The International Emergency Management Society
9th Annual Conference Proceedings
University of Waterloo, Canada, May 14-17, 2002

ADVANCES IN TRAVEL DEMAND FORECASTING AND WHAT THEY MEAN FOR EMERGENCY PREPARDENESS

Joseph Kammerman

Texas Transportation Institute

Keywords: Travel Demand Forecasting, Population Synthesizer, Modal Split, Time-of-Day

Abstract:

Within the transportation field, many emergency management questions can be answered by travel demand forecasting (TDF).

TDF is the science of quantifying the amount of travel in large transportation systems. TDF predicts travel demand and transportation system performance based on facility inventories and surveys (or projections) of demographic and economic activity. These projections have typically been limited to aggregate estimates of origin-destinations, transit passenger demand, daily auto travel, and rough travel time. Recent advancements have now made it possible to make more detailed forecasts of person movement and better estimates of travel times.

The TDF community has focused on many issues that are significant to emergency management professionals. These issues include: population location, population by time-of-day, population mobility, network representation, regional micro-scale simulation, and system visualization. These improvements are the focus of this paper. They provide planners with a more detailed understanding of current mobility and the impact of changes to the transportation network. Many of these advancements are currently being implemented in Portland, Oregon. This paper will demonstrate what the emergency management community can expect from emerging TDF technology, and how the technology might benefit them.

Introduction

Effective emergency preparedness requires a host of information inputs. The information needed includes population mobility, hazard identification, and reestablishing community continuity. Some of the above information needs are met within the transportation field with the emergence of new technologies. In order to establish training exercises, respond to events, and manage incidents emergency professionals need information about transportation accessibility and an understanding of how and why population and freight moves during the day. Within the transportation field, transportation modeling is where many emergency management questions can be answered. These questions include evacuation modeling and population location. This paper will demonstrate what the emergency management community can expect from emerging travel demand forecasting (TDF) and related technologies and how these technologies might benefit the community.

A transportation network is a fragile system. Emergency managers planning for a crisis event need to recognize the problems that currently exist to better plan their response. The 2001 Urban Mobility Report estimates that an average person loses thirty-six hours a year due to traffic congestion and that the current transportation network operates eight hours a day under congested levels. [1] So when the East coast network was inundated with evacuees during the terrorist event of September 11, 2001 in New York City and Washington D.C. and the week of September 13,1999 during Hurricane Floyd in South Carolina and Georgia the transportation network was brought to a stop. The perceived threat from these disasters increased travel times between high-risk areas and alleged safe areas, reminding decision makers of the vulnerability of the transportation network. Hurricane Floyd alone caused travel times to reach a 15-hour peak along a 100-mile span [2]. In New York City on September 11th during the terrorist event at the World Trade Center, 1.3 million residents and workers were asked to evacuate Lower Manhattan. These individuals needed to use new modes of transportation, as heavy rail and vehicular traffic were limited. This paper demonstrates how TDF methodologies currently used for highway congestion and air quality analysis, can answer many evacuation and other transportation related questions.

Methodology

The research within this paper utilized primary and secondary sources. Secondary sources include materials from the Department of Transportation (DOT) and Environmental Protection Agency (EPA) Travel Model Improvement Program (TMIP) clearinghouse and quick response reports and case studies from various other entities. Primary sources include DOT representatives and other transportation agencies.

Background

TDF is a tool that supports the urban transportation planning process. It is a series of analytical techniques, used to asses future demand for transportation facilities and services. It involves estimating the impacts of various changes on the transportation system and how they affect travel demand. These changes could include rerouting traffic along a freeway due to a flood or a shift in travel modes with the implementation of a new rail service. TDF plays a significant role in informing decision makers of the potential needs, alternatives to meet those needs, and potential impacts of their choices [1].

TDF models are divided into a four-step process: trip generation, trip distribution, mode choice, and trip assignment. Trip generation forecasts the number and purpose of trips. Trip distribution determines the destination of trips. Mode split predicts how trips will be divided among available modes. Trip assignment predicts the route choice. Typically, a TDF model forecasts 20 to 25 years into the future to evaluate proposed changes to the network.

The Transportation Analysis Simulation System (TRANSIMS) and the processes associated with it are taking TDF practice into the next generation of travel models. Key emphasis in TRANSIMS includes activity-based trips and microsimulation. Activity-based trips connect trips in a chain like fashion with the same start and end point. For example, the daily activity of an individual person could be represented using the following sequence: home, work, shop, eat, home. This sequence departs from the current practice that counts each trip separately. This improvement provides more detailed information and leads to a more informed analysis. TRANSIMS is considerably more data intensive and requires a higher level of traffic analysis then current TDF models. Testing of the TRANSIMS model is currently underway in Portland, OR.

