Develop a Research Roadmap and Strategies for U.S. National Multimodal Inter-Regional Passenger Travel Demand Analysis

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Abstract

University of Maryland (UMD) and OakRidge National Laboratory (ORNL) are currently working collaboratively on an FHWA-funded project in which future research needs, research roadmaps and strategies will be developed to estimate multi-model inter-regional (i.e. long distance) passenger travel by origin-destination pairs. The research team has completed a synthesis of data sources and methodologies for national travel demand modeling, and specifically for multimodal inter-regional passenger travel flow estimation in and outside the US. An expert workshop will be held at UMD in January 2010. The expert opinions, along with lessons from current national travel modeling practices, will help the research team define future research needs, and outline future research maps and strategies toward developing a model to estimate multimodal inter-regional travel in the US. The model will take into account trip generation and trip distribution for multiple modes of passenger travel (i.e., highway, rail, and air). The project will be completed in March 2010. This short paper summarizes the background of this research, methodological options for national travel demand analysis, available data sources, and next steps.
Keywords: National travel demand model; Direct demand, Trip-Based, Tour-Based, Activity-Based, Microsimulation analysis; Intercity transportation; Origin-destination estimation; Multimodal Travel Analysis System (MTAS).

1. Introduction

The U.S. has a long history of employing metropolitan travel demand models to guide transportation planning and decision-making in urbanized areas. Since the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, a significant number of State highway agencies have started to develop and implement State-wide travel demand models to meet policy and legislative development needs. Now more than 20 States have operational statewide travel demand models. At the U.S. national level, current and future multimodal freight flows are available from the Freight Analysis Framework (FAF), developed by the Federal Highway Administration (FHWA), U.S. Department of Transportation (USDOT) to analyze national freight policy. However, on the passenger travel front, multimodal interregional origin destination data are still lacking. The lack of this multimodal passenger inter-regional origin destination data limits the USDOT's ability to conduct quantitative analysis for infrastructure investment (e.g. high speed rail, the interstate highway system, next-generation air transportation system) and operational effectiveness needs.

In addition to enabling national-level infrastructure investment and operational analysis, a national Multimodal Transportation Analysis System (MTAS) for the U.S. has several important additional benefits:

1. Improve the capability of statewide travel demand models for analyzing long-distance passenger travel (more than 20 states in the U.S. have developed operational statewide transportation models with varying degrees of sophistication, with 10 additional states either in the process of developing or revising their statewide transportation models);
2. Reduce duplicate efforts in data collection and long-distance travel modeling at various state DOTs during the development of statewide models;
3. Provide an authoritative tool for multi-state corridor analysis;
4. Ensure the consistency of boundary conditions (e.g. base and future year traffic flows) as individual agencies engage in inter-regional transportation planning analysis;
5. Estimate the impact of globalization and international passenger travel on the U.S. transportation system and the resulting investment needs;
6. Support national- and interregional-level evacuation planning in preparation for natural hazards and targeted attacks;
7. Model the evolution of pandemic deceases due to inter-regional and international passenger travel and produce transportation-related strategies for decease control.

The following section synthesizes various methodological options for national travel demand modeling. Due to the paper length requirements, the focus is on current practices and strategies that have produced operational multimodal national travel models. Section 3 describes the data sources for these operational national and interregional travel demand models around the world. Available data sources in the U.S. are also briefly summarized. Section 4 concludes the short

paper by discussing the next steps in the development of the U.S. national Multimodal Transportation Analysis System (MTAS).

2. A Synthesis of National Travel Demand Modeling Methods

After reviewing more than forty studies/projects in Australia, Canada, Europe, Japan, and the U.S., we categorize national travel analysis methods into four groups: (1). Direct demand and elasticity analysis; (2). Trip-based travel demand models; (3). Tour/Activity-based models and agent-based microsimulation; and (4). Statistical origin-destination demand estimation without underlying behavioral/economic theories. All methods are capable of producing multimodal origin-destination demand matrices from available data sources, and have produced operational models (though in one case, the model is not dedicated to transportation analysis).

