Modeling pedestrian evacuations

Tsunami Evacuation Clearance Time - Balboa Island

- Low - Overnight
- Low - Daytime
- Med - Overnight
- Med - Daytime
- High - Overnight
- High - Daytime

Time (hours)

SAFFR scenario tsunami arrival time
1st Simulation Iteration
10th Simulation Iteration

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U.S. Geological Survey
Categories of evacuation studies

Agent-based model

- To track individual movement along road network to safe point
- Focus on individuals or cars
- Good for specific scenario and likely congestion

Least-cost-distance model

- To map travel times to safe zone by calculating “costs” due to varying land
- Focus on evacuation landscape
- Good for overall insight, mixed populations, and varied landscape
Data input

Agent-based model
- Roads (typically)
- Flat surface area
- Population points (parcels)
- Census block resident/car #
- Agent “behavior”

Least-cost-distance model
- Landscape - roads, landcover, etc.
- Elevation (slope, directionality)
- Population points (parcels, user)
- Census, businesses, user supplied
Agent-based modeling

Software platforms

- Many proprietary software
- Open source – e.g., MATSim

Outputs:

- Mortality estimates for specific scenarios
- Animations of movement
- Time-based snapshots
Agent-based modeling

Keon et al., 2014

Table 1. Summary of simulations (casualties and survivors).

<table>
<thead>
<tr>
<th>Refuge Sites</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>TEB</th>
<th>TOTAL</th>
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<tbody>
<tr>
<td>(a) Base Case</td>
<td>Saved</td>
<td>1015</td>
<td>357</td>
<td>2282</td>
<td>1794</td>
<td>357</td>
<td>549</td>
<td>180</td>
<td>186</td>
<td>9</td>
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<tr>
<td>Killed</td>
<td>45</td>
<td>42</td>
<td>150</td>
<td>768</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>0</td>
<td>1056 (* )</td>
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<tr>
<td>(b) TEB</td>
<td>Saved</td>
<td>1015</td>
<td>357</td>
<td>2276</td>
<td>156</td>
<td>357</td>
<td>549</td>
<td>180</td>
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<tr>
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<td>45</td>
<td>42</td>
<td>150</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>0</td>
<td>939 (*11% )</td>
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<tr>
<td>(c) Bridge</td>
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<td>936</td>
<td>2282</td>
<td>1794</td>
<td>357</td>
<td>549</td>
<td>180</td>
<td>186</td>
<td>9</td>
<td>7308</td>
</tr>
<tr>
<td>Killed</td>
<td>45</td>
<td>123</td>
<td>150</td>
<td>108</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>0</td>
<td>477 (*55% )</td>
</tr>
<tr>
<td>(d) TEB + Bridge</td>
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<td>1015</td>
<td>750</td>
<td>2276</td>
<td>156</td>
<td>357</td>
<td>549</td>
<td>180</td>
<td>186</td>
<td>9</td>
<td>1761</td>
</tr>
<tr>
<td>Killed</td>
<td>45</td>
<td>48</td>
<td>150</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>0</td>
<td>540 (*48% )</td>
</tr>
<tr>
<td>(e) Low Bridge</td>
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<td>1015</td>
<td>864</td>
<td>2282</td>
<td>1794</td>
<td>357</td>
<td>549</td>
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<tr>
<td>Killed</td>
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<td>103</td>
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<td>198</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>0</td>
<td>549 (*48% )</td>
</tr>
<tr>
<td>(f) TEB (Alt.)</td>
<td>Saved</td>
<td>1015</td>
<td>357</td>
<td>2282</td>
<td>663</td>
<td>357</td>
<td>549</td>
<td>180</td>
<td>186</td>
<td>9</td>
<td>1818</td>
</tr>
<tr>
<td>Killed</td>
<td>45</td>
<td>42</td>
<td>150</td>
<td>3</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>78</td>
<td>569 (*65% )</td>
</tr>
</tbody>
</table>

Cannon Beach Evacuation simulator, Karon and Yeh, 2011
Least-cost-distance modeling

Software platforms

- GIS – e.g., ArcMap
- USGS Evacuation Analyst – built on ArcMap

Outputs:

- Maps of travel time
- Exposure numbers and profiles as a function of travel time
Pedestrian Evacuation Analyst Workflows

1. Create a portfolio for the study area
2. Preprocess input data
   - Digital elevation model
   - Land use/land cover
   - Hazard zone
   - Safe zone
3. Create evacuation surfaces and maps
   - Calculate path distance
   - Create evacuation surface
   - Determine maximum time value
   - Create time map
4. Model potential vertical-evacuation sites
   - Process vertical evacuation sites
   - Merge safe zones
5. Incorporate population data
6. Develop charts and graphs

<table>
<thead>
<tr>
<th>Portfolio preprocess</th>
<th>Land-cover preprocess</th>
<th>DEM preprocess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Path distance</td>
<td>Evacuation surface</td>
<td>Hazard-zone preprocess</td>
</tr>
<tr>
<td>Time map</td>
<td>Safe-zone merge</td>
<td>Vertical evacuation</td>
</tr>
<tr>
<td>Graphs and charts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Least-cost-distance modeling

Implications of vertical-evacuating siting

Modeling for areas with variable hazards
Comparison of approaches
Both approaches are useful for evacuation modeling but in different ways

Agent-based
• Population #’s & sites well constrained
• Focus on population movement
• Focus on specific scenario
• Loss estimation and clearance times
• Decision support for scenario

LCD-based
• Desire for flexibility in population
• Focus on evacuation landscapes
• Focus on worst case @ site
• Maps and graphs
• Outreach product for public
## Use of tools for emergency management

<table>
<thead>
<tr>
<th>Feature</th>
<th>Agent-based</th>
<th>LCD-based</th>
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</thead>
<tbody>
<tr>
<td>Ease of use</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Assess population composition/distribution</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Attention for vulnerable populations</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Scenario-specific loss estimation</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Establishment of evacuation routes, assembly areas, evacuation areas</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Incorporation into emergency response plans and better planning</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dissemination of information and better response by the public</td>
<td>✗</td>
<td>✓</td>
</tr>
</tbody>
</table>