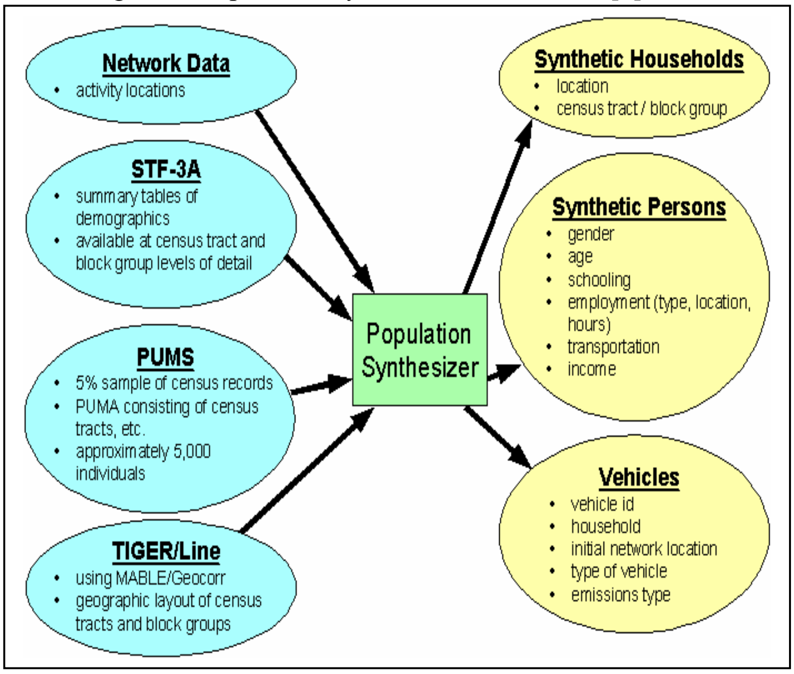
Findings

The following findings demonstrate how the TDF process can directly affect emergency preparedness. These findings are based on current practices within the field and improvements that are currently occurring in TDF.

Population Location – Population location is important to emergency management because it identifies and determines the possible impacts of a disaster event. Where the population is situated will affect the response. During the 1994 Northridge Earthquake in Los Angeles, CA emergency managers knew responders should dispatch to residential areas rather than business because of the 4:30am time of incident. This decision was clear, but if the incident had occurred at 6:30pm the choice would not have been as clear. Population location also refers to the difference between populations in motion compared to static. If an incident occurs during high travel times the disaster effect takes on a different meaning. To better manage transportation facilities prior to and during a disaster, the location of the population needs to be identified and incorporated into emergency plans. In the TDF process this population location need is currently addressed with the development of the population synthesizer and the traffic analysis zone structure.

A population model is built into a TDF model using U.S. Decennial Census demographic data, travel surveys, and the Census Transportation Planning Package (CTPP), which is part of the Census 'long form.' CTPP collects information on worker and commuting characteristics by using location of residence, place of work, and worker flows among small areas [3]. Travel surveys are conducted by planning agencies that include: personal household characteristics, activity at special generator locations and commercial truck information. After the data has been collected and validated it is place into Traffic Analysis Zone (TAZ) for analysis.

Figure 1: Population Synthesizer Framework [4]



All TDF models create multiple TAZ areas within a single study area with each individual TAZ containing information on population, households, and employment. This information is a statistical sample used to represent an entire population. A single TAZ population is generally 400 to 1000 household trips depending on the size of the study area making the population statistically aggregate.

The need for further analysis from TDF models led to a need for more disaggregate information. The population synthesizer, is part of the TRANSIMS development, and can possibly have the greatest influence on emergency planning. The reason is that in the TRANSIMS model population is disaggregated into a synthetic individual within a simulated house, one synthetic individual for every real person. Individuals are given an itinerary that tracks their movement throughout the day. Instead of 1000 TAZ areas, planners now need to track 200,000 itineraries. This data is then validated to the most current census findings. The disaggregate level of data allows for more interaction amongst synthetic individuals within the model set, which provides better information on travel behavior. At this level of detail emergency managers can gather a richer data set to test future policies.

Time-of-day – Time-of-day modeling is important because it forecasts the time a trip is made. During September 11th, the time of the incident and the response that followed was based around where the population was located at that time. If the incident had occurred three hours earlier at

6:00am rather then 9:00am the response and the devastating impact would have been dramatically different. During a sudden onset disaster, traffic flow will vary depending on the time of the incident.

