TRANSIMS Training Course at TRACC

Transportation Research and Analysis Computing Center

Part 0

Application of TRANSIMS to Large Metropolitan Areas

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Unit **0**

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U.S. DEPARTMENT OF ENERGY

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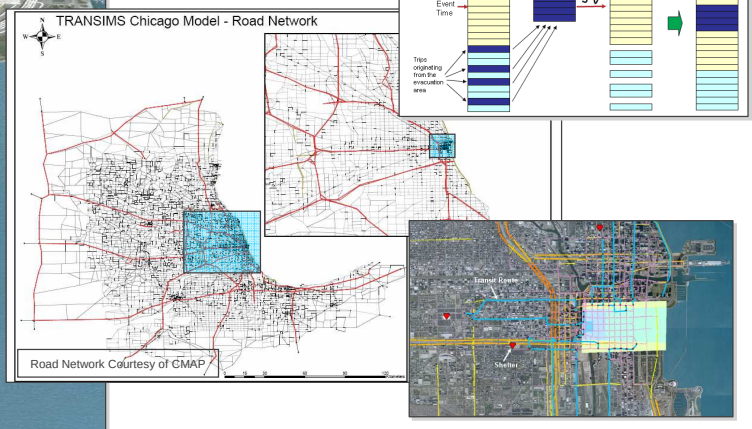
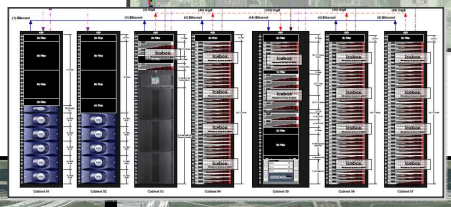
TRANSIMS Model of the Chicago Metropolitan Area

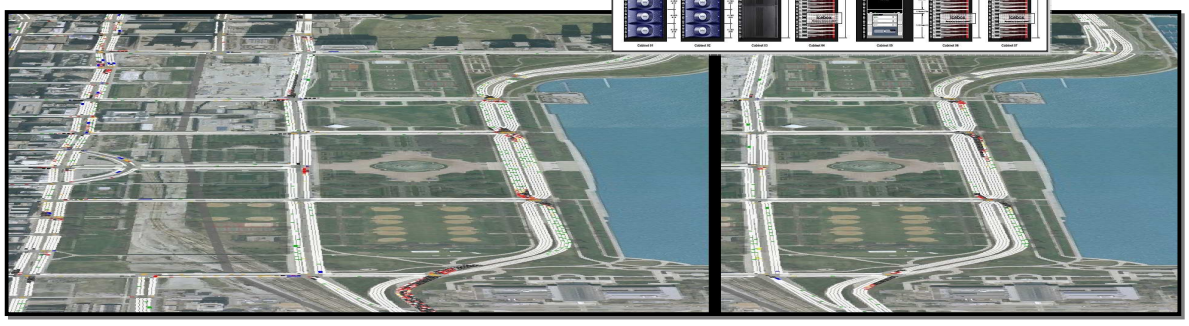


- TRANSIMS is a state-of-the-art transportation simulation code developed by USDOT. A high fidelity model has been created for the Chicago Metropolitan Area, running on the TRACC high performance computing cluster

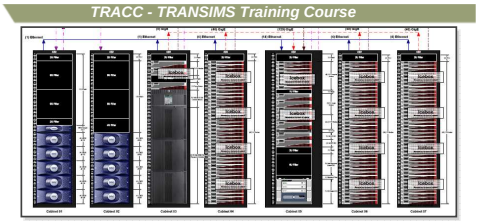
TRANSIMS Model of the Chicago Metropolitan Area

- TRANSIMS requires massive computing resources for large metropolitan areas
- TRACC conducts targeted research, e.g.
  - Evacuations for the Chicago Business District
  - Transportation planning for Chicago
- Outreach activities: TRACC provides user support to enable other TRANSIMS applications on the HPC cluster:
  - Washington DC, Los Angeles, Atlanta, Buffalo, others





TRANSIMS User Support and Training



- TRACC is providing training courses on TRANSIMS to the transportation research community in the US
  - Training courses are offered approximately 4 times per year in varying locations
  - Participation is free, and training courses are broadcast over the Internet to reach additional users
- TRACC is holding additional training sessions on emerging capabilities through the Internet
- The goal is to build a strong community of expertise

About Argonne: One of DOE's Largest Research Facilities

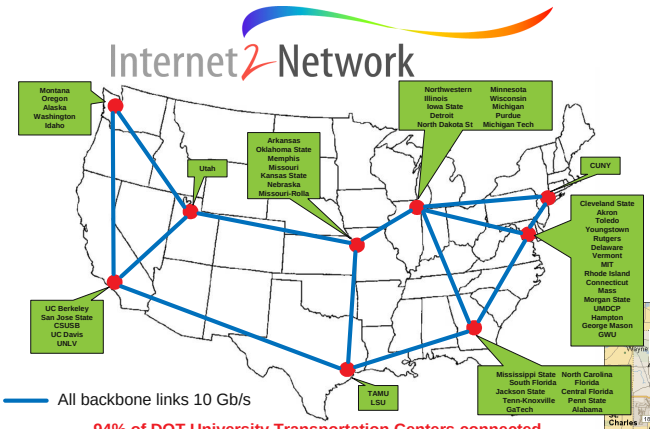
http://www.anl.gov/

- Located 25 miles from the Chicago Loop, it was the first national laboratory, chartered in 1946
- Operated by the University of Chicago for the U.S. Department of Energy
- Major research missions include basic science, environmental management, and advanced energy technologies
- About 3,000 employees, including about 1,000 scientists and engineers, of whom 750 hold doctorate degrees
- Annual operating budget of about $475 million (80% from DOE)
- Since 1990, Argonne has worked with more than 600 companies and numerous federal agencies.

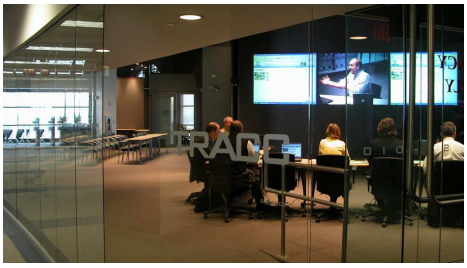
TRACC - A National User Facility to Meet USDOT Advanced Computation Needs

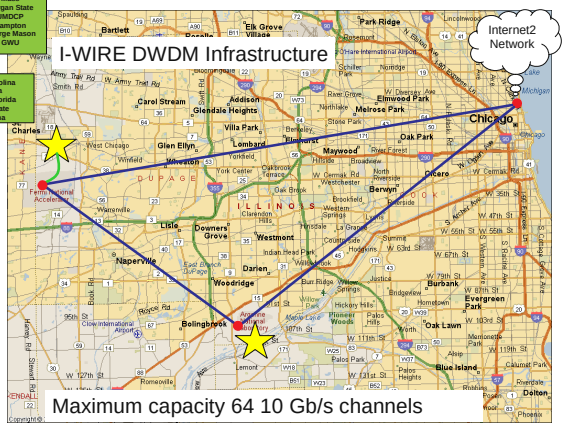
- USDOT and USDOE transportation research programs, private industry, and state and regional transportation agencies are moving to simulation-based design and analysis for improvements in efficiency, economics, and safety
- Higher fidelity analysis in areas such as crashworthiness, aerodynamics, combustion, thermal management, weather modeling, and traffic simulation require access to state-of-the-art computational and visualization facilities
- Argonne expertise in high-performance computing and transportation system analysis provides the basis for a national HPC user facility and a focal point for computational research for transportation applications

TRACC: Location and Connectivity



94% of DOT University Transportation Centers connected

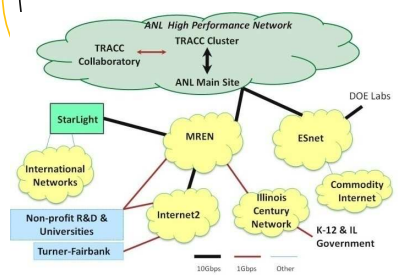




TRACC – High Performance Computing for Transportation Research and Applied Technology

