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Using Variable Speed Limits to Improve Safety During Fog Events: A Case Study of I-77 in Virginia

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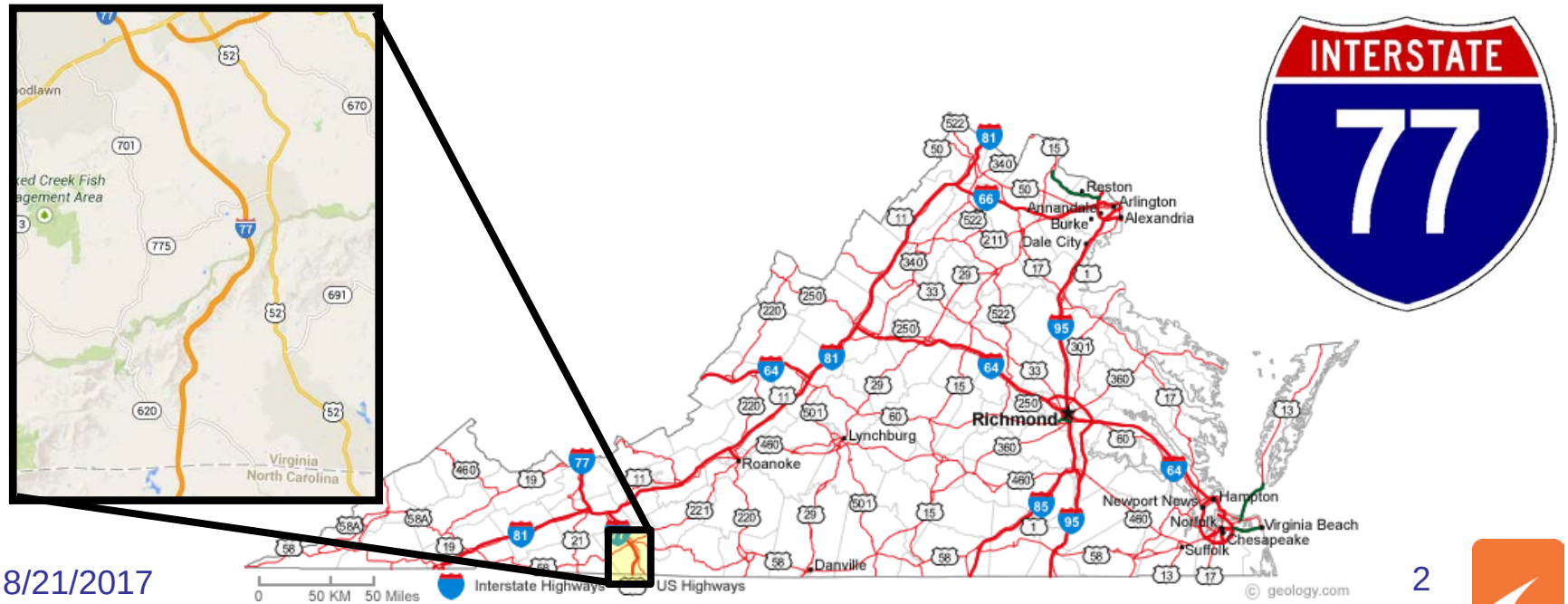
Site Description

- I-77 is a rural, 4 lane mountainous freeway in southwest Virginia
- 18,000 AADT with 27% trucks
- 65 mph base speed limit



Safety Issues on I-77

- Frequent, dense fog creates dangerous driving conditions for motorists on I-77
- Low visibility leads to chain-reaction rear-end crashes
  - 95 car crash event with 3 fatalities March 30, 2013
  - 28 car crash event on October 3, 2014

I-77 VSL System

- A $7.5 million VSL system was activated in October 2016
  - 13 DMSs
  - 36 full matrix VSL signs
  - 8 VSL cutout signs
  - 25 CCTV cameras
  - 22 Wavetronix sensors
  - 14 RWIS stations
- Enabling legislation
- Speeds archived at TOC

