Title:

A Transportation Systems Analysis Model (TSAM) to study the impact of the Small Aircraft Transportation System (SATS).

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Abstract:

In this poster, authors explain a System Dynamics model developed for measuring efficiency of the Small Aircraft Transportation System (SATS) that NASA has been developing to enhance intercity travelers' mobility in the country. The model is comprehensive in the sense that it includes multi-modes such as automobile, commercial airlines and rail. It also considers different types of decision makers such as travelers, airlines, Federal Aviation Administration (FAA) and Federal Rail Administration (FRA) that dynamically interact with each other based on its own interest. The model allows users to change several critical but uncertain parameters such as the price for SATS trip, airports for SATS operations, etc. This feature enables users to do "what-if" type of study. Technically, the model is developed as a stand-alone tool with a Graphical User Interface that encloses all computational procedures written in MALTALB. Socio-economic data and computational results are represented at a county level using the Geographical Information System (GIS).

Introduction

The National Aeronautics and Space Administration (NASA) has been developing a new air transportation called “Small Aircraft Transportation System (SATS)” to enhance intercity travelers’ mobility in the country. Unlike conventional General Aviation (GA) vehicles, the new system has been predicated around four advanced technical capabilities [Trani et al., 2003]:

1) High-volume operations at airports without control towers or terminal radar facilities,
2) Lower adverse weather landing minimums at minimally equipped landing facilities,
3) Integration of SATS aircraft into a higher en route capacity air traffic control system with complex flows and slower aircraft, and
4) Improved single-pilot ability to function competently in complex airspace in an evolving NAS.

The SATS is welcome not only by individual pilots but also by the “air-taxi” industry that provides “point-to-point” service transporting passengers based on travelers’ requests. One of the natural and critical questions then becomes: What will be the impact of the SATS technologies on the intercity transportation system?

The potential benefits expected from this new system include: 1) reducing intercity travel time by bypassing congested highway and hub-airports, 2) economic development of all size of cities/towns by providing enhanced accessibility to air transportation, 3) providing environmentally friendly solutions by introducing cutting-edge aircraft manufacturing technologies.

There are many facets in the analysis of SATS technologies and in general in the planning such a system. The assessment of SATS impacts includes 1) demand analysis for the new system, 2) mobility analysis in terms of travel time saving, energy costs/savings, and 3) forecasting the future state of the transportation system if SATS is successful. As a part of this assessment study, the authors have been developing a decision support tool that provides decision makers with answers to some of these complex issues. One example scenario is to estimate the SATS demand if the travel cost for the new mode of transportation is $1.5 per seat per mile rather than $3.5 per seat per miles charged for on-demand air taxi services. Another situation to be explored is the demand if the new aircraft is able to fly reliably from thousands of airports in the U.S. beyond the reach of commercial services.

To answer these and many other questions, authors have developed a Transportation System Analysis Model (TSAM) to study SATS. There are two subjects involved in developing the decision support tool: 1) methods to estimate the potential demand for SATS and to assess the impacts on the existing air transportation system, and 2) techniques to represent the results so that the decision makers can use the tool in a more convenient way.

In this paper, we explain the methods for assessing the demand and impacts, and also introduce the techniques to represent the output data using GIS tools. The remaining part of this paper is organized as follows. In the next section, we present steps for estimating intercity travel demand by mode including SATS. In the following section, we explain the technical components and the structural design of the TSAM model. We then illustrate outputs gathered in several aspects using GIS tools. Finally, we conclude this paper with some remarks and further enhancements to the existing model.

Steps for Assessing SATS Demand and Impacts

The approach to study the deployment of SATS, in the presence of other competing forms of transportation (including electronic commerce and information technologies) is shown in Figure 1. The proposed model is designed based on the Systems Dynamics methodology and incorporates, available submodels to assess the impact of potentially disruptive transportation technologies in society at the national and regional levels. In this context, System Dynamics is implemented as a continuous simulation model to be calibrated using historical data and employing SATS technology demonstration studies as the results become available. Ultimately, the method proposed yields macroscopic measures of effectiveness such as travel times benefits, noise impacts, fuel and energy usage, non-user economic benefits, air transportation system congestion and delays etc.
The diagram shown in Figure 1 includes several important proven feedback loop structures that are characteristic of existing transportation systems and shows their effect on the regional and national economies. It should be remarked that the blocks depicted in Figure 1 have two implicit attributes: 1) time dependencies and 2) spatial dependencies.

Figure 1 also depicts the following critical steps to study the SATS transportation concept from a life cycle point of view. These steps are:

a) Inventory of existing NAS infrastructure including current and future concept of operations (for both SATS and non-SATS aircraft),
b) Intercity trip generation analysis (including in all modes),
c) Intercity trip distribution,
d) Intercity modal split,
e) Trip assignment in air transportation network analysis, and
f) Air transportation system performance assessment.

In the first step, a variety of **inventory** related data describing the current and future air transportation system has been surveyed and analyzed. The inventory encompassed not only air transportation facilities such as airports, runways, air traffic control systems, but also county-based socio-economic data such as population, household income, etc. (The data sets used will be discussed in detail later.) To estimate travel demand, we employ a traditional multi-step modeling process to study travel behaviors. The multi-step modeling process includes: 1) trip generation, 2) trip distribution, 3) mode choice, and 4) trip assignment [Meyer and Miller, 1994; Morlok, 1984].

