MUSTANG: Measurement Utilities for Sensing Transportation Activity in Non-Urban Geographies

Rural Data and Operations Challenges, Solutions and Recommendations for the Eastern Transportation Coalition

Final Report

1/25/2026

Prepared by: The Eastern Transportation Coalition

This report characterizes the unique challenges of rural highway operations including available data, resource constraints, and telecommunications in contrast to urban highway operations. The report shares solutions and best practice and makes recommendations resulting from stakeholder feedback across the coalition for inclusion in Coalition programs moving forward.

Acknowledgements

Executive Summary

The *Measurement Utilities for Sensing Transportation Activity in Non-Urban Geographies* (MUSTANG) project aims to document the challenges facing rural highway transportation systems management and operations (TSMO) in contrast to urban areas, collect and communicate best practices with respect to data and telecommunications, and make recommendations to the Coalition and to industry to improve rural TSMO moving forward. This was accomplished through stakeholder engagement with representatives from five states within the Coalition, each with significant rural transportation infrastructure, planning, and operations experience.

Rural transportation corridors and their operations differ from their urban and metropolitan counterparts, primarily due to lower population densities which in turn translate into less demand and subsequent lower roadway volumes. However roadway miles do not diminish with density, and thus rural operations have to cover the vast rural network of interstates, collectors and distributors that connect rural townships, services agriculture as well as provides paths for recreation and inter-city movement – and typically do this with a lower resource budget in terms of manpower and funding in contrast to urban and metropolitan regions. Many of the new 'big data' sources, referred to herein as probe data, came of age serving the TSMO needs in more populated areas where recurring congestion from excess roadway demand is dominant. Similarly, the telecommunications infrastructure in populated areas is typically pervasive, such that cellular connectivity outages are rare either to support TSMO or to communicate with travelers. In contrast, in rural areas

Figure ES-1: Population Density in the Coalition region

connectivity and robustness of cellular coverage are more suspect. The population density of the Coalition region is shown in Figure ES-1, with the regions corresponding to the five Coalition stakeholder engagements outlined in black. These regions span Kentucky, Vermont, and portions of Pennsylvania, Virginia and Florida.

MUSTANG concentrated its focus in two primary topic areas, that of traffic data availability and quality for rural roadway applications, and robustness of the telecommunications networks that service rural roadway operations. Industry-sourced traffic information from probe data has transformed urban highway operations, providing improved situational awareness on the flow of traffic across the region, detecting flow
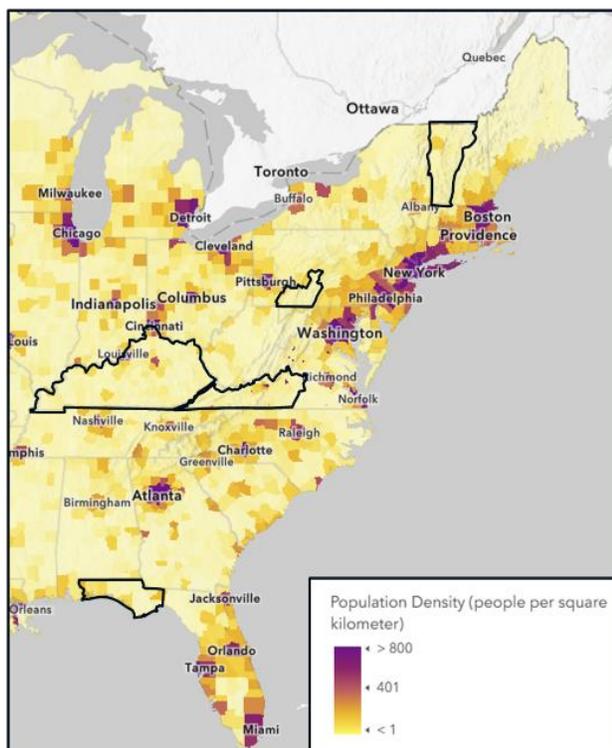
anomalies, and providing real time traveler information through changeable message signs and 511 systems, as well as consumer smartphone navigation applications. In comparison, probe data on rural roadways, though now readily available, is not as mature or robust as its urban counterparts. The effectiveness of probe data is challenged in rural areas due to lower traffic volumes, resulting in fewer probe vehicle samples, which in turn makes incident detection more challenging as well as induces greater latency in comparison with urban coverage. Compounding this issue is the less robust nature of wireless data telecommunications in low density areas, particularly when combined with rugged terrain. As probe data has grown and evolved, the industry has partially overcome the data sampling issues through greater overall vehicle probe penetration rates combined with methodologies such as 'store and forward' data communications – but still lags in effectiveness compared to urban counterparts. Wireless telecommunications infrastructure has also steadily improved in the last two decades as communications networks are upgraded (3G, 4G, and 5G technology) and expanded, though again these improvements are typically initiated first in higher density areas while rural areas trail. Adding to the challenge of rural TSMO is the inherent nature of rural operational concerns which differs significantly from urban areas dominated by demand-induced congestion. In rural areas traffic management concerns are closely associated with inclement weather (flooding, snowstorms, etc.), incident/crash response, or roadway construction and maintenance activities (work zones), but rarely excess demand induced congestion. Even with a severe incident or inclement weather, the traffic volumes may be so low that probe data is much less effective reporting such incidents in a timely fashion.

The five stakeholder interactions contained common themes with respect to data and telecommunication with each region implementing effective strategies to improve and advance TSMO for their rural region. Highlights from these engagements are summarized below.

- The **Kentucky Transportation Cabinet** (KTC) emphasized the need for consistent and robust cellular coverage throughout the state to support TSMO. Recent prioritized cellular service offerings for safety and emergency personnel (KTC contracts with AT&T FirstNet) have resolved many of the cellular issues in and around its metropolitan areas and any city or town with significant population. However, the rural areas of the state, particularly its most rural areas in the eastern Appalachia region, remain challenging. The sparse population does not present a return on investment for the national cellular carriers. Although populated places typically have coverage through regional or national carriers, coverage along roadways connecting rural populations centers is often lacking. Travelers accustomed to modern consumer navigation apps frequently find themselves in rural areas with no service through their national carrier, either due to lack of signal coverage, or lack of data roaming agreement with the regional carrier. Such telecommunications challenges were common to most of the stakeholders – particularly those in highly rugged areas within the Appalachian Mountain range (see Figure ES-2). The KTC closely monitors available cellular service offerings and coverage of the multiple carriers covering the rural regions of the state to ensure its TSMO program has the best connectivity possible.

- **Vermont Agency of Transportation** (VTrans) emphasized both data and telecommunication issues. Similar to Kentucky, Vermont is challenge by gaps in cellular service that impact not only TSMO but is also an economic development and equity concern for the state. This prompted Vermont to perform an independent and comprehensive assessment of cellular coverage of all service providers in the state. This independent analysis of the availability and robustness of wireless voice and data coverage helps inform policy decisions and infrastructure improvements [15]. VTrans also emphasized the challenges of a rural state embracing modern probe data – and shared successful pathways of how a predominantly rural department of transportation was able to successfully start incorporating these new data tools. In a small state it is common for a staff member to wear many hats which aids in spreading the use of big data across disciplines and knowing who to contact. There can be increased expectation of collaboration in new undertakings in a small state where staff will also see each other at social events (i.e. school activities and supermarkets). It's critical for a small state to make many uses of operations data (not just for TSMO) because the cost of the data is a bigger percent of the stretched-thin budget than in bigger states. The return on investment has to be high. Vermont strategies for adopting operations data included identifying an internal champion, recognizing staff resource limitations and addressing through strategic partnerships, education opportunities, and internal networking opportunities for knowledge sharing. Many of the tactics employed by Vermont were also evident in other stakeholder interactions and serve as a guide for any rural

Figure ES-2 Much of the Coalition is located in highly rugged areas (landform ruggedness scale >7) of the Appalachian mountain range

transportation organization to effectively embrace probe data for its organization.

- The **Southern Alleghenies Planning and Development Commission, Pennsylvania** is a rural transportation planning organization (RTPO) covering many of the highly rural counties in south central and southwest areas of the state. As a planning organization, comprehensive and accurate data is key to their transportation planning responsibilities. The RTPO emphasized the

contrast between available resources (both staff and funding) to acquire, process and analyze both transportation infrastructure and operations data. They recommend that state DOTs, whenever possible, take a wholistic approach to outsourced transportation data that includes rural regions, as well as the GIS and data science support needed to make full use of these data sets for rural regions.