As an example current TDF models demonstrate travel in one movement for a single day, 50 trips went from TAZ 12 to TAZ 45. Sensitivity to time is not included. However, due to air quality policies, TDF models are now moving forward to include a time of day split. Large and serious areas with poor air quality are considered nonatainment areas and are required to do some level of time of day analysis. This analysis is usually divided into an AM peak, a PM peak and off-peak periods. Emergency plans that are sensitive to time of day movement would benefit greatly from this current process. TDF allows the user to test an emergency scenario at three different time periods within the same location in order to determine the effects on the transportation system.

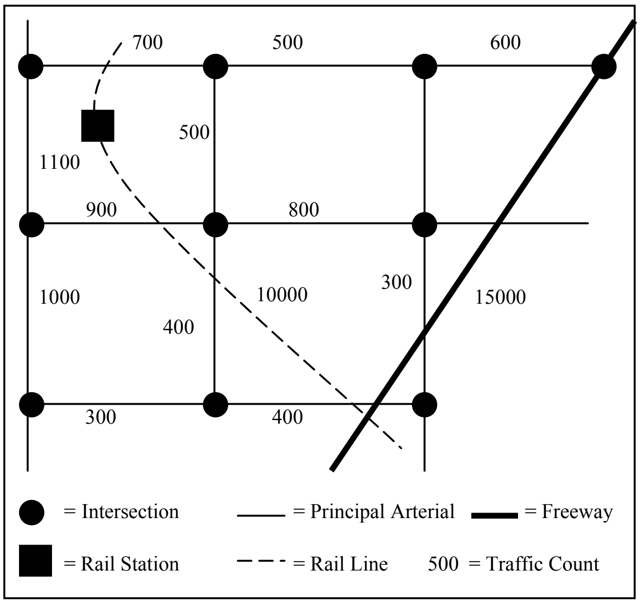
Network – The TDF network is important to the emergency management field because it provides a coarse representation of a transportation system. When the Bay Bridge, which connects San Francisco to Oakland, CA, collapsed during the Loma Prieta earthquake in 1989, decision makers needed to find a way to reroute 300,000 daily travelers. An accurate network will provide emergency management a tool to test possible alternatives and measure their effectiveness.

When planning for a disaster, it is imperative to understand the transportation network. Rarely does a crisis occur that does not involve some aspect of transportation. The location of roadways and transit lines and how they interact will affect how people evacuate a hazardous location and how responders get in. TDF models are built with extensive consideration to accurately represent a study areas transportation network.

Networks are more then random lines crisscrossing each other on a sheet of paper. Each TDF model generates roadways and the available transit lines with information that includes speed1, capacity and accessibility. When a CSX train carrying hazardous materials derailed and caught fire in a tunnel in Baltimore, MD, on July 18, 2001, the accident closed the entire vicinity for at least two days. Traffic that normally flowed in and out of the area was detoured onto other arterials in the area. Using the TDF network and their characteristics can help generate information about the capacity of the other roadways in the area and help to transfer the demand that previously had been met by the affected facility to other areas.

Current TDF models use links to represent roads and transit network sections as represented in figure 2. Link attributes include length, capacity, speed and area type. The policies that direct the TDF model development will determine the network's level of detail required in a study area. A large aggregate model can function with only principal arterials and freeways identified while a disaggregate model will need collectors (streets that collect traffic from local streets in neighborhoods, and channels flow into the arterial system) and minor arterials included. The analysis required for the model will dictate the level of effort

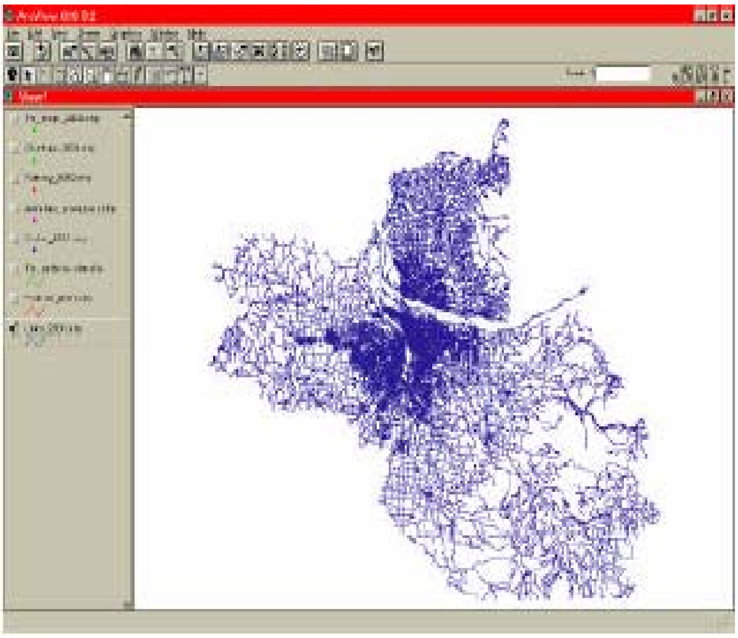
Figure 2: Example of a transportation network with only principal arterials, freeway, and rail line



