Investigation of the Impact the I-94 ATM System has on the Safety of the I-94 Commons High Crash Area

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Overview

- Project Objectives
- I-94 High Crash Area and VSL System description
- Data Collection
- Analysis Methodologies
- Results
- Conclusion
Project Objectives

- Monitor the operation of the I-94 VSL system at the I-94 high crash area to detect any adverse effects the system may have on safety.
  - Utilize MTO surveillance equipment to detect all crashes and near-crashes in the high crash area
  - Utilize high resolution traffic measurements to detect large changes in crash generating shockwaves.
- Conduct a thorough Before-After study of the impact the I-94 VSL system has on the safety of the I-94 high crash area.
  - Evaluate effect of system on crash and near-crash rates
  - Evaluate response of drivers approaching the high crash area
  - Identify changes in shockwave characteristics
Variable Speed Limit System

- Automatically detect congestion
- Preemptively reduce upstream speeds to lessen shocks within the traffic stream
- I-94 System:
  - Lane by lane indications
  - Structures every half mile
Site Description

- Highest crash frequency location in Minnesota
- Significant recurrent congestion
- Primary bottleneck at intersection of I-94 westbound and ramp from I-35W northbound
MTO I-94 Field Lab Instrumentation

- **Three Rooftop Locations**
  - Third Avenue
    - 4 Surveillance Cameras
    - 3 Machine Vision sensors
  - Augustana
    - 2 Surveillance Cameras
    - 2 Machine Vision Sensors
  - Cedar
    - 2 Surveillance Camera
    - 1 Machine Vision sensor

- **Video recording period:**
  - 10 AM to 8 PM
  - Weekdays only
Analysis Methodologies (1)

- Video based event identification
  - Locate and count all crashes and Near-crashes
  - Count Shockwaves
Analysis Methodologies (2)

- Loop Detector-Based Congestion Analysis
  - Quantify the change in propagation speed and extend of congestion
  - Detect changes in speed patterns before and after
Analysis Methodologies (3)

- Crash and Near Crash Trajectories
  - Visualize temporal and spatial extend of congestion
  - Visualize activations of VSL system
  - How many VSL drivers involved in events have seen before the crash?
Analysis Methodologies (4)

- Shockwave Characteristics Analysis
  - Cross correlation of vehicle speeds
    - Visualize shockwave activity
    - Measure shockwave speed

\[ r(t_D) = \frac{\sum_i [(x(i) - \bar{x})(y(i - t_D) - \bar{y})]}{\sqrt{\sum_i [(x(i) - \bar{x})^2]} \sqrt{\sum_i [(y(i - t_D) - \bar{y})^2]}} \]
Analysis Methodologies (4)

- Shockwave Characteristics Analysis
  - The Correlogram

![Correlation between Middle and Portland Autoscores for 7-25-2013](image)

- Congested Conditions
- Uncongested Conditions
- VSL Actuations
Results
Incident Locations

- At right, frequency of crashes along the high crash area
  - Small frequencies within Cam-1 region resemble ‘background’ crash rate
  - Much more frequent crashes within Cam-2 and Cam-3
## Frequency of Crashes and Near-Crashes