- **Florida Department of Transportation – NorthWest District 3 SunGuide Center – Chipley, FL** has responsibility for traffic operations across a long rural interstate corridor connecting the population centers of Pensacola and Tallahassee. The rural transportation management center (TMC) makes full use of modern data tools. The TMC employs the Regional Integrated Transportation Information System (RITIS) not only for probe-based traffic monitoring, but RITIS also implemented a module to bring in radio data feeds from local law enforcement and emergency response in order to share data seamlessly – an approach that provides for the majority of initial detection of roadway incidents coming through traditional emergency reporting channels. Close coordination with local law enforcement and emergency response personnel (even co-location) was a common theme with stakeholders that typically provided the initial detection of any significant event on the network. The Florida TMC also emphasized the value brought by WAZE traffic feed made available through their DOT's GIS system to monitor for, and respond to minor incidents before they became significant impediments to traffic flow. This TMC, whose region is not rugged in comparison to other Coalition rural stakeholders, has reliable cellular service throughout the large majority of its service area. It uses a 'radio emulator' smartphone application, allowing them to mimic the benefits of a dedicated radio channel to coordinate incident response, further emphasizing the need for a robust wireless communications infrastructure.

- **Virginia DOT Southwest Traffic Operations Center** covers the eastern side of the Appalachian Mountain range opposite of Kentucky. Similar to Florida, a major interstate corridor (I-81) spans the region connecting major population centers, but otherwise the region covers some of the least populated areas of the state. This VA TMC emphasized the need (and benefit) of a robust communication system across all personnel and intelligent transportation system (ITS) assets. VDOT continuously monitors its statewide ITS network for downtime, and uses 'pay-for-performance' contracting to encourage maximum uptime. VDOT also makes extensive use of resource sharing agreements for fiber optics along roadways for broadband data backhaul – a major asset for its rural ITS operations. Similar to Kentucky, VA maximizes cellular connectivity through use of priority service providers (Verizon) as well as dual-SIM devices for maximum reliability. The Virginia Southwest Traffic Operations Center also noted key cultural and organizational evolution that provide benefits. The ITS and traffic divisions, though organizationally separate, function in a highly coordinated fashion so that networks and equipment are efficiently deployed and managed jointly. So too, the VDOT personnel are becoming more technology savvy, both through additional education, as well as through generational impacts as younger employees bring with them a 'digital native' perspective to their positions.

Common TSMO Tools, Data and Technology in Rural areas:

Stakeholder engagement included many common themes that spanned data, telecommunications, and rural DOT culture.

Rural Traffic Data: The MUSTANG initiative began with a focus on 'big data' for rural transportation. Data was a major point of discussion with each stakeholder, but each stakeholder had unique challenges and perspectives. 'Big data' many times played a supporting role to other sources of data in the theater, providing overall situational awareness of the network, while ITS specific sensors, or other data systems informed on initial incident detection. A major theme in the data space is the benefits from close coordination with law enforcement officials (LEOs) and other emergency response. In Florida, their RITIS analytics platform has a specialized module that monitors all LEO and emergency response radio channels in the region, providing their TMC direct access to incidents as they are reported. Florida as well as Virginia reported that most initial incident detections (>90%) were derived either from co-location with emergency response and dispatch (i.e. VDOT), or tight integration with their data systems (i.e. Florida).

The analytics provided by most probe data systems are typically speed, travel time, queuing, and other aspects most commonly associated with the concerns of recurring congestion in urban and metro areas. Although the Coalition's Transportation Data Marketplace (TDM) data has been tested in rural areas, efforts to validate the data typically have failed to locate any slowdowns in traffic during the typically two-week test period over the past two decades, with one exception from Stowe, Vermont in which slowdowns associated with a busy ski weekend were analyzed (which could be argued was a recurring congestion event). Validation methods currently centered on recurring congestion events need to evolve to reflect accuracy and value of data for rural TSMO. One such method is to analyze and validate data following a major weather event that impacts roadway access such as flooding or a winter snow storm. Another effective method was to monitor the 'confidence indicator' in each vendor's data stream, a metric initially introduced over concerns of accurate reporting during off-peak hours now informs on quality of coverage in rural areas.

Whereas urban probe data is often used to detect and monitor the myriad of recurring and non-recurring congestion events in a metropolitan area, rural incidents are typically first reported through traditional emergency dispatch. However, one aspect of rural TSMO data needs for which probe data may provide benefit is that of monitoring the roadway for 'passability' in addition to speed and congestion. The ability to assess and monitor when a road can no longer be safely traversed during floods or winter storms (as well as the converse of when the facility returns to normal operation after such events) is of equal (or perhaps greater) importance for rural TSMO as compared to speed data that reflects demand related congestion. In addition to TSMO, such data was reported to save rural states a considerable amount of time and resources in updating its transportation resilience plan, adding to the return on investment. Although existing data and tools incubated in metropolitan regions may be able to infer insight for such various purposes, current transportation data analytics tools may not be directly designed for such functions to support rural TSMO. Both Vermont and Florida worked with their analytics providers for solutions that met their unique rural TSMO needs.

With respect to emerging 'big data' sets, Florida noted that the availability of WAZE data through the state's GIS data system had a significant impact on their ability to respond to minor incidents before they began to impact traffic flow such as disabled vehicles and roadway debris. Although managing these large data sets is challenging, modern analytics tools have allowed them to filter extraneous information, and find user reported minor incidents that have potential for roadway restrictions and lane blockages.

Kentucky reported that a primary data concern was not data input, but rather sharing critical roadway conditions with commercial navigation providers such that they route travelers and freight appropriately when primary routes are blocked, an area that the Coalition may provide benefit through unified collaboration with industry.

Effective strategies, tactics, and technologies for rural TSMO data include:

- Close coordination and integration with traditional emergency response typically provides the majority of initial incident detections. Either tight data system integration or co-location of the TMC with emergency dispatch is recommended.
- In rural areas probe data provides overall situational awareness across the network, showing the larger scale consequences of major incidents. However, the lower traffic volumes in rural areas typically results in higher latency, and so it typically lags other data sources for incident specific detection and information, as such probe data may play a supporting role to other forms of detection such as ITS detectors or direct field observations, particularly for crash related incidents.
- Rural TSMO may be able to capitalize on emerging 'big data' such as WAZE to detect and respond to small incidents (i.e. disabled vehicles or roadway debris) before they escalate to major traffic impacts. Though management and filtering of these emerging 'big data' feeds can be challenging, Florida DOT has enabled constructive use of the data feed through central systems and appropriate tools to manage the volume of information.
- Data needs of rural regions differ from urban and metropolitan regions. Working directly with probe data providers for metrics and analytics appropriate to the rural context is essential. Probe data analytics tools as well as validation methodology need to evolve to meet the needs of rural TSMO accordingly.
- TSMO data needs are highly context specific. For example, traveler safety in southwest Virginia is highly impacted by fog in mountainous areas. Accurate detection of fog formation, and prompt notification to drivers to reduce speed is critical. This currently requires dedicated ITS devices for detection and notification, something that probe data or 'big data' currently has no capability to address, however, probe data can indicate the extent to which traffic flow responds to such warnings.
- Transportation data, be it for operations or planning, is less abundant in rural areas, and funding is minimal to acquire such data. As outsourced data continues to grow and evolve, wholistic procurement approaches at the state level that provide both state-wide data sets, as well as GIS, data science, and other analytics resources to leverage 'big data' are needed.

Wireless Communications Infrastructure: Although MUSTANG started with an emphasis in data, most conversations had stronger emphasis on the critical role of modern telecommunications infrastructure, and its challenges and solution paths. Public wireless communications connectivity (3G, 4G and 5G voice and data services), which are typically taken for granted in urban and metropolitan areas are much less robust in rural areas. Cellular coverage is typically available in small towns, but can be highly susceptible to outages either from weather or over-subscription (too many people trying to use it at the same time). Coverage between populated places can be sparse or non-existent in some areas – particularly in regions with rugged terrain. Stakeholders all commented that cellular coverage as well as broadband internet have improved (many noting additional investment due to the impact of COVID) and is anticipated to continually evolve and improve, however it continues to lag its urban and metropolitan counterparts. Even so, the cellular telecommunications network remains a critical tool for rural TSMO. All stakeholders in some fashion monitored cellular coverage closely to understand its strengths and weaknesses, as well as to leverage cellular service to maximize rural TSMO investments.

Outages of wireless network communications can impact data collection from ITS devices and the ability to communicate with travelers either through agency assets (such as 511) or consumer navigation smartphone applications. Over the past decade, the proliferation of priority cell service from national carriers has brought benefits to traffic management, first responders and other safety critical applications, resolving issues related to over-saturation of the network during emergencies and major incidents.