Research Objectives

- Determine driver behavior before system activation
- Define a control algorithm for the VSL system
- Assess effectiveness of the system post-activation

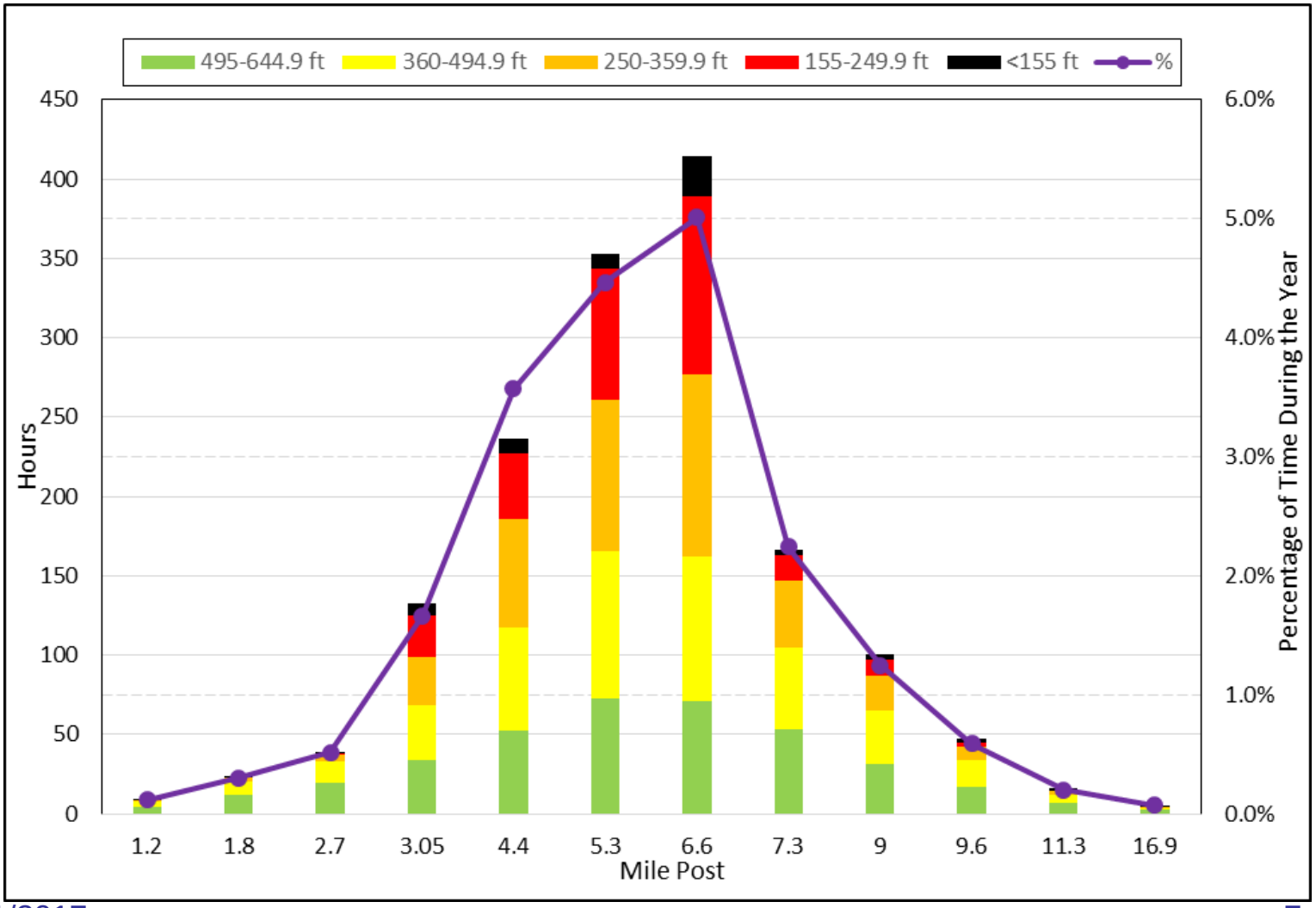
Characterizing Visibility

- Existing RWIS visibility sensors provided estimates of visibility in feet
- These could be used to find an estimated safe speed based on stopping sight distance