Direct Demand and Elasticity Analysis

A number of studies have adopted aggregate direct demand models to estimate multimodal intercity passenger travel demand in Australia, Canada, Ireland, Spain, and the U.K. (e.g. Kraft 1970, Lum and Gillen 1983, Acutt and Dodgson 1996, Bel 1997, Wardman 1997, among others). In these direct demand models, the aggregate passenger travel demand between an origin-destination (OD) pair by each individual transportation mode is expressed as a function of socio-economic, land use, and demographic characteristics of the origin and the destination, as well as the attributes of the transportation mode (e.g. travel time, cost, other service factors) and its competing modes serving this OD pair. Cobb-Douglas and flexible function forms are typically employed for model specification. The coefficient estimates can be converted into various indicators of demand elasticities (e.g. the elasticity of demand for intercity rail with respect to rail cost, automobile travel time, and economic/population growth), which provide direct policy implications. Direct demand models can also provide aggregate forecasts of multimodal travel demand for each OD pair and each mode, given future background conditions and transportation system scenarios. The aggregate nature of direct demand models is suitable for national-level travel analysis. However, one may argue that they do not take full advantage of the information contained in available travel data and that more disaggregate travel models can be developed.

Trip-Based Travel Demand Models

Of all the national travel demand models we reviewed, the trip-based four-step approach is the dominant methodology, and has been employed in national models in counties including Germany, Italy, Japan, Netherland, Sweden, Switzerland, the U.K., and the U.S.; and in European continental transportation models (Leitham 1994, Gunn 1997, Lundgvist and Mattsson 2001, Daly 2005, Yao and Morikawa 2005, Ashiabor et al. 2007, Cambridge Systematics 2008, among others). The Dutch National Model System (NMS) probably started in 1985, and is representative of the trip-based approach. The NMS adopts a disaggregate system in its four-step model, with stages of license holding, mode choice, and time-of-day decisions all linked together with models of car-ownership, trip frequency and distribution, and all based on analyses of individual choices. The linkages among these choice dimensions are considered with a nested logit specification. Traffic assignment methods range from static whole-day methods to multi-

class stochastic equilibrium algorithms. In these four-step models, the zone system contains several hundred to nearly 7,000 zones; trip purposes typically are divided either into business and personal travel only or into categories based on trip ends and purpose (the later is more common for countries with smaller geographic coverages and thus have relatively richer behavioral data for intercity travel in their national surveys); modal options include car, bus, regular rail, high speed rail, and air; and feedbacks between the modeling steps ranges from being nonexistent to fully integrated systems (e.g. the Japanese High Speed Rail model). More recent versions of national travel demand models in several European countries recognize tours, trip chaining, and time-of-day dynamics, which will be discussed in the next section. There are also two notable efforts in the U.S. toward the development of national travel demand models. Researchers at Virginia Tech (Ashiabor et al. 2007, Baik et al. 2008) have developed a four-step Transportation Analysis Model (TSAM) which is based on county-level zones and considers commercial air, air taxis, and automobiles. Rail is not considered because the model is developed to analyze the market share of the light jet/air taxi system. Network assignment is composed of commercial airline and air taxi assignment only for the same reason. Cambridge Systematics (2008) also conducted a study, in which a comprehensive framework for the preparation, development, estimation, validation, and implementation of a U.S. national travel demand model is proposed. It should also be noted that many statewide models in the U.S. also have developed four-step procedures to consider national multimodal passenger travel with one trip end in the specific state. For instance, the models in Oregon, Michigan, Ohio, among other states have incorporated relative coarse U.S. national zone structures (often based on state borders) and halo zones for adjacent states (often based county borders).

