PERFORMANCE EVALUATION APPLICATION FOR THE I-95 VARIABLE SPEED LIMIT SYSTEM

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Background

• I-95 NB between MP 115-130, south of Fredericksburg experiences significant recurring and non-recurring congestion, especially in the summer.

• Speed variations are present, along with higher crash rates

• In June 2022, VDOT activated a VSL system on the corridor
I-95 VSL Field Elements
Background

• The system includes 24 detector stations that are all generating per-vehicle record (PVR) data.

• The VSL system aims to improve both safety and operations in this congested section
VSL Algorithm

**Conditions Worsening**
- Traffic destabilizing
  - LL Vol Stdev of 4 past periods > 3.5 v/30-s for 4+ consecutive periods and T Vol > 1600 vph for 4+ consecutive periods
  - Or
  - Avg Speed < MSL for 2+ consecutive periods and T Vol > 1600 vph for 2+ consecutive periods
  - Or
  - Avg Speed < MSL for 3+ consecutive periods.
- LL Occupancy > 22% for 2+ consecutive periods or Avg Speed < 60 mph for 3+ consecutive periods
- LL Occupancy > 29% for 3+ consecutive periods or Avg Speed < 50 mph for 2+ consecutive periods
- Avg Speed < 40 mph for 2+ consecutive periods

**State A**
- Free Flow
- No Speed Reduction
- Warning
- No Speed Reduction

**State B1**
- Turbulent Conditions
- RS = 35 mph

**State B2**
- Pre-Breakdown
- RS = 35 mph

**State C**
- Breakdown
- RS = 35 mph

**Conditions Improving**
- Traffic stabilizing
- LL Vol Stdev < 3 v/30-s for 4+ consecutive periods and Avg Speed > MSL mph for 4+ consecutive periods
- LL Occupancy < 10% for 2+ consecutive periods and Avg Speed > 60 mph for 2+ consecutive periods
- LL Occupancy < 14% for 2+ consecutive periods and Avg Speed > 50 mph for 2+ consecutive periods
- LL Occupancy < 17% for 2+ consecutive periods and Avg Speed > 40 mph for 2+ consecutive periods

**Original Parameters**
- Calibration Parameter
- Can be adjusted by location & prevailing condition

**Vdot**
Sensors produced raw PVR data that consists of a unique vehicle ID, time, location (detector station ID, lane), speed, etc.

The VSL system produced posted speed limit (PSL) data that had time stamp, location, and VSL recommended speed.

The system produced an average of 1 million rows of data every day.
Project Objective

• This project developed a performance evaluation application to assess operations and safety

• With the application, the system performance could be easily analyzed despite the large volume of data.

• Focus of this presentation is on how the system data was analyzed and some representative key findings, not on system construction and operation.
# Evaluation Performance Measures

<table>
<thead>
<tr>
<th>Speed compliance</th>
<th>Operations</th>
<th>Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Change in mean speed</td>
<td>• Change in delay</td>
<td>• Change in crash frequency by crash severity</td>
</tr>
<tr>
<td>• Change in speed distribution</td>
<td>• Change in travel time reliability (expressed in using multiple measures including travel time index and different percentiles of speed)</td>
<td>• Change in collision type by severity</td>
</tr>
<tr>
<td>• Change in speed compliance</td>
<td>• Change in speed-flow fundamental diagrams</td>
<td>• Change in secondary crashes</td>
</tr>
<tr>
<td>• Change in speed standard deviation</td>
<td>• Change in capacity and throughput</td>
<td>• Change in crash rates</td>
</tr>
</tbody>
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VSL Data flows

• PVR and PSL data were merged based on time and location.

• Over 250 million rows of data were ingested into a PowerBI application for analysis.
Application Example

Speed Compliance

- **30 sec. Average PVR Speed distribution when PSL = 55 mph**
  - Lane: 1
    - Select all
    - 1_Left
    - 2_Center
  - Date: Sunday, November 20, 2022
  - Day: 1.Monday
  - Time Index: 0.00

- **Count of Avg Speed by Speed Bin by Lane**
  - Lane: 1
    - Count of Avg Speed

- **Count of Avg Speed by Speed Bin (Sum of lanes)**
  - %GT Count of Avg Speed

- **Volume of Upstream**
  - Lane: 1
    - Average of Avg Speed
    - Standard deviation of Avg Speed
    - 1_Left: 65.46, 12.47
    - 2_Center: 62.84, 11.30
    - 3_Right: 60.17, 10.62
    - Exit Lane: 53.20, 7.98
  - Total: 62.59, 11.70

- **Volume of Upstream**
  - Count
  - Count_lessPSL
  - Count_lessPSLs
  - Count_lessPSLs10
  - Total: 167992, 30795, 51443, 86373
Operations

• Travel time for each 5-minute timestamp is calculated by adding average travel time of each section for the whole corridor.

• Speed-flow curves represent only one detector station’s data, and each point describe a feature of 5-minute interval’s traffic.
VMT Comparison by Season

Average Daily VMT Per Detector

Winter - Before  Summer  Fall  Winter  Winter New Alg.
Traffic Impacting Events

• Mobility and safety are likely impacted by many factors:
  • Work zones
  • Weather
  • Traffic volume
  • System outages
  • Crashes
• Added filters to the tool so that “apples to apples” comparisons between before/after data could be performed.
## Crash Data - Frequency

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Crash Frequency</th>
<th>Change from 6/22/21 - 3/31/22</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>209</td>
<td>+1 (+0.5%)</td>
</tr>
<tr>
<td>Fatal+Injury</td>
<td>41</td>
<td>-6 (-13%)</td>
</tr>
<tr>
<td>Rear End</td>
<td>114</td>
<td>-7 (-6%)</td>
</tr>
<tr>
<td>SS-SD</td>
<td>27</td>
<td>-4 (-13%)</td>
</tr>
<tr>
<td>FO-OR</td>
<td>41</td>
<td>+12 (+41%)</td>
</tr>
</tbody>
</table>
High Speed Vehicles

• Speeds before and after VSL activation were compared, filtering for similar conditions.
• Speed behavior during free flow and congestion remained largely the same.
• The proportion of vehicles traveling more than 10 mph over the recommend speed limit declined by up to 22% during the conditions when 55 mph was posted.
Conclusions

• The developed tool was able to process large volumes of data quickly and efficiently.

• Early results also showed positive trends, especially during transitional speeds. Results continue to be monitored with the developed application.
We would like to acknowledge the members of the I-95 VSL project team for their support and assistance during this project:

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