Title:

Development of a Decision Support Model Using MapObjects to Study Transportation Systems

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Abstract:

This paper describes the integration of a general intercity transportation model using GIS tools. Decision support transportation models that integrate GIS components provide a rich environment to study complex transportation phenomena with multiple decision variables. In this paper, we present a decision support model developed to study the impacts of introducing a novel mode of transportation called the "Small Aircraft Transportation System (SATS)". We use Visual Basic as the integration environment in this model to deliver a stand-alone final product. The integrated model consists of several components including: 1) a System Dynamics model to study SATS impacts and coded in Matlab and converted into Dynamic Link Library (DL), 2) several types of socio-economic data sets required in the transportation system modeling process and stored in MS Access data format, and 3) geographical representation of data sets used and the analysis using MapObject.

Introduction

The National Aeronautics and Space Administration (NASA) is studying the feasibility to develop a new air transportation called "Small Aircraft Transportation System (SATS)" aiming to intercity travel mobility in the country. SATS can improve a travelers' mobility by providing air service nearby the origin and destination places of travel. Unlike conventional General Aviation (GA) vehicles, the new system has been predicated around four unique technical capabilities (http://sats.nasa.gov/):

> 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 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 dollars 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, we have developed a Decision Support Model (DSM) 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 briefly introduce the methods for assessing the demand and impacts, and then more focus on the representation of the output data using GIS tools. The remaining part of this paper is organized as follows. In

the next section, we introduce the basic methods. In the following section, we explain the technical components and the structural design of the DSM model. We also illustrated outputs gathered using GIS tools. Finally, we conclude this paper with some remarks and further enhancements to the existing model.

Methods 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 1.1. The proposed model relies 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, Systems 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. I 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. 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).
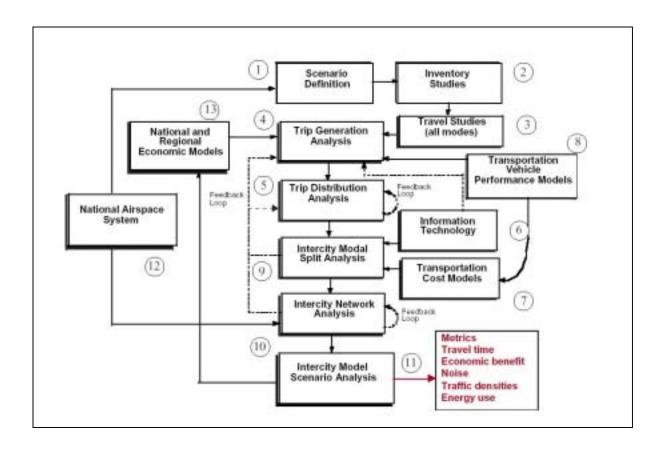
Figure 1. A System Dynamics Approach for Intercity Transportation Analysis.

