VSI Labs AV Readiness Study Data

Q: **Eric Hill (MetroPlan Orlando):** Weather is an issue to consider: rain, snow, high winds, etc. Are you considering these?

A: Peter Jager (Utah DOT): We are considering a study this fall to evaluate at night and in other weather conditions. It could be challenging to schedule in "other weather conditions" but would be very valuable data.

Q: **Christopher Falcos (Massachusetts DOT):** Was the vehicle only using RGB Cameras for detecting lane markings and roadway hazards or multiple forms of detection?

A: Peter Jager (Utah DOT): Lane Keeping Assist (LKA) is primarily camera-based but the study included multiple forms of detection. Quoting from their report "The raw data is collected at the rate of about 80 gigabytes per hour and includes all camera, lidar and radar feeds plus GPS positioning."

C: Christopher Falcos (Massachusetts DOT): Great to know. I had always heard Lidar and radar did better in these contrasting problem areas but good to hear it's not the cure-all the industry likes to act like it is.

C: Peter Jager (Utah DOT): The car has both visual-range cameras and infrared. This study primarily used visual cameras.

Q: **Paul Pisano (Paul Pisano LLC):** In the Redmond case, where it tracked well with the skip lines, does that mean skip lines will be needed in all cases? What happens if they're not there?

A: Peter Jager (Utah DOT): They recommended skip lines in many cases, to keep the vehicle from following the shoulder line as it diverges from the mainline.

C: **Russell Holt (Rhode Island DOT):** Thanks for 'advancing the needle' with these studies. The findings of gaps and failures on actual live/open roadways are to me most helpful, and not only to DOTs but I assume to OEMs as well.

A: Peter Jager (Utah DOT): Thanks, Russell, I only touched on a few of the issues from the complete report. There were many more situations found, but many are similar in nature and recommendations.

Q: **John Hourdos (University of Minnesota):** I see a great lot of evidence that this technology is far from ready to be on the road driving vehicles. For one there is nothing we can do about shadows, on the other the cost of maintaining the required lane markings seemed huge. Am I wrong?

C: Christopher Falcos (Massachusetts DOT): I've heard that other forms of detection can solve/mitigate these issues.

A: Blaine Leonard (Utah DOT): There are multiple sensors on board - this study focused on lane lines detected by cameras - this is how the Lane Keeping Assist system on your car works. LKA shouldn't be used in urban areas, where there are trees, etc. Certain parts of these technologies (like LKA) are ready for broad use - with a human driver. Bringing all of this together into a Level 5 'driverless' vehicle isn't ready yet - and probably not for many years.

Q: **Samir Goel (Texas DOT):** In some jurisdictions, they're pushing a 6-inch-wide stripe instead of the 4-inch-wide stripe. does the wider width make a difference?

A: Doug Gettman (Kimley-Horn): My understanding is that the 6-inch stripe does help. I believe some findings in NCHRP 20-102 (06) support this.

C: Christopher Falcos (Massachusetts DOT): Of course, the problem is (especially in small cities and towns) the added cost to implement 6-inch-wide line striping, and if that causes them to increase the time between repainting, it removes the benefit

C: Ginna Reeder (The Eastern Transportation Coalition): The Coalition's work on AV lane striping (with Connecticut DOT, Consumer Reports, and University of Connecticut) that Lisa mentioned in the intro is going to look at this 4" vs 6" issue, and across vehicles from different manufacturers.

I-24 MOTION Test Bed

Q: **Sanhita Lahiri (Virginia DOT):** This is amazing! What cost (construction and data processing) did you end up with this?

A: Lee Smith (Tennessee DOT): Thanks, Sanhita. Regarding costs, the validation system and 4-mile section are estimated to cost $11.5M. A small investment, given the impact to improve operations that advance the state of the practice.

Here is some additional information about the benefits estimated for emissions specifically was:

- Cost per Kilogram of all criteria pollutants ($/Kg) - $40.03
- Cost per Kilogram of PM 2.5 reductions ($/Kg) - $133.86
- Cost per Kilogram of NOx reductions ($/Kg) - $99.15

Q: **Russell Holt (Rhode Island DOT):** Were any new Tennessee DOT policies or laws passed or needed for the I24 ICM, particularly regarding CAV (or maybe some were already in place that supported the advancement)? Congrats on this project, impressive 'testing ground 'approach on a live/open to a public facility.

A: Lee Smith (Tennessee DOT): Thanks for the kind words. We hope that this project will advance the transportation industry to make our roads safer and more reliable. Tennessee passed legislation to allow for CAV applications in 2017. It was beneficial to have the legal structure in place as we prepared for this project.