$$SSD = 1.47 * V * 2.5\ s + \frac{1.075 * V^2}{11.2\ ft/s^2}$$

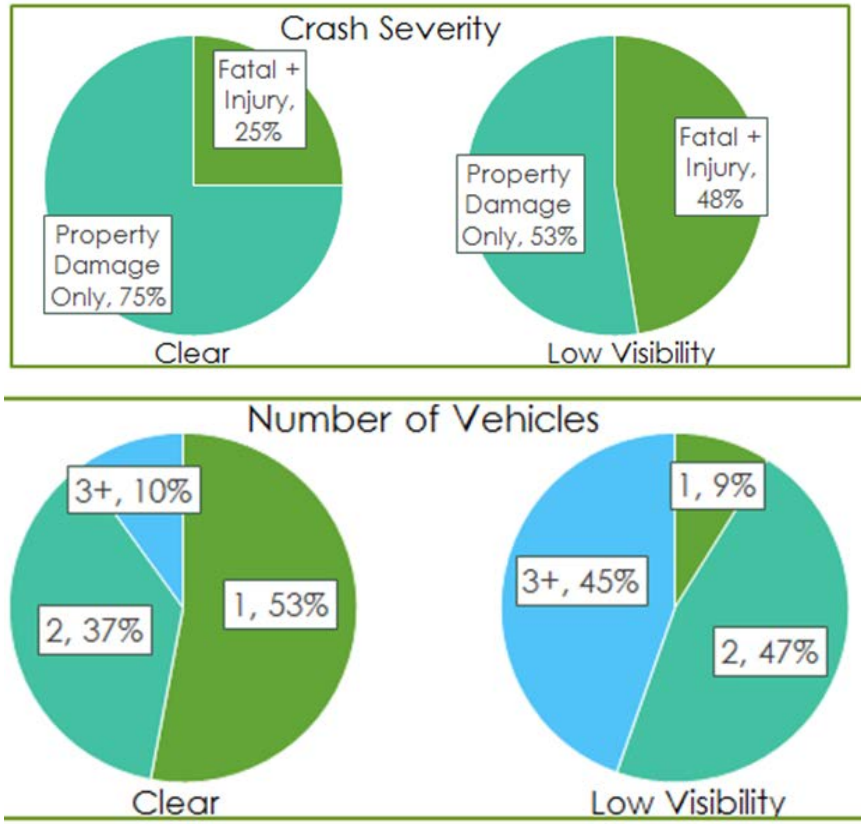
Visibility Range	*Safe Speed*	
> 645 feet	65 MPH	
495 - 645 feet	55 MPH	**LOW VISIBILITY**
360 - 495 feet	45 MPH	
255 - 360 feet	35 MPH	
155 - 250 feet	25 MPH	
< 155 feet	< 25 MPH	

