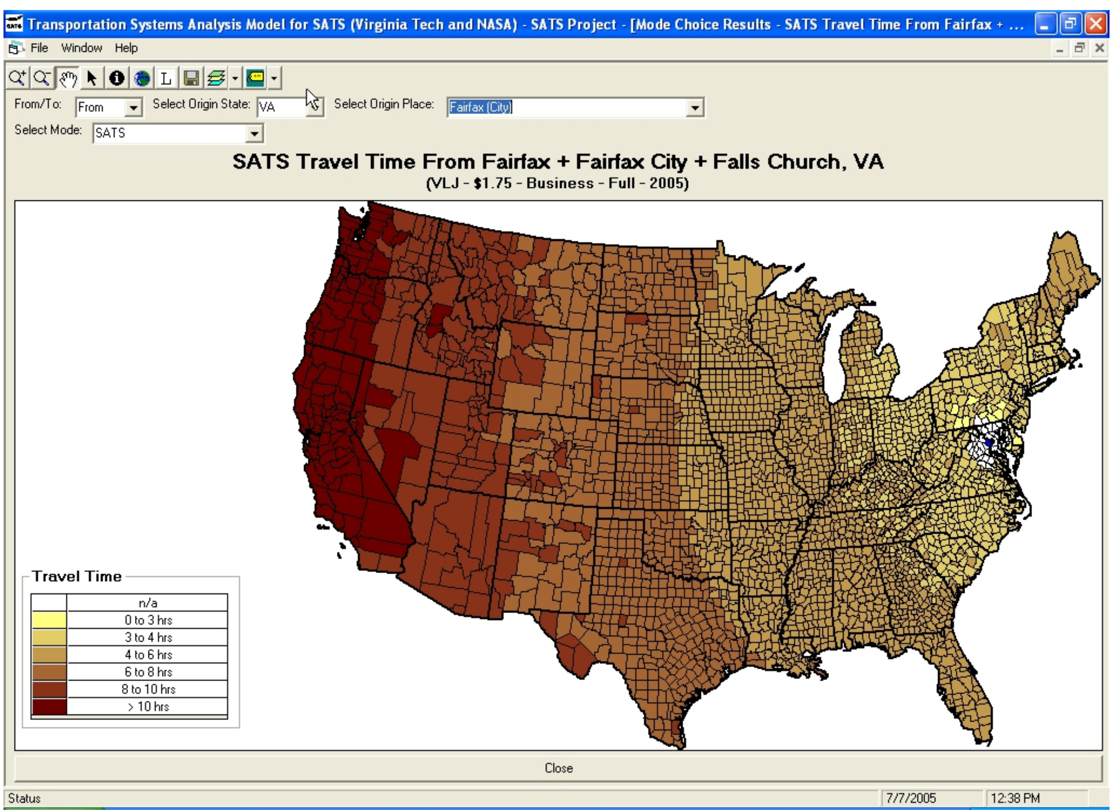


Figure 25: SATS Travel Time for a Business Trip from Fairfax County, Virginia.

Travel Time Comparison Between Modes of Transportation

The travel time comparison maps can be used to identify where a certain mode has an advantage over another one based on travel time. Inefficiencies for a specific mode of transportation can also be identified and analyzed.

Figure 26 compares the travel time between automobile and the fastest commercial airline route from Fairfax County, Virginia for business travelers. The colored counties show that automobile has a travel time advantage over commercial airline. The white counties represent counties that can be reached faster by commercial airline instead of automobile. Automobile is faster than commercial airline for short trips.

Figure 27 compares the travel time between automobile and SATS from Fairfax County, Virginia for business travelers. The colored counties show that automobile has a travel time advantage over SATS. The white counties represent counties that can be reached faster by SATS instead of automobile. SATS is faster than automobile except for very short trips.

Figure 28 compares the travel time between SATS and the fastest commercial airline route from Fairfax County, Virginia for business travelers. The colored counties show that SATS has a travel time advantage over commercial airline. The white counties represent counties that can be reached faster by commercial airline instead of SATS. SATS is faster than commercial airline except for very long trips.

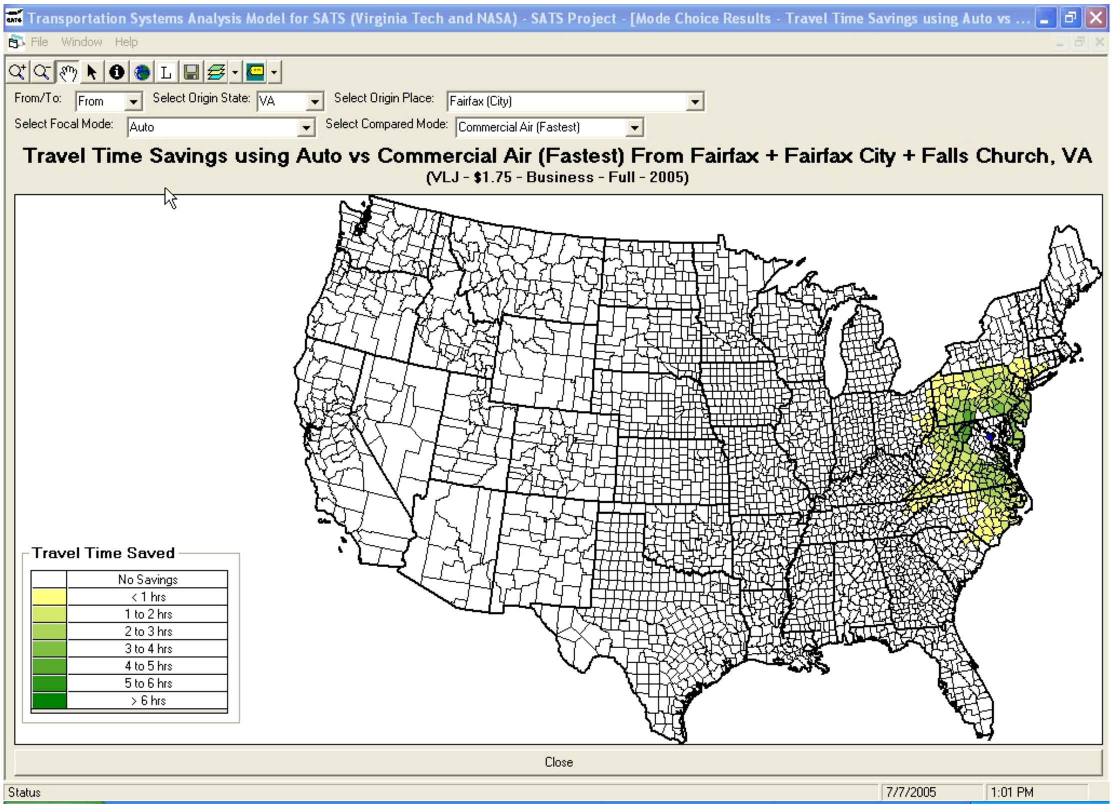


Figure 26: Automobile is Faster than Commercial Airline for Short Trips.

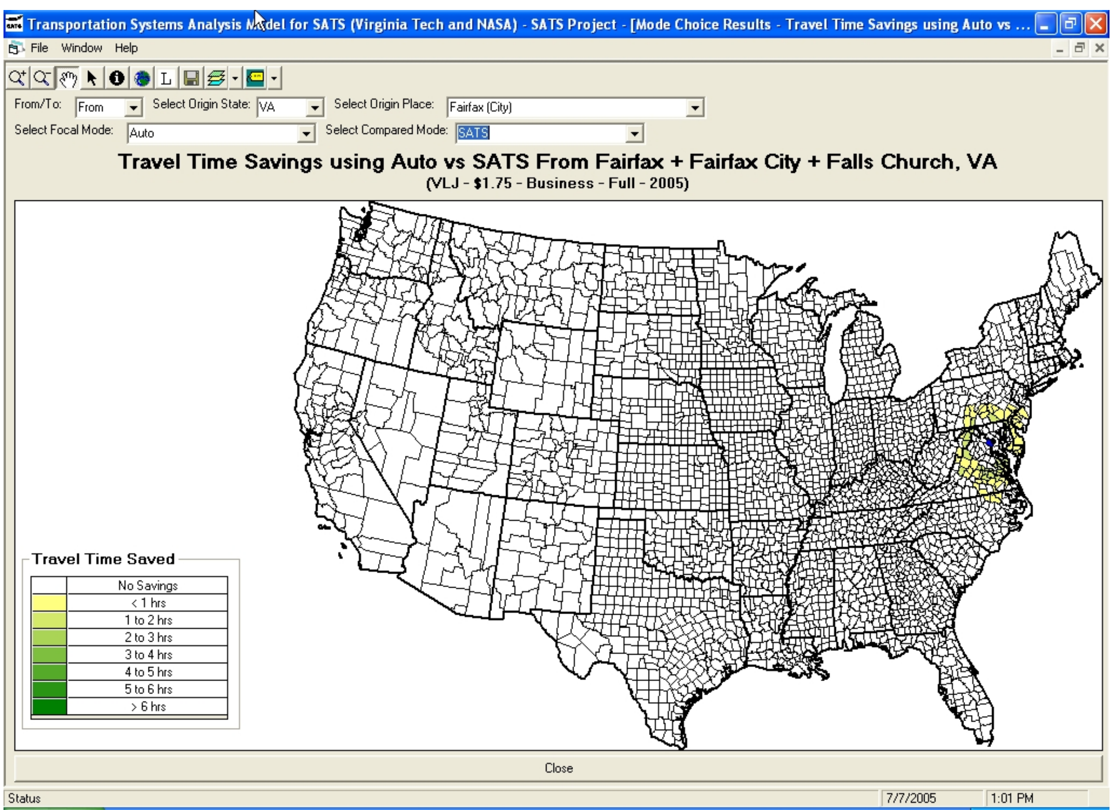


Figure 27: SATS is Faster than Automobile Except for Very Short Trips.

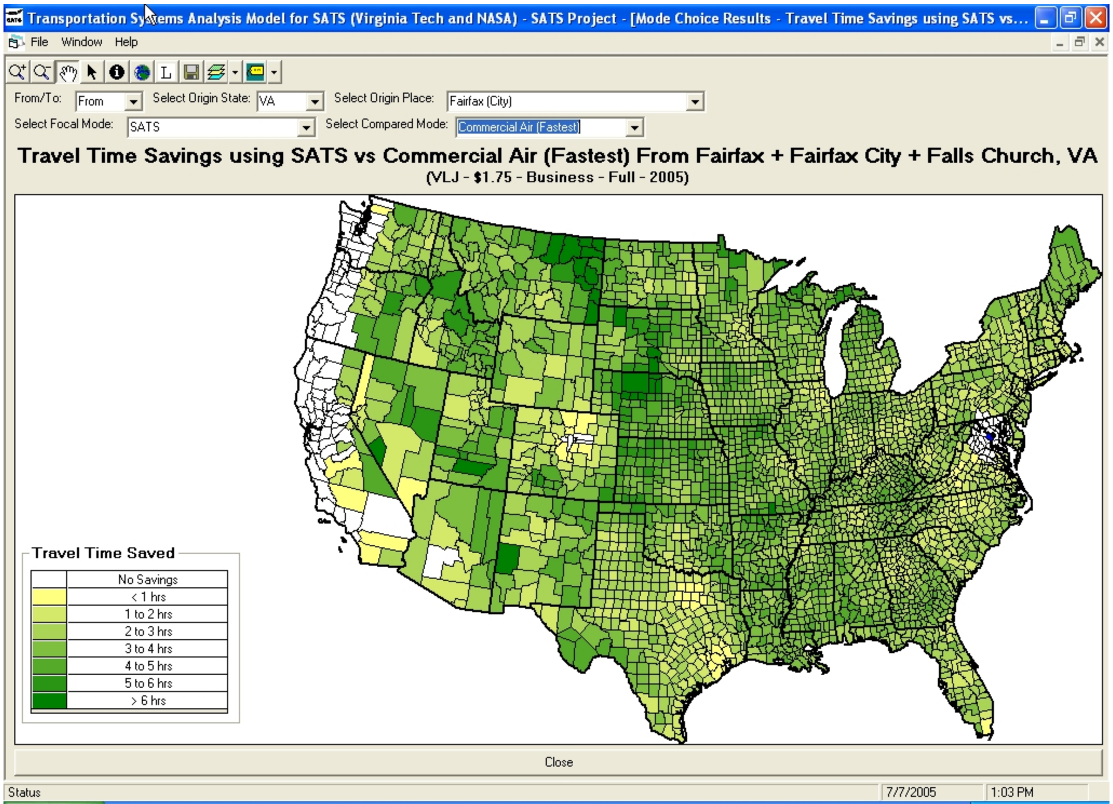


Figure 28: SATS is Faster than Commercial Airline Except for Very Long Trips.

Fastest Mode of Transportation

The fastest mode of transportation map can be used in conjunction with the previous travel time maps to identify the travel time competitiveness between transportation modes. Again, inefficiencies in a specific network can be identified and analyzed.

Figure 29 shows which mode is the fastest from Fairfax County, Virginia to all other counties. In general, SATS is the fastest mode of transportation.

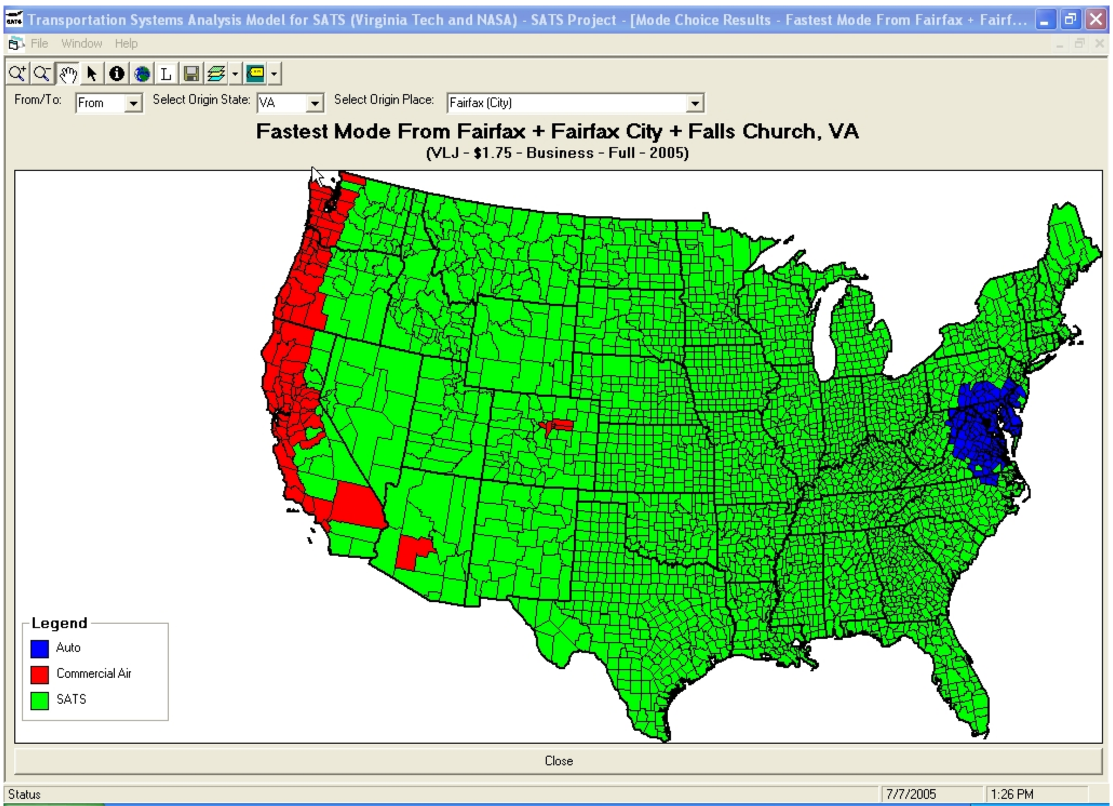


Figure 29: SATS is Usually the Fastest Mode.

