AC 2009-1241: DISASTER PLANNING FOR A LARGE METROPOLITAN CITY USING TRANSIMS SOFTWARE

Lok PASUPULETI, Northern Illinois University
Omar Ghrayeb, Northern Illinois University
Clifford Mirman, Northern Illinois University
Hubert Ley, Argonne National Laboratory
Young Park, Argonne National Laboratory
Disaster Planning for a Large Metropolitan City Using TRANSIMS Software

Abstract

Over the past decade the United States has endured many disasters, both man made and due to the forces of nature. In each case, leadership in the public and private sectors learn that more needs to be done to ensure continuity of life and economy. After a catastrophic event, the public sector leadership has to ensure that government is functioning and that affected communities are provided the proper support. Within the private sector, there is a need to ensure that the employees are cared for and that there is a continuity of the business. We have learned that while the specific needs of the public and private sectors after a catastrophic event are unique, there is an overriding need to prepare for the eventual disaster. Disaster preparation is of extreme importance in providing emergency assistance, allowing for evacuation, or ensuring the communications and public safety needs are met before, during, and after an emergency. For a large metropolitan city, the planning efforts take on many levels, due to the complexity of the groups have jurisdiction over the planning and relief efforts. Northern Illinois University and Argonne National Laboratory, working with the State of Illinois and the Chicago Metropolitan Agency for Planning (CMAP) partnered to study the effect of such a catastrophic event in the city of Chicago.

In any disaster planning scenario, the planners must have the ability to predict how the people who live and work in the region will react to catastrophic events. This planning need to take into account the major and minor transportation routes as well as the public transportation modes, allowing individuals to exit the city. In addition, the planning must also be able to identify routes for emergency vehicles entering and exiting the city, as well as transportation of injured between hospitals. TRansportation ANalysis SIMulation System (TRANSIMS) traffic micro-simulation code, developed by the U.S. Department of transportation, was utilized to model the complex city and its transportation routes. TRANSIMS offers many capabilities that are needed when modeling emergency evacuation scenarios. The software system is capable of simulating individual travelers, their routes, and their transportation mode (such as traveling by car, public transit, or walking) and calculates traffic patterns on the basis of the microscopic interactions between individual vehicles and detailed street network features. This information was developed based upon complex surveys and satellite imaging. Through this software researchers were able to model events and transportation into and out of the city. In addition, undergraduate and graduate students were involved in this complex year-long project. The authors will provide information as to the modeling, input, and output that was obtained. Through an analysis of the motion of the population working and living in the city, planners have a much better
understanding of how to react to emergencies that might occur, and ensure that emergency relief can get to the targeted location in a timely manner.

**Introduction**

Transportation planning is currently undergoing a metamorphosis from a traditional modeling process to microsimulation (Lawson, 2006). Recognizing the need to review and modernize travel models, the U.S. Department of Transportation (DOT) and the U.S. Environmental Protection Agency (EPA) sponsored a research program focused on the preparation of, and experimentation with, microsimulation, referred to as the TR ansportation ANalysis SIMulation System (TRANSIMS) (Lawson, 2006).

TRANSIMS is a traffic simulator which combines the powerful functionality of a time-based routing program with a discrete event microsimulator. Together, they allow for a simulation with an unparalleled level of control and almost unlimited resolution. TRANSIMS has been used for several large city simulations (Washington DC, Alexandria, Chicago, and Portland).

Dallas/Ft. Worth, Texas was the site of the first experiment using TRANSIMS. A 25-square mile corridor was targeted for analysis, with attention being paid to a discrete set of infrastructure changes, primarily using the traffic microsimulator module. The experiment began in 1995, used 10,000 links, and 200,000 synthetic travelers (Lawson, 2006).

TRANSIMS is an urban planning tool that combines census data and household surveys with a description of the transportation network to produce estimates of human mobility. It iteratively evaluates hundreds of thousands of coupled non-linear models to produce a solution to a million-person game (Eubank, 2002). Transportation Analysis and Simulation System (TRANSIMS) is an integrated system of travel forecasting models designed to give transportation planners complete information on traffic impacts, congestion, and pollution. The TRANSIMS software is developed by the Los Alamos National Laboratory (LANL) (Hobeika and Paradkar, 2004).