Fog Distributions 2010-2015



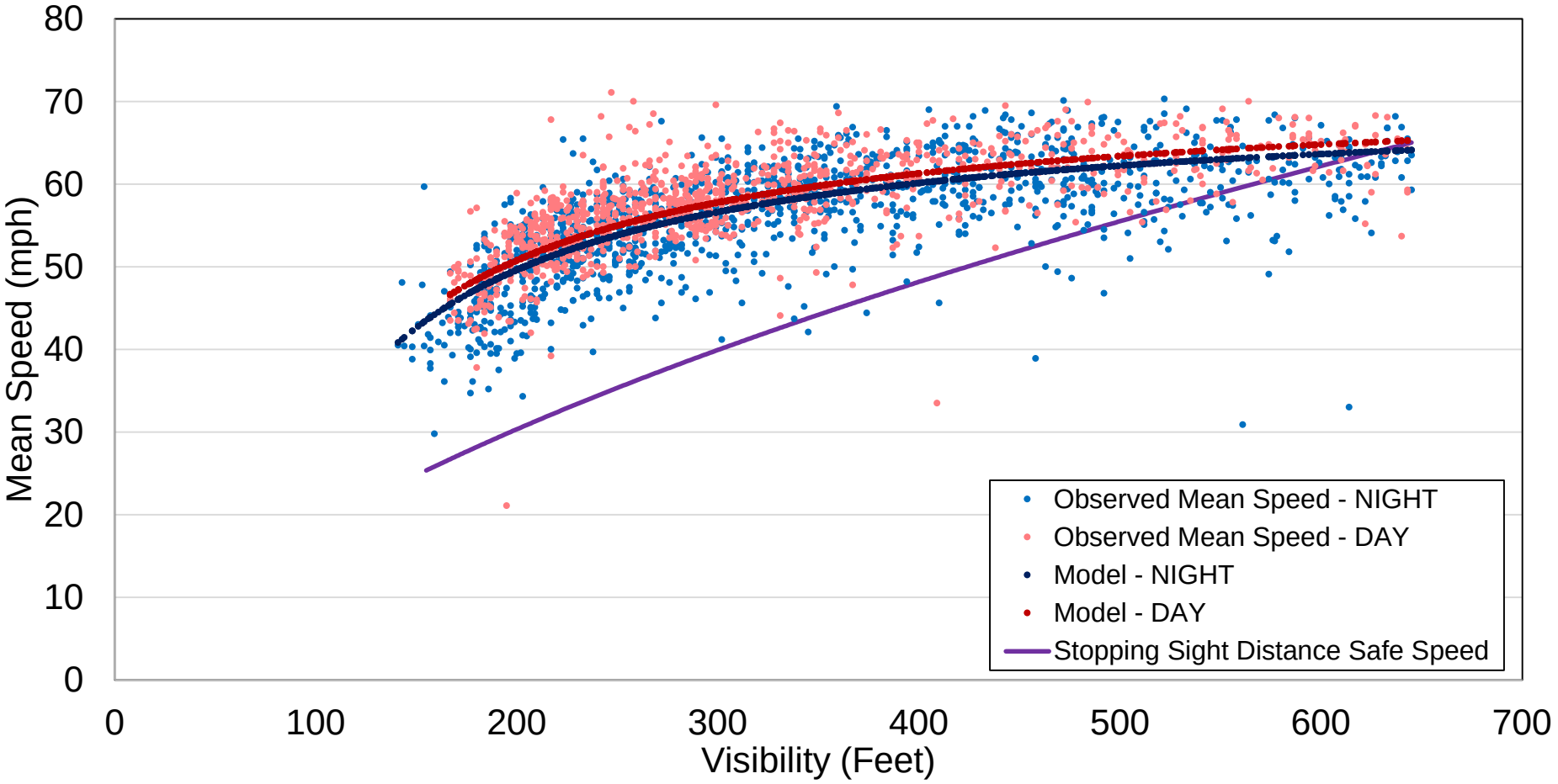
I-77 “Before” Crash Data

- 11% of crashes during fog
- 84% of fog crashes in SB (downhill) direction
- Crash rate more than double than during clear conditions



I-77 SB "Before" Speed vs. Visibility

$$speed = 64.6 - \frac{4204}{visibility} + 1.2 * Night + 6.1 * 6.6SB - 2.7 * 7.3SB$$