Travel Cost for Each Mode of Transportation

The travel cost maps permit analysis of the travel cost for the three transportation modes. They can help identify origin-destination county pairs with unreasonable travel costs.

Figures 30, 31 and 32 show the door-to-door travel cost for business travelers from Fairfax County, Virginia to all other counties for automobile, commercial airline and SATS respectively.

The automobile travel cost takes in account the actual driving cost and the required lodging cost. As a rule, business travelers have an overnight stay every 7.5 hours of driving time. Figure 30 shows that the automobile travel cost increases with driving distance.

The commercial airline travel cost takes in account the access cost to the origin airport, commercial airline fare and egress cost from the destination airport. As expected, Figure 31 shows that commercial airline travel cost is generally cheaper to large airports than to smaller less used airports.

The SATS travel cost has the same components as the commercial airline travel cost. However, access/egress costs are usually lower for SATS since it uses local airports. Also, the SATS flight is planned to fly straight to the destination. As expected, Figure 32 shows that the further the destination is the more expensive the SATS trip becomes.

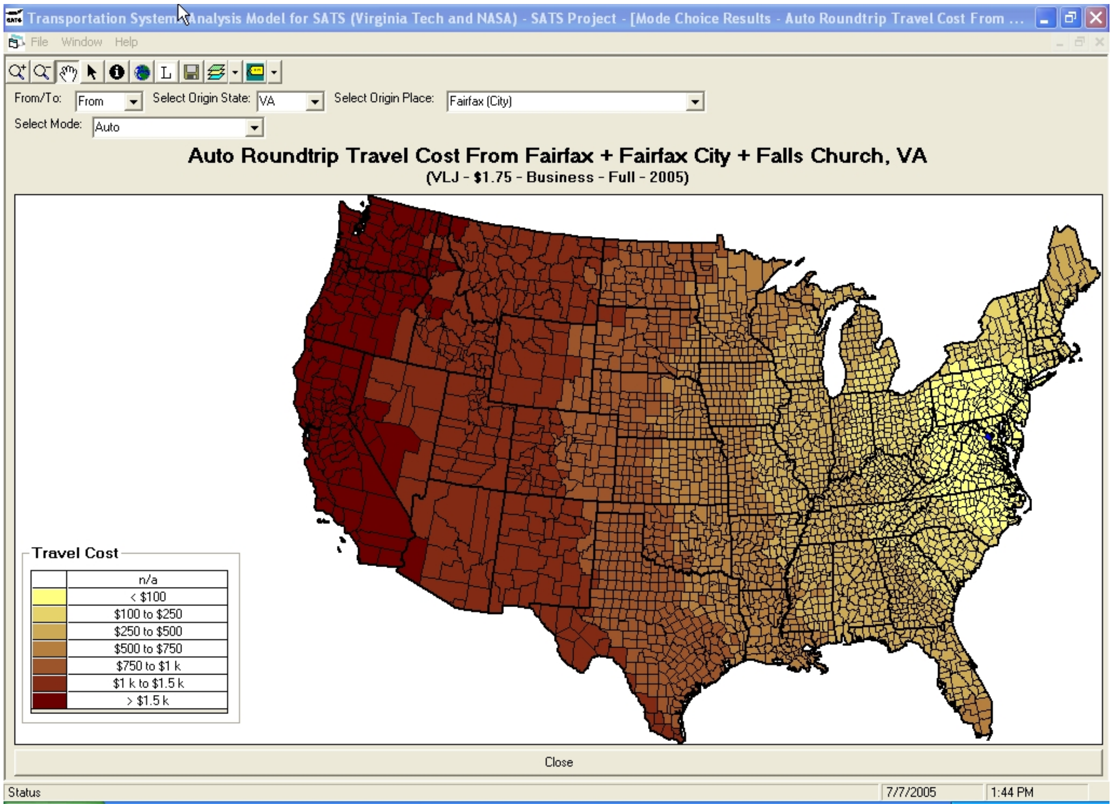


Figure 30: Automobile Roundtrip Travel Cost for Business Travelers from Fairfax County, Virginia.

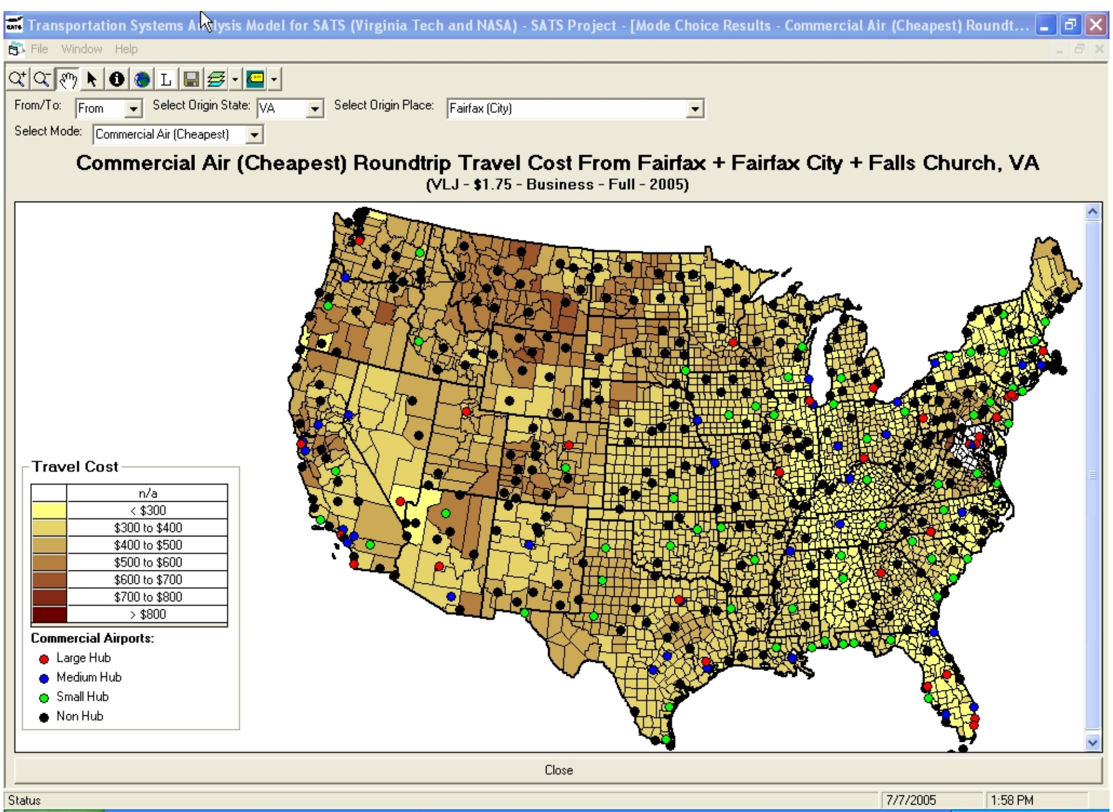


Figure 31: Commercial Airline Roundtrip Travel Cost for Business Travelers from Fairfax County, Virginia.

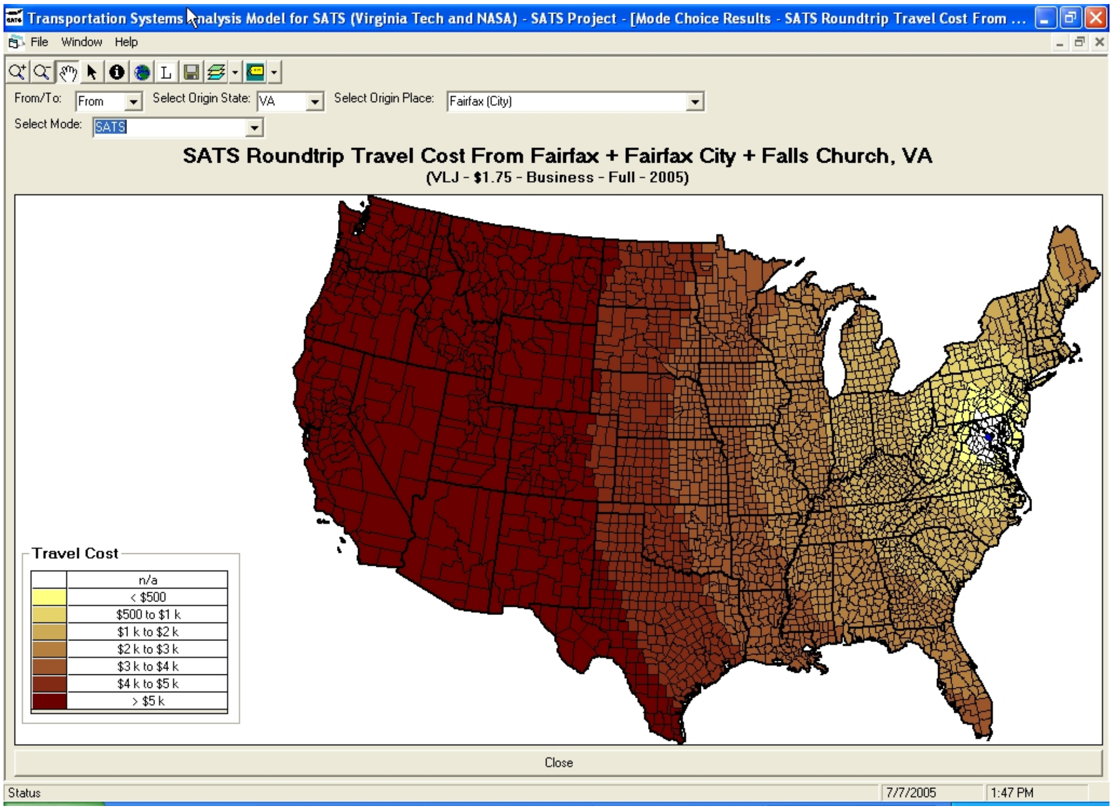


Figure 32: SATS Roundtrip Travel Cost for Business Travelers from Fairfax County, Virginia.

Travel Cost Comparison Between Modes of Transportation

The travel cost between modes comparison maps can be used to compare the pricing competitiveness of the different modes of transportation.

Figure 33 compares the travel cost between automobile and the cheapest commercial airline route from Fairfax County, Virginia for business travelers. The colored counties show that automobile has a travel cost advantage over commercial airline. The white counties represent counties that can be reached cheaper by commercial airline instead of automobile. As expected, automobile is cheaper than commercial airline for short trips to medium trips.

Figure 34 compares the travel cost between the cheapest commercial airline route and SATS from Fairfax County, Virginia for business travelers. The colored counties show that commercial airline has a travel cost advantage over SATS. The white counties represent counties that can be reached cheaper by SATS instead of commercial airline. As expected, since SATS is very expensive, commercial airline is cheaper than SATS for most of the trips.

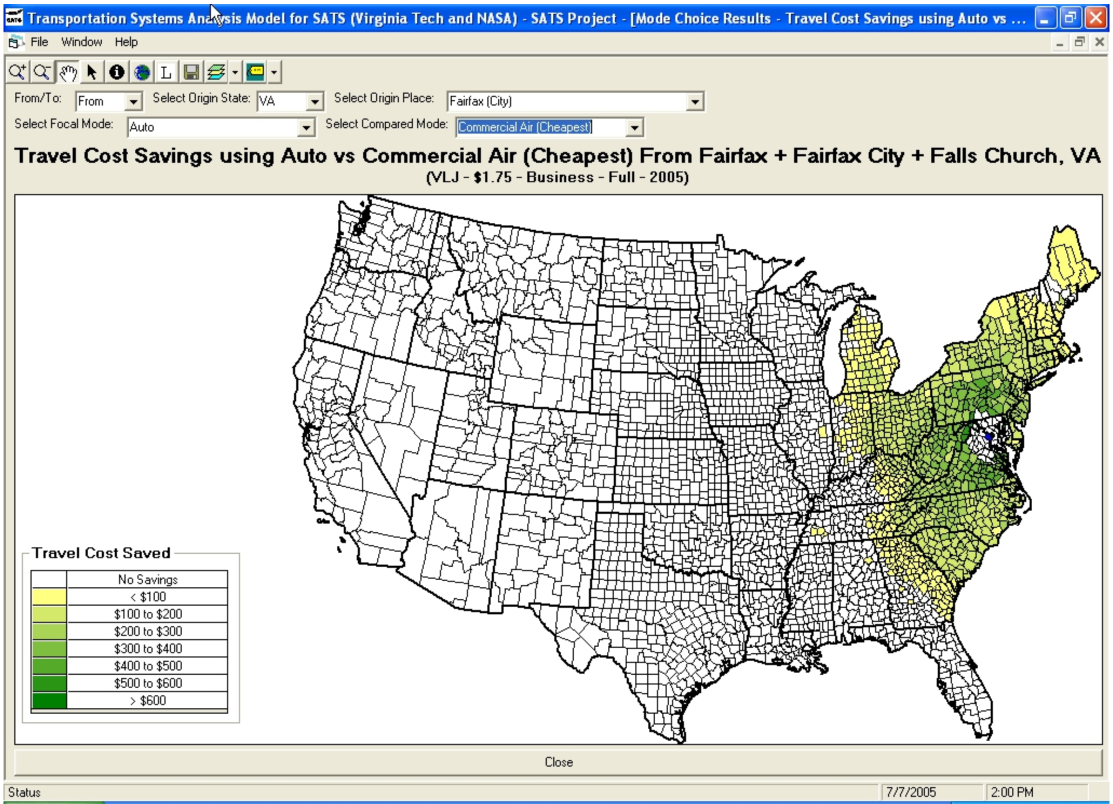


Figure 33: Automobile is Cheaper than Commercial Air for Short Trips from Fairfax County, Virginia.