<table>
<thead>
<tr>
<th>Month</th>
<th>Incidents</th>
<th>Vehicle Volume</th>
<th>Rate</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>NC</td>
<td>C</td>
<td>Total</td>
</tr>
<tr>
<td>Before September 2008</td>
<td>22</td>
<td>1</td>
<td>23</td>
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<tr>
<td>October 2008</td>
<td>56</td>
<td>11</td>
<td>67</td>
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<tr>
<td>April 2012</td>
<td>6</td>
<td>1</td>
<td>7</td>
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<tr>
<td>May 2012</td>
<td>38</td>
<td>5</td>
<td>43</td>
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<tr>
<td>June 2012</td>
<td>82</td>
<td>9</td>
<td>91</td>
</tr>
<tr>
<td>July 2012</td>
<td>128</td>
<td>20</td>
<td>148</td>
</tr>
<tr>
<td>August 2012</td>
<td>107</td>
<td>10</td>
<td>117</td>
</tr>
<tr>
<td>September 2012</td>
<td>30</td>
<td>2</td>
<td>32</td>
</tr>
<tr>
<td>After September 2012</td>
<td>12</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>October 2012</td>
<td>98</td>
<td>9</td>
<td>107</td>
</tr>
<tr>
<td>November 2012</td>
<td>34</td>
<td>3</td>
<td>37</td>
</tr>
<tr>
<td>December 2012</td>
<td>52</td>
<td>8</td>
<td>60</td>
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<tr>
<td>January 2013</td>
<td>45</td>
<td>10</td>
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<tr>
<td>February 2013</td>
<td>22</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>March 2013</td>
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<td>12</td>
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<td>September 2013</td>
<td>47</td>
<td>9</td>
<td>56</td>
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<table>
<thead>
<tr>
<th></th>
<th>Total Incidents</th>
<th>Total Vehicle Volume</th>
<th>Rate</th>
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<tbody>
<tr>
<td>Before incl. 2008</td>
<td>528</td>
<td>4.53</td>
<td>116.62</td>
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<tr>
<td>Before not incl. 2008</td>
<td>438</td>
<td>3.40</td>
<td>128.69</td>
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<tr>
<td>After</td>
<td>827</td>
<td>7.76</td>
<td>106.53</td>
</tr>
<tr>
<td>After excluding Winter</td>
<td>616</td>
<td>4.67</td>
<td>131.92</td>
</tr>
</tbody>
</table>
Time of 1st, 2nd, and 3rd Wave

Plot of Daily First Shockwaves

Plot of Daily Second Shockwaves

Plot of Daily Third Shockwaves (5/8/2012 to 9/7/2012)
Time Delay Between Early Shockwaves

- Time gap between first three observed shockwaves slightly narrower after VSL implementation
- Overall shockwave frequency virtually identical
Loop Detector-Based Congestion Analysis

Five min avg speed
Station# 559 (00 to 05min)

Station# 559 (06 to 10min)

Station# 559 (10 to 15min)

Detector: 2692 (Mean summer speeds)
P-value = 0.051 0.057 0.069 0.004 0.003 0.002 0 0.001 0.001 0.003 0.024

Detector: 2692 (Mean summer speeds)
P-value = 0.008 0.033 0.399 0.131 0.231 0.136 0.091 0.069 0.014 0.021 0.114 0.346
Shockwave Characteristics Analysis
Crash and Near Crash Trajectories

Last Active Variable Speed Limit Gantry Encountered

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Huron</th>
<th>Riverside</th>
<th>Cedar</th>
<th>11th</th>
<th>Park</th>
<th>One or more (sum)</th>
<th>None</th>
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<tbody>
<tr>
<td>Near Crash</td>
<td>89</td>
<td>29</td>
<td>26</td>
<td>54</td>
<td>182</td>
<td>380</td>
<td>209</td>
</tr>
<tr>
<td>Crash</td>
<td>15</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>18</td>
<td>46</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>104</td>
<td>31</td>
<td>32</td>
<td>59</td>
<td>200</td>
<td>426</td>
<td>236</td>
</tr>
</tbody>
</table>
Conclusions

- Based on several different evidence the VSL system does not seem to have influenced the causal factors behind the crashes at the I-94 commons.
  - The flow breakdown at the merge happens with similar frequency.
  - The speed differential between lanes has remained unchanged.
  - The traffic density and headways on the right lane have remained the same.

- The system is visible to drivers later involved in incidents in more than half of the cases.

- In several cases near crashes happen too early for the system to be effective, or too late.

- For half of the cases the system was visible, it had deactivated the VSL on Park because of the spread of congestion further upstream.
Questions?