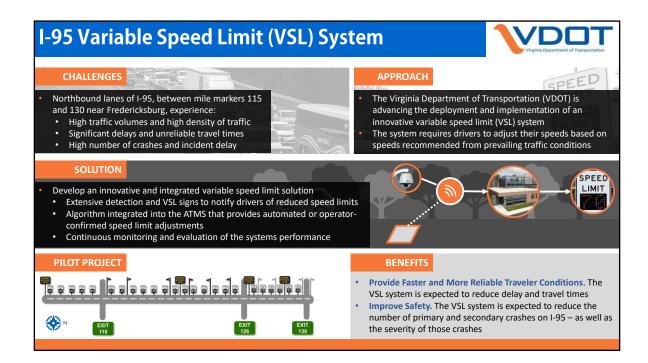
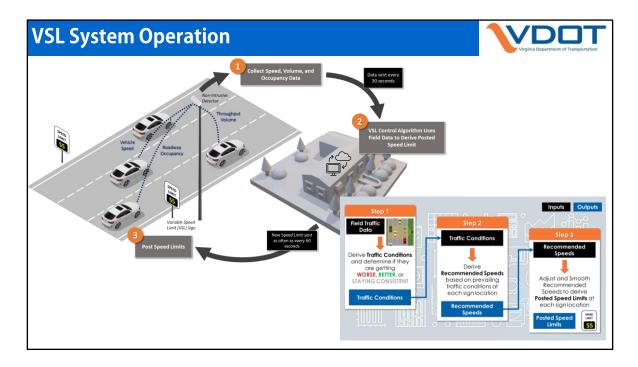


Good afternoon, I am excited to be apart of this webinar and looking forward to sharing our experience using microsimulation modeling for developing and testing a novel Variable Speed Limit algorithm that will be deployed in Virginia.



First, we will start with project background.

- I-95 in Virginia experiences many congestion and safety challenges, such as high traffic volumes and density, observed delay and travel times, and a high number of crashes that also resulted in added incident delay.
- To address these challenges, VDOT is deploying a Variable Speed Limit System that will monitor the corridor and reduce speed limits when congestion events occur.
- The project team reviewed many VSL algorithms deployed around the world to find most were developed for visibility and weather purposes, and only a few were used for congestion events. Of those used for congestion events, most were queue warning systems that <u>reacted</u> to speed reductions observed along the corridor.
- Therefore, the solution the project team developed was a novel congestionprediction VSL algorithm that incorporates extensive field hardware to feed data into the algorithm and alert drivers of speed reductions.
- A pilot project is currently in construction and is anticipated to be deployed in early 2022 with 24 VSL sites at approximately 6/10ths of a mile spacing.
- We anticipate benefits of this system will be faster and more reliable travel conditions and improved safety by providing drivers with more information and reducing the frequency and severity of crashes.

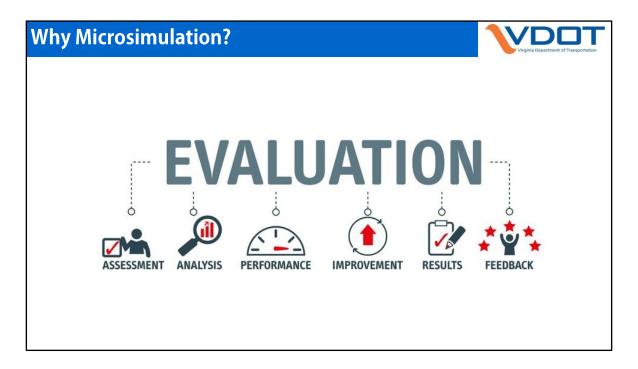


### So, how will this system work?

- VDOT will be deploying Wavetronix detectors that will capture individual vehicle speeds allowing us to aggregate speed, volume, and occupancy averages by lane.
- This data will be collected by the VSL algorithm every 30-seconds
- Lastly, new speed recommendations will be transmitted back to the field to update sign displays as often as every 60-seconds.

## The algorithm itself is comprised of three steps:

- The first step ingests the field data: speed, volume, and occupancy from the detectors at all 24-sites to derive traffic conditions and determine if traffic conditions are getting worse, better, or staying consistent.
- Next, recommended speeds will be developed based on those traffic conditions for every individual site independently.
- Finally, step 3 adjusts and smooths those recommended speeds spatially across the corridor and returns the final posted speed limits.