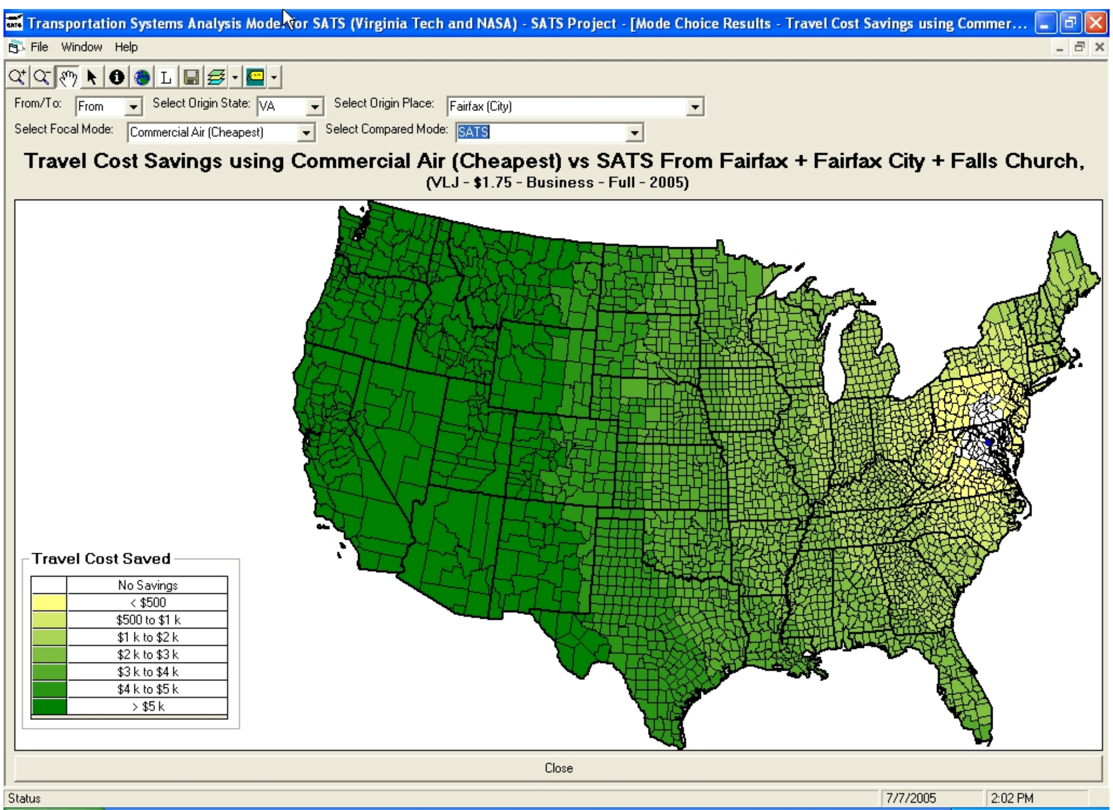


Figure 34: Commercial Airline is Cheaper than SATS from Fairfax County, Virginia.

Least Expensive Mode of Transportation

The least expensive mode of transportation map can be used in conjunction with the previous travel cost maps to identify the travel cost competitiveness between transportation modes.

Figure 35 shows which mode is the least expensive from Fairfax County, Virginia to all other counties. In general SATS is the most expensive mode of transportation. Automobile is the cheapest mode for short trips and commercial airline is the cheapest for medium to long trips.

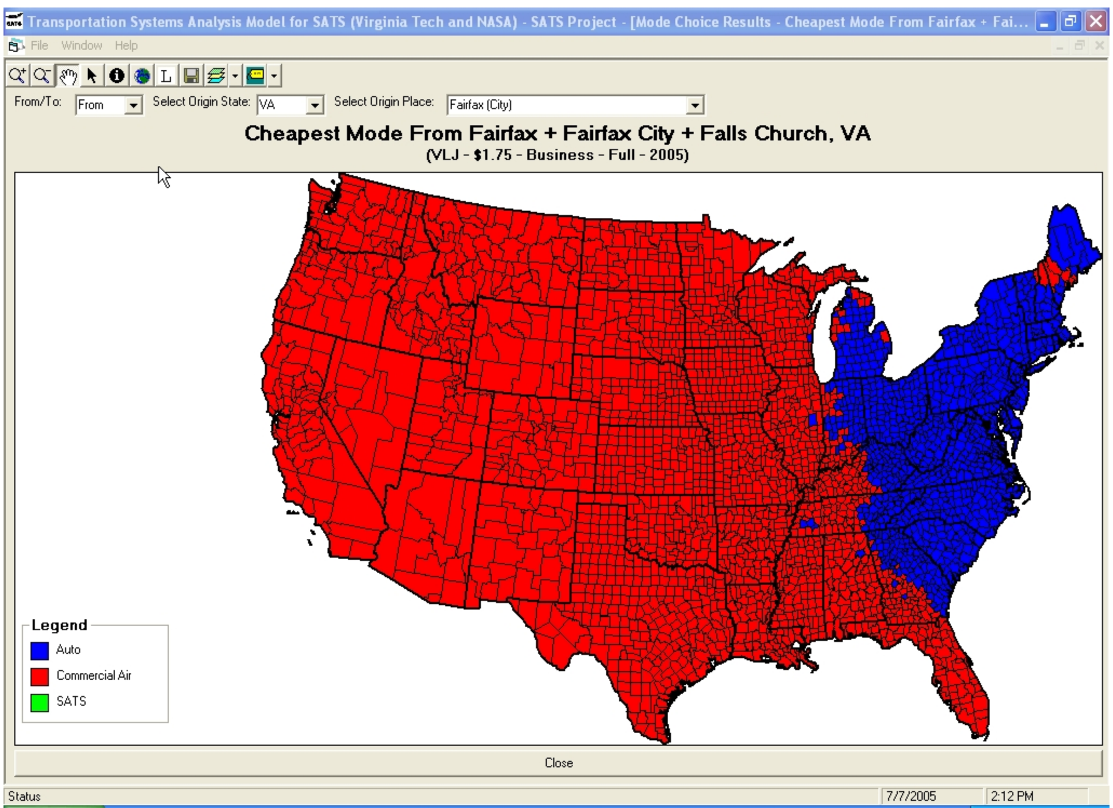


Figure 35: SATS is the Most Expensive Mode of Transportation.

4.2.4 Mobility Analysis

The mobility analysis section in TSAM displays some of the preprocessed data needed by the Mode Choice module. For automobile it contains the driving distance and driving time calculated by Microsoft MapPoint 2004. For commercial airline it displays the flight times [Seshadri, 2003] between the commercial airports derived from the Official Airline Guide [OAG, 2001]. It also contains the commercial airline fares [Murthy, 2003] derived from the Department of Transportation database [DB1B, 2000]. Finally, it illustrates the commercial airline network.

Automobile Driving Distance and Time

The driving distance and driving time was calculated using Microsoft MapPoint 2004. Figure 36 shows the driving distance from Fairfax County, Virginia. Figure 37 shows the corresponding driving time from Fairfax County, Virginia.

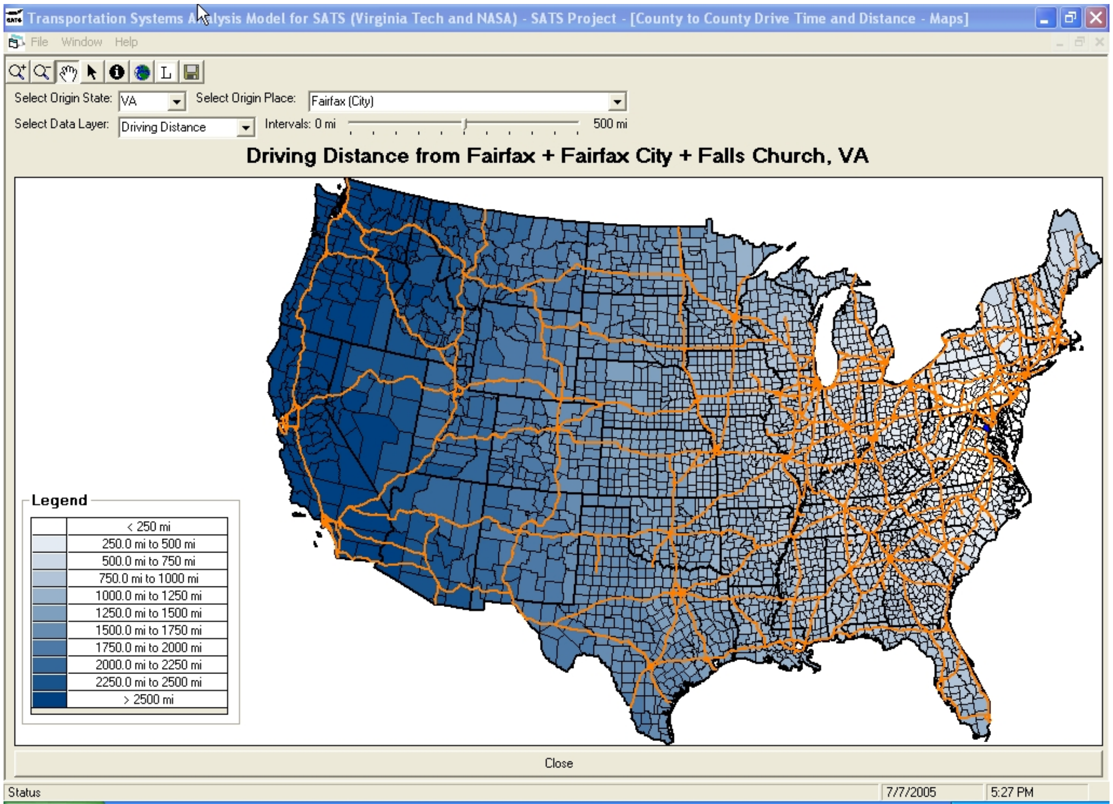


Figure 36: Driving Distance from Fairfax County, Virginia.

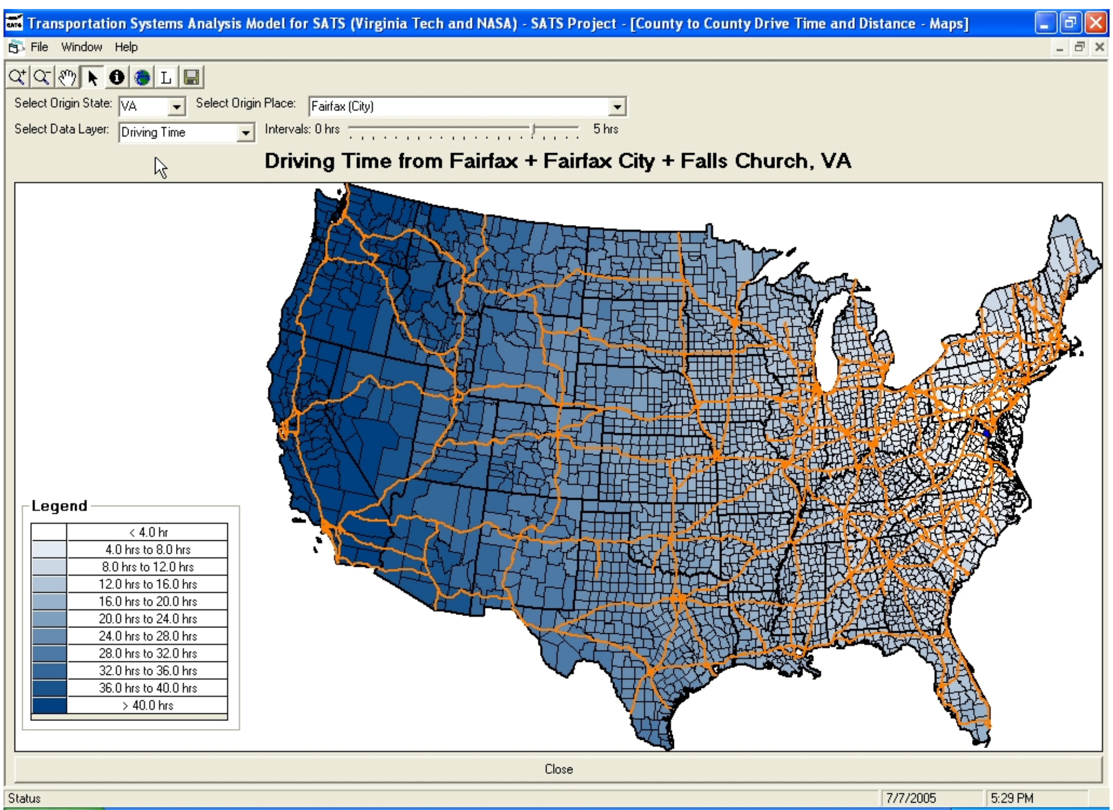


Figure 37: Driving Time from Fairfax County, Virginia.

Commercial Airline Network

The commercial airline network was used to derive the commercial airline travel time can also be displayed in TSAM. Figure 38 shows the commercial airline network from Roanoke Regional Airport, Virginia (ROA) to Chicago O'Hare International, Illinois (ORD). Besides the direct flight to ORD from ROA there are multiple connecting airline routes to reach ORD through other hubs. The schedule is displayed in a second window below the map. The commercial airline network and schedule can be displayed for all the airport pairs. This map is used to verify and debug the commercial airline network used in TSAM.

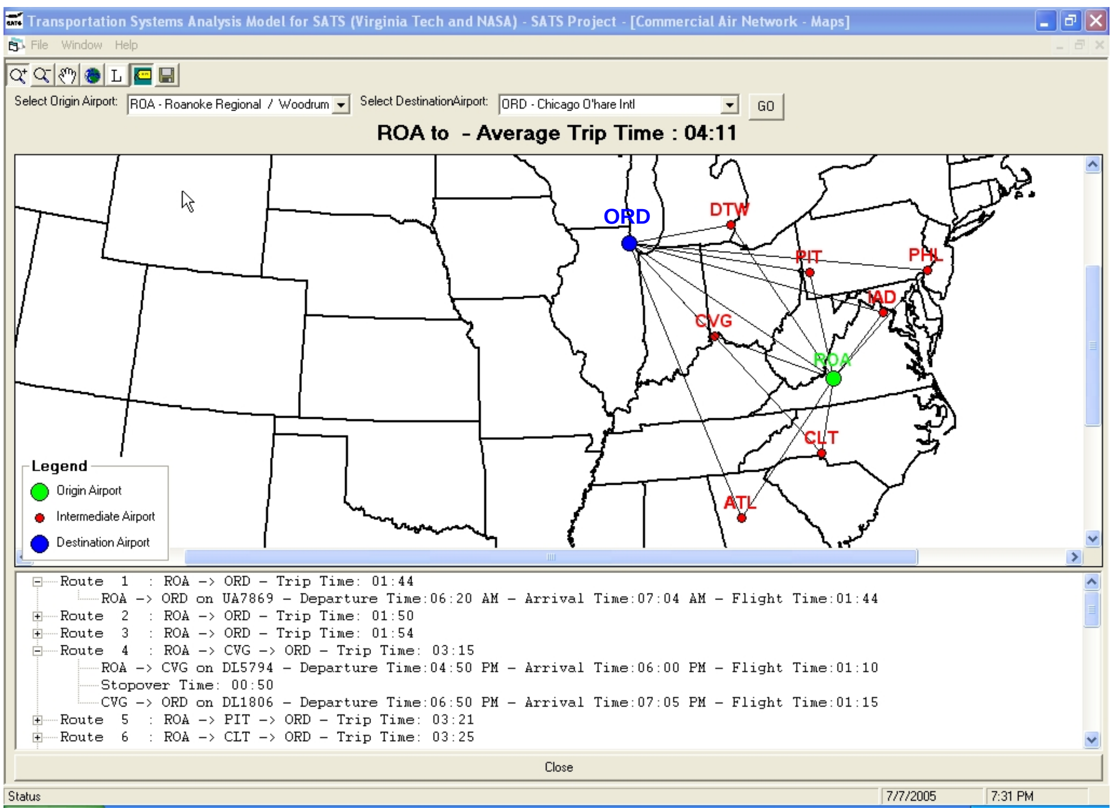


Figure 38: Commercial Airline Network from ROA to ORD.

Commercial Airline Travel Times

The airport to airport one way travel times derived from the commercial airline network are also displayed in TSAM. Figure 39 show the travel time by commercial airline from Washington Dulles International Airport (IAD) to all other commercial airports in the United States. The travel times include flight times and stopover times. This map is used to debug the commercial airline network and travel times used in TSAM.