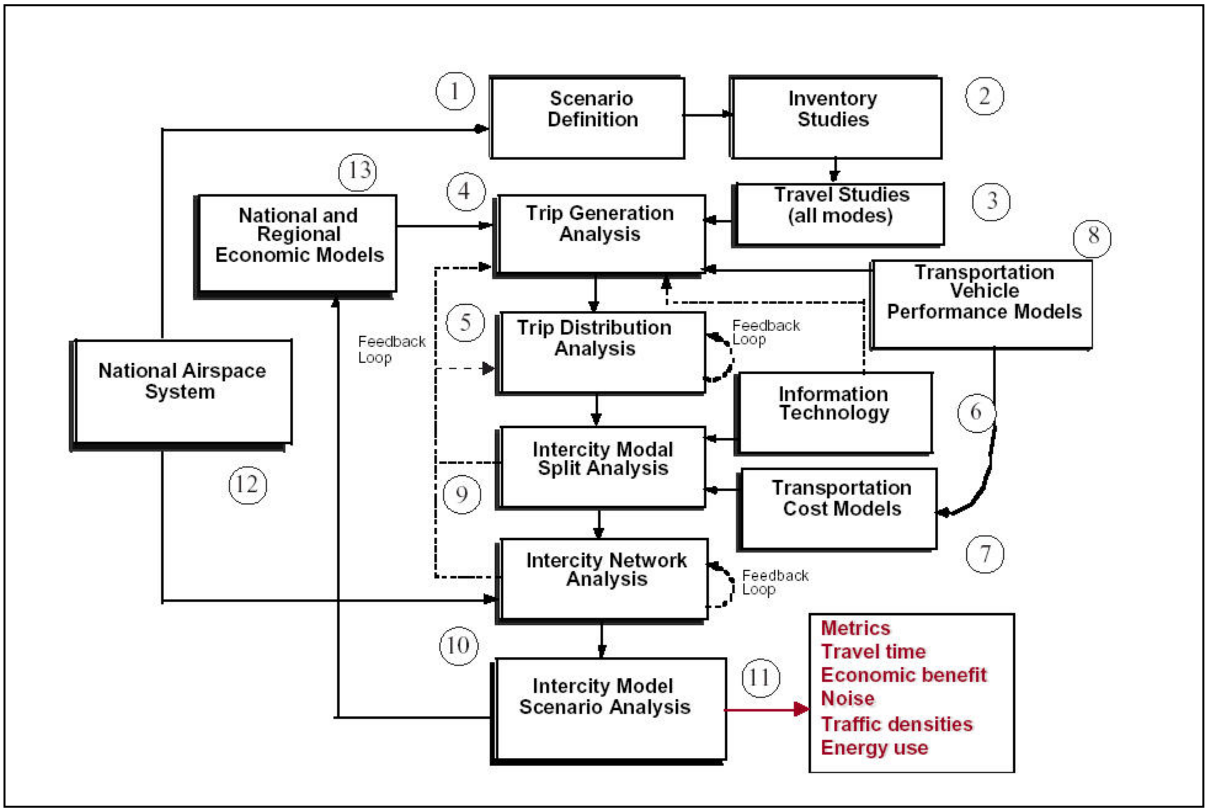

Figure 1. A System Dynamics Approach for Intercity Transportation Analysis.

The modeling process for travel demand is schematically shown in Figure 2. In the Figure, **trip generation** step estimates the number of trips by trip purpose produced by and attracted to each county. Figure 2 illustrates that the output of this procedure is a simple Origin-Destination matrix with two vectors: one for productions and one for attractions. In the **trip distribution** step, we predict origin-destination (O-D) flows, that is, we link the trip ends predicted by the trip generation model to form trip interchanges between counties. This results in a large trip interchange matrix (or sometimes called an origin-destination (O-D) table) showing the number of trips among all county pairs. Note that the units of the trip interchange matrix are person-trips per year between counties. In the trip distribution step, couple of gravity models is calibrated and applied using American Travel Survey (ATS) data. The **Mode Choice** step predicts the percentage of person-trips selecting each mode of transportation while traveling between two counties in the region of interest. The SATS mode competes with conventional transportation modes: i.e., automobile, commercial airline. Figure 2 illustrates that in the mode choice model we decompose the trip interchange matrix obtained in the trip distribution step into three trip interchange matrices representing: 1) automobile mode, 2) commercial airline, and 3) SATS. Note that the output matrices of the mode choice step shown in Figure 2 are also defined at the county level. For the analysis, a so-called "Nested-Logit" model is used after calibration using ATS that provides information on travelers' choices together with travelers' socio-economic characteristics. The **Trip Assignment** step places the O-D flows for each mode of transportation in specific routes of travel throughout the transportation network. In this step, we are also interested in studying the airport-airspace network interactions to assess the impact of SATS operations in the National Airspace System (NAS). This step converts airport-to-airport yearly person-trip O-D tables resulted from the trip assignment step to an airport-to-airport hourly aircraft O-D table using seasonal and hourly variation of trips, average vehicle occupancy rate. Using the airport-to-airport hourly aircraft O-D table, a **Performance assessment** step measures the various types of mobility benefits, costs of the air transportation. The measures include travel times between counties across the country for various mode of transportation, passenger flows between airports, fuel consumption and energy resources used in moving passengers across various O-D pairs, etc. More importantly, the flight demand is also used to measure possible delay at each airport. The delay induced is then used to constraint the demand by adding extra flight time on the air transportation mode. This step also assesses environmental dis-benefits such as noise and emissions which will be used in the feedback to the demand model.

