VISSIM for Evacuation Modeling, Planning, and Optimization

PTV Vision User’s Group Meeting, 2009

Fang Yuan, Ph.D., P.E.
Outline

> Background
> Tools for Evacuation Modeling
> What is an Effective Evacuation Operation
> How to Improve Evacuation Operation
> Case Study
> Conclusions and Recommendations
Background

Emergency Evacuation

> Increased demand vs. limited capacity
> Temporal and spatial constraints
> Uncertain roadway conditions
> Different human behaviors

Evacuation Planning

> Local knowledge based
> Conventional planning models (orderly process)
> Static destination and route assignment
> Operational improvements on designated evacuation routes
Evacuation Modeling Tools

- Dissipation Rate Analysis
  - NETVAC
  - MASSVAC
- Macro Travel Demand Models
  - DYNEV
  - CLEAR
- Meso DTA Models
  - PBS&J
  - EVAC PLAN PACK
  - OREM

- Micro simulation Models
  - OREM
    > Model complex roadway geometry
    > Model myriad traffic management strategies
    > Accurately estimate evacuation times
    > Efficiently identify network bottlenecks (evacuation routes vs. intersections)
Contra-flow Lane

EXIT 212
(I-394 TO I-594)

EVACUATION CROSSOVER

EXIT 17
(I-526 TO I-356)

BARRICADES

To I-10 E/B
(From I-55 S/B)

To I-10 W/B

To I-10 E/B

To I-10 W/B

To I-55 N/B

US 51
What is an Effective Evacuation Operation

MOEs in Literature

> Evacuation times - network clearance time, statistical points ($T_{95}$), range, and standard division
> Evacuation curve - percent cleared EPZ vs. time
> Traffic operational characteristics - e.g. speed, density and travel time
> Loading time and delay
> Clearance time from origins

New MOEs

> Risk factors (time, space, and event dependent)
> Exposure Index

Multi-Tier Evaluation
Tier 1 – Evacuation Time

Objective Function:  \( \text{Min } T_{n\%} \)
Tier 2 – Individual Travel Time and Evacuation Curve

Objective Function: \( \text{Min } \int_{0}^{t^*} Q(t) \cdot d(t) \) (i.e. Total Travel Time)
Tier 3 – Time-Based Risk and Exposure Index

Objective Function:

\[ \min \int_0^{t^*} \left[ 1 - E(t) \right] \cdot R(t) \, dt \]
Tier 4 – Time-Space-Based Risk and Exposure Index

Objective Function: \( \text{Min} \int_0^{t^*} \int_0^S \left[ 1 - E(t) \right] \cdot R(t, s) d(s) d(t) \)

Simplified Case: \( \text{Min} \int_0^{t^*} \sum_a x_a(t) \cdot R_a(t) d(t) \)

Recommendations:

> Give special attention or preferential treatment to area with a higher exposure risk

> Space-based risk can be modeled as additional link cost and weighed together with link travel time for route search and traffic assignment
How to Improve Evacuation Operation

Optimization Efforts in Literature

- Optimal destination assignment
- Staged departure time
- Special routing for heavy vehicles
- Dynamic traffic assignment
- Contraflow operations
- Signal priority and coordination

Case Study

- Time-Based Assignment Optimization
- Risk-Based Assignment Optimization
Case Study

> A regional evacuation operation in the event of a hypothetical nuclear power-plant mishap, where the time-based and space-based risks are practical concerns for planning and in real-world operations.

> A 10-mile EPZ in the vicinity of the Sequoyah Nuclear Power Plant in Hamilton County, Tennessee.

> 29 origins and 8 potential destinations

> 20,000 vehicles
Plan I – Exiting Local Plan

> TVA’s EPA based mainly on the criterion of geographical proximity.

> Zone-to-zone and one-to-one based destination and route assignment.

> About eight hours to evacuate 95% of the total population.
Plan II - Improved Evacuee Assignment Based on Time Saving

Step 1
> Solving a one-destination dynamic traffic assignment (1D DTA) problem, which minimizes individual travel time by finding the time-dependent optimal evacuation destination and route.
> VISSIM: parking lot choice with route guidance; modified 1D network
> The solution provides a lower bound for the evacuation time and evacuation curve – three hours to evacuate 95% of the evacuees.