necessary for the network development.

If planners wanted to simulate a large-scale evacuation from a coastal town they would only need freeways and principal arterials because the majority of the trips generated within the study area would travel to external (outside the study area) locations. Freeways and major arterials are more attractive for long distance travel due to their speeds and limited accessibility. However, they are also known to reach capacity quickly resulting in major delays as seen during Hurricane Floyd. A TDF model with guidelines to test the ability of an area to function under extreme stress can easily be established by rerouting trips to the roadways in question. This knowledge can then be implemented during an actual coastal evacuation to better inform travelers of the delays and reroute travelers to different routes.

Figure 3: Entire Portland Network area [6]



A TDF network with freeways and major arterials would be enough for an analysis when modeling a major evacuation with lead time. However, an evacuation, due to a sudden event on a more disaggregate level, would require more roadways in the TDF network. For instance if a fire occurred within a downtown square block during a typical workday, what would the effect be on the network? For this level of information a network containing city blocks, collectors, and possibly sidewalks will need to be added. For every street closure a vehicle can be rerouted from it usual trip and the effects can be collected for analysis. This type of analysis requires a lot more effort, but the information generated would be invaluable.

Currently Portland, OR has a network with this level of detail within its model. Every road is broken into lanes and sidewalks. Portland's network contains 124,904 links or roadway segments [7]. This includes driveway/parking locations to expressways. This network took over two years to build, however since Portland was the first site to build a network with this much detail, lessons were learned that could be applied to reduce the time investment required by other areas.

The more detailed the network, the more scenarios and policy testing can be done for emergency preparedness. For instance, a policy on the effectiveness of lane reversal during a coastline evacuation can be tested. Using the network developed for Portland, emergency planners can simulate three lanes reversed so seven lanes of an eight-lane highway are moving in the same direction. Once traffic is redirected onto those lanes the results can be compared for analysis. Although most current TDF networks do not have this level of detail they can still be useful on an aggregate level.

Mobility – The issue of mobility is important to emergency management because it reflects the population's ability to move within an area. The capacity in which a population can move will dictate how the request is handled. Whether it is a lead time evacuation like a hurricane or a sudden evacuation from a chemical release, a population needs to move and an emergency manager needs to know how this will occur. The timeliness and the speed will be dependent on the route they chose and their mode of transportation.

Figure 4: Example of Home Base to Work Trip Table [8]

Computed Productions and Attractions		
TAZ	Productions	Attractions
1	25	1,000
2	125	350
3	350	500
4	800	100
5	600	250
Total	1,900	2,200

In the TDF model, the use of production and attraction rates dictates the movement in and out of a TAZ. These rates identify where trips are going. Production rates estimate the amount of trips leaving a TAZ and attraction rates estimate trips entering a TAZ. These rates are placed into a trip table that generates trips between and within TAZ areas. These rates would provide emergency managers with a method to move populations from one area in the community to another. For instance, a scenario is created in which a Hurricane threatens the model area. Emergency managers can manipulate the attractiveness of a TAZ area so that an external TAZ area is overwhelming more attractive then any TAZ within the study area. When the model is calibrated emergency managers will be able to identify what level of congestion will exist on that proposed evacuation route. Alternatives can then be proposed along with traffic control policies that reduce the expected evacuation congestion

This example also leads to TDF models that reduce evacuation travel times during a hurricane evacuation. When a trip is assigned to a TAZ part of its attractiveness is related to the travel time to get to that zone. If emergency managers know the time needed to evacuate an area, the window to announce an evacuation would increase. This means that travel times would be decreasing, allowing for more time before an evacuation is officially requested. This is where better modeling would lead to better planning, which would eventually lead to reduced travel times. Increasing the time needed to request an evacuation would limit loss to business and diminish the stress in a community. During Hurricane Floyd this was clear when residents in Northern Florida were asked to evacuate. When the hurricane completely bypassed the area many residents were upset and frustrated. A TDF model could have been used to analyze the area giving emergency managers a large window to order the evacuation**.**