In the modeling process, various types of data sources are used. The American Travel Survey [ATS, 1995] is a data source that is heavily used across the multiple steps such as trip generation, trip distribution, and mode choice steps. For current and future forecast of socio-economic variables, Woods and Poole data [Woods and Poole, 2003] set is used at county level. The mode choice process requires transportation service related variables for each mode among all county pairs. The variables adopted in this research are: travel time and travel cost. The driving times by automobile between county pairs, for instance, are obtained from the Microsoft MapPoint [MapPoint, 2004]. The flight times between origin and destination airports are analyzed using the Official Airline Guide [OAG, 2001]. In this case, the time for transferring aircraft is also considered if it is needed. In order to obtain complete door-to-door travel time by airline, the ground travel time to access to and egress from airport is also considered together with processing time at the airports. The flight ticket price is estimated using the Department of Transportation DB1B Database [DB1B]. (More complete explanation of the methods employed in the model can be found in Trani et al. 2003.)

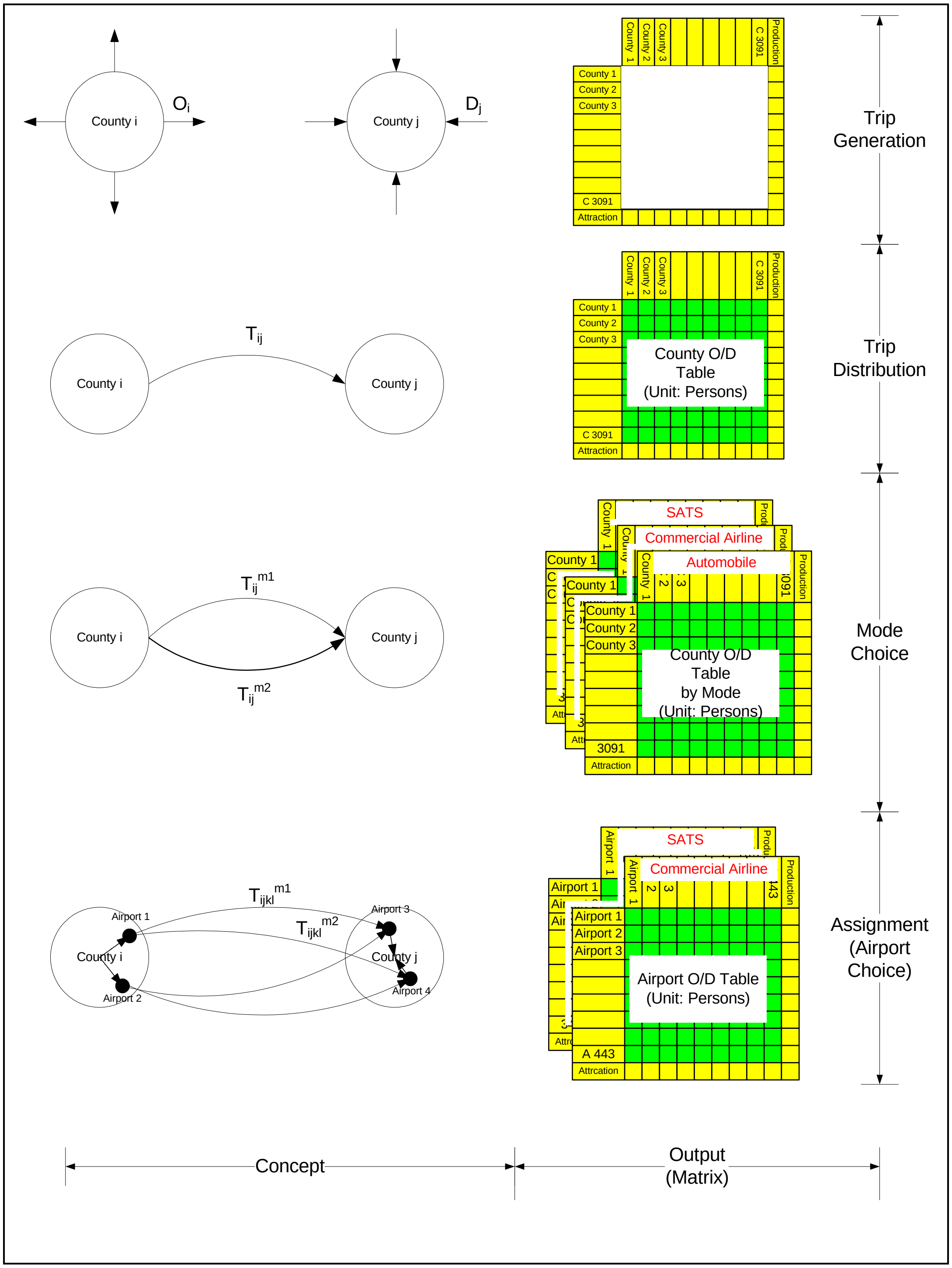

Figure 2. Multi-step Process of Trip Demand Analysis.