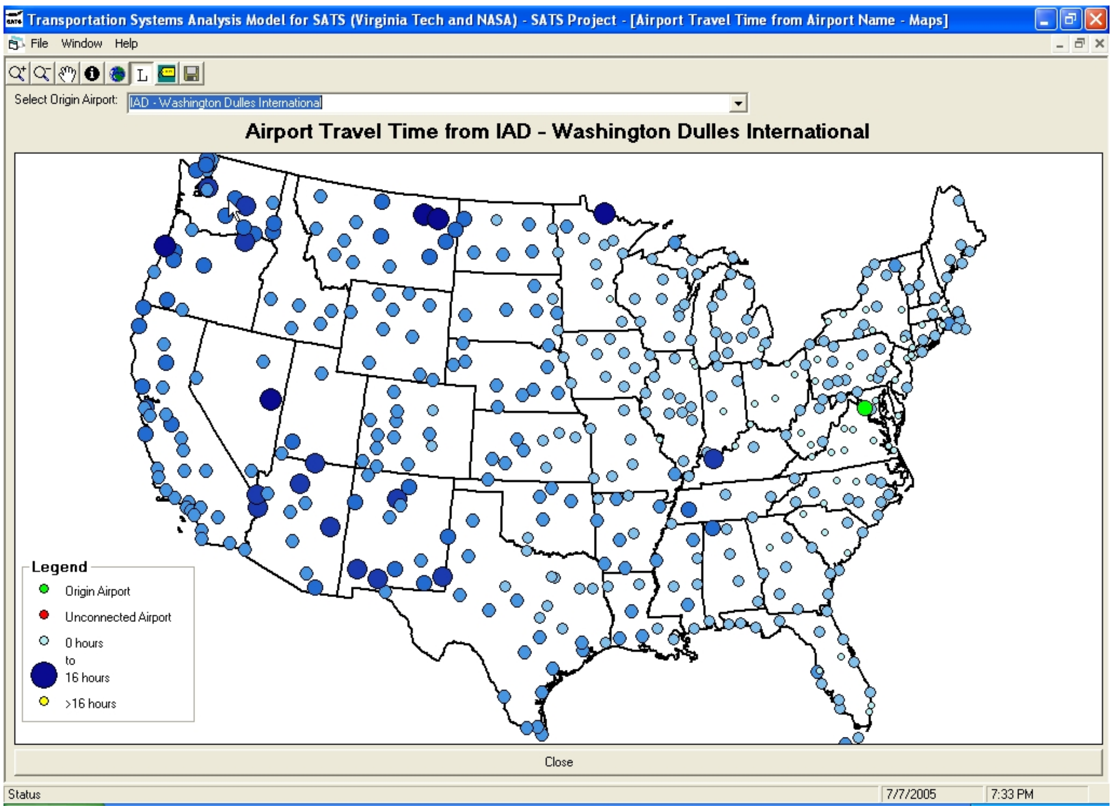


Figure 39: Commercial Airline Travel Times from ROA.

Commercial Airline Fares

The commercial airline fares [Murthy, 2003] extracted from the Department of Transportation Database [DB1B, 2000] are also displayed in TSAM. Figures 40 and 41 show the commercial airline business and non-business fares from Washington Dulles International Airport (IAD) respectively. This map is used to verify and debug the commercial airline fares extraction from DB1B.

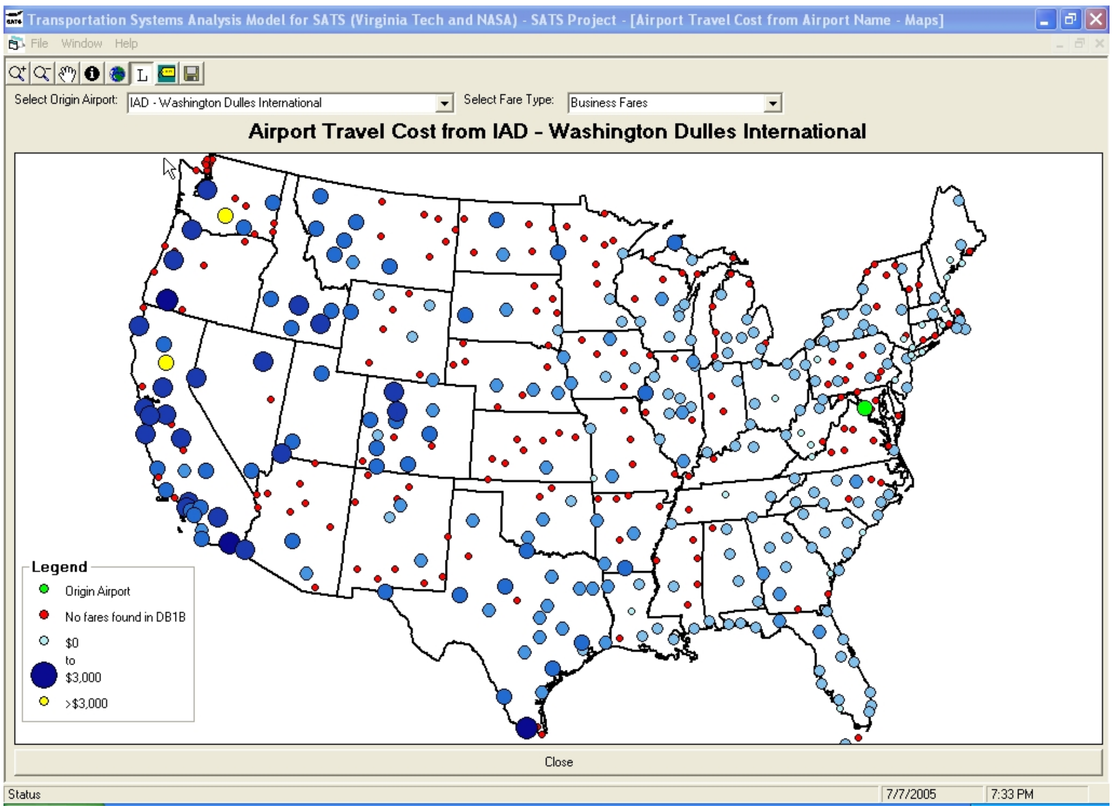


Figure 40: Commercial Airline Business Fares from ROA.

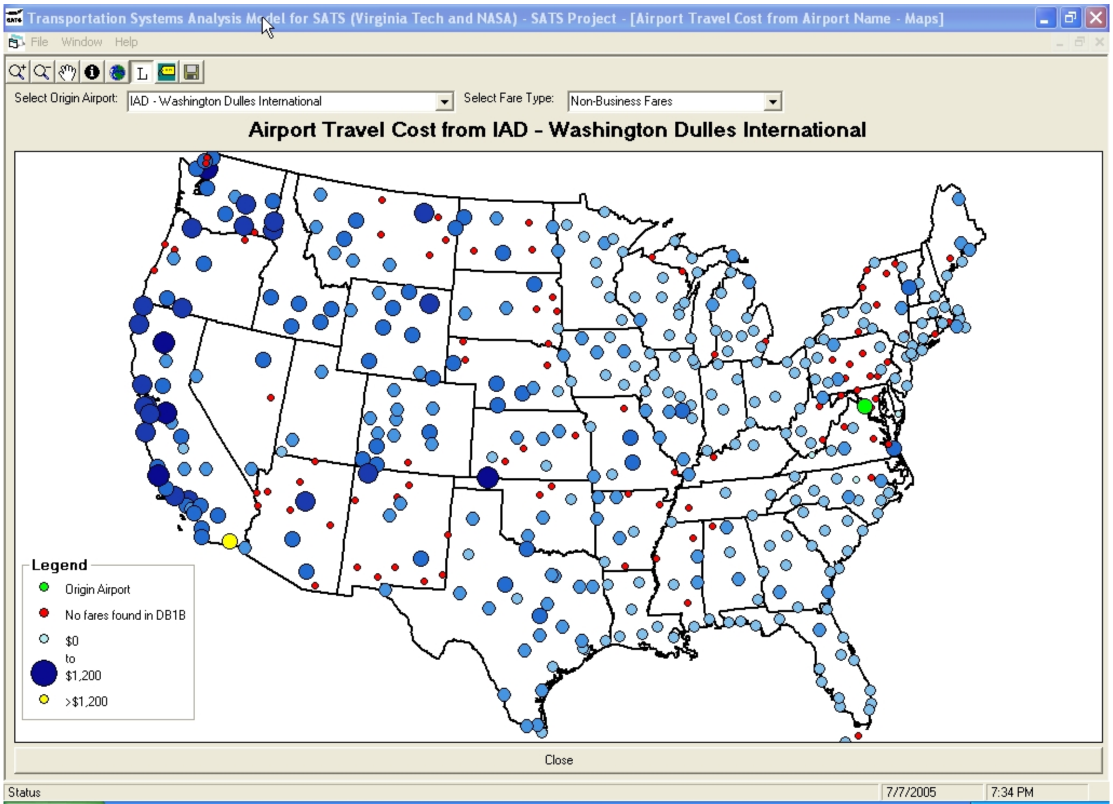


Figure 41: Commercial Airline Non-Business Fares from ROA.

4.3 Travel Time Savings Analysis Results

This section presents the results of the travel time savings due to the presence of SATS calculations discussed earlier in Chapter 3. First, the average travel time for each mode by distance is presented. Then the national and county travel time savings for business and non-business SATS travelers are presented. Finally, the travel time savings by distance are analyzed.

4.3.1 Average Travel Time for Each Mode by Distance

SATS is a fast mode of transportation due to its use of relatively fast vehicles, nearby airports and direct flight paths. Figure 42 illustrates how fast SATS is compared to automobile and commercial airline over distance based on the average one way door-to-door travel time for all trips in the United States. It can clearly be identified that SATS is the fastest mode of transportation for almost any trip exclusive of very short ones. The travel time savings due to the presence of SATS are analyzed in the following section.

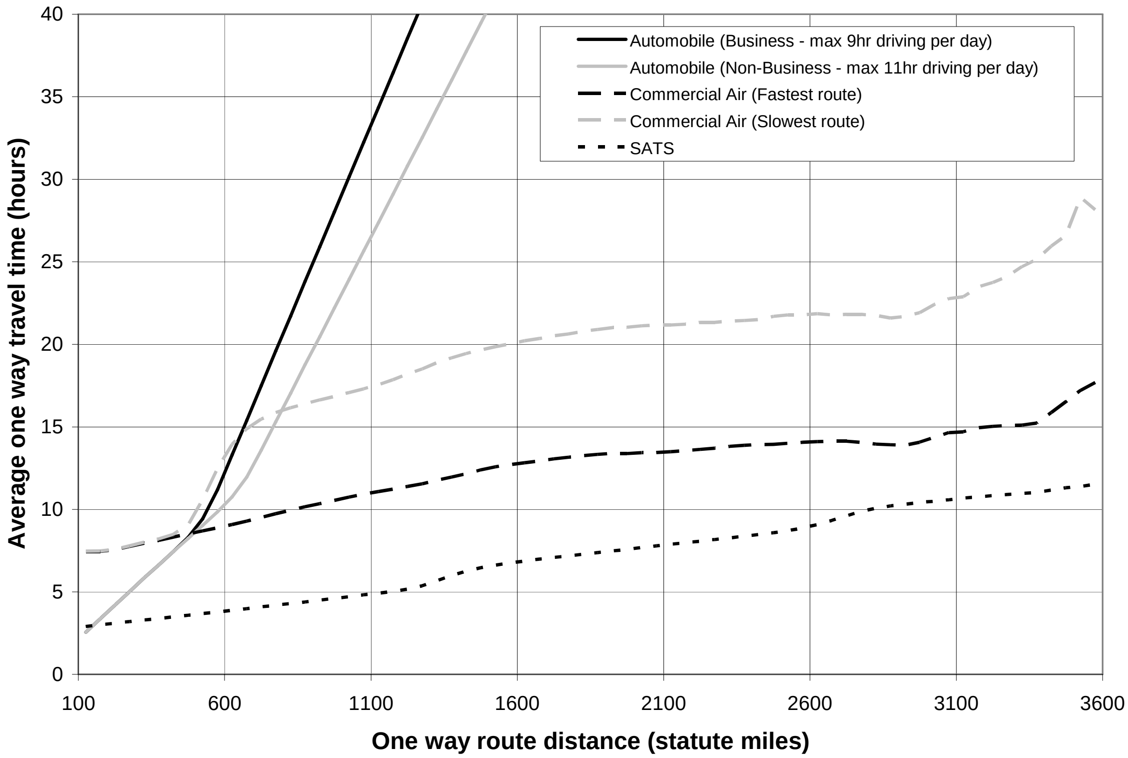


Figure 42: SATS will be the Fastest Mode of Travel in the United States.

4.3.2 Travel Time Savings

SATS can offer large travel time savings to travelers depending on their trip. The travel time savings using SATS depend on how fast automobile and commercial airline are for the same trip. SATS business travelers save 3.3 hours per roundtrip on average. However, non-business travelers save only 1.1 hours per roundtrip on average. Business travelers save more time than non-business travelers because they are predicted to use SATS for longer trips.

Figure 43 illustrates the average travel time savings for SATS travelers depending on the distance of their trip. The travel time savings are larger for medium range trips. However, travel time savings differ greatly between counties and county origin-destination pairs as discussed in the next sections.

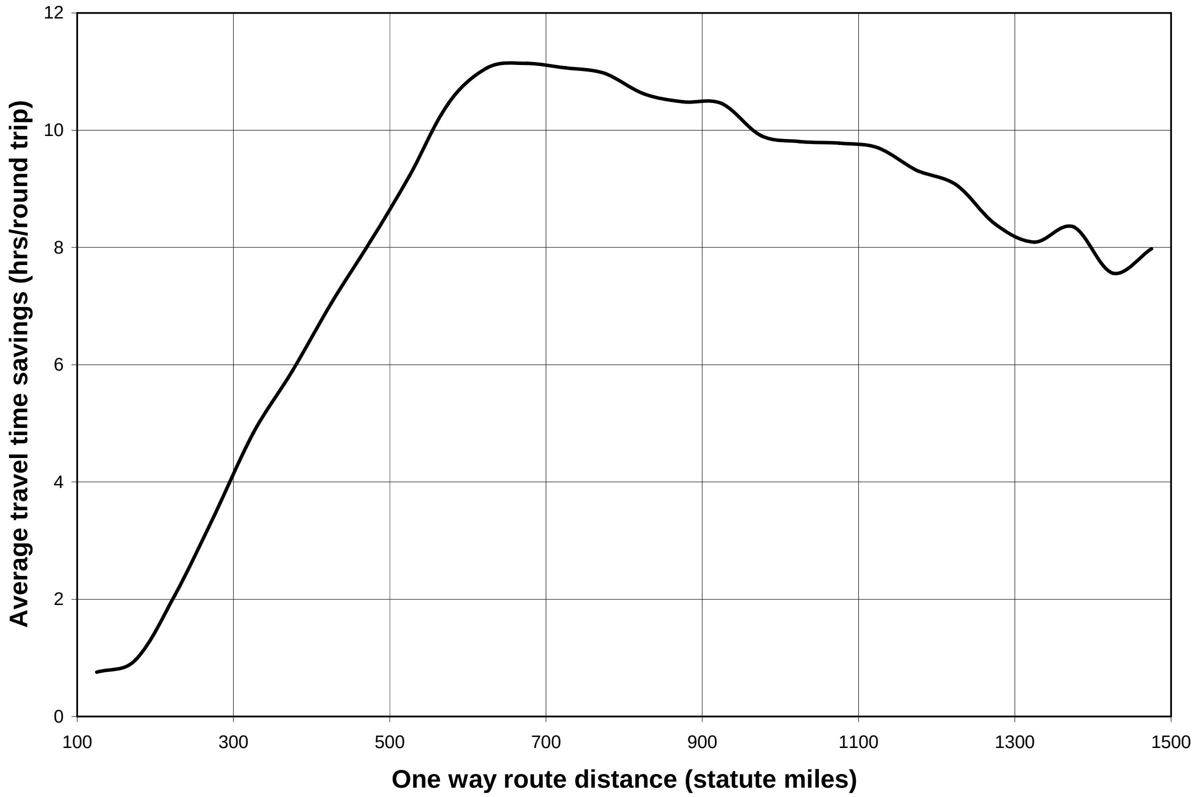


Figure 43: SATS Offers Large Travel Time Savings for Medium Range Round Trips.