Cellular communications is just one component (though a major player) in the overall telecommunications network employed by DOTs. These typically also include fiber connectivity (many times from shared resource agreements) and dedicated wireless data communications devices to reach the 'last mile' to ITS devices. It can also include legacy dedicated radio systems to provide primarily voice communications across vast rural areas as a final fallback connecting law enforcement, emergency response and roadway operations personnel.

Effective strategies, tactics, and technologies for rural TSMO within the telecommunication space include:

- Use prioritized cell service – in the past decade prioritized wireless connectivity for public safety has emerged and is currently available from all national carriers. Use of these prioritized services for either voice or data has proven effective to maintain critical communications during incidents that would normally saturate (and subsequently block) wireless rural cellular connectivity.
- Remain knowledgeable and independently monitor the robustness of the telecommunications networks within the coverage region. For example, Vermont independently assessed cell coverage bandwidth and availability statewide for all carriers. Virginia continuously monitors its ITS network to both understand its vulnerabilities and respond swiftly to outages. Kentucky is aware of the various national and regional carriers, and their potential to complement and 'fill in the gaps' within their region.
- Leverage redundancy, such as multiple carriers, dual-sim cards, and use of traditional (older) dedicated radio networks as available.
- Investigate resource sharing agreements which allow a DOT to negotiate to obtain telecommunications infrastructure (dark fiber) or services in exchange to access to public right-of-way. These can provide a high bandwidth backhaul to central ITS services.

Culture: Stakeholder feedback from Coalition members with rural operations responsibilities consistently brought to the forefront that the culture and resource constraints associated with rural roadway operations differ greatly from their urban or metropolitan counterparts. Constraints include limited staffing with many staff members serving in multiple roles allowing less time to specialize or become familiar with data, tools, and resources at their disposal. Vermont addressed these constraints with one-on-one launch sessions for staff starting to use RITIS, small group training sessions, highlighting Vermont use cases at staff-run quarterly workshops, and working with its Bureau of Innovation, Learning, and Development.

Additionally, traffic congestion due to excess demand at rush hour is rare in rural roadway network operations. Demand related congestion is primarily limited to seasonal recreational periods, holidays, or major events. The primary concerns of rural traffic operations are crashes, inclement weather, and construction and maintenance activities. Many of the modern data tools came of age to address congestion concerns in urban and metropolitan areas, and although useful for rural TSMO, they have yet to fully evolve to directly meet rural needs.

Florida shared that another important difference is that due to lower traffic volumes, rural TSMO typically has greater opportunity to be proactive than their urban counterparts. Due to the sparseness of traffic, rural operations typically have a larger time window to address a developing incident (disabled vehicle or roadway debris)

before it grows to a significant traffic disrupter, if notification is received in a timely fashion.

Virginia commented that though rural TSMO has lagged with respect to the adoption of technology, this is changing quickly as ITS technology and information technology education proliferates in the workforce such that knowledge and expectation of technology solutions grow yearly.

> **Effective strategies for leveraging the unique culture and challenges of rural TSMO:**
>
> - Partnerships are critical to integrate 'big data' and technology into a resource constrained environment. The multiple areas of responsibility of a rural TSMO professional limits their ability to focus on emerging data tools or analytics, and funding constraints typically limit specialized positions for data science or GIS experts. Expertise either from central DOT, or through partnership with a local or regional university provides pathways to leverage existing data and technology expertise and tools.
> - Rural TSMO tends to be geographically isolated, creating less opportunities for professional networking and knowledge sharing. Central champions for advanced data and technology, as well as creating venues (both virtual and physical) to share knowledge and lessons learned are critical to overcome the rural isolation and resource limitations.
> - The fundamental data skills needed to leverage transportation 'big data' as well as advanced technology are becoming more abundant through training and education, as well as a result of 'digital natives' integration into the workforce.

Recommendations to the Eastern Transportation Coalition:

Based on conversations with Coalition stakeholders, industry data providers, along with a review of available literature, the MUSTANG initiative developed the following recommendations for the Coalition moving forward:

- **Emphasize the needs of rural operations and other applications in future evolutions of the Coalition's Transportation Data Marketplace (TDM)**

  Operations staff in rural states should consider using archived operations data for various other purposes such as after-action reports and planning activities. They would benefit their state at that point of bringing more people along for their local big data community of excellence and funding support. Expanding the user base for local big transportation data also expands the community of excellence and funding support. As the TDM continues to evolve along with its data validation efforts, additional emphasis on the use, specifications, and products for rural TSMO are needed. While much of the current data, products and nature of outsourced traffic data was born and nurtured in urban and metropolitan areas, continued growth in the market to address the unique needs of rural areas is needed. This includes both ex-urban and highly rural areas where demand related congestion is less of an issue, and connectivity and

throughput related to incidents, crashes, work zones and weather events tend to dominate. It also include not just data but tools so they become more useful to light users in urban areas as well as address needs in rural areas. Rural users may have less time and less solid data but deal with increasing numbers of severe weather events to manage.

- **Enhance emphasis on rural operations within Coalition working/user groups focused on tools, data, and communications issues**.

  Rural TSMO data analytics (data tools targeted at rural operations) require focused attention. This includes reporting tools that reflect 'passability' of the roadway network – such as 'time since last probe vehicle passage' as well as dashboard tools appropriate for low volume rural work zones, and after-action reporting templates. Such tools need not be a completely separate toolbox, but extensions and evolutions of existing dashboards, and may also prove useful in a more urban context to indicate if an incident has completely blocked a road for some reason. Rural big data users need data tools to be simple and straight forward (tools, dashboards, and trainings). Such and tools need to help TSMO professions tell the story easily and well. Many current visualizations and analysis tools are too complicated for people doing this work a small fraction of their time. Whether it is a subgroup of the Coalition's RITIS user group or a stand-alone group that provides feedback to commercial data providers and the analytics industry, increased emphasis on rural operations probe data and associated tools would result in continued evolution of the TDM, RITIS and the industry to better meet the needs of rural operations and planning.

- **Complement exisitng TDM data validation practices with methods that reflect data quality in rural areas.**

  Much of the TDM data validation in rural areas has attempted to use methods and reporting that was developed for urban and metropolitan regions where demand-related recurring congestion are common, and easy to capture in a periodic two-week long validation exercise. This recommendation is not to cease current validation work that serves the millions of drivers and TSMO needs in larger, more populous urban areas, but to mindful of the differences in application and context of traffic concerns in rural areas, , using methods that capture data quality concerns in less populated and lower traffic areas. Continued exploration and guidance from a rural focus committee could guide this effort.

- **Increase emphasis on rural wireless data communications.**

  Since the effectiveness of rural highway operations are closely linked to the availability and robustness of wireless voice and data communications, it is recommended that the Coalition rural TSMO emphasis explore or partner to assess and benchmark the coverage and robustness of rural wireless telecommunications. Knowing telecommunications capabilities and limitations during major incidents is critical. Data to monitor and assess the quality of wireless telecommunications services may be available from other groups engaged in the telecom world, or (if not) should be considered for inclusion in the TDM in the future.

Rural Transportation Management and Operations is not just an implementation of the disciplines learned from urban and metropolitan counterparts, but presents challenges and demands solutions tailored and refined to the rural context, culture and resource environment. This MUSTANG report examines rural TSMO through stakeholder engagement with five primarily rural Coalition member regions, and shares the insights, best practices, and resulting recommendations to the Coalition with respect to rural TSMO data and wireless telecommunications environments.

Table of Contents

Table of Contents

List of Acronyms

AADT – Annual Average Daily Traffic
ADT – Average Daily Traffic
AHDT – Average Hourly Daily Traffic
API – Applications Programming Interface
CCS – Continuous Count Station
CDMA – Code Division Multiple Access
CVD – Connected Vehicle Data
DOT – Department of Transportation
FDE – Fundamental Data Elements
FDOT – Florida Department of Transportation
FHWA – Federal Highway Administration
FRC – Functional Road Class
GIS – Geographic Information System
HPMS – Highway Performance Monitoring System
LEO – Law Enforcement Officer
MAP-21 – Moving Ahead for Progress in the 21st Century Act
MCOMP - Multistate Corridor Operations and Management Program
MIRE – Model Inventory of Roadway Elements
MUSTANG - Measurement Utilities for Sensing Transportation Activity in Non-Urban Geographies
NFAS – Non-Federal Aid System
PTI – Planning Time Index
REVEAL - Real-Time Volume Estimates from Probe Traffic Data
RITIS – Regional Integrated Transportation Information System
STC – Short Term Counter
TDM – Transportation Data Marketplace
TETC – The Eastern Transportation Coalition
TSMO - Transportation Systems Management and Operations
TTI – Travel Time Index

1.0 Introduction

As Transportation System Maintenance and Operations (TSMO) discipline has been applied outside of metropolitan areas, the relevance of rural vehicle probe data and corresponding rural telecommunications to coordinate response and communicate critical traveler information has grown in importance. Based on 2010 Census data, 97 percent of the Nation's land is estimated to be rural and 70 percent of the Nation's road network is also estimated to be rural.[1] The availability and quality of rural transportation probe data and the robustness of telecommunication infrastructure in these areas present a fundamental challenge and geographic inequity that was the initial focus of the *Measurement Utilities for Sensing Transportation Activity in Non-Urban Geographies* (MUSTANG) initiative.

