Crash Event Modeling Approach for Dynamic Traffic Assignment

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FHWA Planning BAA Project: Open-source DTA Tools for Assessing the Effects of Pricing and Crash Reduction Strategies
• Why model crashes?
• How to model crashes?
  – Crash prediction
  – Simulation tools
  – Safety improvement strategies
• Working example with “Road Diet”
• Modeling complications, limitations
Why Model Crashes?

- How to capture effects of traffic incidents in traffic assignment? (DTA)
- How to enable system-wide or network-wide safety planning?

Sources of Congestion:
- Bottlenecks
- Traffic Incidents
- Work Zones
- Bad Weather
- Poor Signal Timing
- Special Events/Other
Safety Planning Applications

• Incorporating safety in transportation planning
  – Transportation Improvement Plans
  – Implemented by state DOTs & MPOs

• Highway Safety Manual
  – Static crash predictions

• Safety Surrogates
  – Microsimulation
  – Conflicts, speed, etc.

• Hot Spot Analysis

Incident rates predicted based on AADT
Source: WFRC (MPO in Salt Lake City, UT)
How to Model Crashes?

Crash Prediction

Simulation Tools

Safety Improvements
Crash Prediction

- Predict crash frequency (using AADT, V/C, etc.)
  - Highway Safety Manual methodology
Analytical / Simulation Methods

- Option 1: Average Capacity Reduction
- Option 2: Probabilistic Capacity Reduction
- Option 3: Incident Calendar
- Option 4: Hybrid Approach
Option 1: Avg. Capacity Reduction

- Crashes have same average capacity reduction

- Pros: Pre-set capacity reduction for each iteration

- Cons: Simplistic traffic results, cannot capture day-to-day traffic variations
Option 2: Prob. Capacity Reduction

• Analytical point-queue model
  – Can’t capture queue spillback
How to Correctly Model Travel Time Impacts?

• Approach 1: Probabilistic analytical model

$$\text{Avg TT} = \text{Crash prob.} \times \text{Crash TT} + (1-\text{prob.}) \times \text{Link TT}$$

$$22\text{min} = 20\% \times 30\text{ min} + 80\% \times 20\text{ min}$$

• Approach 2: Simulation to capture queue spillback
**Option 3: Crash Calendar**

- **Pros:** captures impacts of different event types over multiple days
- **Cons:** Numerically intensive, sampling errors

<table>
<thead>
<tr>
<th>Incident No.</th>
<th>Starting Time</th>
<th>Incident Duration (min)</th>
<th>Capacity Reduction Ratio</th>
<th>Additional Delay (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Day 1@ 8AM</td>
<td>30</td>
<td>0.3</td>
<td>10.0</td>
</tr>
<tr>
<td>2</td>
<td>Day 12 @8:30AM</td>
<td>30</td>
<td>0.23</td>
<td>6.9</td>
</tr>
<tr>
<td>3</td>
<td>Day 15@ 7AM</td>
<td>30</td>
<td>0.13</td>
<td>3.81</td>
</tr>
<tr>
<td>4</td>
<td>Day 15@ 9AM</td>
<td>15</td>
<td>0.12</td>
<td>1.84</td>
</tr>
<tr>
<td>5</td>
<td>Day 20@ 8AM</td>
<td>15</td>
<td>0.07</td>
<td>1.12</td>
</tr>
</tbody>
</table>
Option 4: Hybrid Analytical/Simulation

Long-term traffic equilibrium

Without Incident
Use light-weight DTA to simulate recurring traffic congestion

With Incident
Evaluate the probabilistic impact of traffic incidents based on queueing model
Selecting Simulation Option

• Trade-offs between event modeling approaches:
  1. Different resolutions lead to different degrees of modeling accuracy
  2. Requires balance between data availability, output uncertainty/accuracy and computational effort
Safety Improvements

• Safety Improvement Strategy Evaluation
  – Improve geometric design (crash prob.)
  – Incident management/response (capacity)
  – Real-time incident information

• Road Diet Example
Road Diet Example Application
Step 1: Traffic Volume Calibration

- Crash prediction from AADT – calibrate first
Step 1: Traffic Volume Calibration
### Treatment Results Comparison
(Expected # Crashes/Year)

<table>
<thead>
<tr>
<th>Street</th>
<th>From</th>
<th>To</th>
<th>Est. AADT</th>
<th>Length (mi)</th>
<th>Base Case</th>
<th>Treatment Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>158th Ave</td>
<td>Jenkins</td>
<td>Walker</td>
<td>23,240</td>
<td>1.35</td>
<td>20.1</td>
<td>22.2</td>
</tr>
<tr>
<td>Murray Ave.</td>
<td>Jenkins</td>
<td>Walker</td>
<td>25,520</td>
<td>1.05</td>
<td>18.5</td>
<td>18.6</td>
</tr>
<tr>
<td>Jenkins Rd.</td>
<td>158th Ave</td>
<td>Murray</td>
<td>15,980</td>
<td>1.49</td>
<td>22.6</td>
<td>18.6</td>
</tr>
<tr>
<td>Walker Rd.</td>
<td>158th Ave</td>
<td>Murray</td>
<td>19,680</td>
<td>1.94</td>
<td>14.2</td>
<td>19.0</td>
</tr>
<tr>
<td>Jay St.</td>
<td>158th Ave</td>
<td>Jenkins</td>
<td>13,650</td>
<td>1.14</td>
<td>5.0</td>
<td>6.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>80.4</strong></td>
<td><strong>85.1</strong></td>
</tr>
</tbody>
</table>

Why did crashes increase?
## Estimated AADT Comparison

<table>
<thead>
<tr>
<th>Street</th>
<th>From</th>
<th>To</th>
<th>Base Case</th>
<th>Treatment Case</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>158th Ave</td>
<td>Jenkins</td>
<td>Walker</td>
<td>21,560</td>
<td>23,240</td>
<td>1680</td>
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<td>Jenkins</td>
<td>Walker</td>
<td>25,300</td>
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<td>158th Ave</td>
<td>Murray</td>
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<td>15,980</td>
<td>-1100</td>
</tr>
<tr>
<td>Walker Rd.</td>
<td>158th Ave</td>
<td>Murray</td>
<td>19,020</td>
<td>19,680</td>
<td>660</td>
</tr>
<tr>
<td>Jay St.</td>
<td>158th Ave</td>
<td>Jenkins</td>
<td>11,890</td>
<td>13,650</td>
<td>1760</td>
</tr>
</tbody>
</table>
Output Visualization: Crash Heat Map
Modeling Complications, Limitations
Levels of Detail:

Planning: One-way link, one-way volumes

Safety: Two-way link, two-way volumes

Issue: Center divider = different prediction equations
Network Structure/Topology

- Omitted intersections
- Intersection definitions
- Zonal connectors influence traffic volumes
Calibration/Validation
Crash Calendar: Time Resolution

• Operations: Peak period, #N modeling periods
• Safety: Annual crash frequency

- Crashes are rare events
  - How can we simulate their occurrence?

- 20 Crashes/Year
- 0.05 Crashes/Day
- 0.01 Crashes/Peak Period
Can we find crash rate equilibrium (long run-times)? How many “days” do we need to simulate?
Summary

• Why Model Crashes?
• Crash Prediction
  – Network compatibility
• Simulation Tools (Hybrid Method)
  – Balance trade offs between approaches
• Safety Improvement Strategy Evaluation