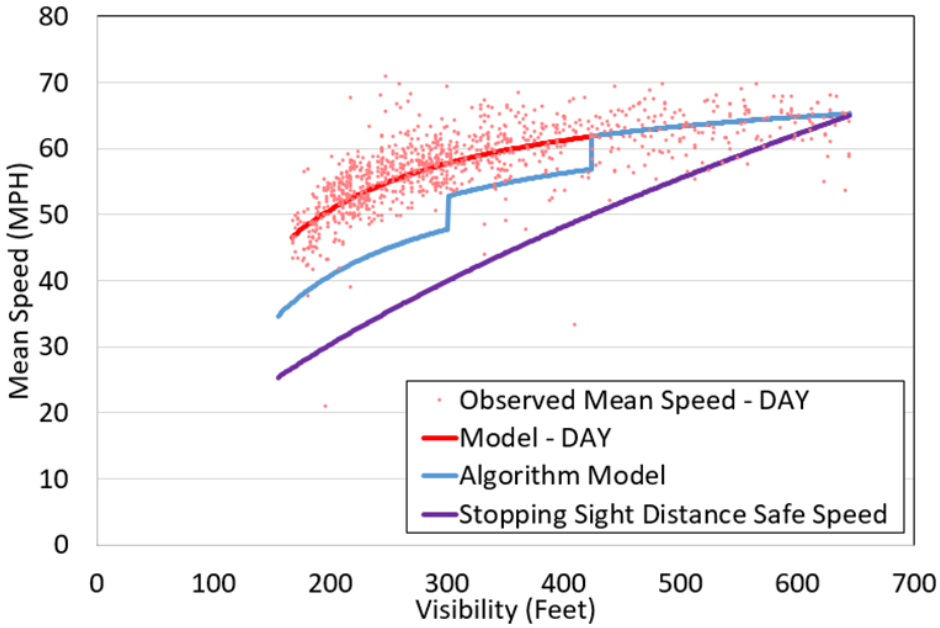


VSL Control Algorithm

- Before conditions show that drivers traveled significantly faster than SSD “safe” speed
- What will happen if we post SSD based safe speed?
- Solution: initially set speeds at level that “splits the difference” between safe speed and current behavior, then iterate if positive effects occur