Q: **John Roberts (Arizona DOT):** Can you speak to the decision process on I 24 with regards to edge processing image data vs centralized processing. Also, any thoughts about using the cloud vs traditional server architecture to process this data and scale the system that you have learned through this project.

A: Will Barbour (Vanderbilt University): We considered both edge and cloud computing to process video into trajectory data but, as you noted, ended up with a centralized, on-premises computing architecture. The reason was multifold:

1) Transmitting this volume of video data to the cloud, even over fiber, would be very costly. We're operating in the territory of a 20Gbps continuous data rate, which is challenging to accommodate even within a local network.
2) Managing the rest of the system infrastructure — cameras, network devices, etc. — is already a significant challenge from an O&M perspective. Adding edge computing devices to the mix would have increased this burden, with a particularly high level of availability/resilience required for computing devices to not have gaps in trajectories.

Q: **Chrissie Collins (Florida DOT):** There are too many variables with striping, what about communication under the roadways that are detectable by the vehicles to stay within a given lane? That could work together with perpetual charging built into the asphalt and include GPS to assist with location.

A: Lee Smith (Tennessee DOT): I agree that there are many variables with striping, it will be a Maintenance challenge for sure. Regarding communication under the roadway, I think there have been studies on this; I think it has merit, but I'm not sure of the results. It would also be a Maintenance challenge.

Connected Vehicles: Privacy, Security, and Spectrum

Q: **Terry Shaw (Kimley-Horn):** What are the urban canyon effects on the range in downtown areas?

A: Doug Gettman (Kimley-Horn): Range reduction can be significant. Anecdotally, from what I've read it seems that CV2X may bounce off buildings a bit better than DSRC, to "see around corners". I recollect that the New York State DOT pilot has generated some good data regarding urban canyon effects in their Manhattan deployment.

Q: **Lisa Miller (The Eastern Transportation Coalition):** For all panelists, what do the next five years look like when it comes to CAV data? How is your agency, university, or company approaching the challenges and expectations for CAV data?

A: Lee Smith (Tennessee DOT): From my perspective, the next 5 years should focus on safety applications and ways to improve operations. The industry needs to focus more because the technology is moving fast and leaving applications and operations behind in some cases.

A: Stan Young (The Eastern Transportation Coalition): The next five years will see tremendous growth in the type and fidelity of transportation data available from connected and automated vehicles. The TETC Transportation Data Marketplace strives to provide its members access to the top-tier transportation data providers using consistent data licensing and sharing terms, making a variety of data products available at fair prices. Standard formats and APIs for such data products will be our emphasis over the next five years, reducing the frictions for agencies to access and consume for the betterment of their planning and operations duties. Interoperable geo-referencing data formats are key, as IoT proliferates into the transportation domain.

A: Will Barbour (Vanderbilt University): Thinking from the university perspective, I expect connected vehicle data to proliferate and drive studies related to infrastructure usage and improvement; however, data from the automated vehicle side seems to be staying siloed with companies and isolated studies. I hope that through research studies performed with industry partners and through CAV testbeds, we can help open up this availability over the next five years. And to support this work, we are investing in computing and data storage infrastructure to a greater extent.

A: Peter Jager (Utah DOT): The next five years will have tremendous increases in-vehicle data, but remains to be seen how much we will be able to access. Changes in the radio spectrum also pose a challenge to data transmission, potentially requiring major hardware changes. Our department will continue to use existing devices to collect what we can and expand our infrastructure for receiving and processing rich vehicle data. We are expanding our applications and exploring beneficial ways to use the data while working with the industry to improve roadway safety through the use of onboard vehicle data. We will also continue to evaluate our infrastructure readiness for automated vehicles.

A: Doug Gettman (Kimley-Horn): I'm hopeful that as the vehicle fleet generally becomes more CV-capable that the value of CV data to IOOs will increase substantially. In five years, it could become viable for IOOs to support signal re-timing, model calibration, and other traffic engineering tasks with CV trajectory data instead of using (or in addition to) technology like tube counters. Some of that same information can come to IOOs for "free" when CV2X takes hold but at the expense of the installation of many RSEs by IOOs. I believe most I2V and V2I applications (other than life-safety applications that truly require low latency message delivery, such as red-light running warnings) can be done with existing cellular communications. The CV data brokers have defined APIs to send CV data to an IOO. What's missing is the reverse pathway/API to get I2V information back to the CV for display by the driver outside of the CV2X channel. We are working with a few public agency IOO clients to provide these centralized APIs for SPaT, MAP, and TIM in our Traction Connect™ Cloud software that utilizes Android Auto and Apple CarPlay as the display surface for driver warnings.