Techniques for Developing a Graphical User Interface for the TSAM Model

To facilitate the interaction between decision makers with a complex transportation model, we constructed a stand-alone Graphical User Interface (GUI). The TSAM GUI is designed to include all four computational steps in the transportation systems analysis process and to present the computational results in various formats such as graphs, tables and maps. To implement this GUI TSAM system we employed the following software elements: 1) Microsoft Visual Basic (version 6.0) for GUI development, 2) Mathworks' Matlab (version 7.0) for computational programming, 3) ESRI's MapObjects (version 2.2) as a mapping tool, 4) Microsoft Access 2000 for data management, and 5) Microsoft's MapPoint 2004 for distance calculation between two cities/townsO-D pairs.

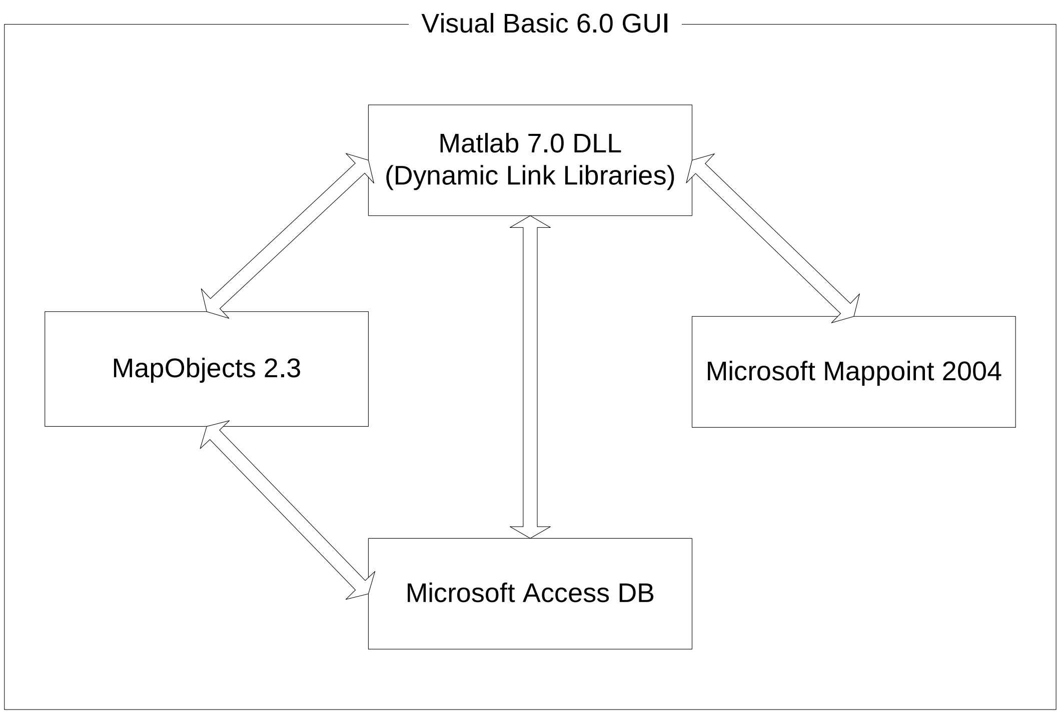

Figure 3. Connections between Developing Tools

Results

The initial screen of the model is shown in Figure 4. Users can navigate the steps using tree menu in the left side of the interface (called the Navigation Window). Figure 5 shows business trips by county estimated in the trip generation step on the U.S. map. Figure 6 illustrates trips traveling from Boston, as an example, to all other counties across the U.S. This is the output of the trip distribution step. The initial screen employed in the Mode Choice step is shown in Figure 7. This screen shows cost alternatives for the auto and SATS modes. For example, the user might want to know the SATS demand function at $1.50 per seat-mile. The model runs to compute the market share by mode using information for each mode including driving time by auto trip, access time to the airport chosen, flight time via commercial flights, flight time by SATS. Figures 8, 9 and 10 show the business trips traveling from Boston by three competing modes: automobile, commercial airline and SATS. In figure 11, predicted total demand from each county by SATS is represented. Figure 12 illustrates the average travel time savings per a traveler using SATS which is one of the key mobility measurements for the SATS Program.