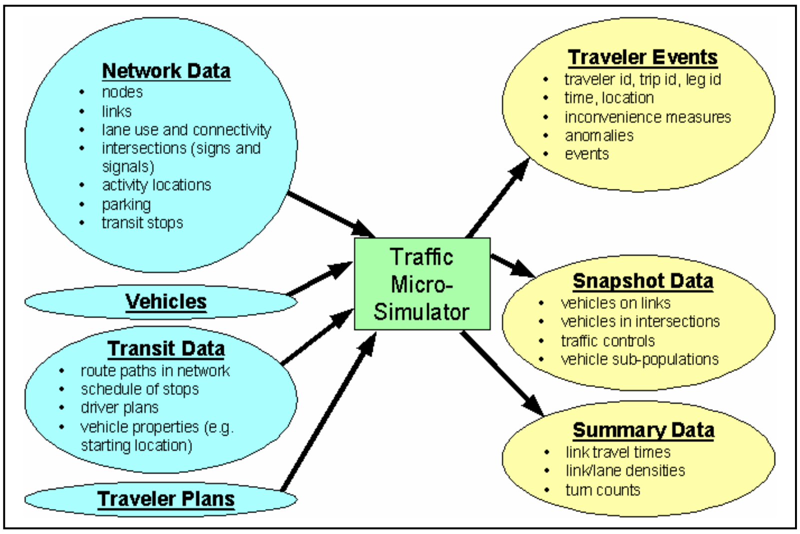
Modal Split – Modal split is important for emergency managers because it refers to the different modes that a community can use to travel. This may include walk/bike, single occupancy vehicle, 2-person vehicle, 3+vehicle, light and heavy rail, bus and ferry. In a sudden onset emergency, the timeliness of a community's reaction will depend on their mode of travel. Each community mode choice model varies depending on the availability of each mode within that area. For a traveler the mode decision is usually based around cost/time to make the trip and person/trip/land use characteristics.

A mode split model creates additional trip tables for each mode when it enters and leaves a particular zone. This information is tallied, and assumptions within the zone can then be made. This information provides emergency managers the vulnerability of a population's ability to move within a zone. During the September 11th attacks in New York City people walked across various bridges due to the rail lines being destroyed and vehicular traffic operating at a minimum level. A large amount of the population in Lower Manhattan relies on the rail line, and when that system failed people were forced to find other means. A TDF model would have recognized this as a problem by closing several commuter lines in the model.

The TRANSIMS model would take the above example a step further. After that group of would be travelers were identified, each itinerary could be augmented for walking trips. Emergency managers could then estimate approximate times it would take to move a population from a hazardous location to a safe location when a transportation network completely fails.

Microsimulation – Microsimulation is a new part of the TDF model and is available in the TRANSIMS model. Microsimulation is important to emergency management because it allows tracking of the activities of a synthetic individual over the course of an entire twenty-four hour day.

Figure 5: Traffic Microsimulator Framework [9]



Currently, when a trip is made from zone to zone, that trip is placed on a road link that includes number of vehicles on that link. With microsimulation, trips can now be calculated across the entire network with sensitivities to road characteristics, such at streetlights and street parking. After the itinerary of a synthetic individual has been developed, their trip begins. The microsimulator will then track each individual along the network second by second and enforce physical constraints like not allowing an individual be in two places at the same time.

In 1996 the microsimulator was used in a case study in Dallas, TX. [10] The case study analyzed two proposed roadway improvements that would alleviate congestion in a business area between 5:30am and 9:30am. One improvement proposed a lane in each direction added to the interstate, and the other was to lower arterial intersections. The metrics for the study included travel time, speed, average vehicle miles, and network reliability. The case study was able to prove the effectiveness of the microsimulator, as the freeway option was more effective until 7:30am when individuals began to empty the freeways and from 8:00am on the street arterials improvements were more effective.