TRACC Is a National USDOT Supercomputing Facility

TRACC High Performance Compute Cluster
- *1024 core /128 compute nodes*
- 180TB Global Parallel File System Disk Storage
- 160TB Archive/Backup Tape Storage

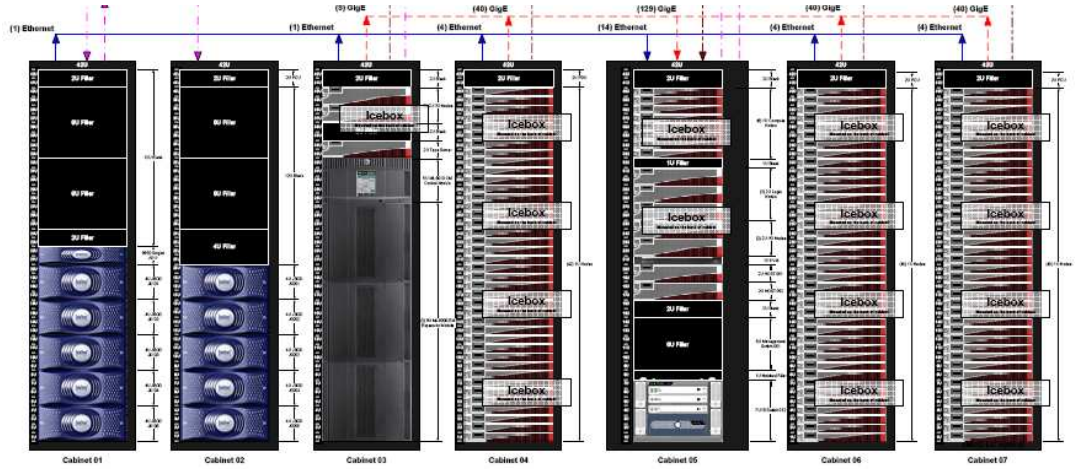


High-bandwidth connectivity is provided via the Argonne high-performance network to world-wide research and education networks (Internet2 and ESnet)

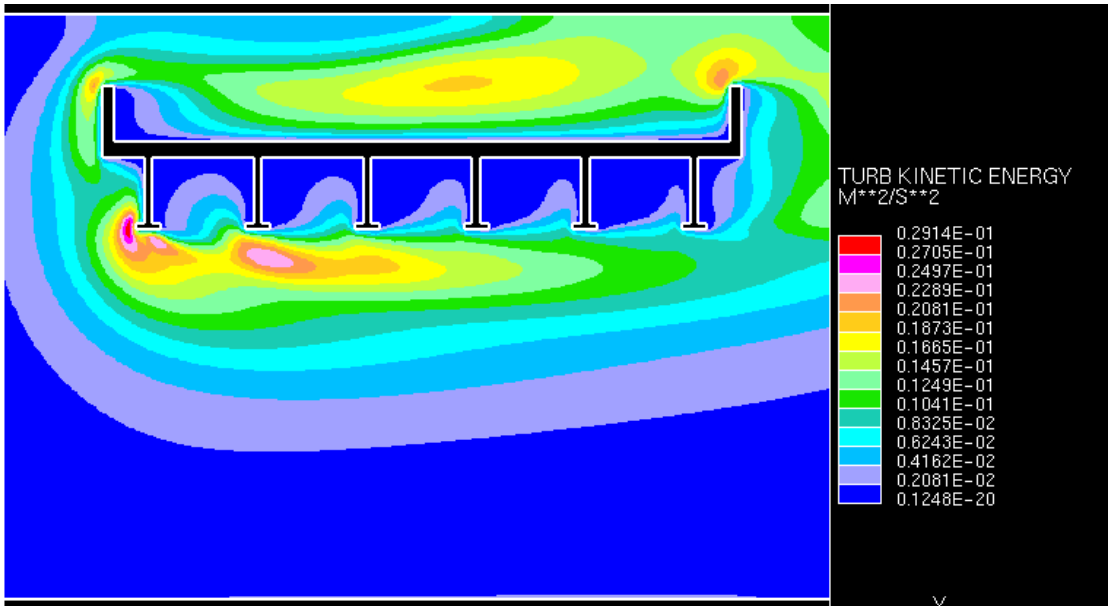
TRACC Collaboratory - Visualization, Access Grid, and Digital Conferencing

TRACC HPC Configuration Diagram

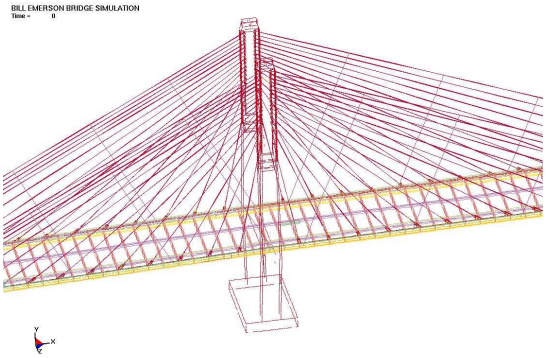
The TRACC computational cluster is a customized LS-1 system from Linux Networx consisting of 1024 core 128 compute nodes, each with two quad-core AMD Opteron CPUs and 8GB of RAM, a DataDirect Networks storage system consisting of 180TB of shared RAID storage, expandable to 750TB, a high-bandwidth, low-latency InfiniBand network for computations, and a high-bandwidth Gigabit Ethernet management network. The system will also include the highest-performance compiler and MPI library available for the AMD Opteron architecture. with a peak performance of ~4 TFlops



Example: 2-D STAR-CD model for reduced scale inundated bridge deck



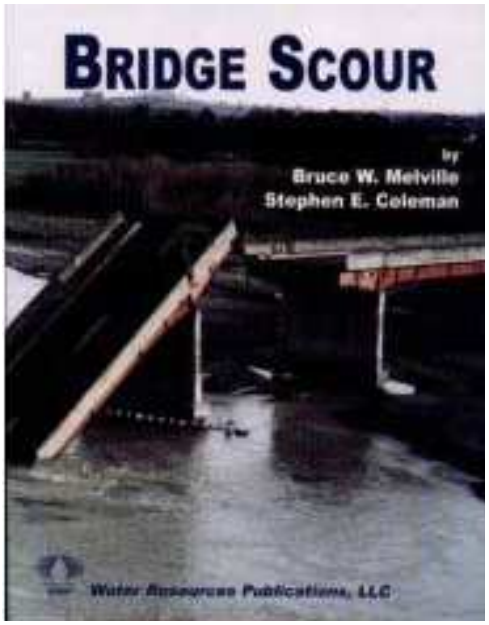
High Fidelity Bridge Modeling and Simulation



- To accurately determine the structural response of bridges to loadings from traffic, high winds, river currents and earthquakes, it is necessary to develop high fidelity numerical (finite element) models and perform transient dynamic analysis using state-of-the-art cluster computers
- The figure on the left shows the Bill Emerson Memorial Bridge that spans the Mississippi River between Illinois and Missouri near Cape Girardeau, Missouri; the figure on the right is a high fidelity model consisting of over 500,000 elements representing the important structural elements of the bridge

Bridge Pier Scour

- Bridge pier foundations can be vulnerable to scour, i.e., removal of river bed material due to rapid flows
- Significant scour depth can affect the stability of pier foundations causing bridge failure, resulting in transport disruption, economic loss and an occasional loss of life (see Figure)
- The factors influencing scour are complex and vary according to type of structure
- High fidelity modeling and simulation is required to accurately predict scour and determine time to structural failure and failure modes



Response of Roadside Hardware to Vehicle Crashes

- Problem
  - Crash testing of a large variety of vehicles into roadside hardware is an extremely expensive proposition **(~$500,000 & 10,000 man-hours/test).**
  - Complexity and a current diverse fleet of automobiles and trucks as well as the next generation vehicles such as hybrid, electric and fuel cell automobiles add significantly to future crash testing cost.