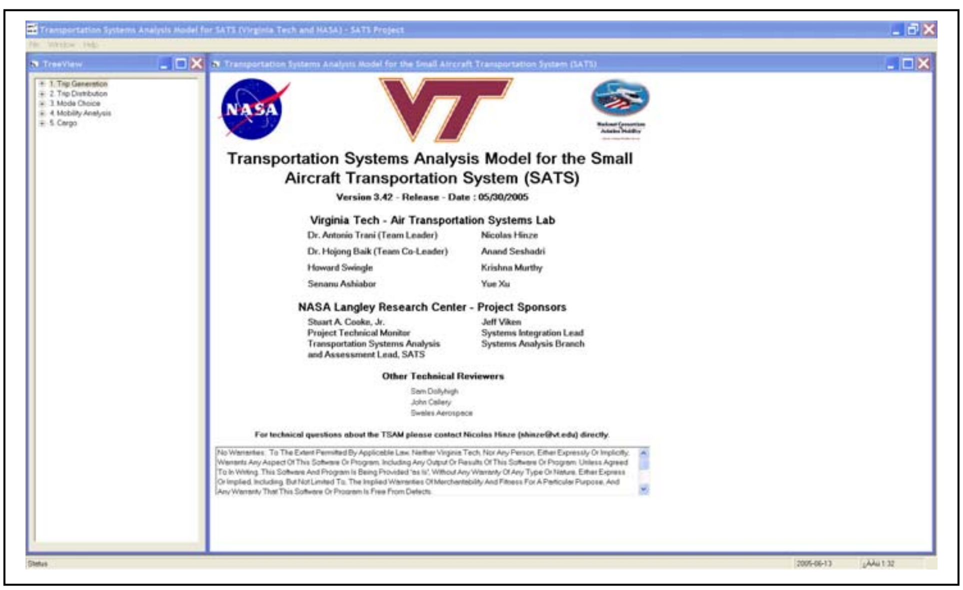

Figure 4. Initial Window of TSAM.

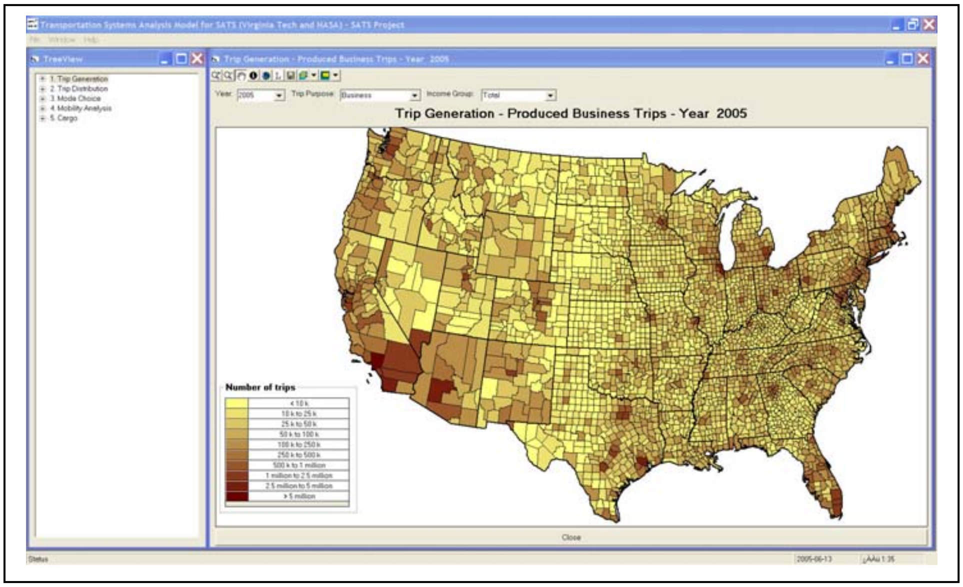

Figure 5. Intercity Trips Generated by County (2005).

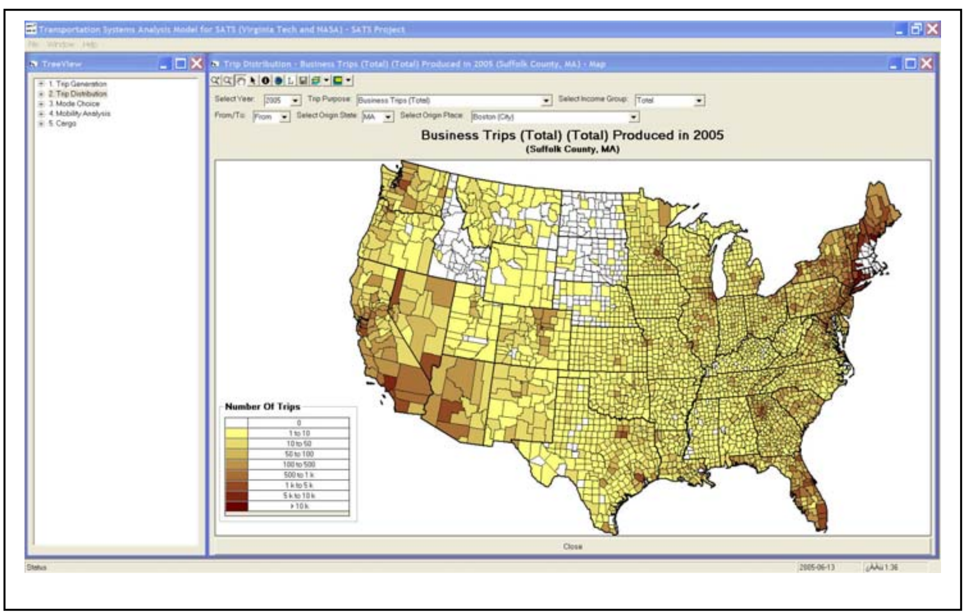

Figure 6. Business Trips Traveling from Boston, MA (2005).