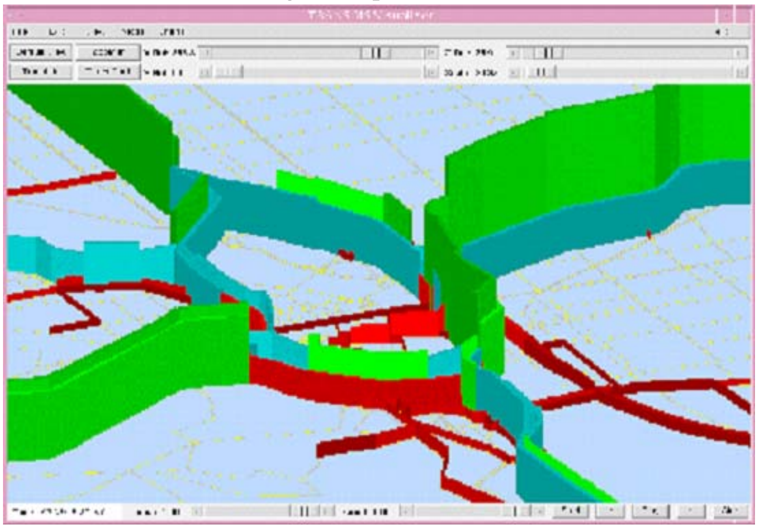
Besides analyzing routes another emergency management use could be testing the effect of a biological/chemical release. Suppose a terrorist released an airborne toxin that could be transmitted from person to person. The toxin plum can be layered on top of the microsimulator highlighting every synthetic person that is affected by the plume. As the individual continues about the network each person that comes into contact with them would be highlighted. This would help provide some information for a risk analysis on possible biological/chemical dangers.

Visualization – The final finding in how TDF can help emergency preparedness is with the advancements in visualization techniques. This is important to emergency management because it provides a method of interpreting the results. Visualization can also help TDF users identify results that normally would have been overlooked.

Current models display their results on a basic computerized map with the travel demand placed on each link. However, more TDF models are moving to a geographical information system (GIS) platform. The main advantage of the GIS system is its ability to relate tabular data to digital maps and relate various sources of spatial data to one another. The GIS system can forecast travel, validate and calibrate the model, test environmental impacts, and measure social impacts.

The TRANSIMS model allows the analyst to dynamically view the output from the microsimulator module. All displays are both temporally and spatially dynamic. This means that spatial areas can be located and zoomed in on in order to provide the best view. Also, the display can move through time to assess the changing characteristics of the roadway network, which potentially can show the congestion points along the roadway network.

Figure 6: Multiple routes overlaid in time to show predicted congestion points [10]



Conclusion

As demonstrated within this paper, there is a lot of information that can be taken from the TDF process and used in emergency management. This information includes work currently done on the location of population, the time of travel, its mode of travel, transportation network development, mobility, microsimulation, and visualization. The TDF results would help provide better transportation information to emergency preparedness plans.

References

1. *Urban Mobility Study*, Texas Transportation Institute, April 2001

2. *Executive Summary: Southeast United States Hurricane Evacuation Traffic Study*, Post, Buckley, Schuh, & Jernigan, Inc., U.S. Department of Transportation, Federal Emergency Management Agency, U.S. Army Corps of Engineers, 2000

3. Introduction to Urban Travel Demand Forecasting – Participant Workbook, National Highway Institute, FHWA-HI-93-045, August 2000

4. TRANSIM Volume 0 – Overview, Los Alamos National Laboratory, LA-UR 99-1658, May 1999

5. Introduction to Urban Travel Demand Forecasting – Participant Workbook, National Highway Institute, FHWA-HI-93-045, August 2000

6. Study Setup: Parameters and Input Data – Network Portland Study Reports, LA_UR-01-5712, October, 2001

7. Study Setup: Parameters and Input Data – Network Portland Study Reports, LA_UR-01-5712, October, 2001

8. Introduction to Urban Travel Demand Forecasting – Participant Workbook, National Highway Institute, FHWA-HI-93-045, August 2000

9. TRANSIMS Volume 0 – Overview, Los Alamos National Laboratory, LA-UR 99-1658, May 1999

10. *TRANSIMS – The Dallas Case Study,* Los Alamos National Laboratory, Texas Transportation Institute, DOT-T-99-04, January 1998

Acknowledgement

I would like to thank the Travel Model Improvement Program team, especially Brian Gardner and Dr. Fredrick Ducca, for their oversight and support. I would also like to acknowledge Dr. John Harrald at the George Washington University for this opportunity.

Author Biography

Mr. Kammerman earned his Bachelor's of Arts in Urban Planning and History from Southwest Texas State University and has just received his Masters of Science in Crisis and Emergency Management from George Washington University. He has worked on travel demand modeling issues over the past four year with the Texas Department of Transportation and currently with the Texas Transportation Institute as part of the Travel Model Improvement Program.