National Travel Time Savings

The total travel time savings due to the presence of SATS are not evenly distributed across the United States. The factors influencing the total travel time savings are total demand and automobile, commercial airline and SATS network. The total demand is not evenly distributed across the United States as shown previously in Figures 13 and 14. The automobile, commercial airline and SATS network influence the travel time and travel cost of each mode of transportation. All these factors play a role in the amount of time saved per SATS traveler.

Figures 44 and 45 show the total travel time savings due to the presence of SATS across the United States for business and non-business travelers respectively. It is clearly shown that most travel time savings happen in counties with high travel demand i.e., metropolitan areas.

Also, total travel time savings for business travelers are clearly higher than for non-business travelers, because non-business travelers do not use SATS as much.

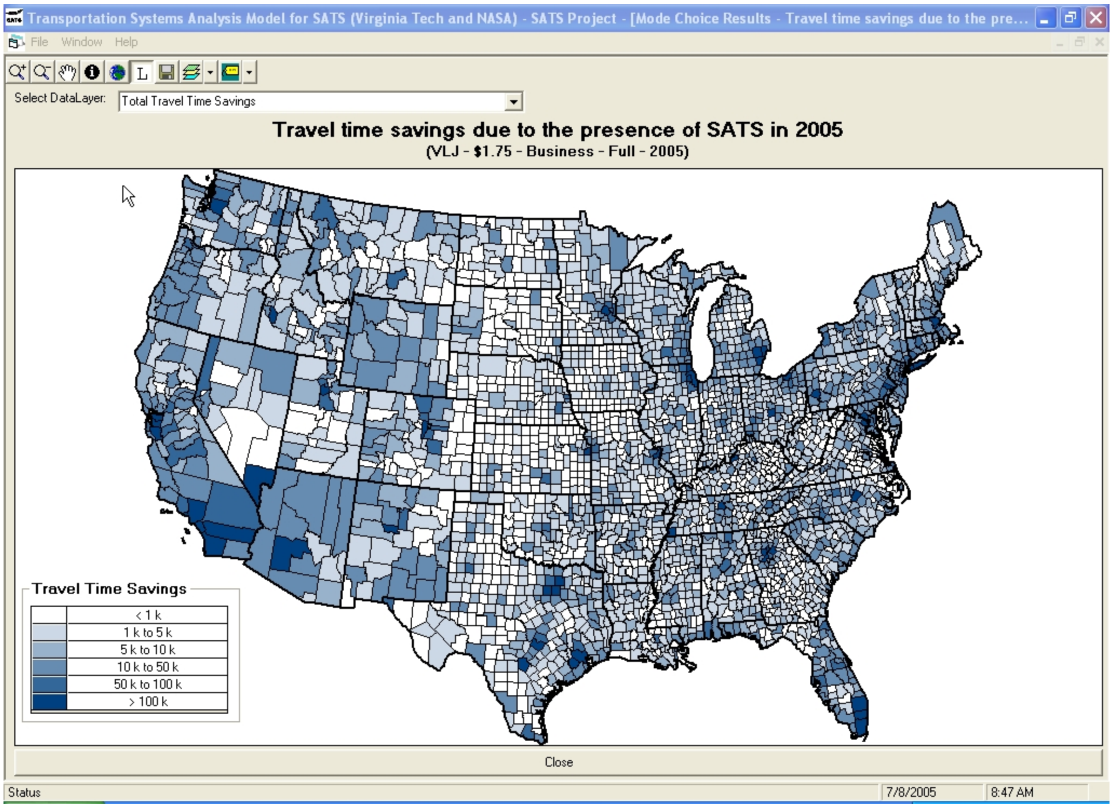


Figure 44: National Total Travel Time Savings for Business SATS Travelers.

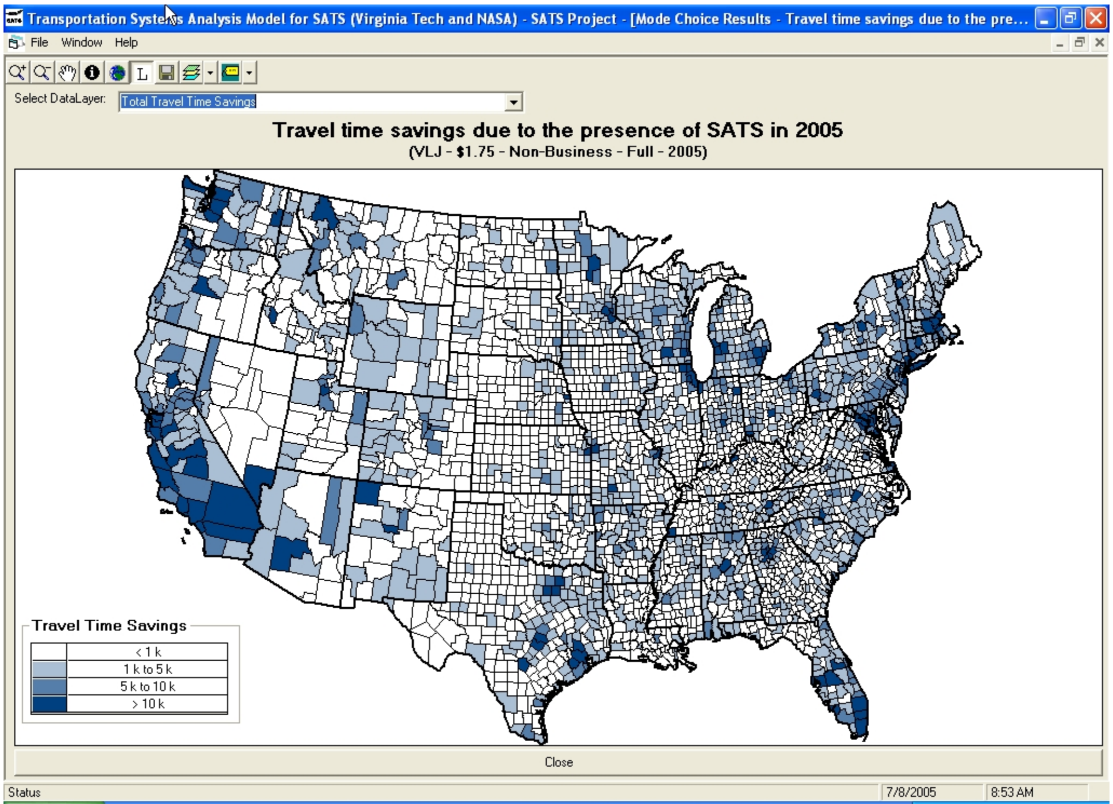


Figure 45: National Total Travel Time Savings for Business SATS Travelers.

The average travel time savings per SATS traveler present a different picture. The higher travel time savings are located in rural areas where the total trip demand is low. This is a complete reversal from the total travel time savings results. SATS time savings are greater in rural areas because its network is more efficient than the automobile and commercial airline networks.

Figures 46 and 47 show the average travel time savings per SATS traveler for business and non-business respectively. Since business travelers are predicted to use SATS for longer trips, business travelers benefit from much better travel time savings compared to the non-business travelers.

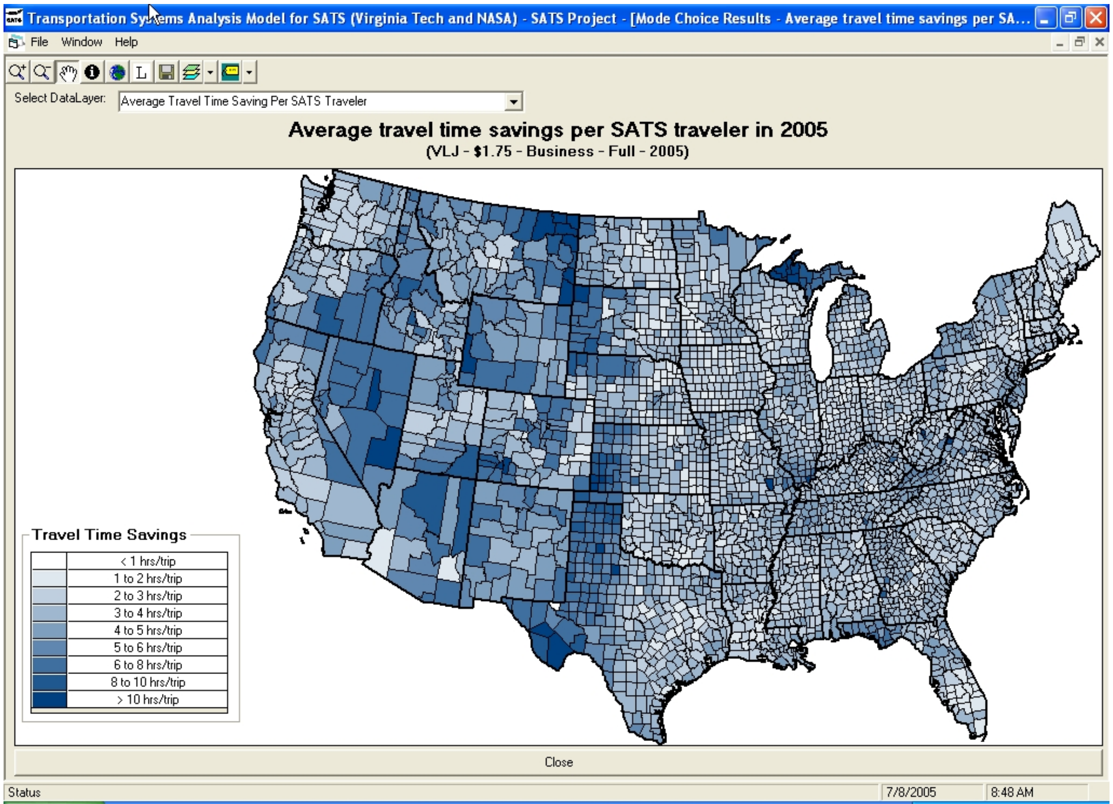


Figure 46: National Average Travel Time Savings for Business SATS Travelers.

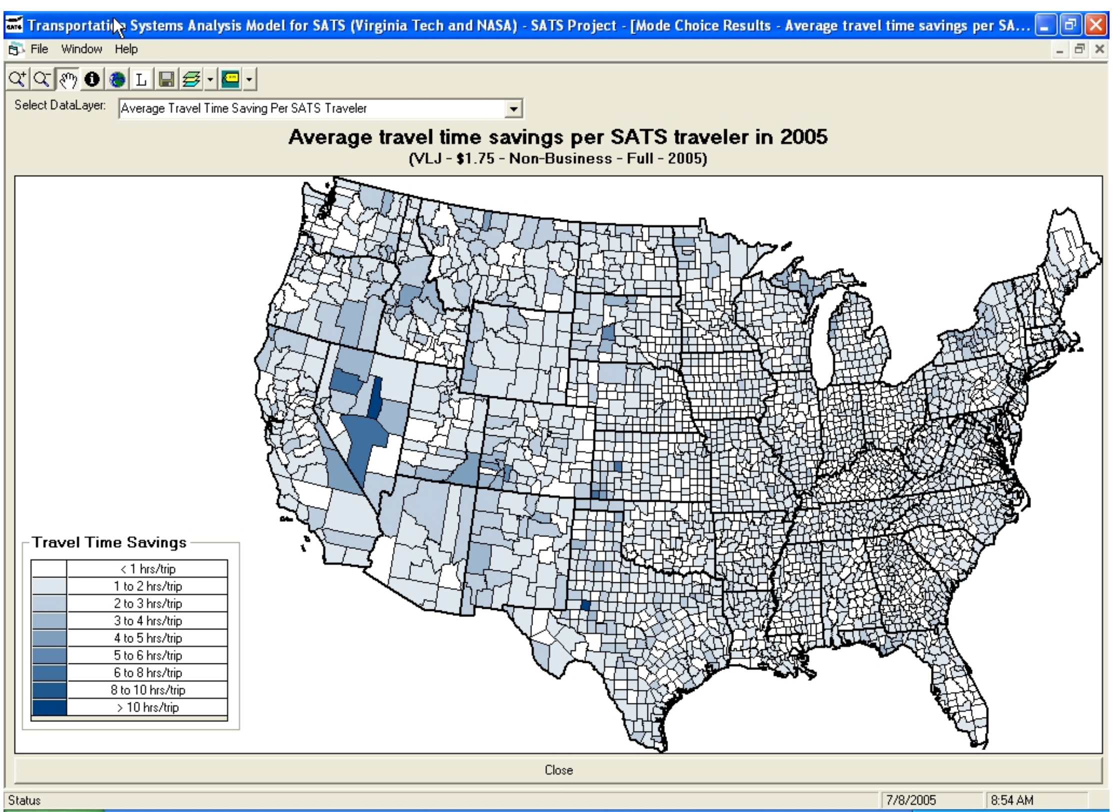


Figure 47: National Average Travel Time Savings for Non-Business SATS Travelers.

County Level Travel Time Savings

TSAM can also display the travel time savings from a focal county to all other counties in the United States. Figure 48 show the total travel time savings due to the availability of SATS travel from Fairfax County, Virginia for business travelers. As expected, most of the travel time savings are between origin-destination pairs with high demand such as metropolitan areas. Figure 49 show the average travel time savings per SATS business traveler from Fairfax County, Virginia. As expected, the higher average travel time savings occur further from the origin and with rural destinations.