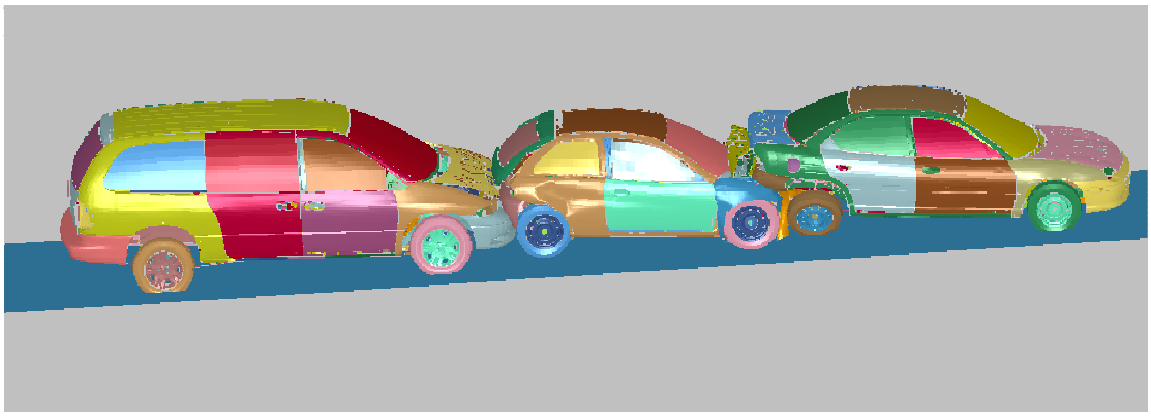
- Significance to US DOT (FHWA)

  High fidelity crashworthiness simulations provide economical alternatives to evaluate crashes and provide data to optimize the design of roadside hardware which is sensitive to vehicle characteristics (mass and height of center of gravity), bumper and hood geometry, and roadside geometry (slopes, embankments, ditches, etc.).

Multiple Vehicle Crash Simulation

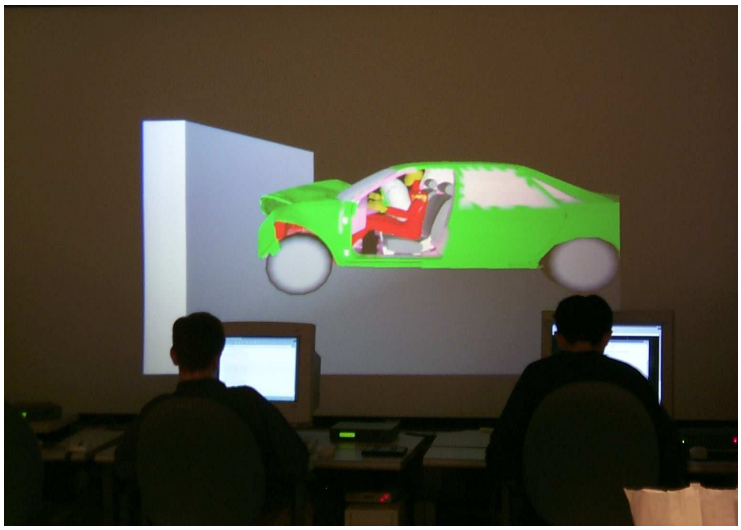
•Multi-vehicle crash simulations (using LS_Dyna code) performed on cluster computers represents the state-of-the-art

•Subdividing the complete model into smaller domains (via domain decomposition) and computing each domain on a single processor significantly reduces total compute time



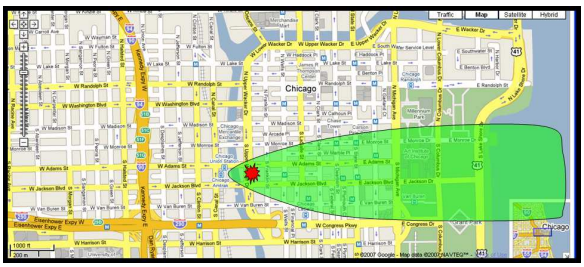
Visualization of High fidelity Simulations

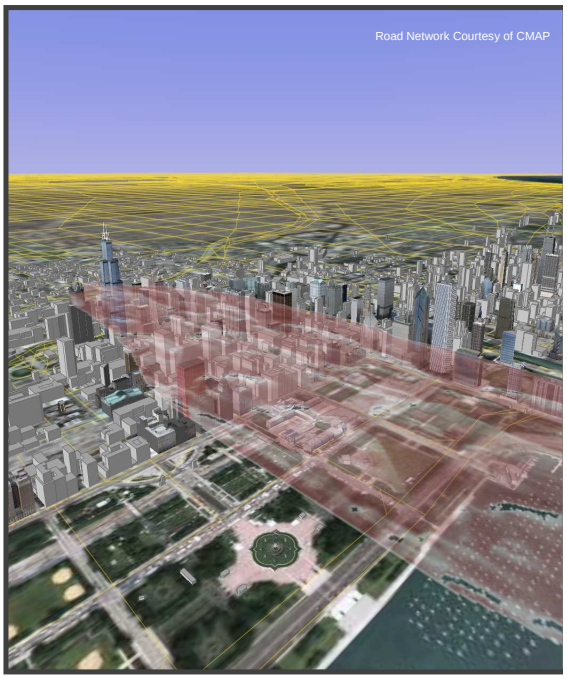
- Visualization is an essential element to understanding the complexities involved in crash analysis
- Virtual reality hardware (CAVE, 1-wall CAVE, Head Mounted VR, etc.) drastically reduces the time needed to understand crash analyses.



Emergency Evacuations of the Chicago Business District

- TRANSIMS has unique capabilities to simulate the effects of emergency evacuations.
- This project has been implemented to model the effects of a no-notice event on the multi-modal regional transportation system in the Chicago metropolitan area.
- This project deals with the dynamic effect on the transportation system.
- Sponsored by the Illinois Terrorism Task Force, the Illinois Department of Transportation, the City of Chicago, and other federal, state and local agencies.





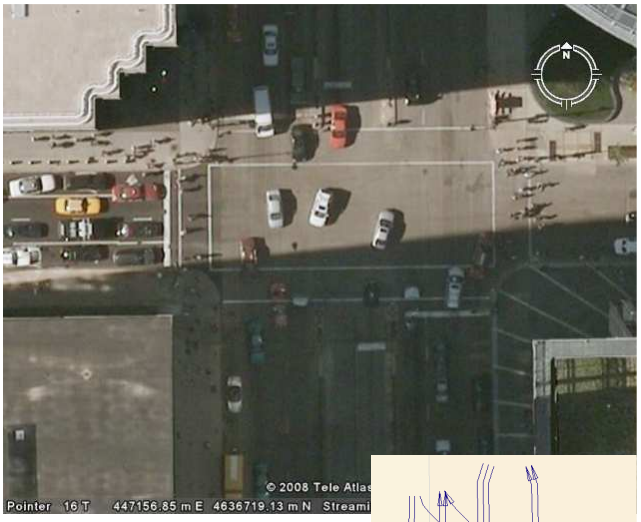
Fundamental Capabilities of the TRANSIMS Approach

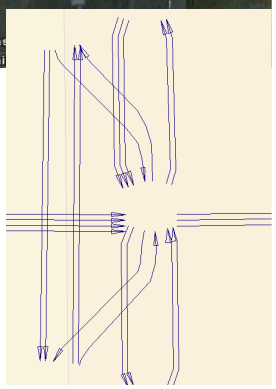
- **Multi-modal transportation** (vehicles, buses, trains, walking, bicycles,…)
- Extremely **large simulation areas**, e.g. Chicago (10,000 square miles)
- Fully time-aware routing of **each individual traveler** for all travel modes
- Microsimulation for large metropolitan areas to determine the interactions between travelers and vehicles to determine **second by second movements**
  - Determination of **vehicle interactions**, such as lane changes, speed changes, passenger loading and unloading, …
  - **Interaction with the road network**, e.g. with traffic signals, speed limits, turn lanes, transit vehicles, …
- This approach overcomes the limitations of traditional traffic forecasting models:
  - Delivering **transportation system performance** as a full function of time instead of static solution for a few time periods (e.g. am and pm peaks)
  - Microscopic interaction between vehicles and travelers delivers **accurate results** compared to simple volume delay functions and aggregate data.
- Main challenges: **Massive demands on computation time** and a need for extremely detailed input data