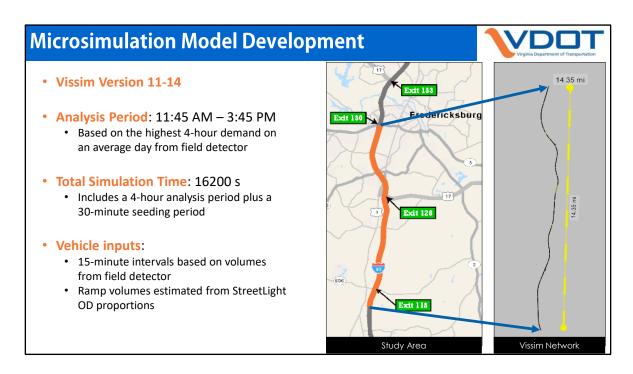


So, why are we using microsimulation?

- As I mentioned at the beginning, we developed a completely new Variable Speed Limit algorithm that has never been used in practice before.
  - We developed the theory and concepts for this algorithm using field data, but we needed a simulated environment to perform testing that would allow us validate algorithm performance and refine thresholds and logic.
  - Most of the time, VSL algorithms are tested with random number generator simulators, which do not follow the laws of traffic flow; therefore, it is difficult to test the effectiveness of smoothing and the influence of events at one location along the rest of the corridor.
- For these reasons, we introduced microsimulation to gather as close to REAL traffic data as possible.
- At the beginning, we used the traffic data to refine the algorithm logic prior to developing the algorithm module.
  - Now that the algorithm module has been developed, we use the
    microsimulation environment to validate and test functionality to make sure
    that all requirements are met for the system before we begin field testing.
  - We are also able to plug the algorithm into the microsimulation model and create a live loop where the real-time simulated data is extracted from the

- model into the algorithm, and the algorithm's recommended speeds are given back to the microsimulation model to adjust speed limits.
- Integration of the microsimulation data and the algorithm with the microsimulation models allow us to perform nearly complete tests of the algorithm prior to field data collection and deployment.
  - These tests have enabled us to correct bugs in the coded algorithm module and make improvements to algorithm functionality... ultimately, expediting the software integration and testing once all field devices are deployed.

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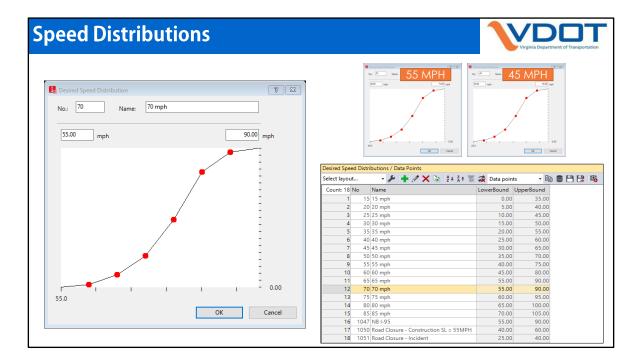
So, what does our microsimulation model look like?

- We created a Vissim model in Vissim 11 representing a four-hour analysis period that was determined from the highest 4-hour demand on an average day.
- The Vissim model was coded with vehicle inputs updating every 15-minutes based on collected detector data, and ramp volumes along the corridor were estimated using StreetLight.

# VSL Sites = Coded at locations defined by VSL system design plans Data Collection Points = Vehicle Detection collecting speed, volume, occupancy every 30-seconds Desired Speed Decisions = Speed Limit Signs Spacing accounted for driver's sight distance to the Speed Limit Sign Data Collection Point: 903 Data Collection Point: 903 Data Collection Point: 903 Possed Speed Decisions = Speed Limit Signs

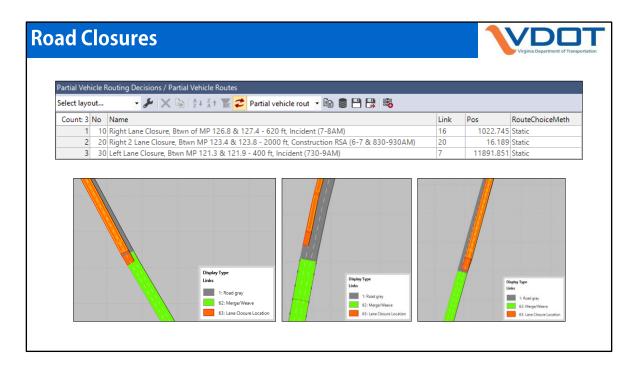
A VSL Site is comprised of vehicle detection and speed limit signs.