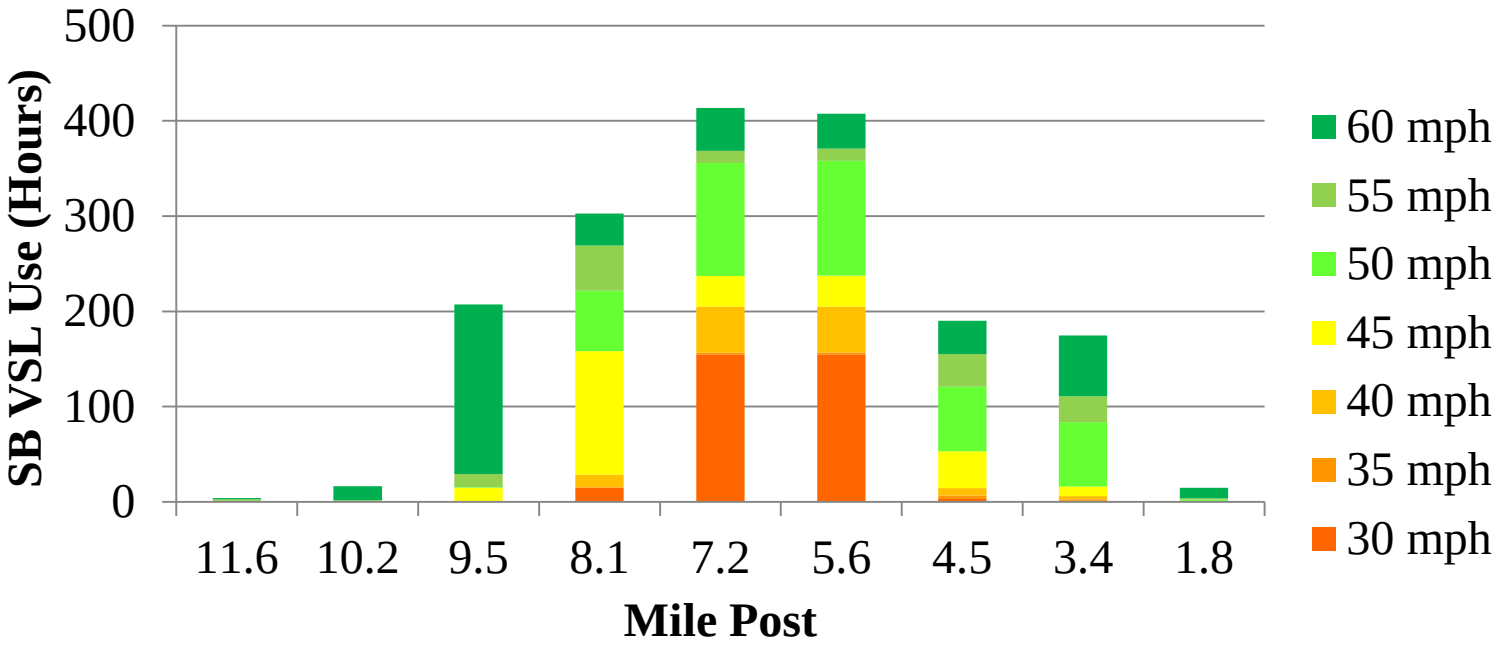
I-77 VSL Control Algorithm

- Step function algorithm used to set seeds at “worst” location
- VDOT controls VSLs from TOC
- Speed limits are smoothed and grouped to transition into and out of fog