10,000 Square Miles Simulation Area

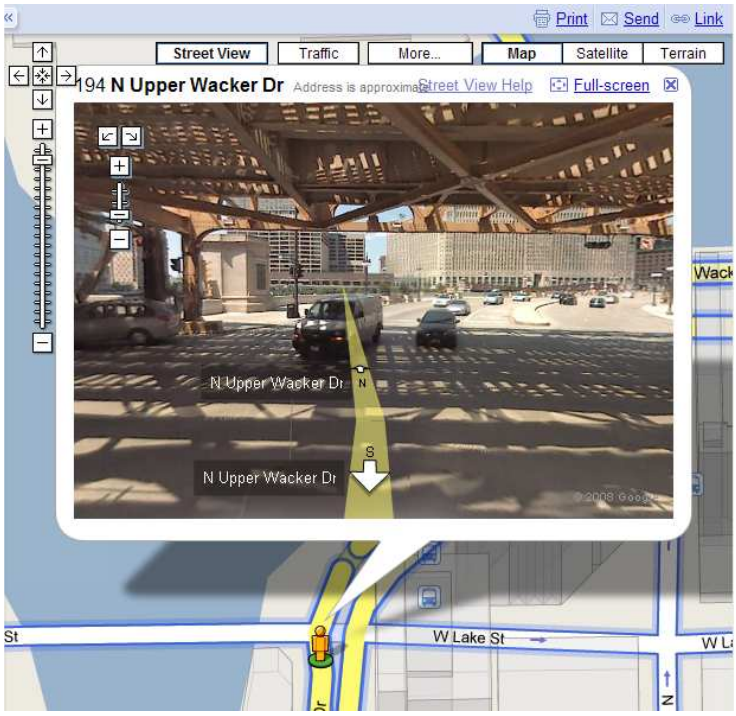
Available Data Sources and the Types of Data Needed

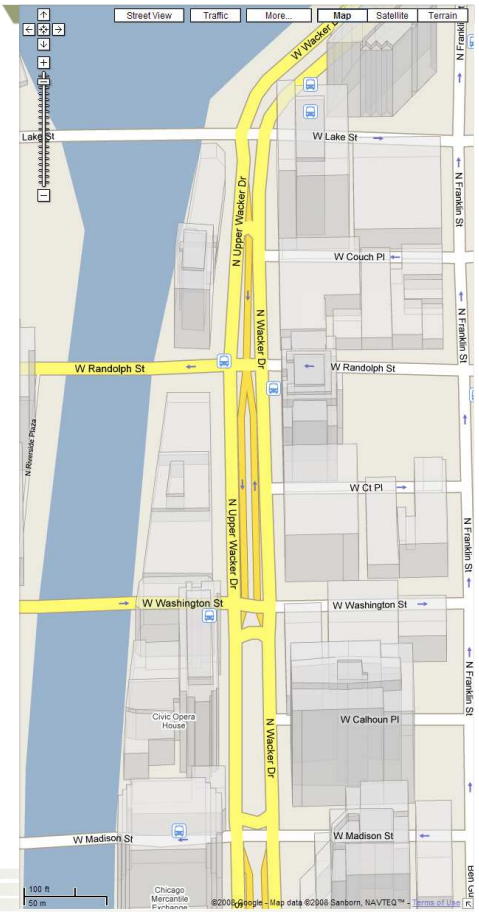
- CMAP and TRACC Network Improvements
- Main focus is on network topology, in particular:
  - Connectivity
  - Number of Lanes
  - Functional Classes
  - Speed Limits
  - Coded Length
  - Capacities, etc.
- For visualization and more precise modeling:
  - Exact geographic locations
  - Shapes along links
  - Correct integration of transit links and stops, etc.