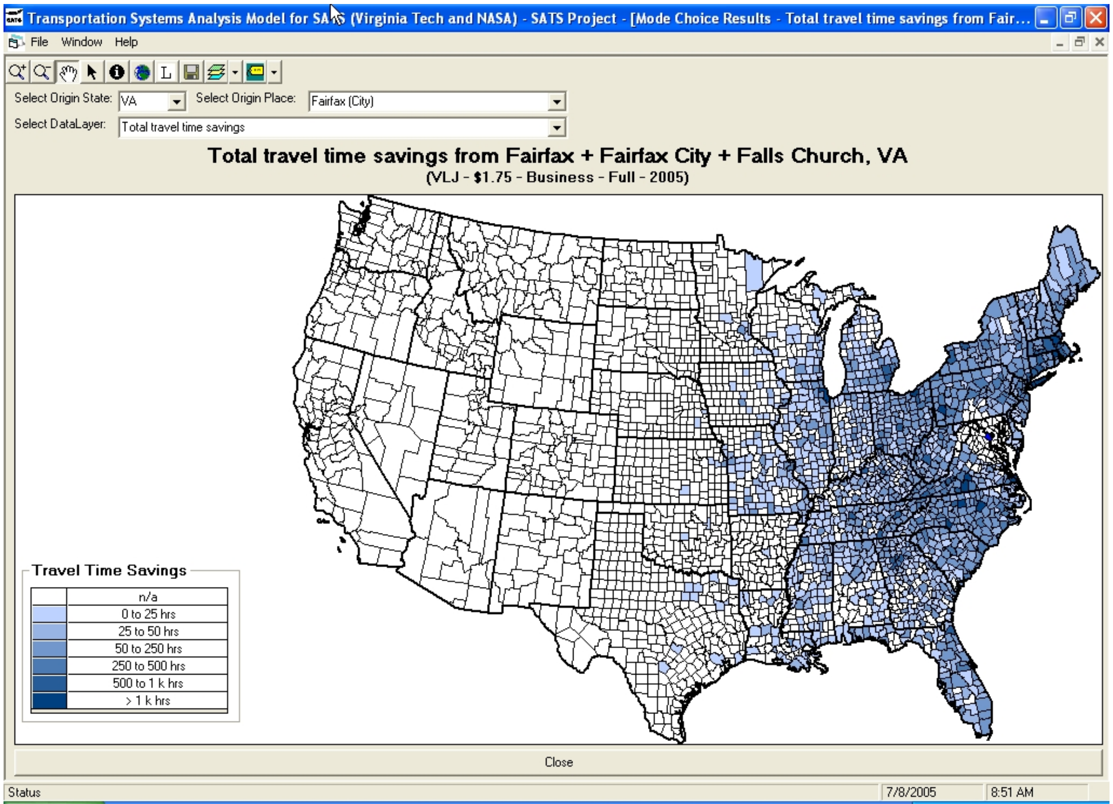


Figure 48: Total Travel Time Savings for Business SATS Travelers from Fairfax County, Virginia.

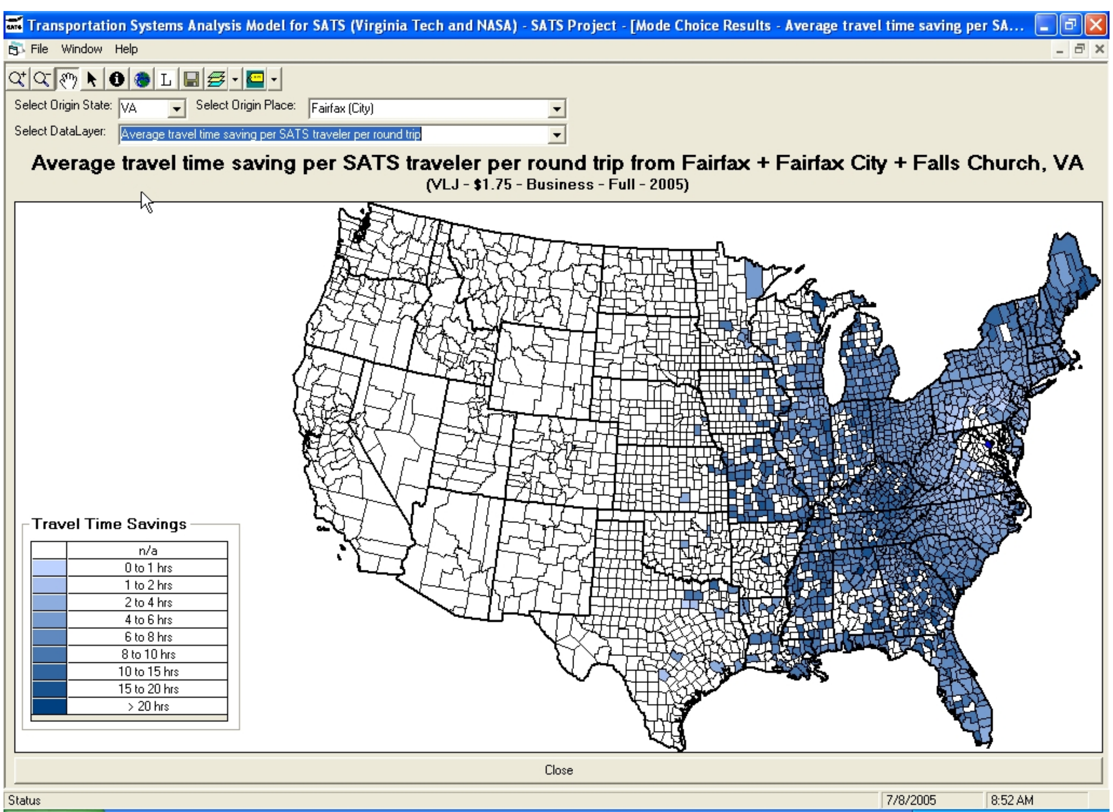


Figure 49: Average Travel Time Savings for Business SATS Travelers from Fairfax County, Virginia.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

5.1.1 Integration of TSAM

The standalone modules of TSAM have been integrated. This eliminated the manual operations required by the user when running analysis in TSAM. The modules have been compiled which, resulted in faster overall running times. Additionally, the operator no longer needs to have expertise in MatLab to run TSAM.

A Graphical User Interface (GUI) was added to TSAM. The GUI improved the usability of the model and eliminated user interaction with the source code previously required to select options for analyses.

Mapping capabilities were also added to TSAM using Geographic Information Systems (GIS) technology. TSAM now automatically maps the inputs and outputs of the different modules allowing the user to analyze the results quickly and spatially. The GUI obviates the need for the user to have expertise in professional GIS software to analyze the results.

The integration also allowed TSAM to become a standalone application. TSAM does not require any third party software to be purchased in order to function. TSAM can also be easily packaged and redistributed allowing it to be installed on any other computer. With these enhancements, the sponsor is now regularly using TSAM to run analysis.

5.1.2 Benefits of TSAM

TSAM is a nationwide transportation systems analysis model. With TSAM an analysts can predict the demand for automobile, commercial airline and SATS into the future. The demand can be estimated for business and non-business travelers and for five income group levels. Additionally, the travel time and travel cost for each mode can be analyzed and compared. Finally, the travel time savings due to the presence of SATS can be calculated.

With all theses results the demand on the interstate network could be derived. These results could be used by the Federal Highway Administration (FHWA) to estimate the future level of service on the interstate network. Using the demand at commercial airports the Federal Aviation Administration (FAA) could estimate future delays at commercial airports. Also, the impact of increased commercial airline travel on the National Air Space (NAS) can be analyzed.

TSAM can be extended to allow analysis of any new mode of transportation such as SATS or improved railroad network. NASA is currently using TSAM to analyze future ridership of SATS compared to automobile and commercial airline. NASA could also use TSAM to analyze other forms of air transportation such as tilt rotor airplanes. Amtrak and the Federal Railroad Administration (FRA) could use TSAM to estimate the impact of an improve railroad network and high speed rail.

TSAM is a flexible model that can theoretically allow analysis of any mode of transportation and estimate its future demand. Therefore, TSAM is well suited for any analyses involving new modes of transportation. TSAM can also be used for corridor analysis in order to analyze localized improvements to a network.

5.1.3 SATS Travel Time Savings

The travel time savings calculation and results show that SATS is a time savings mode of transportation when compared to automobile and commercial airline. Business travelers save about 3.3 hours per round trip when using SATS. Non-business travelers save only 1.1 hours per round trip.

In all but in limited number of exceptions, SATS is the fastest mode in the United States. For certain very short trips automobile is faster, while for certain very long trips, commercial airline is faster. In the great majority of cases SATS saves traveler's time.

5.2 Recommendations

TSAM was integrated using Microsoft Visual Basic 6. This version came out in 1998. TSAM's GUI should be upgraded to Microsoft Visual Basic .NET to be up to date with today's technology standard. After upgrading TSAM's GUI to Microsoft Visual Basic .NET it could be ported to the internet rather easily.

The reduction of TSAM's running times should be investigated using newly available technologies such as parallel programming and clustering. The Distributed Computing MatLab Toolbox is available to add these functionalities to current MatLab code. However, it cannot be compiled at this time and therefore it will prevent a full integration into Visual Basic.

6. REFERENCES

- Arampatzis G, Kiranoudis C.T., Scaloubacas P., Assimacopoulos D., “A GIS-based decision support system for planning urban transportation policies”, European Journal of Operational Research, 2002

- Ashiabor, Senanu, Mode Choice Module, ATSL NASA Report, 2003, http://128.173.204.63/vasats/VT_FY03_final.pdf

- ATS, American Travel Survey, Bureau of Transportation Statistics, 1995, http://www.bts.gov/publications/1995_american_travel_survey/index.html

- BADA, EUROCONTROL BADA MODEL, Version 3.X, http://www.eurocontrol.int/eec/public/standard_page/ACE_bada.html

- Baik, Hojong, Trip Generation Module, ATSL NASA Report, 2003, http://128.173.204.63/vasats/VT_FY03_final.pdf

- Baik,, Hojong, Trip Distribution Module, ATSL NASA Report, 2003, http://128.173.204.63/vasats/VT_FY03_final.pdf

- BMHSR, “Boston to Montreal High-Speed Rail Planning and Feasibility Study”, 2003, http://www.bostonmontrealhsr.org/library.htm

- DB1B, Bureau of Transportation Statistics (BTS), 2000, http://www.transtats.bts.gov/DatabaseInfo.asp?DB_ID=125&DB_URL=

- Murthy, Krishna, Commercial Airline Fares, ATSL NASA Report, 2003, http://128.173.204.63/vasats/VT_FY03_final.pdf

- NTM, “The National Transport Model: Overview”, Department of Transport, UK, 2002, http://www.dft.gov.uk/stellent/groups/dft_econappr/documents/divisionhomepage/030708.hcsp

- OAG, Official Airline Guide, 2001, http://www.oag.com/

- SATS, Small Aircraft Transportation System, NASA Langley, http://sats.larc.nasa.gov/

- Seshadri, Anand Commercial Airline Travel Times, ATSL NASA Report, 2003, http://128.173.204.63/vasats/VT_FY03_final.pdf

- Teorodovic, Dusan, “Airline Operations Research”, Gordon and Breach Science Publishers, 1988

- Trani A. A., Baik H., Swingle H., Ashiabor S., “Integrated Model for Studying Small Aircraft Transportation System”, Transportation Research Record - Aviation, No. 1850, 2003

- Wang X, “Integrating GIS, simulation models, and visualization in traffic impact analysis”, Computers, Environment and Urban Systems, 2004

- W&P, Woods & Poole Economics, 2003, http://www.woodsandpoole.com/

- Xu, Yue, Low Landing Minima (LLM), ATSL NASA Report, 2003, http://128.173.204.63/vasats/VT_FY03_final.pdf

APPENDIX A: FLOWCHARTS

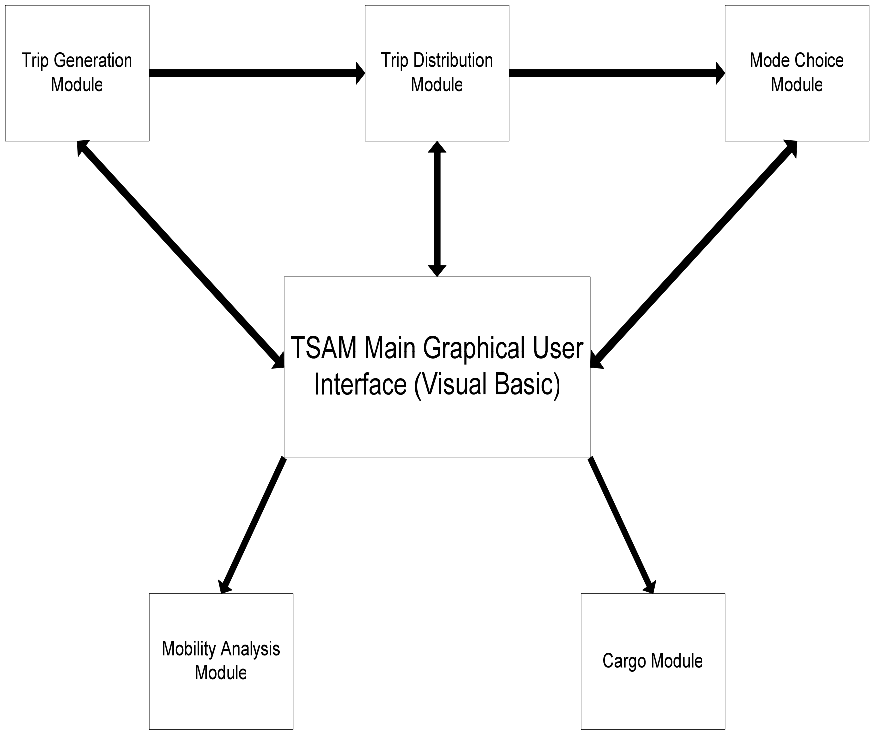


Figure 50: Flowchart Showing the Main Structure of TSAM.

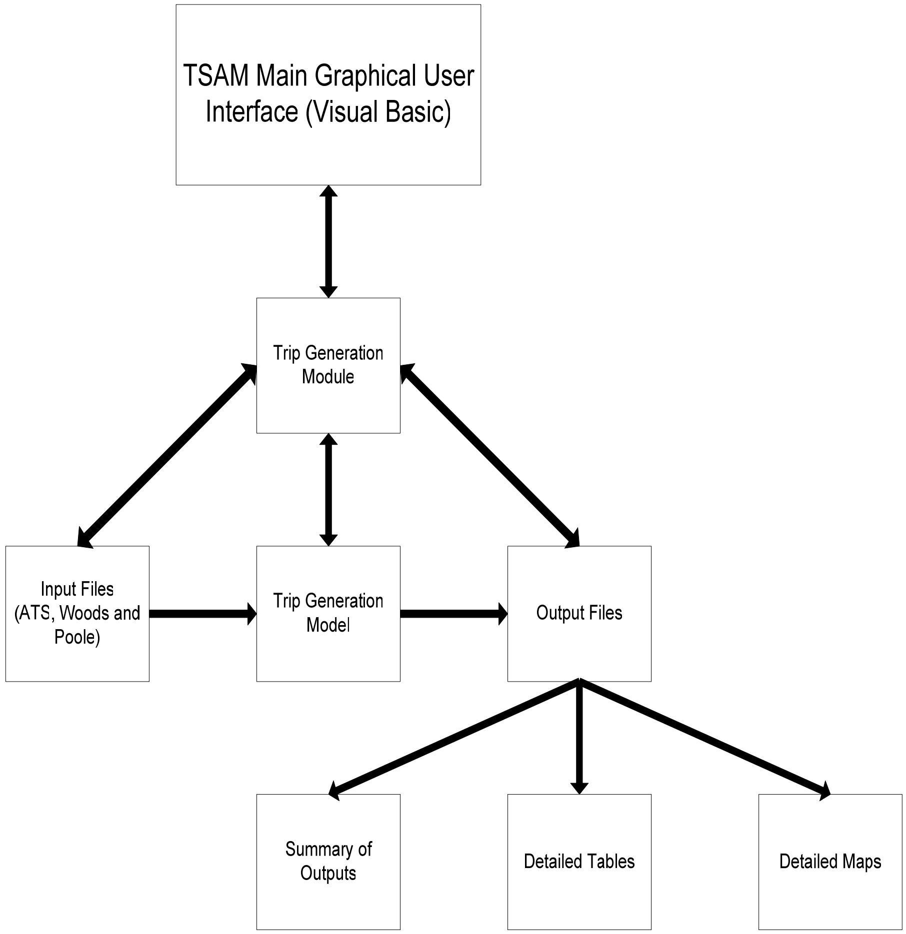


Figure 51: Flowchart Showing the Structure of the Trip Generation Module in TSAM.