The modeling process is shown schematically in Figure 2. In the **trip generation** step, we estimate the number of trips by trip purpose produced by each zone of activity and attracted to other zones. 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 zones. This results in a large trip interchange matrix (or sometimes called an origin-destination, O-D, table) showing the number of trips between an origin to a destination county (see Figure 2). Note that the units of the trip interchange matrix are person-trips per year between counties. The **Mode Choice** step predicts the percentage of person-trips selecting each mode of transportation while traveling between two zones in the region of interest. The general aviation mode competes with automobile, commercial airline, bus, train, etc. Figure 2 illustrates that in the mode choice model we decompose the trip interchange matrix obtained in the trip distribution step into a number of trip interchange matrices consistent with the number of modes studied. In the analysis, we create five O-D matrices representing: 1) ground modes (called "others"), 2) general aviation single-engine aircraft, 3) general aviation multi-engine, 4) general aviation jet, and 5) commercial aircraft. Note that the output matrices of the mode choice step shown in Figure 2 are also defined at the county level. 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 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 person-trip O-D tables by aircraft type to an airport-to-airport aircraft O-D table using average vehicle occupancy rate. Using the results from the trip assignment step, a **Performance assessment** step measures the various types of mobility benefits and 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 complete explanation of the methods employed in the model can be found in Trani et al. (2002).)
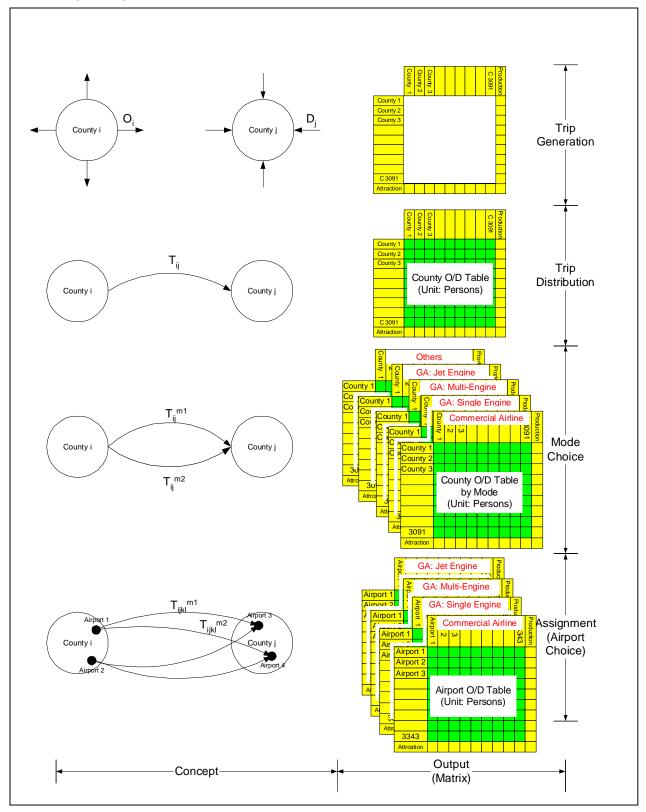
Figure 2. Multi-step Process of Trip Demand Analysis.

Techniques for Developing a Graphical User Interface for the DSM Model

To facilitate the interaction between decision makers with a complex transportation model, we constructed a stand-alone Graphical User Interface (GUI). The DSM 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 DSM 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 shows the relationship among components. Here, it should be remarked that all computational procedures (or modules) described in the previous section were coded in Matlab. The modules were then converted to the Dynamic Link Library (DLL)using the Component Object Models (COM) Builder toolbox in Matlab so that Visual Basic can refer them. MapObjects is employed to represent diverse computational results in a series of color maps with proper scales and legends. Examples of the computational results include 1) number of trips by income level generated from each county, 2) number of trips by mode generated from each county, 3) number of passengers traveling through each airport, 4) travel time savings by SATS systems, etc.
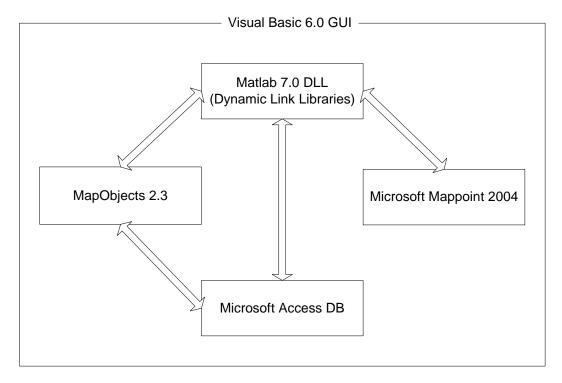

Figure 3. Connections between Developing Tools

Figure 4 depicts functional relationship between the steps and developing the DSM model tools. As explained before, DLLs converted from the source code for each step are used to estimate travel demands. The mode choice step is designed to enable users to conduct an experiment to check the travel times and travel costs for all available modes of transportation between one origin and one destination. In the model, Mappoint is employed to compute driving distances and driving times. Since the travel cost by SATS is not revealed yet, a slide bar control is provided so that user can change the number at their discretion. MapObjects is used to show the travel demand computed at each step. In this process, the results for each county are saved in an Access database file and then represented by MapObjects.