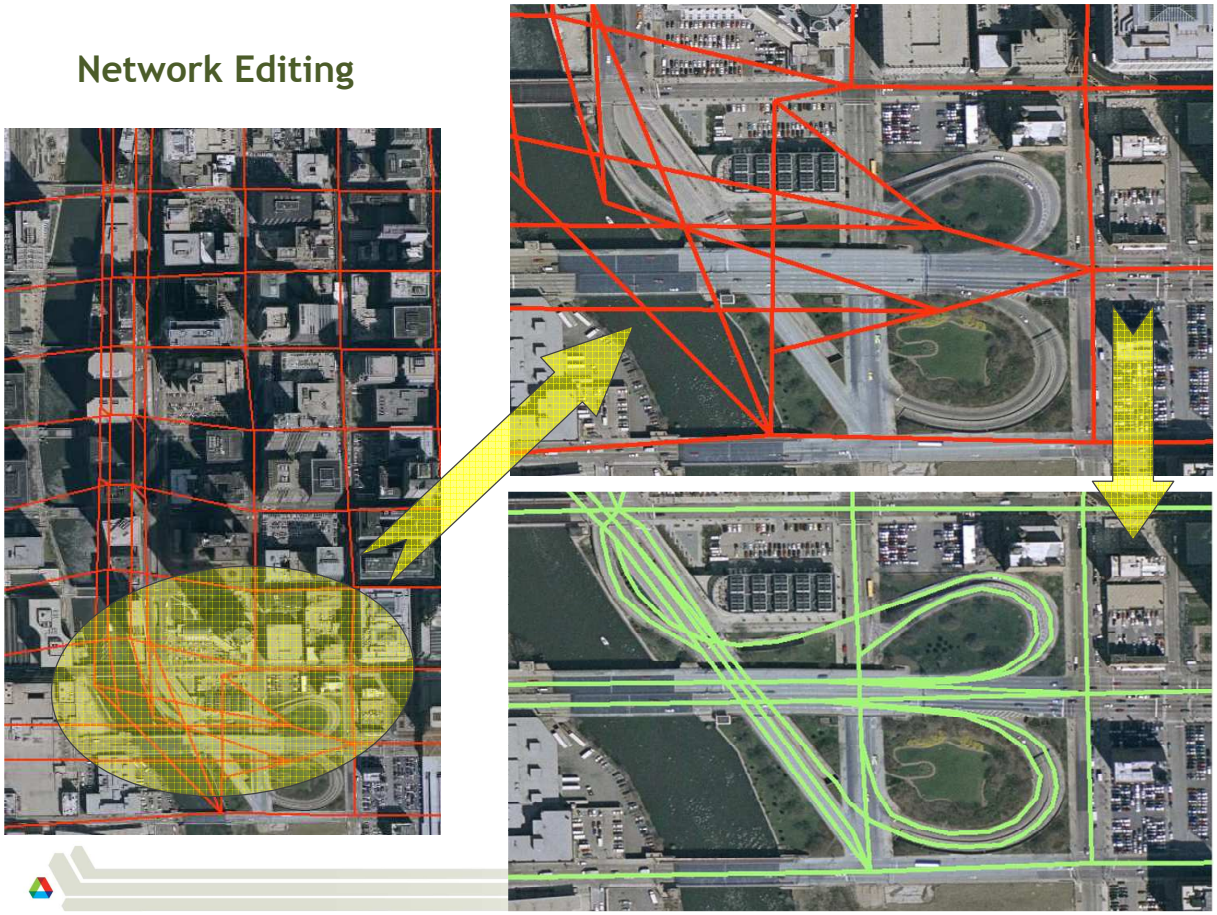


Google Maps and Street View





Network Editing

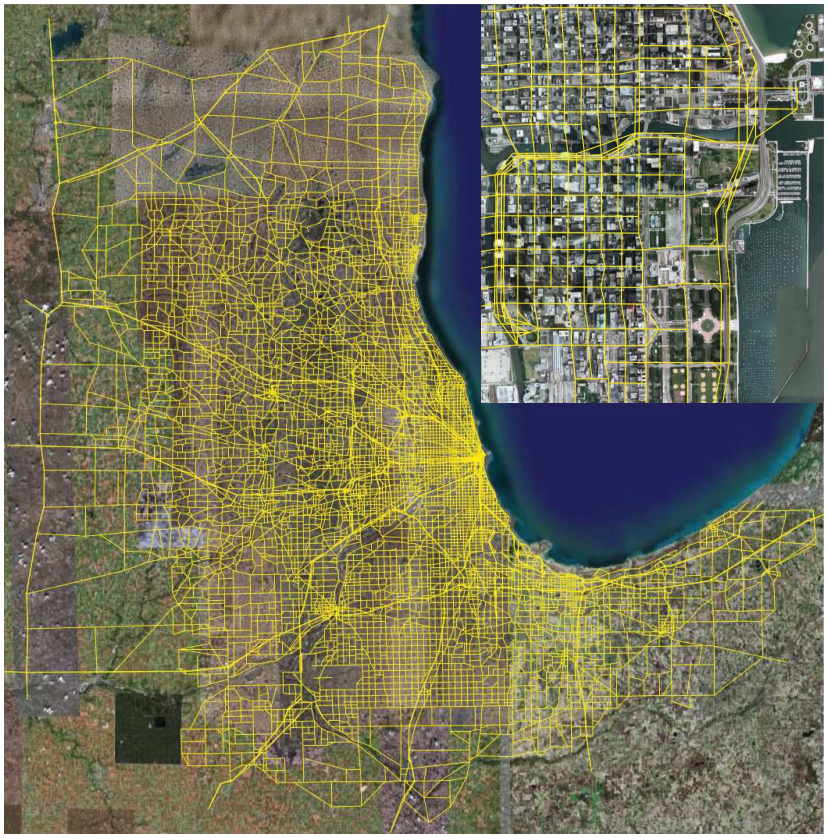


Current Status

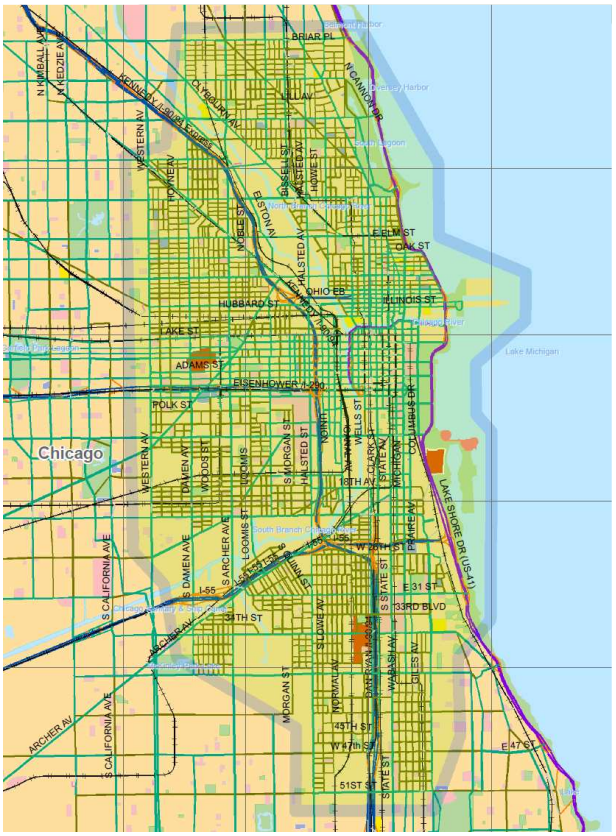
- Each individual lane is modeled
- Pocket lanes are modeled
- Lane Connectivity
- Signals
  - Phasing
  - Timing
- Parking
- Many more details

The Regional Road Network

- ~10,000 square miles
- Road network
  - 40,000 links
  - 14,000 intersections
  - 250,000 locations
- ~28 million vehicle trips
- ~1.5 million transit trips
- Trip tables
  - Break-down by purpose (work, truck, airport, and many more)