Tour/Activity-Based Models and Agent-Based Microsimulation

Several recent national travel demand models in Europe have replaced cross-classification or regression-based trip generation model with tour-based procedures. For instance, the Danish model, PETRA, considers three nested levels of travel representation: trips, tours, and chains (defined as a sequence of daily tours). The Italian model, SISD, distinguishes three alternatives in the generation step for each trip purpose: not to travel, to make one tour, and to make two or more tours. The latest Dutch model, NMS, incorporates time-of-day switching propensities on the demand side. Agent-based mobility simulation has been successfully conducted on the Switzerland national networks for supply-side analysis. As traffic congestion on the intercity highway system worsens in the future, time-dependent network supply analysis will become increasingly important. It is interesting to note that an agent-based microsimulation model of intercity travel has been developed in the U.S. for the purpose of understanding the spread of pandemic diseases and developing countermeasures (Parker and Epstein 2009). This agent-based model simulates travel choices of each household and each person in the U.S.. An individual-level intercity travel module is developed based on a micro-level implementation of the gravity model based on a zip-code level OD zone system.

Multimodal OD Estimation without Underlying Behavioral/Economic Theories

Different from the top-down approach for multimodal OD demand analysis that starts with zone-level socio-economic, demographic, and land use information, OD matrices may also be estimated directly with a bottom-up approach from link-level traffic counts. This method is

usually based on bi-level mathematical programming (i.e.. minimizing errors subject to transportation system equilibrium conditions), and often requires the availability of a historical/target OD matrix and at least partial traffic counts on a significant number of links in the transportation system. Statewide applications of this method have been implemented in California and Tennessee. The MYSTIC project (PDC 2000) in Europe represents another effort in building multimodal (i.e. road, rail, and air) OD matrices from available data sources without relying on travel behavior or microeconomics theories. The project team has developed a heuristic harmonization procedure to directly merge various data sources from seven countries into consistent pan-Europe OD matrices for multimodal passenger and freight travel. The advantage of these direct OD estimation methods lies in its relatively low cost, reliance on available data only, and provision of base-year multimodal OD matrices. With growth factors, these methods can also produce future OD matrices. They may also be used to help with the testing and validation of national travel demand models developed with other approaches. However, these direct OD estimation models are not sensitive to different policy alternatives due to the lack of behavioral/economic sensitivities, and therefore not suitable for scenario analysis by itself.

3. Data Sources

The primary data sources for national travel demand analysis are cross-sectional national travel surveys conducted with various methods (Panel survey data is available in the Netherland). The following table summarizes the type, coverage, frequency, collection method, and quality of various datasets used in several national travel demand models.

The Models	Primary Data Sources	Survey Year	Duration	Data Coverage	Collecting Method
Dutch National Model System (NMS)	Netherlands National Travel Survey (OVG)	1985-present	Continuous	63,000 households in 1999	Computer Assisted Telephone Interview (CATI); One-day travel diary; Supplemented by SP surveys
Great Britain (NTM)	National Travel Survey (NTS)	2000-present	Continuous	5,800 households in 2000	Home interview, and a 7-day travel diary; Roadside interviews; Ticket sales.
Italian Decision Support System (SISD)	Multiple sources	Not the same year	1 year		Household survey, border interview, and traffic counts
Swedish National Model System (SAMPERS)	National Swedish Travel Survey (RiksRVU)	1994-1998	Continuous	30,000 interviews	CATI, and a one-day travel diary
Danish National Transport Model (PETRA)	National Travel Survey (TU)	1995	1 year	13,793 interviews	CATI, and a one-day travel diary
German National Travel Demand Model (Validate)	Mobility in Germany (MiG)	2002	1 year	62,000 persons	Computer Assisted Personal Interview (CAPI)
European Model (STREAMS)	The National Passenger Travel Surveys	Mostly 1994	One common base year	7 EU countries	National passenger travel surveys from 7 EU countries; Tourism survey data; Ticket sales.