Figure 4. Relation between DSM Model Step and Tools.

The initial screen of the DSM model is shown in Figure 5. Users can navigate the steps using tree menu in the left side of the interface (called the Navigation Window). Figure 6 shows business trips by county estimated in the trip generation step on the U.S. map. Figure 7 illustrates trips traveling from a county selected 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 8. 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 data built in the model. Figure 9 provides very detailed information on travel times and travel costs by mode. The information includes: driving time by auto trip, access time to the airport chosen, flight time via commercial flights, flight time by SATS. Figure 10 presents the driving time from a origin place to destination place in Mappoint. The model also provides the fuel consumption and flight trajectory of the SATS mode and for commercial air. Since the trajectory information consists of longitude, latitude, altitude and time, the model is prepared to interface with microscopic simulation models to estimate the number of conflicts expected to occur in National Airspace System. Figure 11 illustrates the estimated SATS trips from San Diego county to all other part of U.S. The DSM model also shows the travel time savings using SATS which is one of the key mobility measurements for the SATS Program.
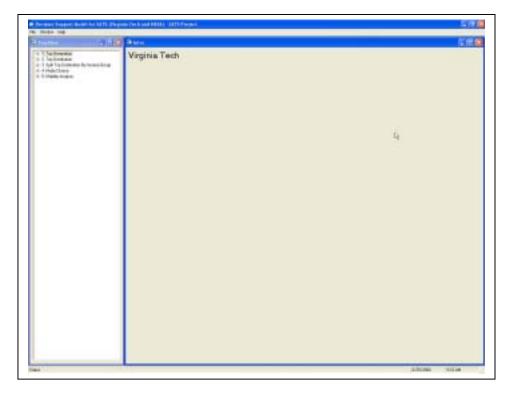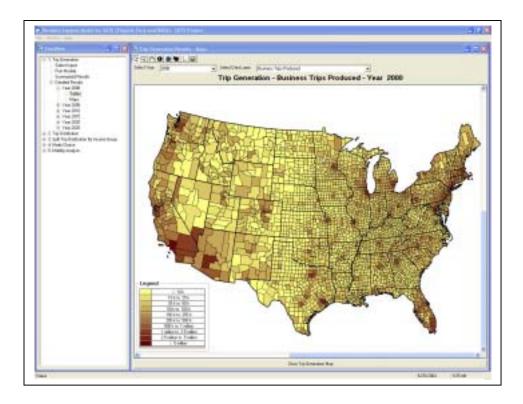
Figure 5. Initial Window

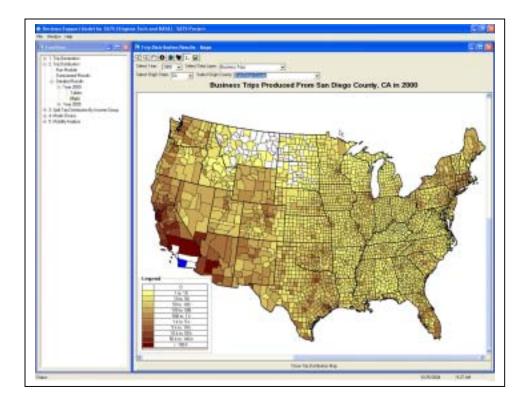

Figure 6. Intercity Trips Generated by County.