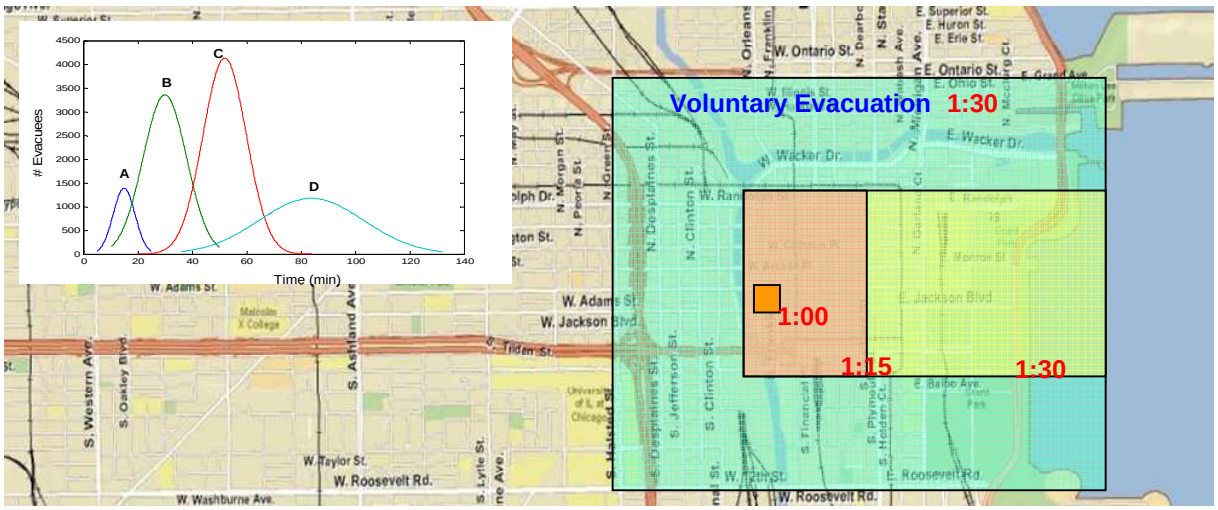


Network Detail 2009

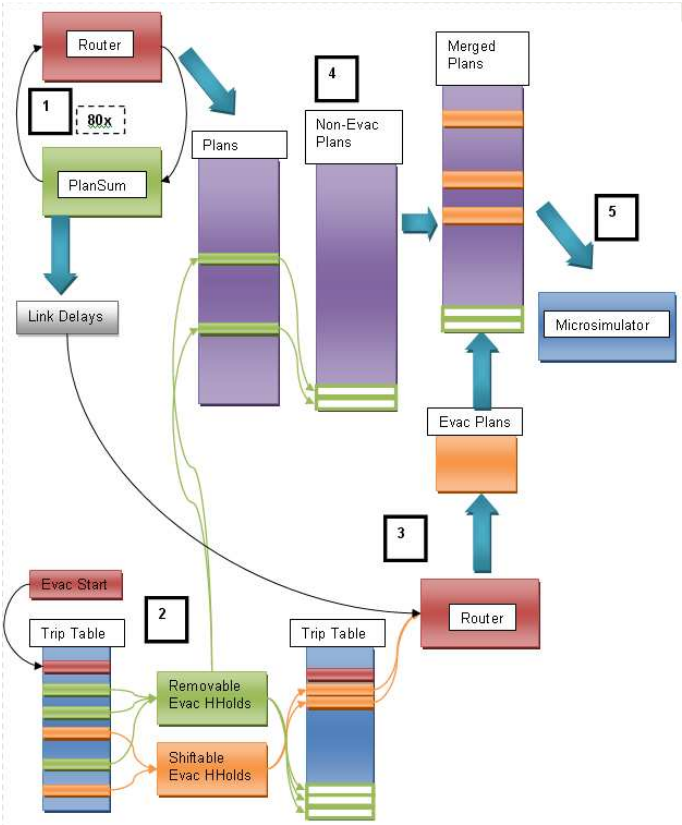


Basic Evacuation Model for Chicago

- Areas to be Evacuated
- S-Curves for Trip Start Times

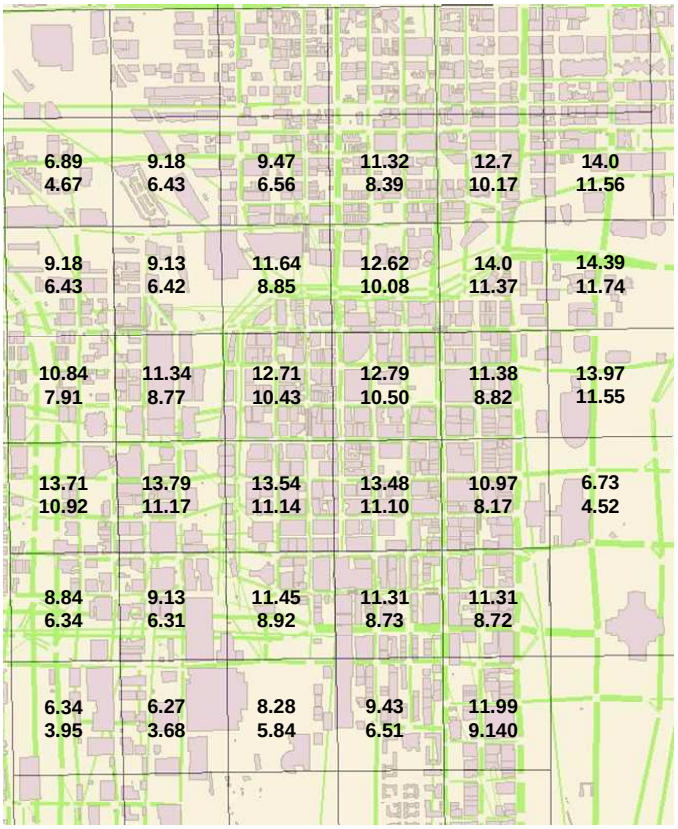


Process Diagram for Emergency Evacuations Using TRANSIMS



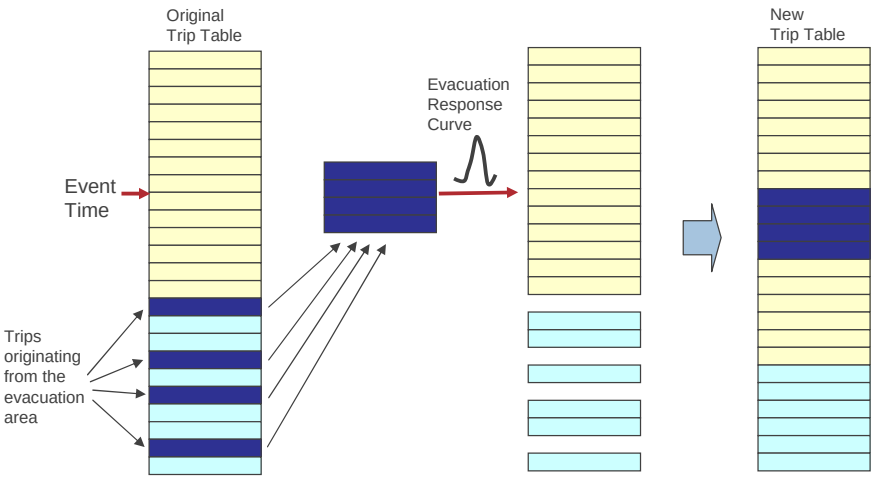
Population Modeling

- Socio-Economic Data
- Fuzzy Logic Methodology
- Building Footprints
- Census Data
- Numerous Data Sources from OEMC and CMAP
  - Pedestrian Counts
  - Boarding and Alighting from Transit
  - Traffic Signals
  - Flow Sensors
  - …



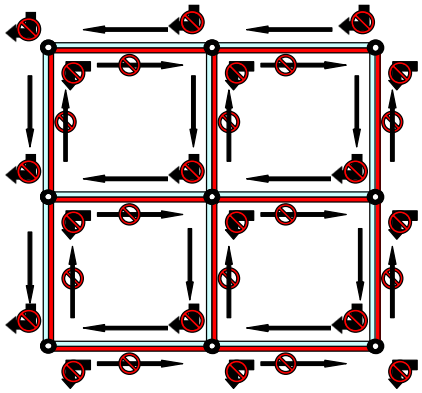
Evacuation Trips

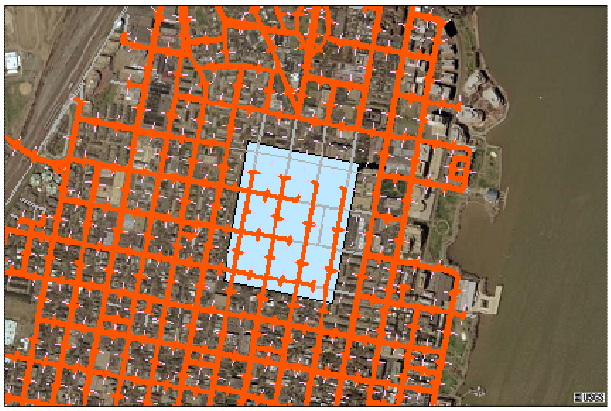
- An initial methodology has been developed to deal with evacuation trips
  - Trips originating in the evacuation zone after the event are moved forward in time and are assigned a new departure time
  - A special distribution of trip origination time is applied (evacuation response curve)



Preventing Trips to Enter the Affected Area

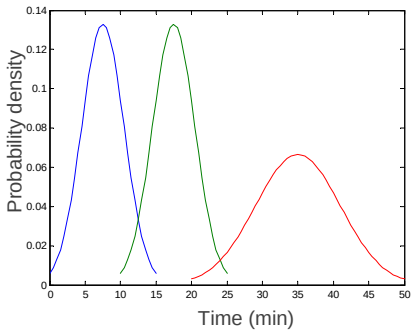
- Trips need to be rerouted so that travelers are not sent into the evacuation area.
- Likewise, evacuation trips from the area are directed out of the area into a specific direction

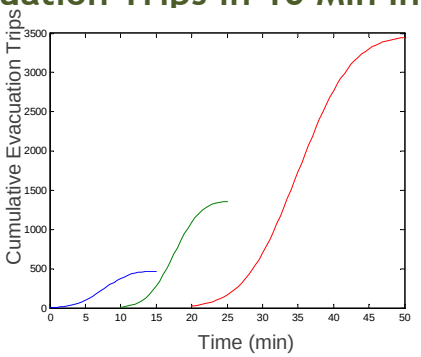


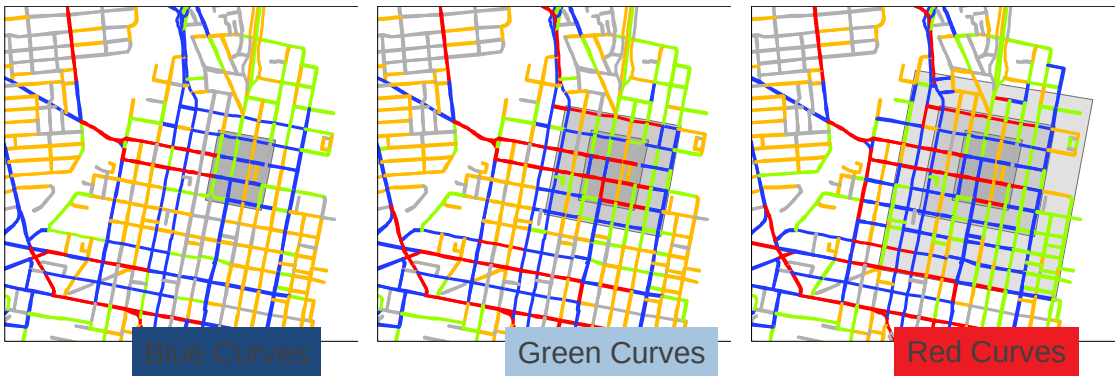


- This is achieved by setting lane restrictions and turn restrictions, both of which can be in effect for selected time periods