Japanese HSR Model	The Inter-regional Travel Survey	2000, 2005	Every 5 years	Approximately 500,000 passengers	Separate one weekday sample interview taken for 5 inter-regional systems (air, rail, sea, bus, and car)l; SP/RP surveys

There are well-know limitations with cross-sectional household- and person-based travel surveys, including high costs and no observations of behavioral changes/dynamics. In order to address these limitations, the national travel survey data are often supplemented by road-side surveys, border-crossing data, smaller-scale stated-preference surveys, modal-specific surveys, tourist information, transit and air ticket sales data, and traffic counts.

Modeling efforts in the U.S. toward a national travel demand model almost rely exclusively on long-distance trip information in the 1995 American Travel Survey (older with over 550,000 >100-mile trips), and the long-distance portion of the 2001 National Household Travel Survey (newer with only 45165 >50-mile trips). A more complete summary of demand- and supply-side data available for U.S. multimodal interregional travel analysis is presented in the table below.

Demand-Side Data Sources

Source(s)	Description of Data	Data Coverage	Period of Data Collection
Census Bureau (http://www.census.gov/support/PLData.htm)	Total American population 18 years or older	All households	2001 (every 10 years)
Census Bureau – 2000 Census Summary File 1 (http://www.census.gov/Press-Release/www/2001/sumfile1.html)	Information on households, individual, and workers in TAZs and census tracts	All 50 states and the District of Columbia	2001 (every 10 years)
Census Bureau – 2000 Census Summary File 3 (http://www.census.gov/Press-Release/www/2002/sumfile3.html)	Income, education, employment status, and place of birth of household members	About 19 million households (1 in 6 of all households)	2002 (every 10 years)
Census Bureau -- 2000 Census Public Use Microdata Sample (http://www.census.gov/Press-Release/www/2003/PUMS.html)	Information on housing units	One percent sample of households	2003 (every 10 years)
Census Transportation Planning Package 2000 Part 1 (http://www.trbcensus.com)	Provides information on individuals and residencies	Not specified	2003 (every 10 years)
Census Transportation Planning Package 2000 Part 2 (http://www.trbcensus.com)	Provides information regarding employment and place of work	Not specified	2003 (every 10 years)
Census Transportation Planning Package 2000 Part 3 (http://www.trbcensus.com; http://www.census.gov/mp/www/spectab/specialtab.html)	Provides information on traffic flow between location of work and home	Not specified	2004 (every 10 years)
American Community Survey (http://www.census.gov/acs/www/)	Includes information on individuals and housing units	One-in-five people and households	2006 (recording monthly; rolling 12 month summations reported each year)
National Household Travel Survey http://nhts.ornl.gov/index.shtml)	Gives insight into travel behaviors of individuals based on trip purposes, trip distances, origins and destinations, and modes of transportation; includes long-distance trip	45,165 person trips for long-distance, multimodal transportation	2001 (updated as needed at no particular frequency)

