Overview of Transportation Modeling and Simulation for Evacuation Planning and Analyses

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Background and History

- Traffic modeling and simulation is not new

- Fundamental tool in the field of traffic engineering

- Particularly useful for "what-if scenario" analyses and comparison of alternatives

- Used throughout the world since the 1970's for assessing evacuations for: nuclear power plant emergencies (required for US NRC licenses), wildfires, hurricanes, terrorist threats, and many other natural and manmade hazards and threats

Scales and Levels of Abstraction

- In general, "more detailed" modeling and simulation has been used for "small" areas and "less detailed" techniques and systems have been used for "large" areas

- This has been changing with increasing computational power and speed, but it remains true for logical and practical reasons

- There are trade-offs between coding level of effort (time and expense) and model level of fidelity (representation of detail)

Primary Families of Traffic Simulation Platforms

- Macroscopic, Mesoscopic, Microscopic – where, generally:

- Micro modeling considers individual driver behavior, vehicle movements, and their interactions with other vehicles and traffic controls, and other specific conditions and incidents

- Macro modeling considers the flow of groups of vehicles related to link capacity and nodal control on road segments

- Meso modeling ranges, somewhat widely, between these two

Concepts and Components of Evacuation Traffic Modeling and Simulation

- Behavioral modeling and assessment (based on threat and response) estimates who will leave, when they will leave, where they leave from, vehicle utilization, vehicle occupancy, etc.

- Travel demand modeling and assessment uses above info to forecast travel destinations, routing, and modal split over time

- Traffic simulation, conducted in this effort, uses demand information over space and time, combines it with network characteristics (lanes, controls, connectivity, etc.) to forecast flow travel conditions (speed, flow, travel time, queuing, delay, etc.)

What It Is…. and What It Is Not

- Simulation is a tool – among many tools in traffic planning and engineering

- Provides a reasonable estimate of operation/travel conditions based on the available data; evacuee behavior and network condition assumptions; and an understanding of traffic process and ability to model them

- Given the infinite number of threats and responses, no model can "predict" specific evacuation, however, it provides reasonable expectations of performance under an assumed set of conditions

- It is effective at demonstrating incremental changes in system performance based on incremental changes in conditions

Outputs and Performance Metrics

- There are many indicators of system performance when assessing evacuation network conditions

- Traffic-related measures typically include travel time, speed, delay, congestion, queue length

- Emergency planning-related measures typically relate to life-safety issues, including: clearance time, hazard exposure duration, number of people unable to evacuate, etc.

- Most of the latter indicator category are computed from the former

Quantitative and Qualitative Results

- Most evacuation traffic modeling and simulation is aimed at quantitative (i.e., numeric) results, which may not always suit everyone

- Increasingly, most new platforms feature visualization tools that permit dynamic representation of system performance

- Visualizations are particularly helpful to pictorially represent, rather that tell, changes over time and space during an evacuation

- However, visualizations are built from numeric data and, while they look impressive, they are only as good as the numbers they are built from

Example Illustrations

- WUI Residential Subdivision - Wildfire, Neighborhood, Microscopic

- Ashland, Oregon - Wildfire, Small City, Mesoscopic

- US Nuclear Regulatory Commission – Model Parameter Assessment

- Florida Keys – Hurricane, Island Chain, Macroscopic (numeric)

- Toronto, Ontario – NPP Emergency, Metro Region, Microscopic

- New Orleans, Louisiana - Hurricane, Metro Region, Mesoscopic

WUI Neighborhood-Level Wildfire Evacuation

- American Society of Civil Engineers, *Journal of Urban Planning and Development*, Volume 133, Issue 1, March 2007
  https://ascelibrary.org/doi/abs/10.1061/%28ASCE%290733-9488%282007%29133%3A1%2873%29

- Understand WUI residential evacuations for wildfires

- Micro modeling of location and number of egress points; traffic volume; and clearance time.

- Conditions/characteristics/constraint variables, included:
    - Housing density
    - Egress opportunities
    - Layout of street network
    - Range of threat-response urgency

Ashland, Oregon - Small Mountain City ETE

- KLD Report https://www.ashland.or.us/Files/KLD_Ashland_Final_ETE_4-13-2021_red.pdf

- Estimate evacuation clearance time for a 6 sq. mi. mountain town of 20,000 with limited ingress egress

- Micro simulation to:
    - Identify areas and populations most vulnerable to fire
    - Support evacuation plan development for city
    - Estimate clearance time for variety of threat scenarios and alternative management strategies
    - Inform protective action decision making

US NRC – Model Parameter Assessment

- NUREG/CR-7269 https://www.nrc.gov/docs/ML2007/ML20070M158.pdf

- Support for federal requirements for licensee evacuation time estimate reports (ETE)

- Assess conditions that could impact simulation results, including:

  - EPZ population
  - Shadow evacuations participation
  - Geographic size of simulation models
  - manual traffic control;
  - Values and assumptions of key simulation model parameter values

FL DOT – Florida Keys Evacuation Analysis

- Estimate evacuation clearance time for 100mi chain of islands

- Conditions permitted mixed modeling, overall spreadsheet "in-and-out" macro model with location-specific micro models

- Unique conditions/characteristics/constraints, included:
    - Single route of varying capacity
    - Varying concentrations of population and participation
    - Minimal environmental impact
    - Development moratorium and no road improvements

Toronto Region – Double Nuclear Plant Emergency

- Evaluate range nuclear power plant emergency-evacuation scenarios to support creation of regional traffic management plan for DOT, police and local government agencies

- Three-level mixed modeling featuring macro, meso, and micro models to reflect location-specific conditions and info needs

- Unique conditions/characteristics/constraints, included:
  - More than 9M lane miles, 500,000 vehicles, 1,000 signals
  - More than 30 scenarios
  - Ramp closures, forced turn routing, detours, etc.

New Orleans Regional Hurricane Evacuation Plan

- Evaluate regional evacuation scenarios to support creation of regional traffic management plan for DOT, police and local government agencies

- Series of models using meso and micro models to evaluate conditions in different locations and levels of detail

- Unique conditions/characteristics/constraints, included:
  - About 5,000 square miles, 500,000 vehicles, 48 hours
  - Examined range of response and traffic management scenarios
  - Contraflow, freeway loading, cross-over locations, etc.