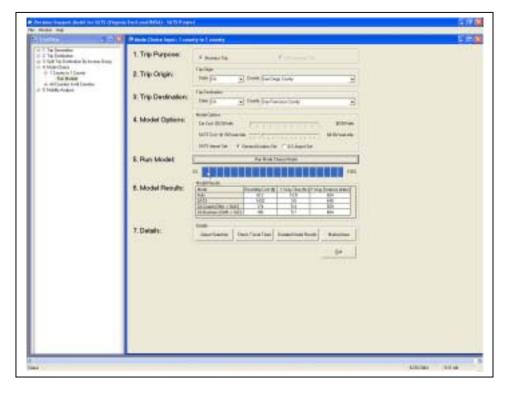Figure 7. Business Trips Traveling from a County.
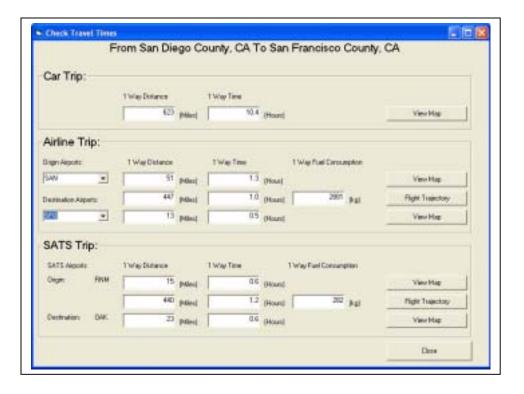

Figure 8. Initial Window for Mode Choice Step.
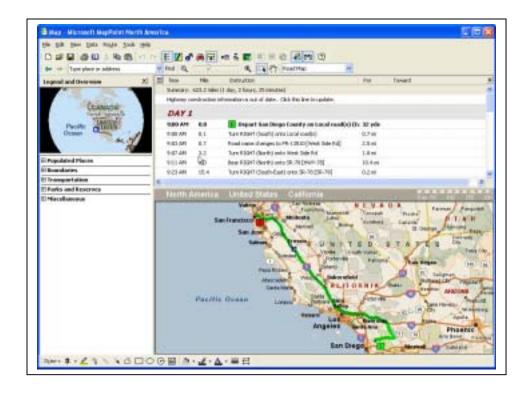
Figure 9. Detail Information on Each Mode.

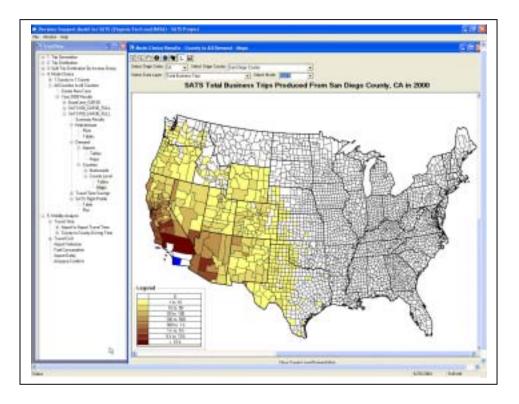Figure 10. Driving Time from Mappoint.

Figure 11. Predicted SATS Demand (from San Diego County).

Conclusion and Future Enhancements

In this paper, we introduce a decision support model being developed to estimate the impacts of a new air transportation system called SATS. The DSM model employs substantial GIS elements to represent complex and spatially distributed outputs. The presentation of graphical information using maps is a more efficient way to understand complex outputs of a county level model. The tool is designed to run stand-alone and can be executed in any Microsoft Windows based PC computer. The end users can explore the procedures step-by-step using the navigation window. This tool is expected to provide decision makers with an analytical toolset to evaluate the proposed SATS system under various assumptions.

The DSM modeling tool presented in this paper is still under further development. The following items are to be added in the near future to enhance its capability.
1) A module for exploring wide ranges of inventory data such as airport, demographic data, aircraft, etc.
2) A module to evaluate airport congestion analysis with consideration of the capacity of air transportation facilities such as airports, airspace sectors, etc.
3) A module to perform statistical summaries of any yearly data such as population, travelers, congestion, etc.
4) Developing a web-based decision support tool using ArcIMS.

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