Congestion Caused by Evacuation Trips in 10 Min Intervals

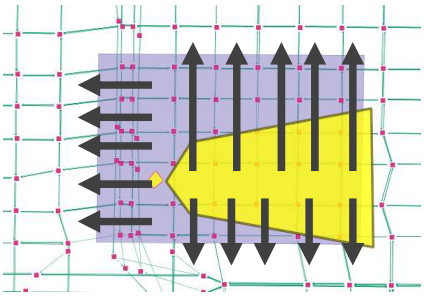






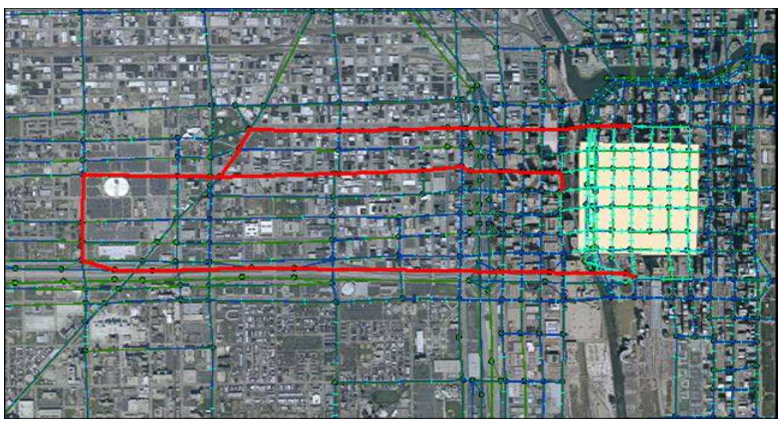
Directional Evacuation

- Directional evacuation minimizes exposeure to the plume
  - Turn prohibitions are used to assure proper re-routing and to keep travelers from entering the area
  - Lane restrictions are used to restrict two-way traffic on LaSalle Road



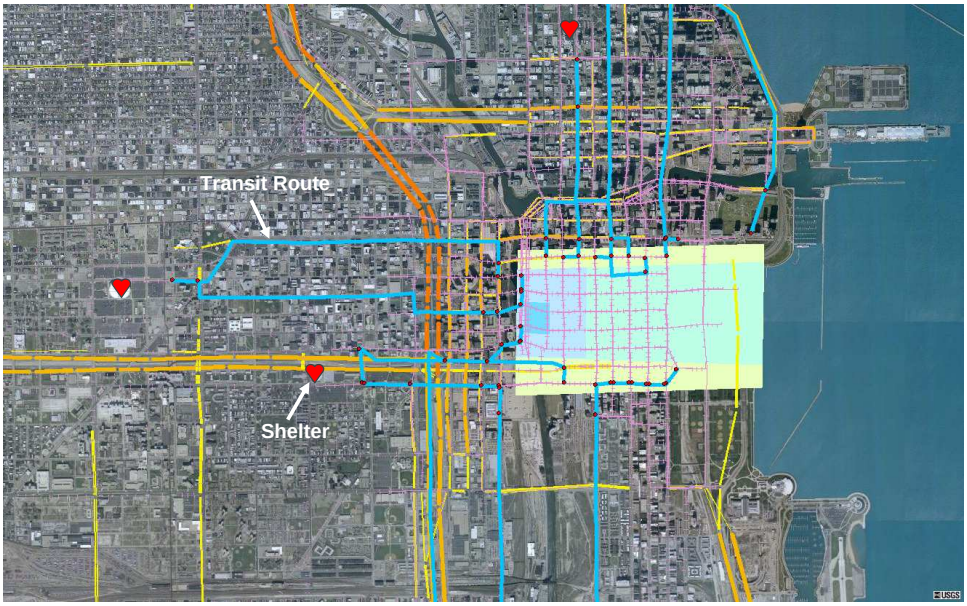
Example Case Study: Evacuation with Transit to a Shelter

- Scenario:
  - The Emergency Response Team secures a few suitable transit stations
  - People in the Evacuation Area are directed to walk to these stations
  - Transit transportation is provided to take them to a shelter location (e.g. United Center)
- TRANSIMS is already able to simulate for each individual person:
  - Delays in leaving buildings
  - Walking towards the closest evacuation stop
  - Flow of buses within congested roads and/or on reserved lanes
  - And more …

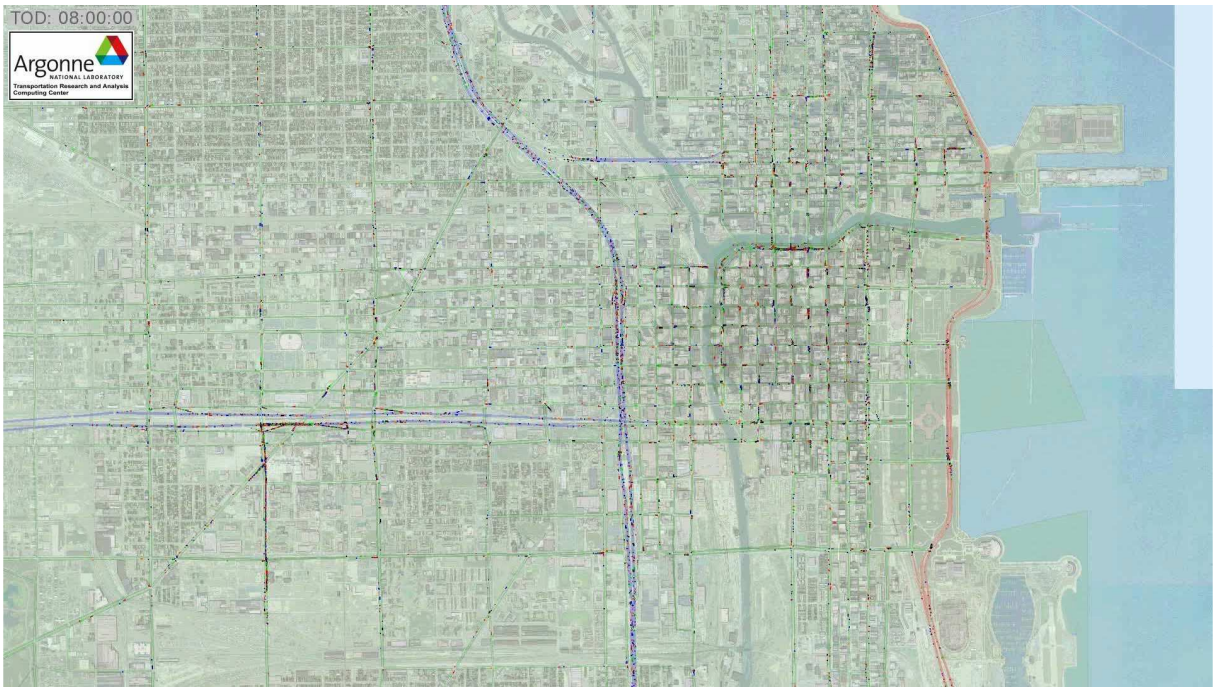


Complex Evacuation Strategies

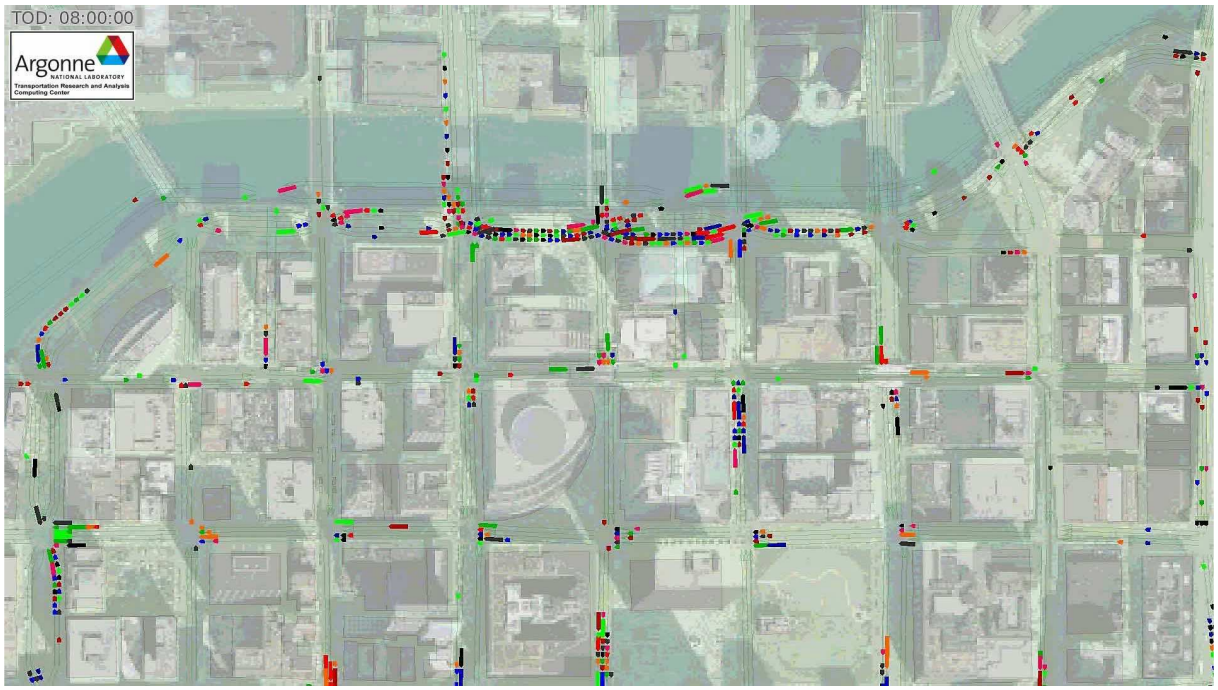
Scenario 4: Evacuation via Transit to Shelters