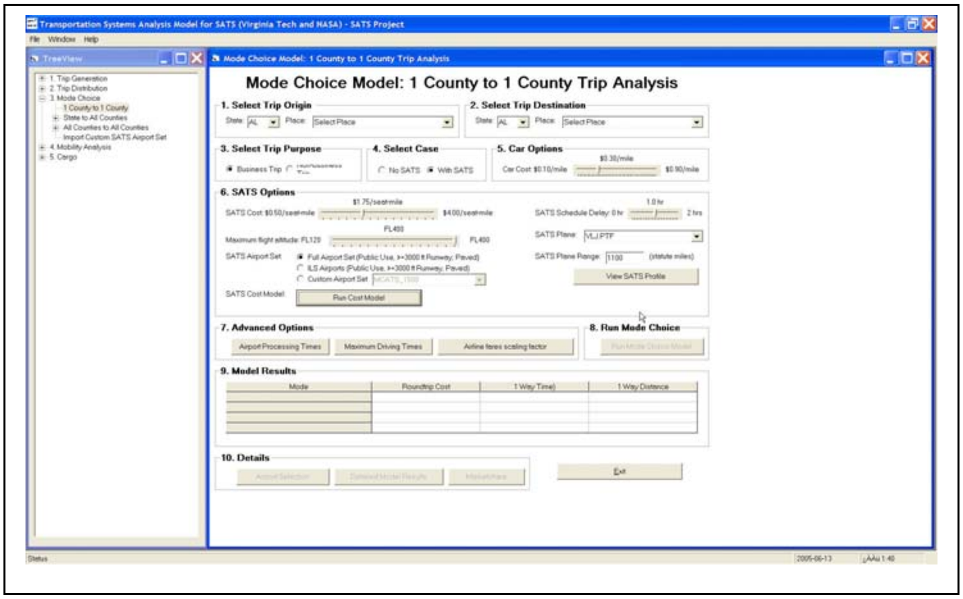

Figure 7. Initial Window for Mode Choice Step.

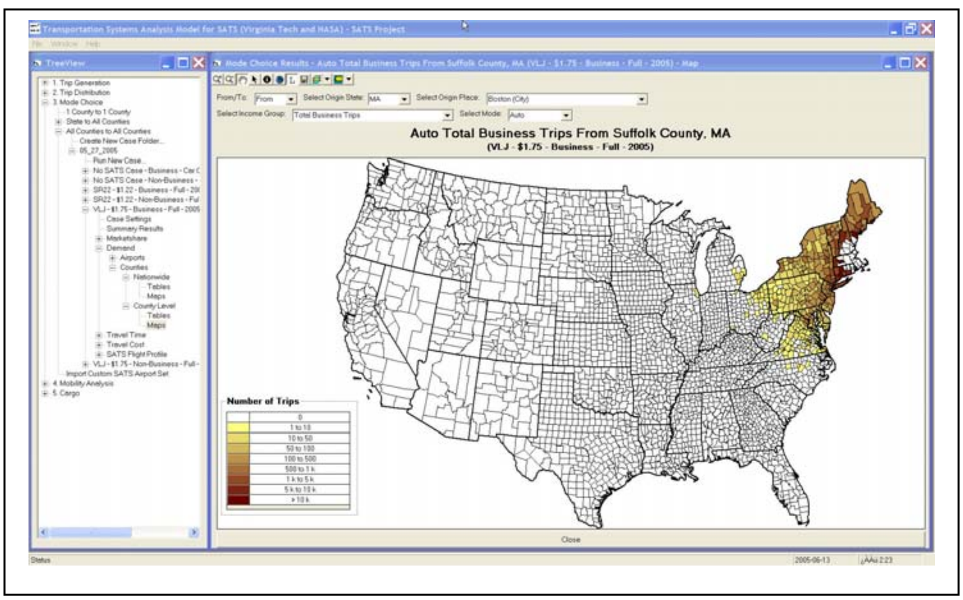

Figure 8. Business Trips Traveling from Boston by Automobile.