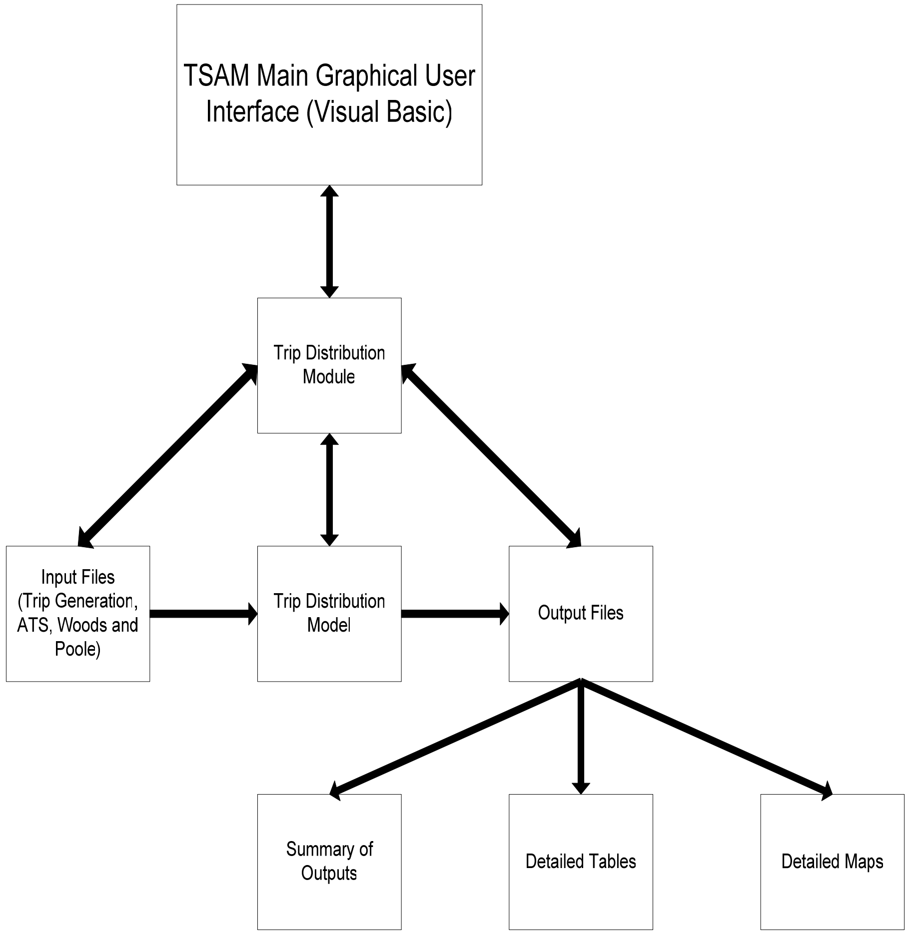


Figure 52: Flowchart Showing the Structure of the Trip Distribution Module in TSAM.

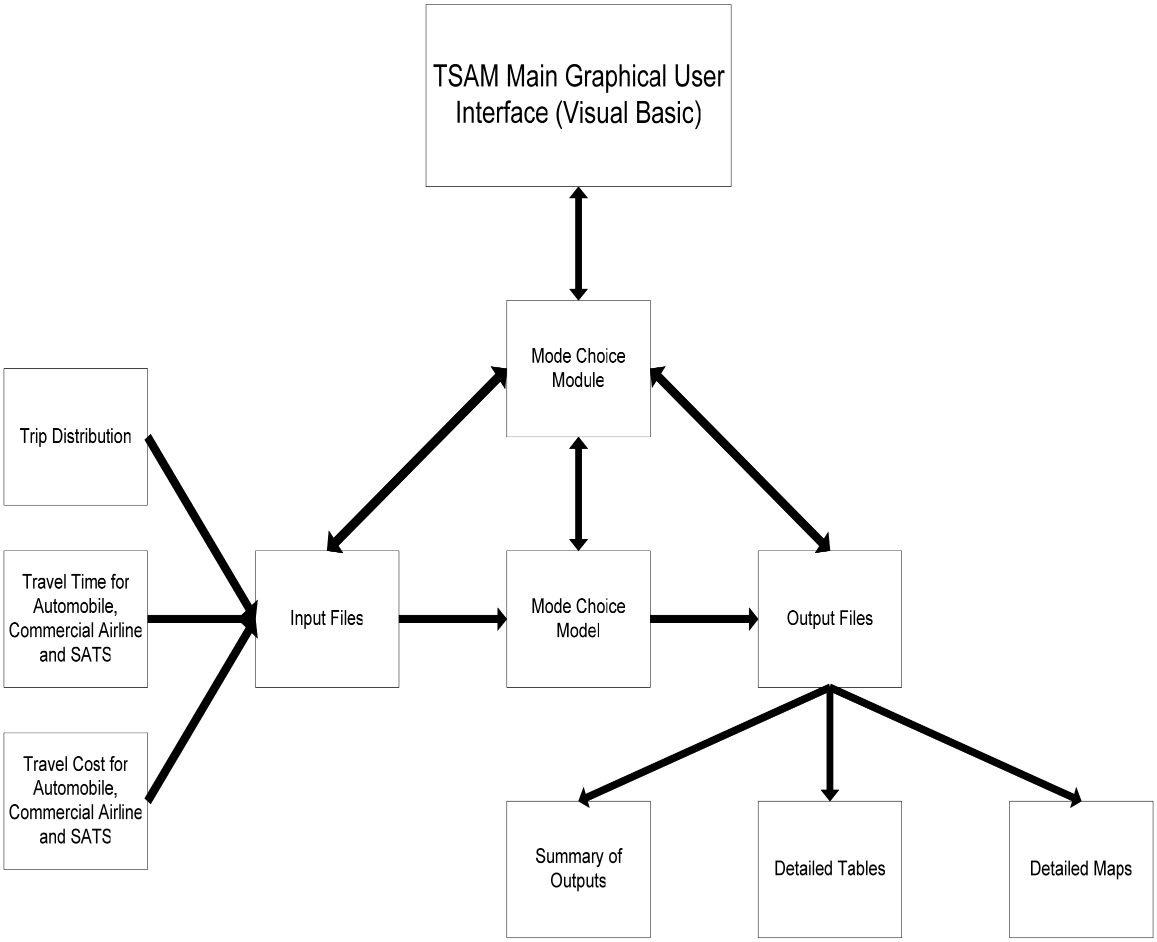


Figure 53: Flowchart Showing the Structure of the Mode Choice Module in TSAM.

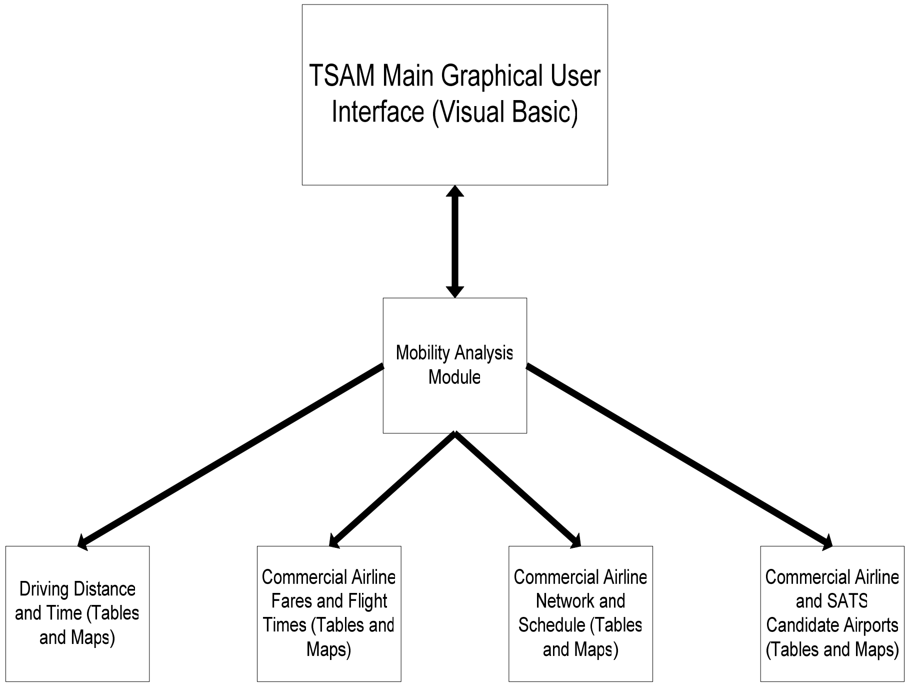


Figure 54: Flowchart Showing the Structure of the Mobility Analysis Module in TSAM.

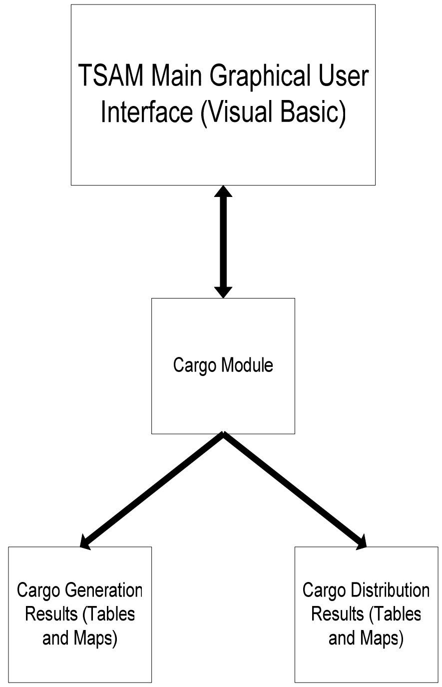


Figure 55: Flowchart Showing the Structure of the Cargo Module in TSAM.

APPENDIX B: FUNCTIONS LIST

Table 2: Main TSAM Graphical User Interface Function List.

Number	Function Name	Programming Language	Function Calls	Description
1	frm_Main.frm	Visual Basic	frm_TreeView.frm frm_Intro.frm frm_NewProject.frm	Manages the basic appearance of the GUI. Creates, loads and saves projects.
2	frm_TreeView.frm	Visual Basic	Everything	Displays the navigational menu to all the modules in the TSAM GUI.
3	frm_Intro.frm	Visual Basic	None	Displays the credits when a new project is opened.
4	frm_NewProject.frm	Visual Basic	None	Creates a new project with the appropriate folder structure.

Table 3: Trip Generation Module Function List.

Number	Function Name	Programming Language	Function Calls	Description
1	frm_TG_SelectInputs.frm	Visual Basic	None	Imports the Woods & Poole input files.
2	TripGeneration.m	MatLab (DLL)	None	Trip Generation Model programmed by Dr. Hojong Baik
3	frm_TG_Settings_Overview.frm	Visual Basic	None	Shows the settings used in the Trip Generation Model
4	frm_TG_Summary.frm	Visual Basic	ReadTripGenerationSummaryResults.m	Displays the summary of the Trip Generation Model results
5	ReadTripGenerationSummaryResults.m	MatLab (DLL)	None	Retrieves the summary of the Trip Generation Model results
6	frm_TG_States_Tables.frm	Visual Basic	ReadTripGenerationStateSummaryResults.m	Displays the summary of the Trip Generation Model results by State
7	ReadTripGenerationStateSummaryResults.m	MatLab (DLL)	None	Retrieves the summary of the Trip Generation Model results by State
8	frm_TG_Tables	Visual Basic	ReadTripGenerationTables.m	Displays the detailed Trip Generation Model results as a table
9	frm_TG_Maps	Visual Basic	ReadTripGenerationTables.m	Displays the detailed Trip Generation Model results as a map
10	ReadTripGenerationTables.m	MatLab (DLL)	None	Retrieves the detailed Trip Generation Model results

Table 4: Trip Distribution Module Function List.

Number	Function Name	Programming Language	Function Calls	Description
1	frm_TripDistribution.frm	Visual Basic	TripDistribution.m	Front screen for the Trip Distribution Model options
2	TripDistribution.m	MatLab (DLL)	SplitTripDistOutput_buss.m SplitTripDistOutput_nonbuss.m SplitTripDisttributionByNonGAandGA.m SummarizeTripDistribution.m aggregateCountyTrips2StateTrips.m applyTripDistrbutionModel.m calcEstTripTable_4.m calcOiDj.m factoring.m progress.m splitByGA_Access_Smooth.m splitByIncome5Group.m summarizeCounty2State.m	Trip Distribution Model programmed by Dr. Hojong Baik
3	frm_TD_Settings_Overview.frm	Visual Basic	None	Shows the settings used in the Trip Distribution Model
4	frm_TD_Business_Summary.frm	Visual Basic	ReadTripDistributionSummaryResults.m	Displays the summary of the Business Trip Distribution Model results
5	frm_TD_NonBusiness_Summary.frm	Visual Basic	ReadTripDistributionSummaryResults.m	Displays the summary of the Non-Business Trip Distribution Model results
5	ReadTripDistributionSummaryResults.m	MatLab (DLL)	None	Retrieves the summary of the Trip Distribution Model results
6	frm_TD_States_Tables.frm	Visual Basic	ReadTripDistributionStateToSt	Displays the summary of the Trip

			ateResults.m	Distribution Model results by State
7	ReadTripDistributionStateToStateResults.m	MatLab (DLL)	None	Retrieves the summary of the Trip Distribution Model results by State
8	frm_TD_Tables	Visual Basic	ReadTripDistributionTable.m	Displays the detailed Trip Distribution Model results as a table
9	frm_TD_Maps	Visual Basic	ReadTripGenerationTables.m	Displays the detailed Trip Distribution Model results as a map
10	ReadTripGenerationTables.m	MatLab (DLL)	None	Retrieves the detailed Trip Distribution Model results
11	frm_TD_PleaseWait.frm	Visual Basic	None	Displays a status bar while the Trip Distribution Model is running

Table 5: One to One Mode Choice Module Function List.

Number	Function Name	Programming Language	Function Calls	Description
1	frm_MC_1TO1_Input.frm	Visual Basic	frm_MC_Airline_Fares_Scaling_Factor.frm frm_MC_Airport_Processing_Times.frm frm_MC_Maximum_Driving_Times_Times.frm frm_MC_CostModel.frm frm_MC_1TO1_Airport_Selection.frm frm_MC_1TO1_CheckTravelTimes.frm frm_MC_1TO1_Detailed_Results.frm frm_MC_1TO1_Marketshare.frm frm_MC_1TO1_PleaseWait.frm ModeChoiceCaptive_OneToOne_SATS.m	Front screen for the one county to one county Mode Choice Model options
2	frm_MC_Airline_Fares_Scaling_Factor.frm	Visual Basic	None	Adjusts the commercial airline fares with a multiplication factor
3	frm_MC_Airport_Processing_Times.frm	Visual Basic	None	Adjusts the airport processing times for commercial and SATS airports
4	frm_MC_Maximum_Driving_Times_Times.frm	Visual Basic	None	Adjusts the maximum driving times by automobile and to SATS airports
5	frm_MC_CostModel.frm	Visual Basic	AircraftCostModel.m	Front screen for the SATS aircraft cost model

6	AircraftCostModel.m	MatLab (DLL)	annual_equivalent_evaluation.m AircraftCostModel.m	SATS Aircraft Cost Model programmed by Dr. Antonio Trani
7	frm_MC_1TO1_Airport_Selection.frm	Visual Basic	None	Displays the candidate airport for Commercial Airline and SATS
8	frm_MC_1TO1_CheckTravelTimes.frm	Visual Basic	None	Displays the driving directions to and from the Commercial and SATS airports
9	frm_MC_1TO1_Detailed_Results.frm	Visual Basic	None	Displays the detailed travel time and travel cost for each transportation mode
10	frm_MC_1TO1_Marketshare.frm	Visual Basic	None	Displays the market share for each transportation mode and income group bracket
11	frm_MC_1TO1_PleaseWait.frm	Visual Basic	None	Displays a status bar while the Mode Choice Model is running
12	ModeChoiceCaptive_OneToOne_SATS.m	MatLab (DLL)	selectCandidateAirports_CA.m progress.m nestedLogitFunction_SATS.m nestedLogitFunction_NoSATS.m createModeChoiceTable.m computeSATS_TimeCost.m	Mode Choice Model programmed by Senanu Ashiabor

Table 6: All to All Mode Choice Module Function List.