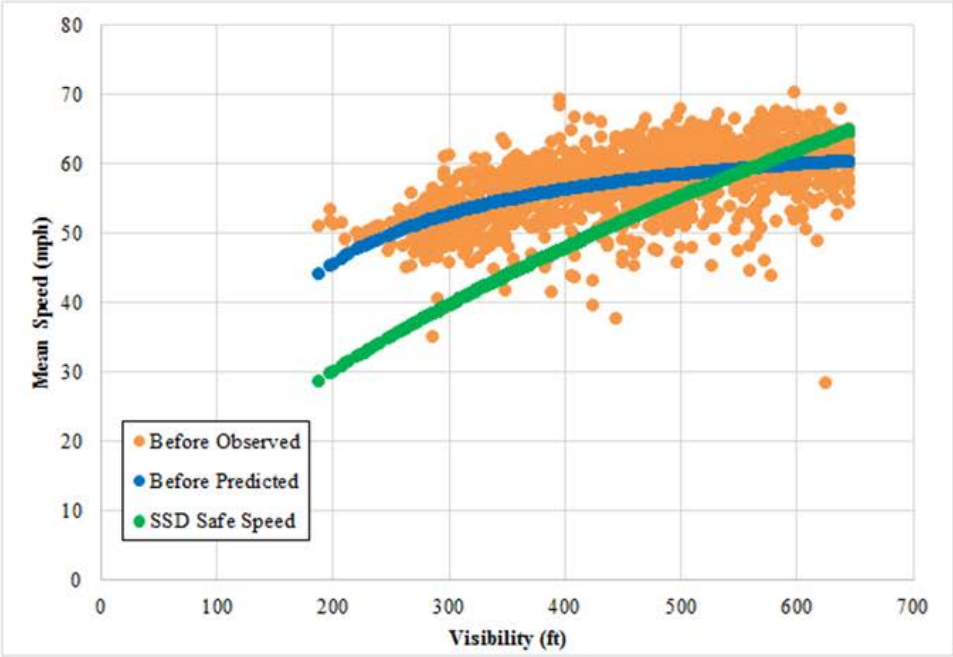
Fog Events After VSL Activation

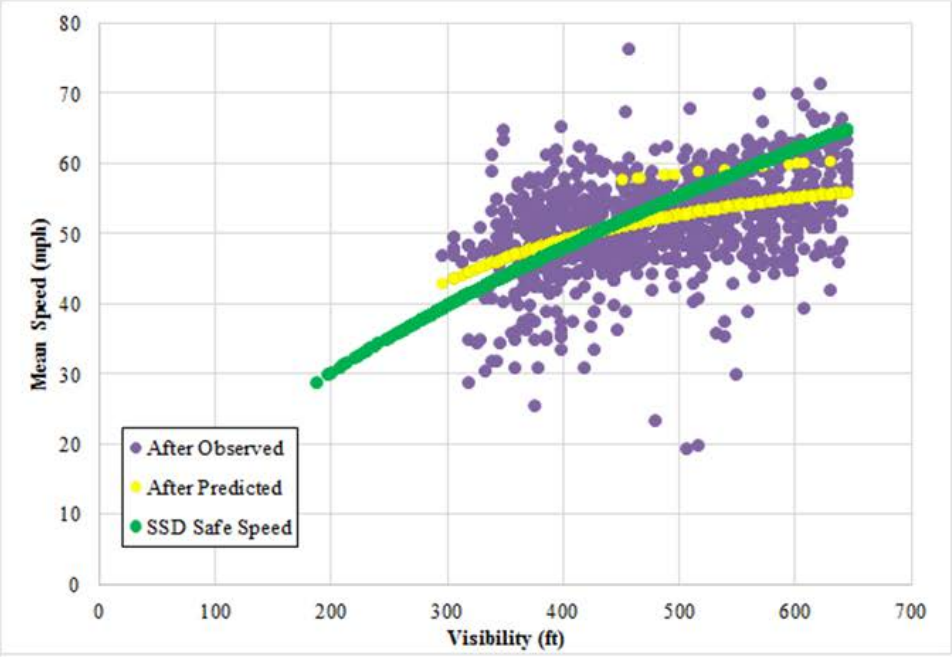
- 58 VSL activations from Oct 2016 to May 2017
  - Median duration 4.9 hrs
  - Three events lasted 50+ hrs



“Before” vs “After” at MP 4.4

$$Speed = 67.26 - \frac{4275.95}{Vis} - 2915.83 \times \frac{VSL}{Vis}$$





Before vs. After at MP 4.4

Statistically significant reductions of about 5-6 mph

Visibility Bin (ft.)	SSD Safe Speed (mph)	Before		After	
		No. of Intervals	Mean Speed (mph)	No. of Intervals	Mean Speed (mph)
495-645	55-65	513	59.9	451	54.1
360-495	45-55	524	56.6	543	50.3
250-360	35-45	297	52.4	74	46.5
155-250	25-35	22	49.8	0	-
<155	<25	0	-	0	-

Deviation from PSL and Location

Values are mean observed speed - posted speed

Milepost	Posted Speed Limit (mph)							
	65	60	55	50	45	40	35	30
11.6	-0.3	2.6	1.8	-	-	-	-	-
10.2	2.2	0	-	-	-	-	-	-
9.5	2.6	4.5	3.7	-	4.3	-	-	-
8.1	0.3	1.7	5.3	4.9	11.1	10.2	-	12.1
7.2	3.8	7.2	9.7	12.5	13.3	17.0	22.4	22.7
5.6	0.5	5.5	5.1	10.2	10.7	14.5	15.6	20.8
4.5	-0.1	2.8	2.6	4.2	3.7	4.2	4.2	-
3.4	2.2	4.4	3.2	6.5	5.3	4.6	-	-
1.8	3.4	4.7	-	-	-	-	-	-

Conclusions and Next Steps

- The VSL did successfully decrease mean speeds by about 5 to 6 mph
- During dense fog, there appears to be a lagged effect where drivers do not decelerate until they experience the event
- Future work:
  - Evaluate crash effects
  - Refine control algorithm

Questions?

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http://www.virginiadot.org/vtrc/main/online_reports/pdf/17-r4.pdf