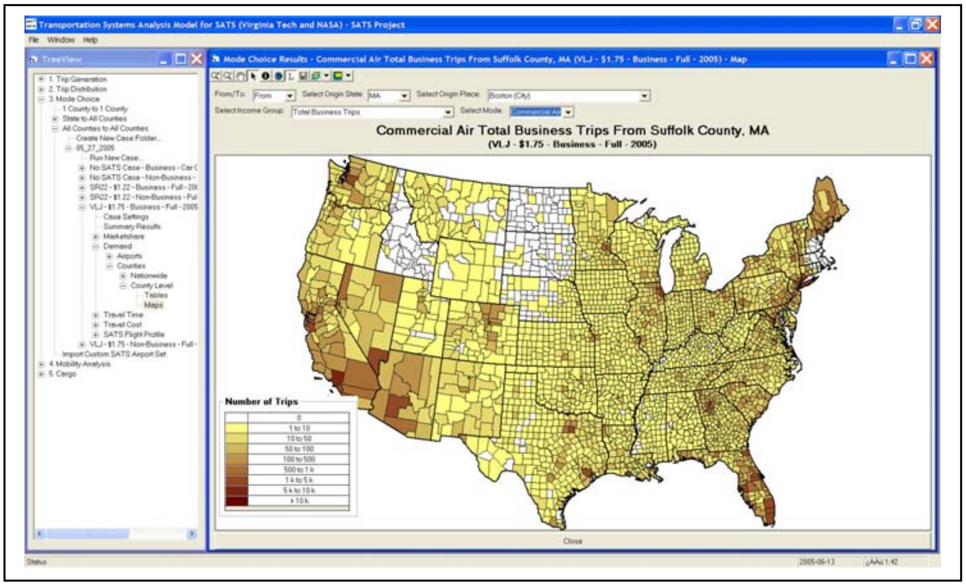

Figure 9. Business Trips Traveling from Boston by Commercial Airline.

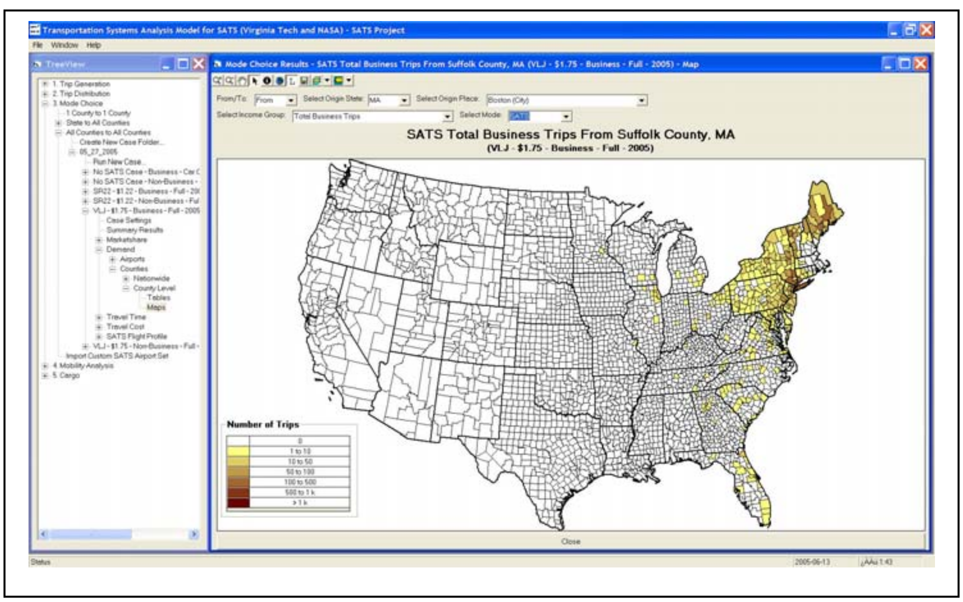

Figure 10. Business Trips Traveling from Boston by SATS.

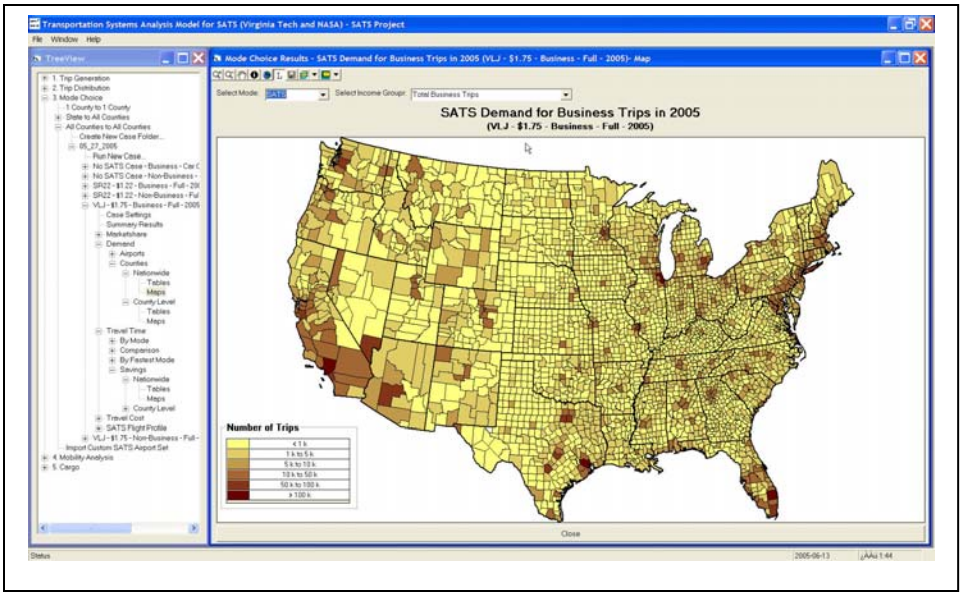

Figure 11. Predicted Total Demand from Each county by SATS.