- All 24 VSL sites were represented in their approximate location based on the design plans.
- Data collection points in Vissim were used to collect lane-by-lane speed, volume, and occupancy at a 30-second interval
- · Desired speed decisions were used to represent speed limit signs
- The spacing between data collection points and desired speed decisions were intentionally coded to represent a driver's sight distance to the Speed Limit Sign



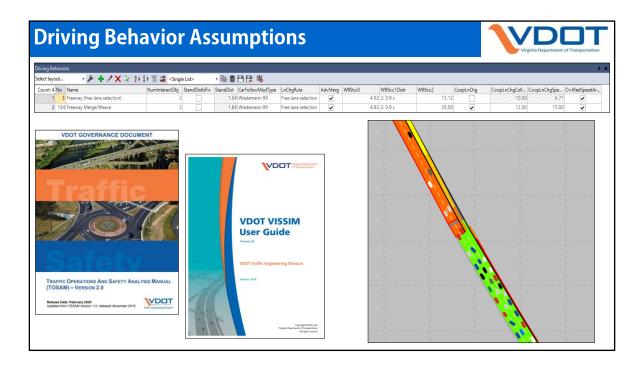
Field data was used to create the baseline empirical speed distribution with a speed limit of 70MPH.

- However, the first challenge that our team ran into was how to select speed distributions for the lower speed recommendations from the algorithm, when the algorithm changes the Desired Speeds in real-time.
  - This is a challenge because we do not know how drivers will react to the speed postings prior to deployment.
  - We tested a number of different assumptions, including using a mirrored distribution to match the 70MPH speed distribution, but adjusted according to the posted speed limit.



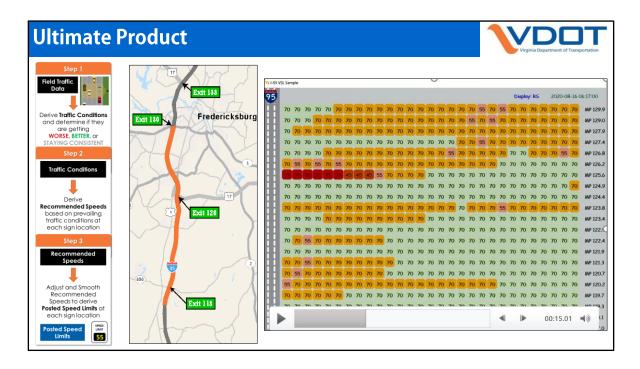
Next, we created a number of road closure scenarios that would result in congestion along the interstate corridor.

- For our baseline model, we coded three closure locations with one and two lane closures on the right and left sides of the highway.
- In Vissim, we coded these lane closures with overlapping links and partial routes that allowed us to only activate the road closure for short periods of time throughout the four-hour simulation.
- In the images on the screen the orange lanes represent the locations where lane closures occurred sporadically throughout the simulation period.
- The green lanes represent merging and weaving links with a dedicated behavior type to ensure realistic lane-changing behavior occurred at these road closures.



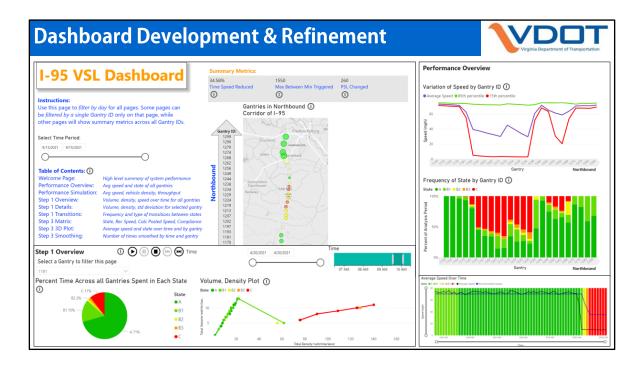
This model was not calibrated in the same way as large traffic analysis models are typically calibrated due to the modeling objectives and the lack of available data for full calibration.

- However, a few tweaks were made in driving behavior from Vissim default freeway behavior to more accurately reflect driving behavior.
- As previously mentioned, a Freeway Merge/Weave behavior was created with an adjusted car-following behavior CC2 value, cooperative lane change behavior, and adjusted deceleration thresholds.
  - These adjustments were informed by the guidance developed in the VDOT TOSAM, Vissim User Guide, and Vissim 11 Evaluation that all contributed to a better understanding of driving behavior in Vissim models.



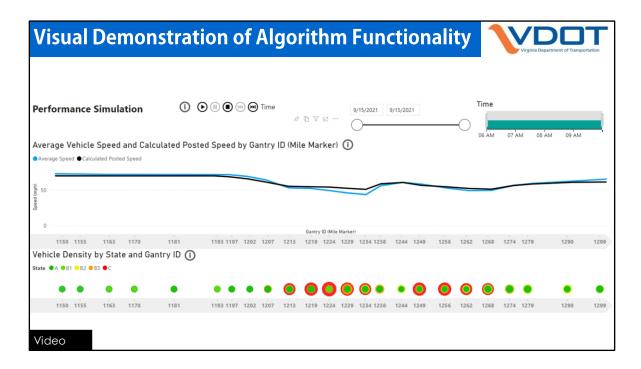
Bringing it all together, this rendering shows the algorithm working in real-time with the Vissim model to collect data and produce speed recommendations.