Development of this tool can be considered as a boon for the traffic planners as TRANSIMS offer increased policy sensitivity, detailed vehicle-emission estimates, and improved analysis and visualization capabilities. The idea behind the development of this tool is that simulating the daily travel with a fine temporal and spatial resolution provides a clear understanding of transportation system’s performance.

**Working of TRANSIMS**

The Transportation Analysis and Simulation System (TRANSIMS), is an integrated set of tools developed to conduct regional transportation system analyses. Transportation Analysis and Simulation System (TRANSIMS) software was developed with the goal of providing state transportation agencies and metropolitan planning organizations a tool that would capture both the complex nature of individual traveler activity and the collective interaction of these activities within the transportation system.

TRANSIMS Step By Step:

- Create a Road Network
- Create a Transit Network
- Obtain Transit Schedules
- Obtain Trip Tables
- Obtain Diurnal Distributions
- Run Trip Converter

- Create Travel Plans from Trips using the Router
- Test the Travel Plans in the Microsimulator
- Iterate Between Router and Microsimulator

TRANSIMS needs detailed information to process and simulate every single person and vehicle in a region. The input files, which can be grouped into 4 different categories, include Transportation Network Files, Census Files, Traveler Activity Survey Files, and Vehicle Information Files. This detailed information includes data about streets, intersections, transit, population, distribution of vehicles, activities in a region, etc.

Typical trip data comes in form of tables describing how many trips are being taken from any traffic analysis zone to any other traffic analysis zone for a given time interval. Trip data is typically aggregated for the whole day. Diurnal distributions describe the total number of trips as a function of daytime. Diurnal distributions vary widely from area to area and from trip purpose to trip purpose. They represent another form of aggregate data and can be used in combination with the corresponding trip tables to reconstruct detailed trips from aggregate data.

Transims provides a tool ConvertTrips to create approximated specific trips for an entire synthetic population based on available trip tables

- Without a synthetic population based on Census data, ConvertTrip creates an artificial person and vehicle for each specific trip to place it onto the network
- Without basing the trips on the activities of a specific person, otherwise related trips appear to be undertaken by different individuals

ConvertTrips generates large trip tables with one record for each specific trip undertaken in the simulation area. It also creates one new synthetic person and one new vehicle for each trip. These records can be used by the TRANSIMS router to create exact travel plans for subsequent use in the microsimulator.

The Route Planner module generates routes for each individual travel plan from a trip file. The router can process both trips resulting from activities as well as simple trip tables, or both. Router builds a step-by-step travel plan that will take the person from their origin location to their destination location. The router uses a trip file generated by ConvertTrips as its main input. Additional inputs are link delays (iteratively obtained from the microsimulator or PlanSum), the road and transit networks, as well as the household and vehicle files. Due to this independent nature of routing, the router needs to use a few tools to make realistic plans like the Link Delays to decrease the speed along certain roads, thus increasing calculated travel time and emulating congestion. The router uses a shortest path algorithm, so it will route traffic around these congested areas whenever possible.
Then route planner and the microsimulator work in an iterative loop to equilibrate the traffic assignments on the network. The router determines the optimal route for each trip and creates precise travel plans. The microsimulator tests the interaction between the vehicles while following these travel plans and determines a new set of link delays replacing the ones used previously by the router. The router and microsimulator iterate until equilibrium is achieved.

This entire working process can be expressed with the following workflow diagram:

---

**TRANSIMS Data Sources**

The data underlying the Chicago Metropolitan Area Planning Commission (CMAP) TRANSIMS Model comes from a variety of sources, but it should be emphasized that the most essential elements have been provided by the Chicago Metropolitan Agency for Planning, CMAP. This includes the initial road and transit network, as well as the trip data, diurnal distributions, and other data related to the four step models employed by CMAP.

CMAP has also spent significant amount of resources and time to support this project and to supervise up to 8 students from Northern Illinois University for about 9 months who were assigned to editing the network, making sure that the entries are correct and that new data was included that was previously unavailable. The students worked at CMAP’s offices in the Sears Tower and used a multitude of data sources to perform these tasks. The resulting network has been checked by CMAP and is deemed to be appropriate to form the basis for the Chicago TRANSIMS Model.

CMAP also defines traffic analysis zones across the Chicago Metropolitan Area, breaking down the region into 1945 individual zones. CMAP provided the zonal information both in the form of a shape file constructed of polygons for each zone, as well as a TRANSIMS-compatible table of...
zone centroids. Both representations of the zonal information are being used at this time. The centroid data is used by TransimsNet to create a first assignment of activity locations to traffic analysis zones. In a second step, LocationData is used to reassign zones based into the polygon into which the activity location falls. This approach creates a spatially adequate allocation of origins and destinations for TRANSIMS to use.