The original objective of the MUSTANG report was to identify and characterize the impact of the above identified challenges as well as collect effective tools, methods, and technology solutions gleaned from Coalition stakeholder engagement. Stakeholder engagement encompassed interviews with representatives from five Coalition member states, each of which contained large portions of rural roadway networks with TSMO operations. The information provided by stakeholders provide lessons learned for other states with significant rural networks, and influenced the recommendations to the Eastern Transportation Coalition (TETC or the Coalition) targeted to be incorporated into the renewal of the Transportation Data Marketplace (TDM) beginning in 2026, with refreshed data sources anticipated in 2027 or 2028. However, as MUSTANG progressed, not only were these initial objectives addressed, aspects of rural roadway operations, its culture, and unique environment –different from their urban and metropolitan counterparts - were shared, identified and discussed. This revealed not only the challenges, but also the unique solution space that is being developed by Coalition members, not just extensions of urban and metropolitan TSMO, but adaptation of data and telecommunication tools and practices to address the unique context of rural TSMO.

The methodology used in MUSTANG is described below.

- The initiative engaged with Coalition states – turning attention to rural TSMO issues with stakeholders to fully characterize the challenge and solutions with respect to data and telecommunications. Stakeholder engagement identified and prioritized data and communication needs as well as solutions on a state-by-state basis. Stakeholders were selected from states with significant portions of their roadway networks spanning rural counties.

- With respect to data: Initial focus was rural transportation data, specifically what is sometime referred to as 'transportation 'big data' or vehicle probe data, that is transportation data provided by third parties that provide travel time and speed, and other transportation metrics derived from fleet telematics, or smart phone applications. Stakeholder engagement resulted not only on feedback on probe data, but also provided a valuable perspective on the unique context and data needs for rural TSMO, and how probe data fit into a larger spectrum of input data

sources and how each brought value. Feedback from stakeholders yielded suggestions of ways to evolve probe data to provide additional benefit to the rural context.

- With respect to telecommunications: The MUSTANG initiative explored the availability and robustness of rural wireless telecommunications. Emphasis was placed on commercial cellular service as a tool for rural TSMO. Although lagging in coverage and robustness in comparison to urban areas, stakeholder feedback readily confirmed its critical role in the larger communications system that also includes fiber backhaul and specialized ITS communications gear for last mile connectivity. TSMO engagement entities shared various emerging solution paths to meet the challenges of harnessing commercial cellular communications networks as part of rural intelligent transportation system operations.

Stakeholder feedback informed best practices, methods and technology as well as any gaps in capability. The latter offered perspectives on rural operations needs to collaborate with transportation data suppliers to develop and evolve innovative products for rural TSMO needs.

Prior Work:
The recent publication by Federal Highway Administration in 2022 entitled *Applying Transportation Systems Management and Operations (TSMO) to Rural Areas[1]* summarized and consolidated the state of practice for rural TSMO. It characterized various aspects of rural transportation as well as requirements of rural highway operations.

- 97% of the Nation's land is estimated to be rural and 70% of the Nation's road network is also estimated to be rural.

- While only 19 percent of the United States population lives in rural areas, 45 percent of all highway fatalities occur on rural roadways. The fatality rate on rural roads is also two times higher than on urban roads.

- Rural areas have telecommunications gaps due to the lack of power and infrastructure deployed. Telecommunications capabilities, where available, can be spotty and less dependable.

- Work zones, crashes, and large weather events are typical nonrecurring events that can cause congestion.

- Collisions between animals and vehicles and the presence of animals on the roadsides are common safety issues encountered in rural areas.

- 90% of posted bridges are in rural areas, and heavy trucks are prohibited from crossing posted bridges. Heavy trucks hauling in rural areas traverse three times the distance as needed in metropolitan areas in order to find a safe bridge to cross

- Rural areas, however, tend to have fewer available detour routes, which causes challenges during incidents, road weather events, or work zones

- In rural areas, a higher percentage of traffic is often for freight and tourism, the disruptions of which can have notable economic impacts.

This FHWA resource is comprehensive in its coverage, and listed many other unique aspects of rural TSMO, many of which were again brought to light and discussed in MUSTANG's stakeholder engagement activities.

With respect to 'dig data' or probe data that reflected speed, travel time, and congestion, as well as applicable uses within the rural TSMO context, no directly applicable literature was identified. Research into the use of probe data as a volume estimator in rural context is beginning to be explored [3,5,6], but is primarily in research today. Probe data emerged in the mid 2000's as an experimental method to assess travel time and congestion on high-volume facilities without the need for sensors. In the early 2010s it matured into a stable tool to assess congestion, primarily in metropolitan areas, and highly traveled freeways, but remained marginal on lower volume roadways. Into the late 2010s, as sampling rates grew, probe data accuracy and effectiveness was no longer questioned on the most frequently traveled roadways, but remained in doubt for rural areas where the lower roadway volumes remain challenging and there was little evidence to support its accuracy and efficacy for rural TSMO. The lull in surface transportation during the pandemic momentarily paused growth and interest in probe data – though other forms of 'big data' began to emerge that reflected travel behavior such as origins and destination data, among others. Now coming out of the pandemic with surface travel back to normal, interest in fundamental probe data and its effectiveness in rural areas has escalated within the Coalition, and is addressed in this MUSTANG report.

Wireless telecommunications likewise is critical to TSMO, be it urban or rural, however, commercial cellular service in rural areas has traditionally lagged behind the capabilities found in urban areas. An inventory of available ITS telecommunications technology and devices dating to 2000 [2] is available, but has been quickly outdated with the advancement in technology and continued improvement of cellular service in the US, both urban and rural. MUSTANG examines the telecommunications networks serving rural TSMO with the growing dependence of commercial cellular service in rural areas.

2.0 Coalition Stakeholder Engagement

A selection of TETC members were surveyed with respect to data and connectivity issues of rural TSMO. States were selected that were geographically dispersed within the Coalition region and represented significant rural roadway operations (and in one case rural transportation planning) responsibilities. A map derived from US census data (see Figure 2.1) depicts the population density of the Coalition regions, with the stakeholder inputs areas outlined in black.
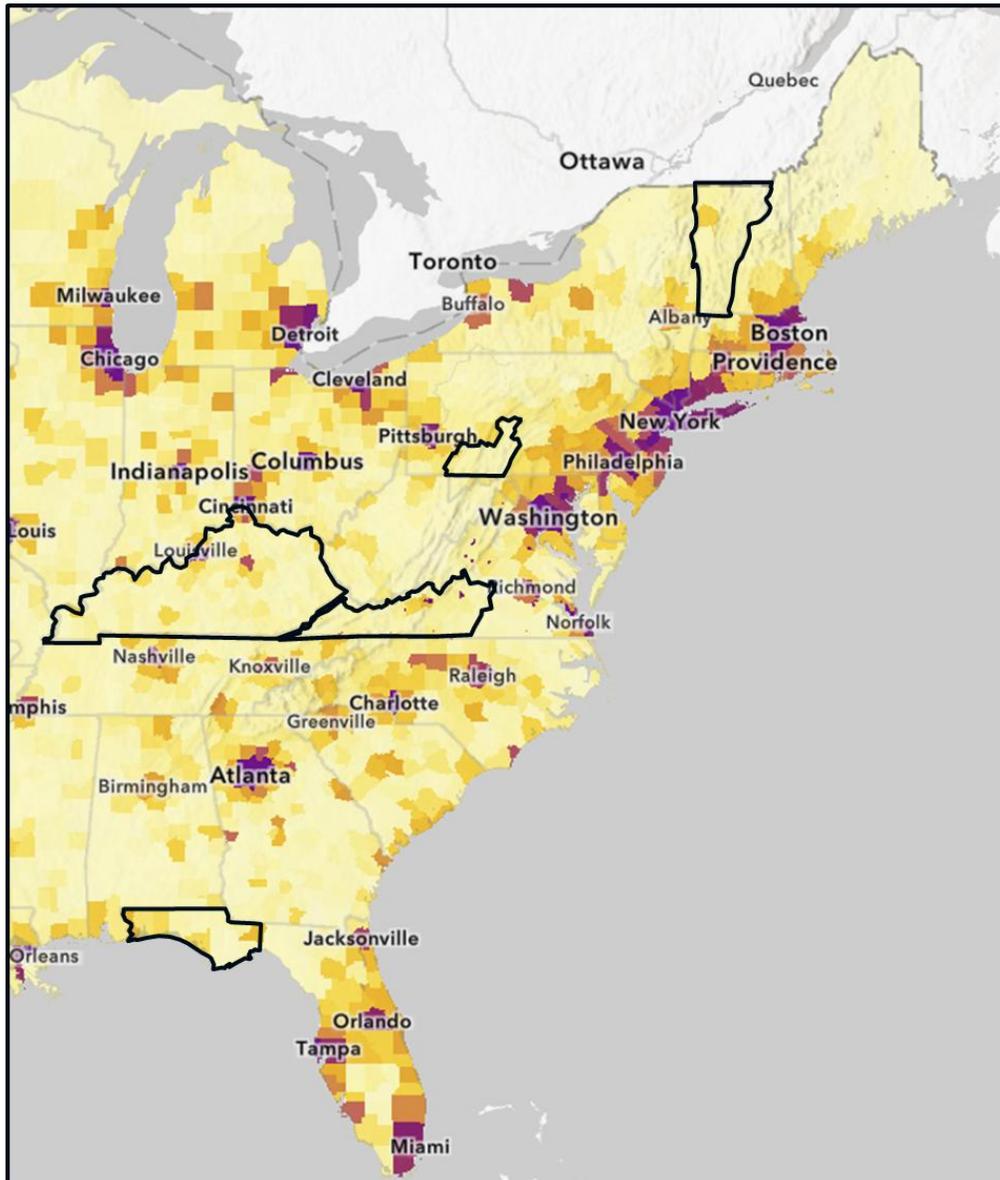
Figure 2.1: Population Density Map of the Coalition based on 2020 Census Data
Source:
https://www.arcgis.com/apps/mapviewer/index.html?webmap=a1926cb43e844c3f82275917d6eab47a