- Each column in the graphic show one 30-second time period and every row represents one of the 24 sites along the corridor
- The letters represent the state of traffic from Step 1 of the algorithm and the speed recommendations represent those from step 2 of the algorithm
- Thus, you can see we were able to use this setup to test each individual step of the algorithm as well as the full comprehensive module



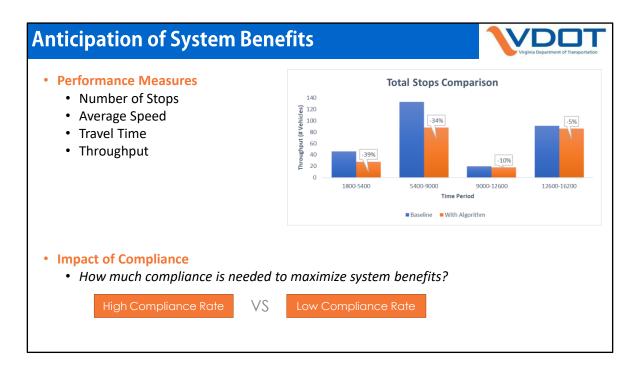
Using the data from running the algorithm with the simulation, we were able to create a dashboard that will run live with the actual VSL system to detail system performance.

- Without running the algorithm with the simulation, we would not have been able to collect meaningful data to begin populating this dashboard until field devices were deployed.
- This has also allowed us substantially more time to refine these dashboards to represent meaningful information that will be used by VDOT when the system goes live.



Development of this dashboard with simulated data has also given us tools to better explain how the system will operate.

- The performance simulator that you see on the screen was taken from our dashboard and depicts simulation and algorithm data aggregated every 5 minutes.
- The line graph on the top represents the average traveled speed from Vissim in blue, and the calculated posted speed – from the algorithm fed into Vissim – in black.
- The X-axis represents each site location based on the actual spacing in field deployment and in the simulation model.
- The second plot on the bottom shows the traffic conditions (where green = good, red = congested), and the size of the dot represents vehicle density at that location.
- As we watch this simulation, we can see how the average speed reacts to posted speed decreases in response to congestion forming in the simulation model due to one of our coded road closures.



This simulation testing environment not only allows us to stress test the algorithm with realistic traffic data in the exact configuration that it will be deployed, but also gives us the opportunity to evaluate system performance to anticipate the benefits the system may offer under varying conditions.

- We are collecting performance measure information such as the number of stops, average speed, travel time, and throughput
  - As you can see on the right side, we are comparing these metrics at different time periods throughout the simulation
- We are also reviewing the impact of compliance of system performance, aiming to answer the question of how much compliance is needed to maximize system benefits.
  - For this analysis, we are reviewing high and low compliance rates by adjusting vehicle types in Vissim to represent different distributions of drivers following the posted speed limits.

# **Challenges & Future Needs**



# **Greatest Challenge = Many Required Assumptions**



- Driving behavior
- Speed distributions
- Congestion events
- Other model coding quirks

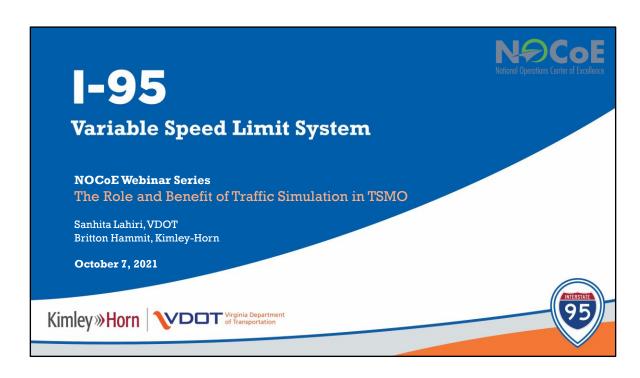


# **Future Research Needs**

- Predictive Analytics
- Measuring System Compliance
- CAV + TSMO Applications
- Others...

Before we conclude, we wanted to summarize the challenges our team has experienced using simulation to test VSLs and begin the brainstorming session on future research needs.

- The greatest challenge by-far that we experienced was the number of required assumptions for developing the simulation model...
  - We needed to make assumptions on driving behavior because we didn't have resources for full calibration
  - We needed to assume speed distributions for vehicles following the VSL system reduced speed limits
  - We needed to create congestion events closing 1 or 2 lanes of varying distances at varying locations
  - And, we also needed to work around various modeling quirks
- Stepping back and looking at the big picture, a few additional research needs include:
  - Predictive analytics for better understanding driving behavior for VSL and other TSMO applications
  - Research into how system compliance can be measured and what system compliance should be assumed for modeling applications
  - And, introduction of CAV technology into TSMO Applications



Thank you for the opportunity to present today, and we look forward to the panel discussion!