The traffic analysis zones have been used in CMAP’s four step model and have been thoroughly shown to be adequate for the Chicago Metropolitan Area. The traffic analysis zones were extended while working on this project, covering additional areas compared to the data sets used initially. This increased the fidelity in some of the areas.

The size of the traffic analysis zones are somewhat proportional to the traffic and population density, and is thus much larger in rural areas compared with urban areas. The size increases with the distance from the Chicago Business District. Milwaukee is not an integral part of this model, and the traffic analysis zones close to Milwaukee are very large, being used to represent traffic origination and arriving in Milwaukee only with regards to its general impact on Chicago. Further network refinements would be necessary to extend simulations into Milwaukee.

The approximate size of this area is 10800 square miles. There are 1944 traffic analysis zones, with 278 zones defining the city of Chicago. The Chicago Business District is broken into 47 zones.

Development of Emergency Evacuation Modeling Methods

The goal of this part of the project is to develop traffic model components that allow simulation of the postulated emergency evacuation scenarios using only the existing TRANSIMS capabilities. Although TRANSIMS was originally developed for normal day traffic simulation, many of its modeling and simulation features may be utilized to recreate the various emergency management actions. The current progress was focused on the development of methods for generating emergency evacuation trips, and imposing proactive traffic control actions in part of emergency management.

Considering the fact that the Chicago Metropolitan Area (CMA) is very vast, it was decided to carry out the development of initial evacuation modeling components using a smaller readily available network of Alexandria, Virginia. Such an approach significantly expedited the development process; undertaking the iterative cycles for the large CMA model would have been impractical without the aid of cluster-based computation (which was not then available). The network and trip data needed for constructing a normal-day Alexandria traffic model was downloaded from the TRANSIMS open-source community. Unlike the CMA model, it was possible to run this simulation in several hours on a PC. This gave us a manageable timeframe for trial runs in part of the development process. Later as the high capacity cluster computer became available and with more progress made in the CMA model development, the development eventually moved to the CMA model.
The efforts in the early phase of this project was focused on the development of simulation model components for implementing the emergency scenarios, generating evacuation trips, restricting the traffic inflow to a certain areas, and rerouting the traffic flows. Such capabilities were mostly realized by modification of trip tables and other network restriction tables. The different methods for Emergency Evacuation Modeling can be explained as follows:

**Method for Evacuation Trip Generation:** A key component of the evacuation model is generating the evacuation trips. This evacuation trip table could be constructed from a normal day trip table according to the following procedure.

- Extract activity locations within the evacuation area; this can be accomplished by using the TRANSIMS SubareaNet module.
- Count the normal-day trip table and identify the trips leaving the activity locations in the evacuation area after the initial time of incidence.
- Change the trip start time according to an appropriate evacuation behavior response curve. Assign the trip ending time according to the original trip duration.

**Method for Road Restriction:** One of the primary needs during an evacuation is that of blocking off an area so that no traffic may pass inside. This accomplishes two primary goals: protecting the outside vehicles from harm and expediting the evacuation of traffic inside due to the decreased influx of outside vehicles. TRANSIMS offers several ways to accomplish this goal, by utilizing lane use restrictions, turn prohibitions, and signal modification. Of these, lane use restrictions and turn prohibitions prove to be most useful.

**Method for Traffic Rerouting:** There are several motivations for controlling traffic movements in an evacuation scenario. First, if the disaster is developing spatially over time, controlled movements can keep traffic moving away from the point of incident. Second, congestion can be reduced by undertaking rerouting instruction that will: reduce turning or spread out traffic flow. By re-routing in certain ways, avenues can be opened up for emergency responders to get the disaster area more quickly. Finally, specific re-routing takes the need for decision out of the driver so that more effort can be concentrated on reducing collisions.

**Method for Traffic Light Synchronization:** For most of the Chicago network, signals are constructed automatically by TRANSIMS utility called IntControl. Signals phases are created based on turn requirements while the lengths of these phases are based on the competing capacities of the intersecting roads and these phases may be in any order. IntControl does not consider adjacent signals when it makes its phasing decisions. This can produce an unrealistic set of patterns for densely signalized areas like the Chicago Loop area.