Number	Function Name	Programming Language	Function Calls	Description
1	frm_MC_ALL2ALL_Run_New_Case.frm	Visual Basic	frm_MC_Airline_Fares_Scaling_Factor.frm frm_MC_Airport_Processing_Times.frm frm_MC_Maximum_Driving_Times_Times.frm frm_MC_CostModel.frm ModeChoiceCaptive_AllToAll_SATS.m	Front screen for the all county to all county Mode Choice Model options
2	ModeChoiceCaptive_AllToAll_SATS.m	MatLab (DLL)	SummarizeModeChoiceOutput_All2All_SATS_TTTS.m SummarizeModeChoiceOutput_All2All_CA_TTTS.m SummarizeModeChoiceOutput_All2All_C2C_SATS.m SummarizeModeChoiceOutput_All2All_C2C_CA.m SummarizeModeChoiceOutput_All2All_C2C_Auto.m SummarizeModeChoiceOutput_All2All_Auto_TTTS.m SummarizeModeChoiceOutput_All2All_A2A_SATS.m SummarizeModeChoiceOutput_All2All_A2A_CA.m SummarizeModeChoiceOutput.m roundTripsFnctn_SATS.m	Mode Choice Model programmed by Senanu Ashiabor

			roundTripsFnctn_NoSATS.m progress.m nestedLogitFunction_SATS.m nestedLogitFunction_NoSATS.m createModeChoiceTable.m ComputeAutoCostAndTime.m BinModelOutput_All2All.m	
3	frm_MC_ALL2ALL_PleaseWait.frm	Visual Basic	None	Displays a status bar while the Mode Choice Model is running
4	frm_MC_ALL2ALL_Airports_Tables.frm	Visual Basic	ReadAirportTotalTripsTable_SATS.m	Displays the demand at the Commercial and SATS airports as a table
5	frm_MC_ALL2ALL_Airports_Maps.frm	Visual Basic	ReadAirportTotalTripsTable_SATS.m	Displays the demand at the Commercial and SATS airports as a map
6	ReadAirportTotalTripsTable_SATS.m	MatLab (DLL)	None	Retrieves the demand at the Commercial and SATS airports
7	frm_MC_ALL2ALL_Airports2All_Tables.frm	Visual Basic	ReadAirportToAirportTables_SATS.m	Displays the demand from the Commercial and SATS airports to all other airports as a table
8	frm_MC_ALL2ALL_Airports2All_Maps.frm	Visual Basic	ReadAirportToAirportTables_SATS.m	Displays the demand from the Commercial and SATS airports to all other airports as a map
9	ReadAirportToAirportTables_SATS.m	MatLab (DLL)	None	Retrieves the demand from the Commercial and SATS airports to all other airports
10	frm_MC_ALL2ALL_NW_Tables.frm	Visual Basic	ReadModeChoiceTripTables_SATS.m	Displays the demand at the county level for all transportation modes as a table

11	frm_MC_ALL2ALL_NW_Maps.frm	Visual Basic	ReadModeChoiceTripTables_SATS.m	Displays the demand at the county level for all transportation modes as a map
12	frm_MC_ALL2ALL_C2All_Tables.frm	Visual Basic	ReadModeChoiceTripTables_SATS.m	Displays the demand at the county level to all other counties for all transportation modes as a table
13	frm_MC_ALL2ALL_C2All_Maps.frm	Visual Basic	ReadModeChoiceTripTables_SATS.m	Displays the demand at the county level to all other counties for all transportation modes as a map
14	ReadModeChoiceTripTables_SATS.m	MatLab (DLL)	None	Retrieves the demand at the county level for all transportation modes
15	frm_MC_ALL2ALL_NW_Marketshare_Tables.frm	Visual Basic	ReadMarketshareOutput_SATS.m	Displays the market share at the county level for all transportation modes as a table
16	frm_MC_ALL2ALL_NW_Marketshare_Maps.frm	Visual Basic	ReadMarketshareOutput_SATS.m	Displays the market share at the county level for all transportation modes as a map
17	frm_MC_ALL2ALL_C2All_Marketshare_Tables.frm	Visual Basic	ReadMarketshareOutput_SATS.m	Displays the market share at the county level to all other counties for all transportation modes as a table
18	frm_MC_ALL2ALL_C2All_Marketshare_Maps.frm	Visual Basic	ReadMarketshareOutput_SATS.m	Displays the market share at the county level to all other counties for all transportation modes as a map
19	ReadMarketshareOutput_SATS.m	MatLab (DLL)	None	Retrieves the market share at the county level for all transportation modes
20	frm_MC_ALL2ALL_C2All_TC_Tables.frm	Visual Basic	ReadTravelCostTables_SATS.m	Displays the travel cost at the county level to all other counties for all transportation modes as a table

21	frm_MC_ALL2ALL_C2All_TC_Maps.frm	Visual Basic	ReadTravelCostTables_SATS.m	Displays the travel cost at the county level to all other counties for all transportation modes as a map
22	ReadTravelCostTables_SATS.m	MatLab (DLL)	None	Retrieves the travel cost at the county level for all transportation modes
23	frm_MC_ALL2ALL_C2All_TCC_Tables.frm	Visual Basic	ReadTravelCostComparison_SATS.m	Displays the travel cost comparison at the county level to all other counties between all transportation modes as a table
24	frm_MC_ALL2ALL_C2All_TCC_Maps.frm	Visual Basic	ReadTravelCostComparison_SATS.m	Displays the travel cost comparison at the county level to all other counties between all transportation modes as a map
25	ReadTravelCostComparison_SATS.m	MatLab (DLL)	None	Retrieves the travel cost comparison at the county level to all other counties between all transportation modes
26	frm_MC_ALL2ALL_C2All_TCCM_Tables.frm	Visual Basic	ReadTravelCostCheapestMode_SATS.m	Displays the cheapest transportation mode at the county level to all other counties as a table
27	frm_MC_ALL2ALL_C2All_TCCM_Maps.frm	Visual Basic	ReadTravelCostCheapestMode_SATS.m	Displays the cheapest transportation mode at the county level to all other counties as a map
28	ReadTravelCostCheapestMode_SATS.m	MatLab (DLL)	None	Retrieves the cheapest transportation mode at the county level to all other counties
29	frm_MC_ALL2ALL_C2All_TT_Tables.frm	Visual Basic	ReadTravelTimeTables_SATS.m	Displays the travel time at the county level to all other counties for all transportation modes as a table

30	frm_MC_ALL2ALL_C2All_TT_Maps.frm	Visual Basic	ReadTravelTimeTables_SATS.m	Displays the travel time at the county level to all other counties for all transportation modes as a map
31	ReadTravelTimeTables_SATS.m	MatLab (DLL)	None	Retrieves the travel time at the county level to all other counties for all transportation modes
32	frm_MC_ALL2ALL_C2All_TTC_Tables.frm	Visual Basic	ReadTravelTimeComparison_SATS.m	Displays the travel time comparison at the county level to all other counties between all transportation modes as a table
33	frm_MC_ALL2ALL_C2All_TTC_Maps.frm	Visual Basic	ReadTravelTimeComparison_SATS.m	Displays the travel time comparison at the county level to all other counties between all transportation modes as a map
34	ReadTravelTimeComparison_SATS.m	MatLab (DLL)	None	Retrieves the travel time comparison at the county level to all other counties between all transportation modes
35	frm_MC_ALL2ALL_C2All_TTFM_Tables.frm	Visual Basic	ReadTravelTimeFastestMode_SATS.m	Displays the fastest transportation mode at the county level to all other counties as a table
36	frm_MC_ALL2ALL_C2All_TTFM_Maps.frm	Visual Basic	ReadTravelTimeFastestMode_SATS.m	Displays the fastest transportation mode at the county level to all other counties as a map
37	ReadTravelTimeFastestMode_SATS.m	MatLab (DLL)	None	Retrieves the fastest transportation mode at the county level to all other counties
38	frm_MC_ALL2ALL_TravelTimeSavings_Tables.frm	Visual Basic	ReadTravelTimeSavings_SATS.m	Displays the travel time savings due to the presence of SATS at the county level as a table

39	frm_MC_ALL2ALL_TravelTimeSavings_Maps.frm	Visual Basic	ReadTravelTimeSavings_SATS.m	Displays the travel time savings due to the presence of SATS at the county level as a map
40	frm_MC_ALL2ALL_C2All_TravelTimeSavings_Tables.frm	Visual Basic	ReadTravelTimeSavings_SATS.m	Displays the travel time savings due to the presence of SATS at the county level to all other counties as a table
41	frm_MC_ALL2ALL_C2All_TravelTimeSavings_Maps.frm	Visual Basic	ReadTravelTimeSavings_SATS.m	Displays the travel time savings due to the presence of SATS at the county level to all other counties as a map
42	ReadTravelTimeSavings_SATS.m	MatLab (DLL)	None	Retrieves the travel time savings due to the presence of SATS at the county level to all other counties
43	frm_MC_ALL2ALL_SATSFlightProfile_Table.frm	Visual Basic	ReadFlightSpeedProfileSATS.m	Displays the SATS average speed versus distance as a table
44	frm_MC_ALL2ALL_SATSFlightProfile_Plot.frm	Visual Basic	ReadFlightSpeedProfileSATS.m	Displays the SATS average speed versus distance as a plot
45	ReadFlightSpeedProfileSATS.m	MatLab (DLL)	None	Retrieves the SATS average speed versus distance
46	frm_MC_ALL2ALL_Summary.frm	Visual Basic	ReadSummarizedModeChoiceOutput_SATS.m	Displays the summary of all the Mode Choice results as a table
47	ReadSummarizedModeChoiceOutput_SATS.m	MatLab (DLL)	None	Retrieves the summary of all the Mode Choice results

Table 7: Mobility Analysis Module Function List.

Number	Function Name	Programming Language	Function Calls	Description
1	frm_A2A_TC_Tables.frm	Visual Basic	ReadAirportToAirportTravelCost_SATS.m	Displays the DB1B fares from each Commercial Airport as a table
2	frm_A2A_TC_Maps.frm	Visual Basic	ReadAirportToAirportTravelCost_SATS.m	Displays the DB1B fares from each Commercial Airport as a map
3	ReadAirportToAirportTravelCost_SATS.m	MatLab (DLL)	None	Retrieves the DB1B fares from each Commercial Airport
4	frm_A2A_TT_Tables.frm	Visual Basic	ReadAirportToAirportTravelTime_SATS.m	Displays the travel time from each Commercial Airport from the OAG schedule as a table
5	frm_A2A_TT_Maps.frm	Visual Basic	ReadAirportToAirportTravelTime_SATS.m	Displays the travel time from each Commercial Airport from the OAG schedule as a map
6	ReadAirportToAirportTravelTime_SATS.m	MatLab (DLL)	None	Retrieves the travel time from each Commercial Airport from the OAG schedule
7	frm_C2CDriveTimeDistance_Maps.frm	Visual Basic	ReadC2CDriveTimeDistanceTables_SATS.m	Displays the driving distance and driving time calculated with MapPoint from all the counties as a table
8	frm_C2CDriveTimeDistance_Tables.frm	Visual Basic	ReadC2CDriveTimeDistanceTables_SATS.m	Displays the driving distance and driving time calculated with MapPoint from all the counties as a map
9	ReadC2CDriveTimeDistanceTables_SATS.m	MatLab (DLL)	None	Retrieves the driving distance and driving time calculated with MapPoint from all the counties

10	frm_CA_Network_Maps.frm	Visual Basic	ReadCANetwork_SATS.m	Displays the Commercial Airline network between two airports as a map and a table
11	ReadCANetwork_SATS.m	MatLab (DLL)	None	Retrieves the Commercial Airline network between two airports
12	frm_Airport_Selection_Tables.frm	Visual Basic	ReadCandidateAirports_SATS.m	Displays the candidate airports for Commercial Airline and SATS as a table
13	frm_Airport_Selection_Maps	Visual Basic	ReadCandidateAirports_SATS.m	Displays the candidate airports for Commercial Airline and SATS as a map
14	ReadCandidateAirports_SATS.m	MatLab (DLL)	None	Retrieves the candidate airports for Commercial Airline and SATS

Table 8: Cargo Module Function List.

Number	Function Name	Programming Language	Function Calls	Description
1	frm_CARGO_Generation_County_Tables.frm	Visual Basic	ReadCargoGenerationCountyTables.m	Displays the Cargo Generation Results for each county as a table
2	frm_CARGO_Generation_County_Maps.frm	Visual Basic	ReadCargoGenerationCountyTables.m	Displays the Cargo Generation Results for each county as a map
3	ReadCargoGenerationCountyTables.m	MatLab (DLL)	None	Retrieves the Cargo Generation Results for each county
4	frm_CARGO_Generation_Airports_Tables.frm	Visual Basic	ReadCargoGenerationAirportTables.m	Displays the Cargo Generation Results for each airport as a table
5	frm_CARGO_Generation_Airports_Maps.frm	Visual Basic	ReadCargoGenerationAirportTables.m	Displays the Cargo Generation Results for each airport as a map
6	ReadCargoGenerationAirportTables.m	MatLab (DLL)	None	Retrieves the Cargo Generation Results for each airport
7	frm_CARGO_Distribution_County_Tables.frm	Visual Basic	ReadCargoDistributionCountyTables.m	Displays the Cargo Distribution Results for each county as a table
8	frm_CARGO_Distribution_County_Maps.frm	Visual Basic	ReadCargoDistributionCountyTables.m	Displays the Cargo Distribution Results for each county as a map
9	ReadCargoDistributionCountyTables.m	MatLab (DLL)	None	Retrieves the Cargo Distribution Results for each county
10	frm_CARGO_Distribution_Airport_Tables.frm	Visual Basic	ReadCargoDistributionAirportTables.m	Displays the Cargo Distribution Results for each airport as a table
11	frm_CARGO_Distribution_Airport_Maps.frm	Visual Basic	ReadCargoDistributionAirportTables.m	Displays the Cargo Distribution Results for each airport as a map
12	ReadCargoDistributionAirportTables.m	MatLab (DLL)	None	Retrieves the Cargo Distribution Results for each airport
13	frm_CARGO_GrowthFactors_Airports_Tables.frm	Visual Basic	ReadCargoGrowthFactorsAirportTables.m	Displays the Cargo Growth Factor Results for each airport as a table

14	frm_CARGO_GrowthFactors_Airports_Maps.frm	Visual Basic	ReadCargoGrowthFactorsAirportTables.m	Displays the Cargo Growth Factor Results for each airport as a map
15	ReadCargoGrowthFactorsAirportTables.m	MatLab (DLL)	None	Retrieves the Cargo Growth Factor Results for each airport