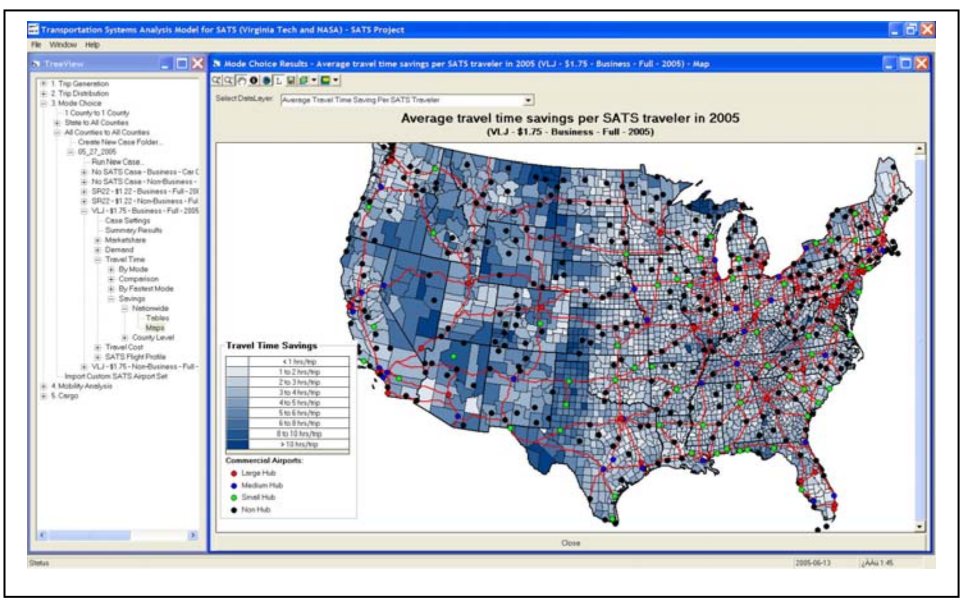

Figure 12. Average Travel Time Saving per a Traveler (2005).

Conclusions and Further Studies

In this paper, we introduced an intercity transportation model that estimates the SATS travel demand in the U.S. using series of estimation steps, and assess impacts of the newly generated SATS demand on the intercity transportation system. The impacts are measure in several aspects including total travel time, travel time savings, fuel consumption, etc. The model also allows users to change values of some critical variables such as the price of SATS, airport sets for SATS operation. This capability might be a useful tool for assessing the impacts of different political or technical options.

The model is designed based on the system dynamics concept, but is still in the stage of development. The current model does not have explicit feedbacks loop yet. In other words, model does not currently constrain air travel demand based on airspace or airport capacity. The airline flights are not influenced by environmental impacts such as noise and emission either. These feedback loops are currently being added. The figure 13 shows the flight trajectories generated by SATS flight demand for a single day. The trajectories are used as an input for demand-capacity analysis that measures delays in airspace. The induced delays are fed into the mode choice step so that air travelers consider the extra delays when they make their travel modes.

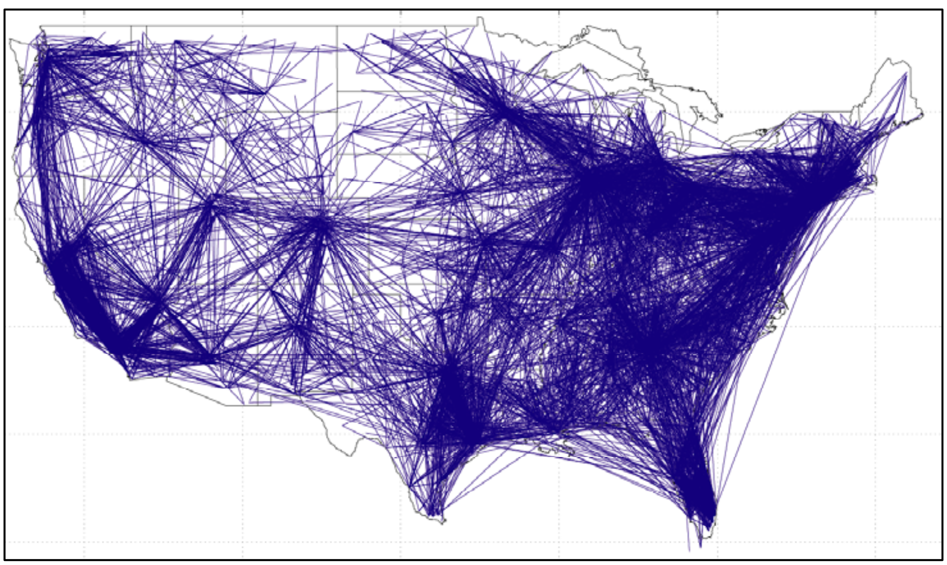

Figure 13. Flight Trajectories across NAS.

Besides, following issues are still needed to be characterized in the model: How will airline evolve in the future? Will they reach an equilibrium state in the long term through merging and acquisition (M&A) process? How will Federal Aviation Administration (FAA) react to the increasing flights? Will they built a new big hub airport or apply demand control policies such as auction system currently being tested in some U. S. airports. From the modeling view point, these issues are critical in the sense that they directly influence travel demand and eventually lead a totally different equilibrium state.

Acknowledgment

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