The five Coalition stakeholder members included:
- Kentucky Transportation Cabinet
- Vermont Agency of Transportation

- Pennsylvania Southern Alleghenies Rural Planning Organization
- Florida Northwest District 3 SunGuide Center
- Virginia Southwest Region Traffic Operations Center

Much of the rural regions within the Coalition boundaries are not only sparsely populated, but are also highly rugged as depicted in Figure 2.2. Four of the five stakeholder participants fall within the Appalachian mountain region with highly rugged terrain.

Landform categories
- 1–2
- 3–6
- 7–15
- 16–21
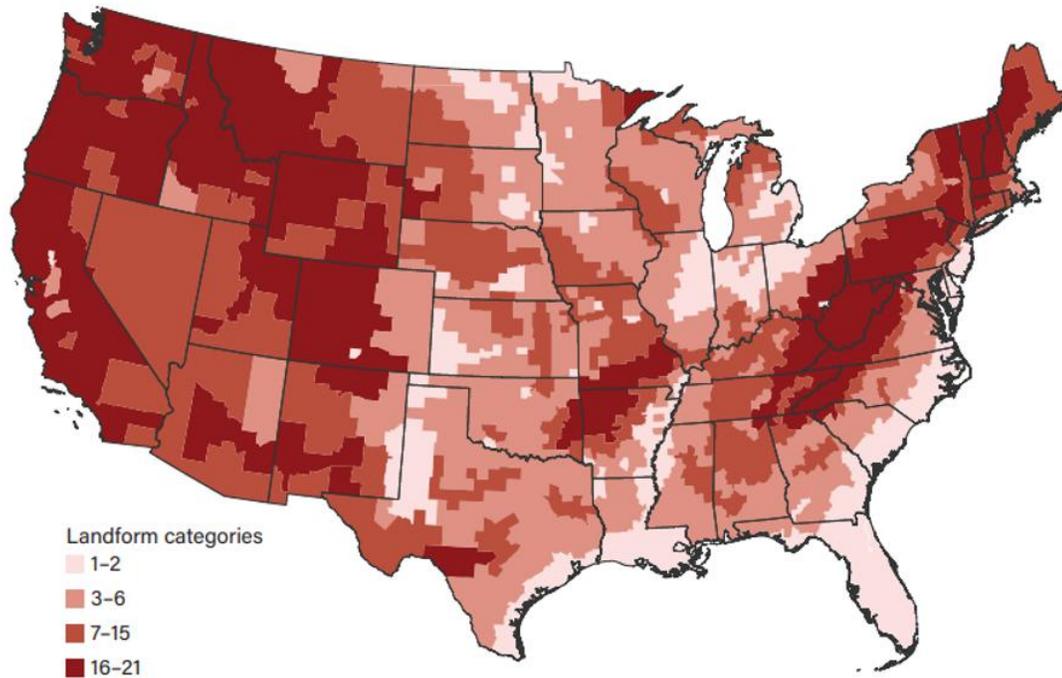
Figure 2.2: A Terrain Ruggedness Map of the US from US Department of Agriculture
Source:
https://ers.usda.gov/sites/default/files/_laserfiche/publications/107028/ERR-322.pdf?v=88165

Discussions and interviews were conducted with the five Coalition member representatives during 2025. Their feedback with respect to rural TSMO in the areas of transportation data and wireless telecommunications are summarized following.

2.1   Kentucky Transportation Cabinet

The Kentucky Transportation Cabinet (KYTC) overseas roadway operations across the state, much of which is sparsely populated, and with rugged terrain, particularly in the eastern regions of Kentucky. (See Figure 2.1.1) The KYTC provided stakeholder input to the MUSTANG initiative in late
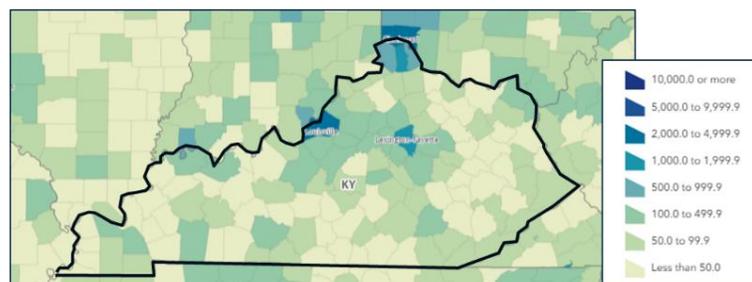
Figure 2.1.1: Population Density of KY
Source: US Census Bureau

January of 2025. Telecommunication challenges in the form of adequate cell phone coverage came up immediately as a concern for rural operations. Reliable cell phone coverage across the state has been an issue historically. In the last few years, AT&T introduced 'FirstNet', a service that provides higher priority to first responders and other emergency and safety workers. FirstNet service has addressed many of KYTC's concerns at the state level, particularly in and around the major population centers where existing cellular voice and data connectivity can be prioritized for safety functions.

However, coverage in Kentucky's most remote areas, that of Appalachia in the eastern third of the state, remains problematic due to several reasons. Lack of population deters investment by national carriers, and the rugged terrain makes it difficult both for infrastructure deployment and signal propagation. The dominant carrier in the region is Appalachian Wireless, a regional entity, not a national carrier. This makes it problematic for people with national carriers to roam on the network. Appalachian Wireless is a Code-Division Multiple Access (CDMA) carrier, which has historically aligned with Verizon style network connectivity. The low density of the eastern Kentucky region has not (to date) created a large enough business demand for major carriers (AT&T, Verizon, and T-Mobile) to negotiate roaming deals with the regional carrier. While rural cellular network coverage has continued to improve in recent years, coverage challenges are still an ongoing concern in Kentucky – particularly in eastern Kentucky. A map of coverage for Appalachian Wireless is shown in Figure 2.1.3 below, noting its home coverage area is limited exclusively to Eastern Kentucky.
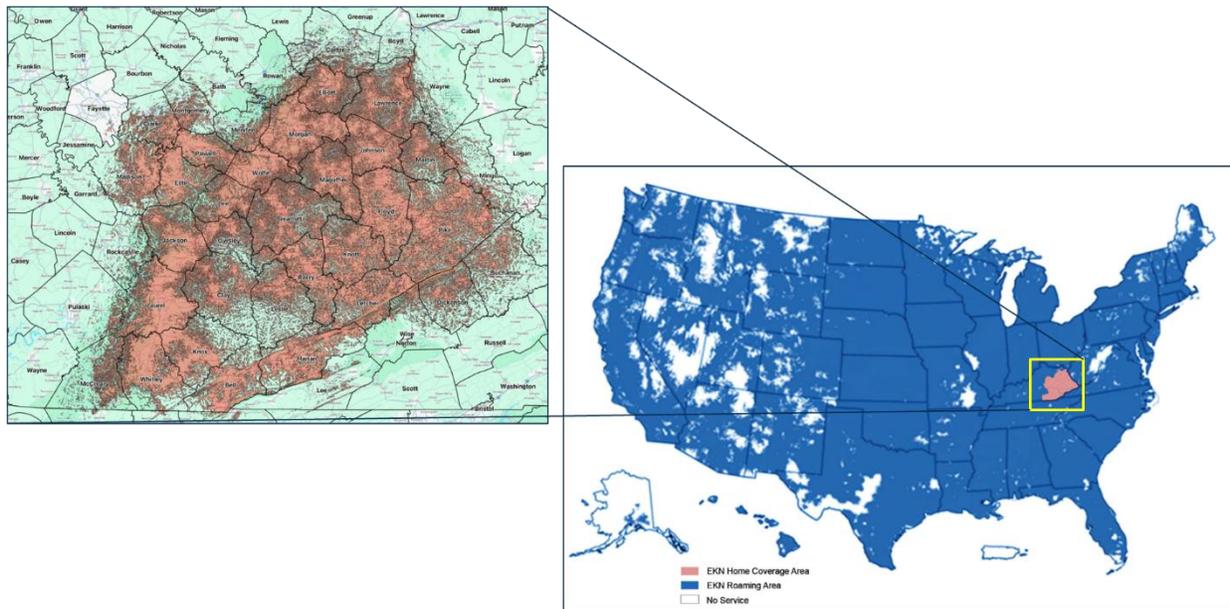
Figure 2.1.3: Appalachian Wireless Coverage Map
Source:
https://appalachianwireless.com/coverage-maps