	information (trips at least 50 miles from the origin)		
Longitudinal Employer –Household Dynamics Program (http://www.fhwa.dot.gov/planning/Census/lehd.htm; http://lehd.did.census.gov/led/index.html)	Quarterly records of income and employment situation of nearly all individuals	Not specified	2006 (updated quarterly)
State Employment Security Departments (http://www.subnet.nga.org/workforcecouncilchairs/StateEmpTrainAg.htm)	Provides information on the employment or unemployment status at a state level	Not specified	2007 (monthly updates)
U.S. Department of Labor Bureau of Labor Statistics (NAICS) (http://www.bls.gov/data/home.htm)	Publishes monthly data on employee earnings, hours worked, and the number of employees	Not specified	2006 (updated quarterly)
U.S. Department of Labor Bureau of Labor Statistics (SIC) (http://www.bls.gov/data/home.htm)	Published monthly data on employee earnings, hours worked, and the number of employees	Not specified	Stopped in 2003 (previously updated quarterly)
U.S. Census Bureau Employment Opportunity (EEO) (http://www.census.gov/eeo2000/index.html)	Residential data, residence to work location flow data, and worksite data; used for affirmative action	471 census occupations, 268 Office of Personnel Management occupations, and 8 state and local government occupational categories	2004 (updated every 10 years)
Woods and Poole Metropolitan and County historical and forecast data (http://www.woodsandpoole.com/)	Projects up to year 2040 information on employee earnings per industry; includes 900 variables on economics and demographics data	Not specified	2007 (updated annually)
InfoUSA (http://www.infousa.com/)	Information on sales	Not specified	2007 (updated quarterly)
Dun and Bradstreet business data (http://www.selectory.com/Selectory/Login.aspx; http://www.dnb.com/us/)	Potential use in determining freight data	Not specified	2007 (updated quarterly)
Automatic Data Processing National Employment Report (http://www.adpemploymentreport.com/index.aspx)	Used to compare with BLS employment statistics; generates monthly nonfarm private payroll statistics	Represents approximately 400,000 businesses and 23 million employees	2008 (updated monthly)

Supply-Side Data Sources

Source(s)	Description of Data	Period of Data Collection
National Highway Planning Network (NHPN) (http://www.fhwa.dot.gov/planning/nhpn/; http://www.bts.gov/publications/national_transportation_atlas_database/2007/html/nhpn_lin.html)	Defines over 450,000 miles of current and proposed highways, ranging from minor rural roads to interstates. It considers the geospatial aspects of highways.	2005
Oak Ridge National Highway Network (ONHN) (http://www.cta.ornl.gov/transnet/Highways.html)	Attributes of roadways and their locations are outlined; it is mainly used for understanding vehicle routes and scheduling issues	2004
Highway Performance Monitoring System (HPMS) (http://www.bts.gov/publications/national_transportation_atlas_database/	Offers insight on the performance, usage, accessibility, and operation of highways	2006

2007/html/hpms.html)		
NAVTEQ (http://www.navteq.com)	Describes attributes of roads related to their accessibility (turn restrictions, one way streets, barriers, and other restrictions	Varies by year
U.S. Census Bureau (http://www.census.gov/geo/www/tiger/tiger2005fe/tgr2005fe.html)	Uses USGS data to provide information on the cartographical and geographical details of the Census tracts, including the defined area boundaries of those zones	2005
Federal Railroad Administrations (FRA) (http://www.bts.gov/publications/national_transportation_atlas_database/2007/zip/railway_lin.zip)	Provides data on the railroad systems inside the 50 states and the District of Columbia	N/A
CTA Railroad Network (http://cta.ornl.gov/transnet/RailRoads.html)	Includes information on every railroad in the United States, Canada, and Mexico in operation since at least 1993, and was intended to generate accurate intercity route combinations	2005
ORNL (http://cta.ornl.gov/transnet/Intermodal_Network.html)	Provides details on the nation's highways, railroads, an waterways, and connection points between those modes of transportation	2002 (with occasional updates at nonspecific times)

4. Developing a Research Roadmap for the U.S. Multimodal Interregional Passenger Travel Demand Analysis

As the next step for this project, the University of Maryland (UMD) will host an expert workshop on January 14, 2010 in Washington, DC. Representatives from FHWA, other USDOT modal agencies, major stakeholders that provide intercity passenger travel services (air, rail, and intercity bus), experts experienced in multimodal interregional travel demand modeling, and the UMD-ORNL research team will discuss data and modeling issues related to U.S. national passenger travel demand analysis. The product of this workshop will be a research roadmap that can help USDOT and FHWA prioritize future research tasks toward the national Multimodal Travel Analysis System (MTAS). If this short paper is accepted at the Innovations in Travel Modeling Conference, this research roadmap will certainly be included in the presentation.

References

Not provided due to short-paper length limit. Available in the project interim report or upon request.