Examples for High Resolution Visualizations



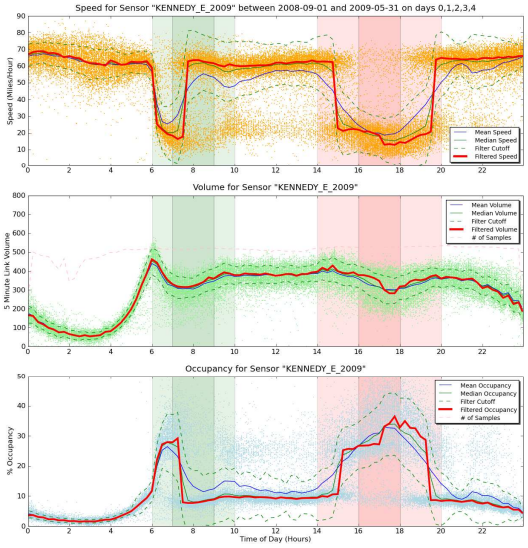
Examples for High Resolution Visualizations



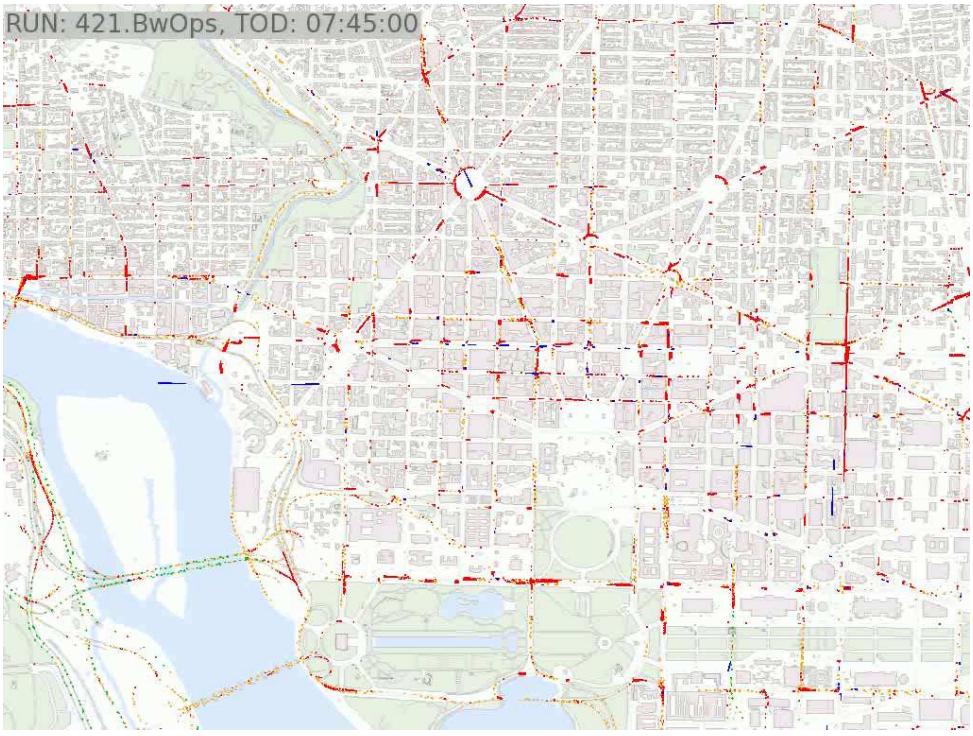
Chicago 2016 Illustrations

TRANSIMS Validation and Forecasting

- GCM sensor data has been captured for 8 months
- ~750 active sensors
- 5 minute volumes and speeds
- Valuable for future work in the Chicago area, e.g. dynamic traffic assignment other than TRANSIMS
- Data mining for special events and other potential validation of emergency conditions



WHATS – White House Area Transportation Study



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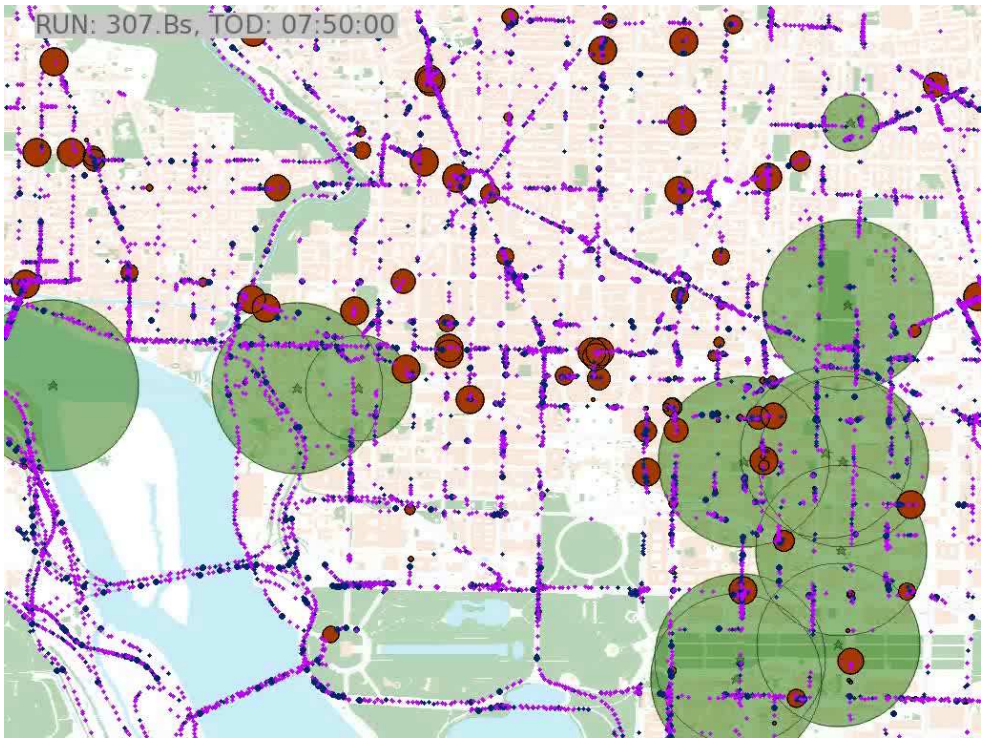

Credits and Acknowledgements

- GIS visualization materials were mostly developed at Argonne based on the TRANSIMS tools developed by AECOM for USDOT
- Washington Visualizations were provided by AECOM Consult
- Road network and trip data was provided by the Chicago Metropolitan Agency for Planning
- Northern Illinois University provided students both to CMAP as well as Argonne to work on the emergency simulation models and to improve the road network
- IDOT, IEMA, USDOT, and IEPA provided the funding for much of the work described in this document
- In addition, OEMC, FEMA, and DuPage County are part of a steering committee to direct the work on this project
- USDOT provided the funding for the TRACC computing center and the resources necessary to perform these training session