The goal for correcting the signal structure for the Loop would serve the dual purpose of: making the simulation a closer semblance of reality, and reduce artificially created congestion during the evacuation period. In order to properly change a signalization, it is necessary to alter 3 tables: the timing plan table, the phasing plan table, and the signalized node table.
Provision of Transit Transportation for Evacuation: A central point in many evacuation strategies is the usage of transit to evacuate large quantities of people without congesting the road network. These people would then be brought to pre-designated shelter areas. This scenario was investigated in a few different ways for the CMA evacuation. Common in all of these was the shelter selection and transit routing.

Development of Real Time Sensory Data Mapping Methodology

Traffic simulation is an important potential tool for municipal emergency preparedness planning. There is an emerging need for interactive planning which require short planning cycles and flexibility to keep up with rapid changing requirements.

TRANSIMS generates ‘normal day’ model which is valid only in statistical sense. To be used as an operation planning tool, it is necessary to adjust the traffic model in real-time to reflect the actual traffic situations based on roadside traffic monitoring sensors and other online data. Since TRANSIMS model involves extensive iteration process and complex network, model modification requires long computing time.

The Graduate students of NIU under the guidance of ANL Researchers are working to blend the external real time data into the TRANSIMS software to predict accurate traffic conditions. After making an analysis of the TRANSIMS model it was established that modifying the link delay table is the best way to achieve the desired objective. This would change the work flow of the TRANSIMS model. The link delay table is the only input file to the router that would be affected by adopting this methodology for incorporating the external data.

The traffic sensor data from all the expressways and toll ways in the Chicago area has been procured from the IDOT and this data have been refined to embed it into the TRANSIMS for modifying the link delay table. This can be achieved by defining an algorithm that combines the real-time data obtained from external sources with the link delays obtained from the micro simulator, to produce a refined link delay table that enables the router to generate routes based on the actual traffic conditions on a given day at a given time. Since the spatial and temporal resolution of the sensors are sparse compared to the traffic network, the effort will focus on devising a mapping method that interpolates in spatiotemporal domain.

The following specific objectives have been established as steps in the development of Real Time Sensory Data Mapping Methodology:

- Establishment of traffic system and data requirements
- Development of spatio-temporal mapping algorithm for interpolating sensor data
- Implementation of link-delay update method and integration into TRANSIMS tool
- Development and demonstration of validation method

The modified work flow diagram would be as follows:
The proposed improvement will allow real-time monitored information of the traffic condition – traffic counts and/or weather conditions – to be incorporated in the traffic model ‘on-the-fly’. This improvement will enhance the accuracy of the traffic prediction, and allow optimal routing of utility vehicles in real situations. The source code of the link delay program and the router will be changed to incorporate the external data into TRANSIMS.

Conclusion

After the tragedies of 9/11, the United States, and many other countries around the world have been looking to develop transportation evacuation plans to ensure that their populations are safe. These countries are also looking to ensure survivability and continuity in the event of another catastrophe. As was shown in this work, using TRANSIMS software, researchers and planners have an analysis tool which allows them to plan for these catastrophic events and to also evaluate strategies to deal with evacuation of the cities in danger. As was shown in this work, the usage of this complex software allows the users to simulate the traffic and pedestrian patterns in the urban centers. Through the knowledge of the interaction with the traffic, and roads needed for both evacuation of the population (or portion of the population) and the entry of emergency vehicles into the effected areas, planners have a tool to plan for the evacuation. This tool allows the user to model key intersections and portions of major roadway systems under emergency conditions, and it also allows for the examination of vehicle travel times. The research team relied heavily on student involvement at all phases of this work. The initial phases of the project required a
group of undergraduate students to compare current thoroughfare (from major highways to minor roads) databases with satellite mappings of the given region to determine if the databases are up-to-date. Once this was completed, the students, overseen by the authors and the Chicago Metropolitan Area Planning Commission, entered the information into the system along with information on population locations and public transportation routes. Information on typical population travel routes, timing, and population residency was also entered into the system. The results of this input provides information into egress and entrance routes into the city in cases of emergency.

References


Hubert, Ley, Young, Park, Michael, Hope, Vadim, Sokolov, Adrian, Tentner, Dave, Weber, Alex, Betts and Joe, Reitzer (2008). Modelling and Simulation of an Emergency Evacuation Scenario for the Chicago Metropolitan Area, 35-42 and 137-159.