Using Traffic Simulation for Emergency and Disaster Evacuation Planning

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The September 11 attacks have made clear that the likelihood of occurrence of many previously thought low-probability events, such as for example a radiological event at a nuclear plant or the release of toxic gases to the atmosphere, have to be reassessed. To protect the population that could be potentially affected by this type of man-made disasters (as well as natural disasters such as hurricanes, earthquakes, forest fires), vehicular evacuation is one alternative that needs to be evaluated. One of the key factors used in evaluating the effectiveness of evacuation as a protective action option is the estimate of time required for evacuation; that is, the time associated with clearing an area at risk to areas considered safe. Once evacuation is identified as a viable protective action strategy, considerable planning and analysis is required to develop an evacuation plan which best serves the population at risk.

Oak Ridge National Laboratory (ORNL) has developed a sophisticated simulation modeling system (named OREMS) which can be used to estimate evacuation time and to develop evacuation plans for different events or scenarios (e.g., good vs. bad weather conditions, day vs. nighttime evacuations) for user-defined spatial boundaries. The system permits to experiment with alternate routes, destinations, traffic control and management strategies, and evacuee response rates. For every scenario it is possible to identify evacuation or clearance times, traffic operational characteristics (e.g., average evacuation speed), bottlenecks, and other information necessary to develop effective evacuation plans and to conduct transportation infrastructure vulnerability studies.

A substantial amount of effort goes into developing the emergency evacuation plans. However, those plans are nearly worthless if the relevant information that is input to the models (i.e., network topological information and spatial demographic data) is not kept up-to-date. During an emergency, and to evaluate if vehicular evacuation of the population at risk is a feasible alternative at all, there must be a high correlation between what the simulation models predict for a given strategy and what is really observed if that strategy is implemented. Predictions based on outdated data cannot offer such high correlations; but even worse than that, results can be misleading (e.g., predicting shorter evacuation times) thus putting the population at higher risks than necessary. Therefore, it is paramount to maintain the information current. As part of the National Consortia on Remote Sensing in Transportation (NCRST), ORNL is developing algorithms and methodologies to integrate remote sensing information into the OREMS. This will not only simplify the task of creating the evacuation plans, but most importantly it will help maintain those plans up-to-date. (An example showing the importance of maintaining the network information updated for a nuclear plant evacuation plans is included in the presentation).

Future research include extending those algorithms and methodologies to assess traffic information in real-time using remote sensing information during emergency evacuations; developing population estimation models that combine land-use information, derived from remote sensing images, and other sources of information (e.g., census tract data), to assess the location of the daytime population of the areas at risk; and integrating OREMS and PADRE (a protective action decision model also developed at ORNL) that will allow better estimates of impacts to the population in disasters such as release of toxic gases produced by accidents or terrorist attacks.
Oak Ridge Evacuation Modeling System (OREMS)

- Developed by ORNL
  - Center for Transportation Analysis
  - Emergency Management Center
- for FEMA and the U.S. Army
  - Chemical Stockpile Emergency Preparedness Program (CSEPP)
    - Aberdeen Proving Ground, MD
    - Anniston Army Depot, AL
    - Blue Grass Army Depot, KY
    - Deseret Chemical Depot, UT
    - Newport Chemical Depot, IN
    - Pine Bluff Arsenal, AK
    - Pueblo Chemical Depot, CO
    - Umatilla Chemical Depot, OR
Evacuation Planning Studies with OREMS

- Estimates of evacuation times
  - Evacuation Time
  - Population at Risk
- Identification of evacuation routes
  - Best Route Choices
- Identification of bottlenecks
  - Potential Traffic Trouble Spots
- Development of traffic management strategies
  - Best Traffic Control & Management Strategies
Network Characteristics
OREMS Results

Evacuation time: 05:44
Start time: 22:00
50% evacuated at: 23:05
75% evacuated at: 23:50
95% evacuated at: 01:10
End time: 03:44
OREMS Results
Reverse-Lane Strategy
Emergency Evacuation Analysis with OREMS

- Evacuation Time
- Bottleneck Identification
- Evacuation Management Strategies
  - Capacity Increase Strategies
  - Traffic Control Strategies
  - Dynamic/Static Routing Strategies
  - Transit & Emergency Veh. Dispatching
  - Departing Time Planning Strategies
  - Emergency Staff Deployment Strategies
  - Shelter Site Location Strategies
  - Incident Strategies
  - Clean-up Prioritization
- Vulnerability Studies
Evacuation Planning Process

Environment Conditions

Input Database

Simulation of Vehicular Evacuation

Analysis of Results

Are Results Acceptable?

Archive Plan

Modify Strategy
Evacuation Planning Process

- Environment Monitoring System
- Retrieve and Implement Plan
- Input Database
- Simulation of Vehicular Evacuation
- Analysis of Results
- Are Results Acceptable?
  - Yes: Archive Plan
  - No: Modify Strategy
Remote Sensing Information
Remote Sensing Information
Remote Sensing Info & Emergency Evacuation Planning

Plan Maintenance Module

Decision Support Module

Database Update (Remote Sensing, GIS)

Above Thresholds?

Notify Planner

Yes

No

Archived Plans

Simulation of Vehicular Evacuation

Evacuation MOEs
Analysis Area

Sequoyah Nuclear Plant
Basic Scenario

- Nighttime Radiological Accident
- Good Weather, Winds from East
- Evacuation of Area West of Nuclear Plant
  - Vehicle Occupancy: 2.5 ppv
Basic Scenario
Scenario 2: Imperfect Network Information

- Radiological Accident
- Clear Night, Winds from the East
- Road Capacity Reduction on Arterial
  - Lane 1 Closed Due to Construction
  - Lane 2 Reduced Speeds Because of Lateral Obstructions
- Emergency Evacuation Planners Unaware of Road Capacity Reduction
Scenario 2
Scenario 3: Automated Network Info Updates

- Radiological Accident
- Clear Night, Winds from the East
- Road Capacity Reduction on Arterial
  - Lane 1 Closed Due to Construction
  - Lane 2 Reduced Speeds Because of Lateral Obstructions
- Emergency Evacuation Planners Notified by Plan Maintenance Module of Surpassed Threshold
Scenario 3: Reverse-Lane Strategy
Future Work

- Real-time Information
- Daytime Population Assessment Using Remote Sensing Information
- Integration with PADRE (Protective Action Decision Model + Plume Dispersion Model)
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