Cellular coverage issues like those faced in eastern Kentucky can create various problems in the realms of rural operations and data. Drivers may have difficulty accessing critical public resources (511 and 911) as well as private navigation services (Google Maps, Waze, Apple Maps). Even though coverage may be generally available, particularly within and adjacent to population centers in rural areas, continuous

coverage along rural routes may be "spotty" or have significant gaps. Non-continuous coverage impacts data connectivity to the KYTC crews deployed on the network. The ability of users to call in for help in the event of an emergency or crash may also be impacted due to limited coverage. This is amplified during inclement weather and other emergencies where weather effects can diminish existing cellular coverage.

Another ongoing, concurrent issue is working relationships with private navigation companies for appropriate detours and truck routes in mountainous regions as well as information about posted bridges. These private navigation companies (such as Google Maps, Waze, and Apple Maps) serve a large majority of the traveling public, but they use only a simplistic routing algorithm that does not take into account terrain, current weather events, or vehicle weight. This was particularly problematic during recent flooding in Kentucky's eastern region. Coordinating with navigation companies to provide travelers appropriate alternative routes, particularly for heavy trucks, is a critical issue for KYTC, and one that possibly coordination with TETC may provide benefit.

With respect to probe traffic data, KYTC uses traffic data provided by HERE both for operations (real-time travel time, speeds, and other transportation data sets) as well as historic traffic metrics of travel time and speed that are bulk downloaded and integrated into the KYTC data environment approximately every other year. Much of the data from HERE is used in the more populated regions for traffic management as part of ITS. Rural transportation issues are typically not related to excess demand on the roadways. Even a crash or incident may not create enough delay to register a slow down due to low traffic volumes. Rural TSMO data traffic issues are somewhat independent of the HERE data feeds which primarily inform metropolitan area traffic.

2.2   Vermont Agency of Transportation

As a highly rural (see Figure 2.2.1) without major metropolitan areas, the Vermont Agency of Transportation (VTrans) was one of the last states in the Coalition to procure and use probe data for TSMO and other purposes. After extensive internal preparations it launched in 2023. By late 2025 over 200 VTrans staff, plus staff at 25 other Vermont entities had started using RITIS to make better-informed decisions and work more efficiently. This includes municipal police departments and sheriff's offices.

VTrans staff participated in the 2025 Transportation Research Board meeting session titled "*Data Analytics for Optimizing Rural Transportation Performance*". Staff presented *"How Vermont is Using Big Transportation Data"* *[13].* The issues and concerns with respect to use of probe data are summarized below. Additional material from the TRB presentation is provided in Appendix A. These concerns, issues, and recommendations are representative of many rural

Figure 2.2.1: Population Density of VT
Source: US Census Bureau

TSMO operations across the Coalition region, and provide guidance to any rural transportation agency with respect to adoption and use of 'big data' in a rural context.

- **'Big Data' Accuracy and Confidence in a Rural State**

  Vermont has one designated metropolitan statistical area centered around Burlington of just over 220,000 people, approximately a third of the State's population. Of the states in the stakeholder engagement, Vermont is by far the most consistently rural (low population density) throughout the state, with rural TSMO characterizing all the TSMO activity in the state. As such Vermont was not an early adopter of probe vehicle technology within the Coalition. As a member of the Coalition, they were aware of the probe data resources and that they had been growing in accuracy and efficacy, but they had not pursued any probe data products or analytics. Being familiar with the results of the TDM validation studies from the origins in 2008 helped alleviate concern about the accuracy of probe data. Coordination and discourse with probe data vendors, staff at states that already used the data, and collaboration with Coalition TDM staff were instrumental in providing understanding of the value proposition for Vermont. An appreciated metric was 'Confidence Score' which is required of vendors who participate in the TDM. Use of confidence scores is addressed in the section 3.1. They provide a sense of percent real data rather than historic data on different classes of roads. Vermont conducted internal informal validation and participated in a TETC validation study on VT 108 (Mountain Road). A 2024-2025 VTrans research project on work zone performance standards included evaluation of where the TDM big data is likely a useful source.

- **Coverage quality constraints from volumes and cell coverage**

  Vermont emphasized that rural areas primarily present data sampling issues for vehicle probe data due to low volumes. However, areas with unreliable or no wireless communications coverage also affect real-time use of the data. Whenever real-time data is lacking, a probe data vendor infills data using either free-flow speed, prevailing speed limit or historical averages and observations. Partnership with the Vermont Department of Public Service (DPS) helped with understanding where there is likely to be cellular coverage throughout the state. DPS independently maps coverage by provider to inform policy and projects that will provide service to more Vermonters. Discussion with cell service providers is useful as there was a technology upgrade rolling out during the first assessment; a second assessment started in 2025. Additional details of the assessment and maps reflecting the results of cell coverage assessment are provided in Section 3.2. Appendix B provides additional details with additional overage maps of assessment findings.

- **Socializing this new data capability within the agency, and the need for a data 'champion'**

  The high value of a champion for new undertakings at DOTs has come up in various recent studies, for example NCHRP 08-151 [16], and was essential to launching big data in Vermont. Staff are busy,, so it takes a trusted voice in a leadership position to help staff make the time to learn and explore new contents. In some cases, staff in a rural state may be less used to taking on new approaches. In other cases new approaches are sold as good, even in rural

areas, then turn out not to be, causing suspicion for future innovation. On a more positive note, staff in smaller states may be more likely to start from trust relationships or knowing who to call which makes it easier once there's a start with a new technology. There was extensive internal discussion of whether to proceed with big data in Vermont, and there continues to be extensive internal personal outreach within Vermont's big data circle. VTrans staff also appreciated the collaboration and support of the Coalition, CATT Lab, and their data provider (INRIX Inc.).

Figure 2.2.1 depicts the adoption of big data within Vermon beginning in the second quarter of 2023. The graphs chart the number of users, the approved Data Use Agreement (reflecting the number of sub-jurisdictions such as counties and townships also utilizing the data), and the usage in sessions of the analytics tools. Such data is critical to show leadership the importance and use of transportation probe-data, and its return on investment for a small state.
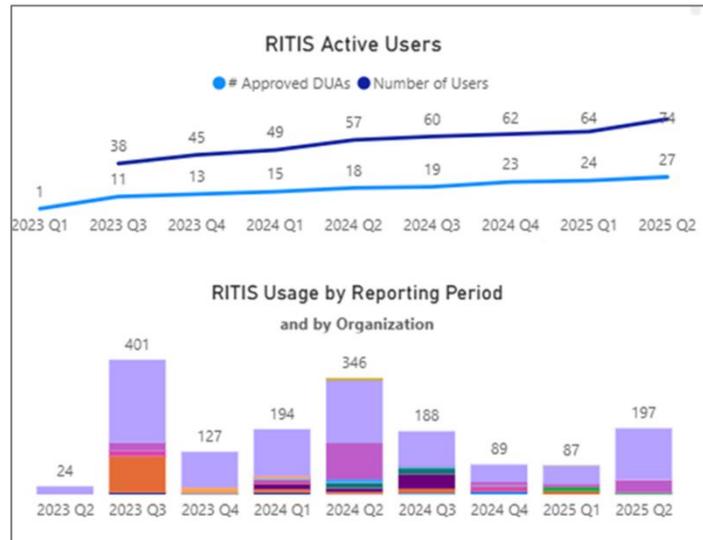
Figure 2.2.1: Population Density of SAPDC
Source: Vermont Agency of Transportation

- **Cross-Border Analysis is a Unique Issue**

   Somewhat unique to Vermont is its need for cross-border collaboration and analysis, as it shares a border with Canada. Whereas the TDM's data use agreement assures the ability to share data both internally with sub-jurisdictions and externally with other states, it did not anticipate the need for sharing with bordering countries. Vermont procured it's data with the optional ten-mile travel time and speed data buffer, extending into Canada. VTrans coordinates regularly with the Eastern Border Transportation Coalition. The data analytics suite utilized by Vermont (RITIS) is not, however, designed to analyze and visualize data across two countries.