Step 2
> Finding the overall best assignment for planning by tracing the real-world destination/route used by the majority of evacuation traffic flowing from an origin to the dummy destination.
> Implementing a one-to-one based static destination/route assignment – about seven hours to evacuate 95% of the evacuees.
Comparison of Efficiency

Percent of Evacuees Departed EPZ

Plan I

Plan II
## Comparison of Efficiency

<table>
<thead>
<tr>
<th></th>
<th>Plan I</th>
<th>Plan II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evacuation Time (min)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 95% Evacuated</td>
<td>484</td>
<td>405</td>
</tr>
<tr>
<td>- 100% Evacuated</td>
<td>631</td>
<td>540</td>
</tr>
<tr>
<td><strong>Total Travel Time (hour)</strong></td>
<td>32,763</td>
<td>29,676</td>
</tr>
<tr>
<td><strong>Total Travel Distance (mile)</strong></td>
<td>193,642</td>
<td>197,403</td>
</tr>
<tr>
<td><strong>Total Evacuation Exposure[1]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Time-Based [2]</td>
<td>1</td>
<td>0.90</td>
</tr>
<tr>
<td>- Space-Based [3]</td>
<td>1</td>
<td>4.47</td>
</tr>
<tr>
<td>- Time-Space-Based [4]</td>
<td>1</td>
<td>6.20</td>
</tr>
</tbody>
</table>

**Note:**
1. Measures of exposure are relative values with a base of one for plan I.
2. Time-based risk is assumed to be proportional to the time.
3. Space-based risk is assumed to be reverse proportional to the square distance from the hazard source.
Plan III - Improved Evacuee Assignment Based on Risk Saving

Step 1

> Modeling the space-based risk as additional link cost
> Solving the 1D DTA problem, which now is to minimize individual travel cost as a combination of travel time and exposure index.

Step 2

> Finding the overall best assignment for planning by tracing the real-world destination/route used by the majority of evacuation traffic flowing from an origin to the dummy destination.
> Implementing a one-to-one based static destination/route assignment – short evacuation time as plan II and low evacuation exposure as plan I
Comparison of Efficiency

**Percent of Evacuees Departed EPZ**

- **Plan I**
- **Plan II**
- **Plan III**

**Cumulative Percentage (%)**

- Plan I
- Plan II
- Plan III

**Time (min)**

- 0 60 120 180 240 300 360 420 480 540 600

**Vehicles within Radius**

- 2 miles
- 4 miles
- 6 miles
- 8 miles
- 10 miles

- 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

**Time (min)**

- Plan I
- Plan II
- Plan III

**Vehicles within Radius**

- 2 miles
- 4 miles
- 6 miles
- 8 miles
- 10 miles

- 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

**Time (min)**

- Plan I
- Plan II
- Plan III

**Vehicles within Radius**

- 2 miles
- 4 miles
- 6 miles
- 8 miles
- 10 miles

- 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

**Time (min)**

- Plan I
- Plan II
- Plan III

**Vehicles within Radius**

- 2 miles
- 4 miles
- 6 miles
- 8 miles
- 10 miles

- 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

**Time (min)**

- Plan I
- Plan II
- Plan III

**Vehicles within Radius**

- 2 miles
- 4 miles
- 6 miles
- 8 miles
- 10 miles

- 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

**Time (min)**

- Plan I
- Plan II
- Plan III
# Comparison of Efficiency

<table>
<thead>
<tr>
<th></th>
<th>Plan I</th>
<th>Plan II</th>
<th>Plan III</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evacuation Time (min)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 95% Evacuated</td>
<td>484</td>
<td>405</td>
<td>398</td>
</tr>
<tr>
<td>- 100% Evacuated</td>
<td>631</td>
<td>540</td>
<td>545</td>
</tr>
<tr>
<td><strong>Total Travel Time (hour)</strong></td>
<td>32,763</td>
<td>29,676</td>
<td>23,318</td>
</tr>
<tr>
<td><strong>Total Travel Distance (mile)</strong></td>
<td>193,642</td>
<td>197,403</td>
<td>182,713</td>
</tr>
<tr>
<td><strong>Total Evacuation Exposure[1]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Time-Based [2]</td>
<td>1</td>
<td>0.90</td>
<td>0.71</td>
</tr>
<tr>
<td>- Space-Based [3]</td>
<td>1</td>
<td>4.47</td>
<td>0.96</td>
</tr>
<tr>
<td>- Time-Space-Based [4]</td>
<td>1</td>
<td>6.20</td>
<td>1.01</td>
</tr>
</tbody>
</table>

**Note:**
1. Measures of exposure are relative values with a base of one for plan I.
2. Time-based risk is assumed to be proportional to the time.
3. Space-based risk is assumed to be reverse proportional to the square distance from the hazard source.
Conclusions and Recommendations

> VISSIM is an efficient tool for evacuation modeling, evaluation, planning, and optimization

> By combining the space-based risk and the travel time in route searching and traffic assignment, better destination assignment (and improved evacuation efficiency) may be obtained.

> Implementation considerations:
  - Analyze prevailing risk factors per site
  - Model site-specific (geographical) constraints
  - Model the impact of meteorological conditions, e.g. prevailing wind direction
  - Integrate with other operational constraints and strategies
PTV. The Transportation Experts.

PTV America, Inc.