- **Staff Capacity**

   Staff bandwidth to engage and assimilate the new data and tools was and remains an issue. Small rural states need to fulfill most of the same tasks as states with many more staff people. A result is little time or bandwidth to devote to new tools especially if the contents may not be as useful in rural areas. This was partially addressed with Vermont's ongoing approaches to socialize probe data. It's been very effective to make brief tailored "dog-and-pony" presentations at existing staff meetings and to sit, often one-to-one, with people starting to use

RITIS. The periodic VTrans Big Data Meeting contains tutorials developed by the ITS Manager and a Systems Planning Coordinator, which present materials focused on Vermont uses of big transportation data. There is an Extended Core Team with a power user from each division. They help plan quarterly two-hour Vermont big data workshops open to all potential state, regional planning commission/MPO, municipal, and other users.

Vermont provides an effective example of a highly rural state (not just rural counties or districts within a larger state) embracing probe data, all while recognizing its roots and adjusting for the uniqueness of rural operations and geographies.

Sections 3.1 and 3.2 provide in-depth look at data and telecommunication issue, much of which is based on Vermont experience with rural TSMO. Appendices B & C provide additional detailed information on *Mobile Wireless and Broadband Coverage in Vermont* and *Use of Confidence Scores for Vermont Coverage Assessment*, respectively.

2.3 Southern Alleghenies Planning and Development Commission, Pennsylvania

The project team engaged with the Southern Alleghenies Planning and Development Commission (SAPDC), a regional planning agency for the highly rural six-county region in south/southwest Pennsylvania. As part of its work, SAPDC also serves as the rural transportation planning organization (RTPO) for four of those counties – Bedford, Fulton, Huntingdon, and Somerset as shown in Figure 2.3.1 and 2.3.2.
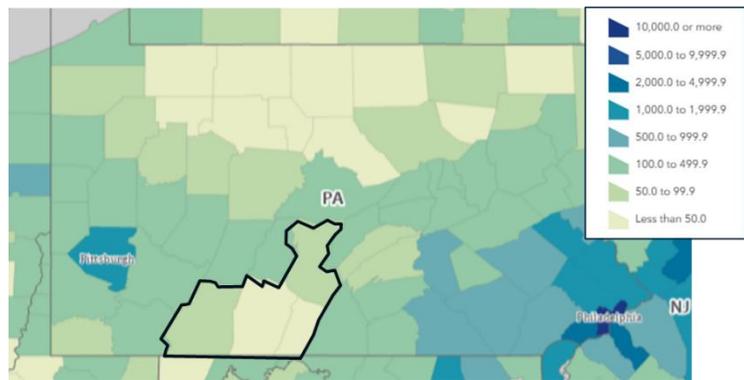
Figure 2.3.1: Population Density of SAPDC
Source: US Census Bureau

The SAPDC is primarily charged with planning functions for the region's transportation network, which involves a critical need for data and telecommunications. Although planning functions do not occur in real-time as compared with many TSMO functions, the needs and requirements for data and telecommunication within transportation planning correlate with those voiced from TSMO stakeholders.

Regional Transportation Planning Organizations (RTPOs), also called Rural Planning Organizations (RPOs), generally operate in non-metropolitan areas to conduct outreach to the public and local officials and provide transportation planning support under contract to state departments of transportation (DOTs). One of their key roles is to assist state DOTs with completing their requirements for statewide planning in rural areas and to enhance the outreach conducted to local officials and the public. Rural transportation planning greatly expanded after Congress passed the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, with its emphasis on local participation, and again with the 1998 Transportation Equity Act for the 21st Century (TEA-21) that elevated the role of rural local officials in statewide planning. (https://ruraltransportation.org/about-rtpos/)

With respect to telecommunications

Robust rural telecommunications continue to be a struggle in the RTPO's four-county service area, though there has been some improvement since the Coronavirus (COVID-19) pandemic. There was limited residential access to internet/broadband and the concept of work from home/school at home that emerged during the pandemic brought that issue to light. The pandemic exposed poor broadband infrastructure as a regionwide issue, resulting in many of the region's residents accessing the internet from the parking lot of the public library or other local facilities. This has resulted in several public broadband investments in the region, primarily in wireless telecommunications technologies.
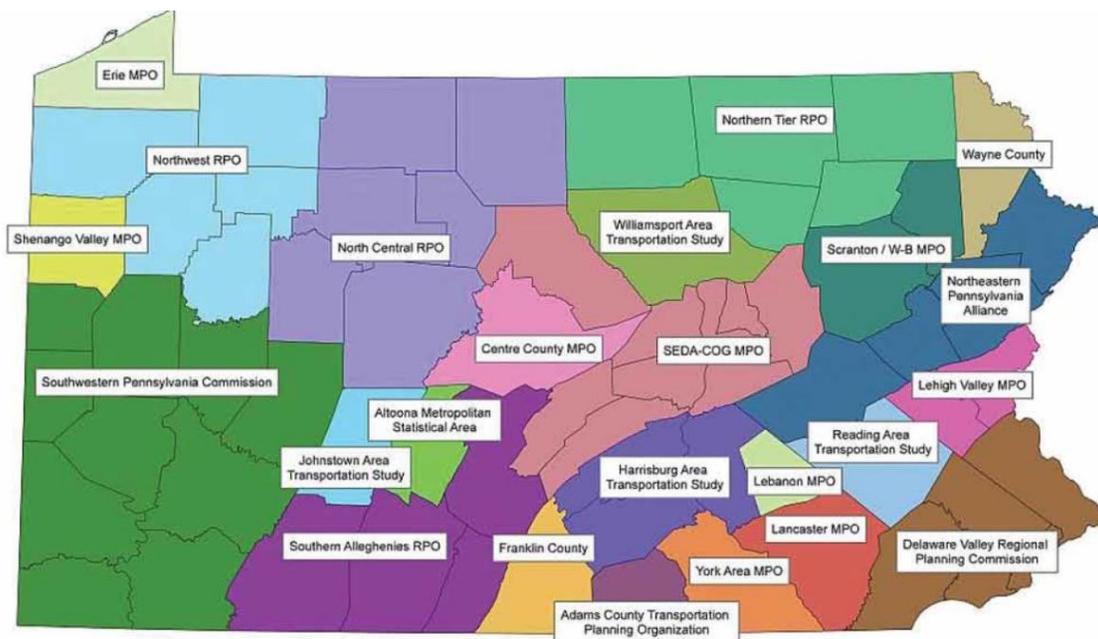
Figure 2.3.2: County map of Pennsylvania, with Southern Alleghenies RTPO marked in purple in the southwest region of the state
Source: PennDOT

Federal Communications Commission (FCC) guidelines for "high speed internet" have recently been increased for download and upload speeds – from 25MB per second and 300KB per second respectively to 100MB per second and 20 MB per second. This increase reflects growing demand for greater bandwidth as well as new technological capabilities. In response to the need for better rural broadband, a non-profit 501(c)3 organization called Alleghenies Broadband, Inc (ABI) was established. ABI's mission is

> *"...digital equity in the six-county Southern Alleghenies region by partnering with Internet Service Providers (ISPs) and other stakeholders to provide high-speed internet connections and necessary resources to residents and businesses within our community. … Rural areas throughout the USA face unique challenges in obtaining access to reliable internet services. Extending cable lines over large areas and difficult terrain has led to minimal investment in rural communities with low population density. Particularly in the aftermath of the Coronavirus pandemic where families, businesses, health care providers and schools lacked internet*

service, we can no longer allow our citizens to go without reliable internet service. The Southern Alleghenies region is committed to bringing significant investment to our rural communities so we no longer go without reliable, high-speed, affordable internet services."

Prior to the COVID-19 pandemic, rural internet access was more commonly equivalent to dial up speeds. Similarly, cellular coverage in rural areas lagged significantly behind urban areas, perhaps with only 2G in many areas if coverage was available. Cellular coverage is present in populated areas and along major roads and interstate highways, but was lacking in the majority of highly rural, less populous regions. These gaps in coverage continue today, though there have been some improvements. In response to the pandemic's impact, public initiatives have made strides in addressing the public broadband (home internet) problem, primarily with various wireless technologies that provide connectivity without the need for inground cable or fiber infrastructure. Antennas and satellite dishes on residents' homes connect to tower locations to offer basic services. The towers were designed and sized so that they could eventually handle the requirements for modern cellular service, which some major carriers are beginning to leverage.

Robust wireless service outside of rural towns remains a known issue. The major highway system tends to have good cellular coverage, largely to serve the demand of freight and trucking services that rely significantly on digital logistic services of which cellular data communications are the backbone. The lack of strong cellular coverage in the RTPO region has led to challenges in attracting and maintaining various transportation services such as ride sharing (e.g., Uber/Lyft), as well as the dissemination of traveler information (511 and consumer navigation services) outside of populated towns.

With respect to data

Regional planning agencies also tend to leverage geographic information systems (GIS) to supplement transportation planning capabilities. In the Southern Alleghenies region, digital data is scarce for rural areas in contrast to urban areas. Data specific to transportation infrastructure (e.g., structures, roadway widths, volumes, speeds, asset management) are abundant in the more urban areas of the state (e.g., Philadelphia, Pittsburgh), but scarcer for rural counties where map layers for even road center lines may be challenging to obtain. If data is needed, the SAPDC typically queries PennDOT Engineering District 9-0, which has one full-time GIS person on staff to provide support. As an example of the data difficulties encountered in rural areas, recently, the RTPO needed sidewalk infrastructure data in order to apply for a grant. Data on existing sidewalks (location and condition) was not available in digital or other format, requiring a dedicated effort to create. It took the RTPO two years of internal effort to create this data on a budget of $13,000 to establish existing conditions as a pre-requisite for applying for funds to improve sidewalk conditions. With respect to 'big data' resources for use in transportation planning, whether it is operations data such as speed and travel time or infrastructure data such as locations and condition of roadways, sidewalks and paths, if industry sourced data are available through the state DOT, such data needs to cover the entire state and flow to rural areas since it is unlikely that rural areas would have finances to purchase such data. Also, since rural areas

typically lack data science or GIS expertise on staff, provisions for access to such expertise is also needed.

Traffic counts are also a good example of data needed to complete transportation planning functions. Special counts using traditional pneumatic tube technology are still common in these rural regions. Historical records of traffic counts are available through PennDOT and the county. Some data is available through request via the Local Technical Assistance Program (LTAP), such as for investigating reported speeding problems, however, technical assistance funds (such as LTAP) are growing increasingly competitive. Availability of 'big data' sources that span traffic volumes would greatly benefit the planning functions in rural areas.

In summary, the data and telecommunications needs shared by SAPDC for transportation planning functions align with the data and telecommunications needs for TSMO in rural areas. The lack of broadband and cellular coverage is a primary issue that impacts quality of life and connectivity of rural citizens, a need that was amplified with the COVID-19 pandemic. Cellular coverage outside of core towns remains lacking for most of rural Pennsylvania. Data resources are scarce, and even if available through commercial sources, would likely fall beyond the resource capacity for SAPDC and its counterparts to procure and analyze. Central data resources and data procurements through PennDOT, county government offices, and other entities are helpful to provide the digital resources needed in transportation planning functions.

2.4 Florida Department of Transportation – Northwest District 3 SunGuide Center – Chipley, FL

The Florida Department of Transportation (FDOT)'s Northwest Florida District 3 SunGuide Center is a regional traffic management center (RTMC) in Chipley, Florida covering the rural regions between Pensacola on the western border and Tallahassee metropolitan area on the east, a distance slightly less than 200 miles. The RTMC system operates on a fiber optic network that extends 235 miles along Interstate 10 (I-10), beginning at the Alabama state line in Escambia County to Jefferson County,

located immediately east of Tallahassee. Chipley, FL is located about halfway between the two metro areas, to the north of I-10.
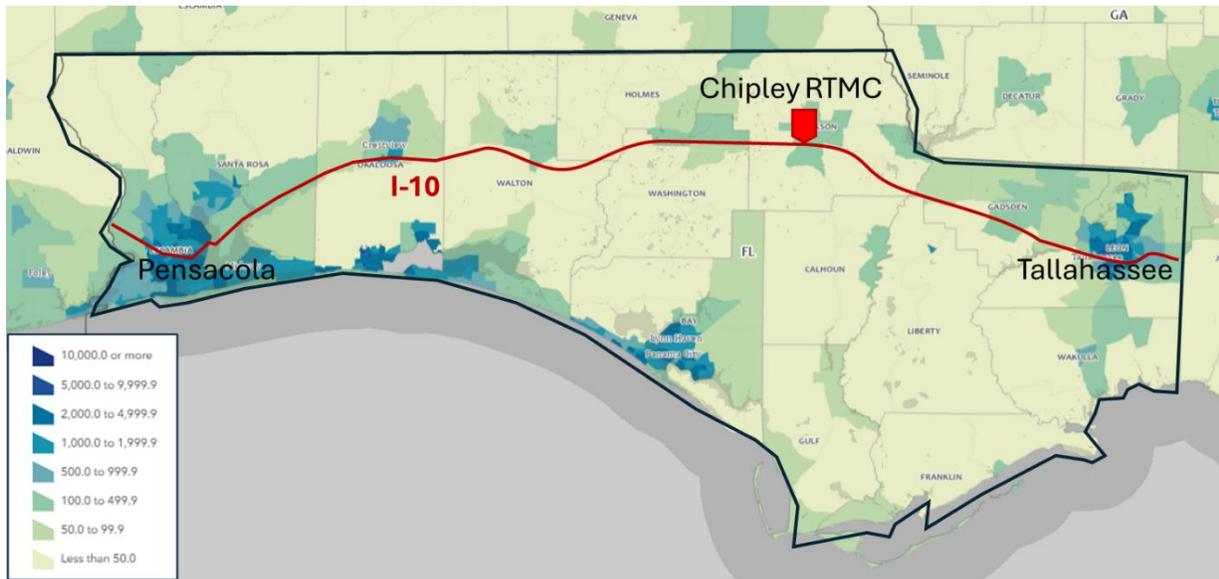
Figure 2.4.1: Population density map of Northwest Florida District 3
Source: US Census Bureau

About 90% of traffic management responsibilities at the Chipley RTMC are associated with the flow of traffic on rural parts of the I-10 corridor, traversing through sparsely populated counties in Florida. The majority of the population in these counties is concentrated along the coast, making the inland area around I-10 even less dense and highly rural. A population density map for the region is shown below in Figure 2.4.1 reflecting the sparse population along the I-10 corridor, and the surrounding region, typically less than 50 people per square mile. Busy seasons for the RTMC at Chipley coincide with major holidays (e.g., Fourth of July) during which service patrols and the RTMC are fully staffed.

Concerning Data …

The RTMC staff use various data and analytics tools at the RTMC center. The FDOT RTMC in Chipley makes extensive use of the Regional Integrated Transportation Information System (RITIS) as well as central FDOT data systems to monitor and respond to incidents along the corridor. Closed circuit television (CCTV) camera coverage is available along I-10, however, the coverage is sparse and not sufficient to monitor all reported incidents.

Within the RTMC, staff leverage RITIS to access HERE data to monitor the roadway system. Coverage through RITIS includes all of the I-10 corridor, 56 miles of U.S. 231 (from the Alabama state line and ending in Bay County) and a 9-mile stretch of U.S. 90, from its intersection with U.S. 231 to the Northwest Florida SunGuide Center in Chipley. Additionally, custom dashboards are developed to monitor the arterial routes outside the ITS deployment, as needed.

RITIS has been tailored to include access to public radio data feeds in this rural region. A total of 18 feeds provide monitoring of law enforcement officers (LEO), fire, and

emergency medical services (EMS) audio from emergency response and dispatch. This allows the TMC to proactively monitor events as they unfold with information from local sheriff and law enforcement. Many times, this allows service patrols to respond before the incidents begin to impact traffic on the major freeways.

Use of RITIS also allows the RTMC not only to view its cameras feeds, but it also allows FDOT to share them with local law enforcement and emergency personnel in the area. Emergency response personnel are also able to input information into the RITIS system that may impact traffic, giving the RTMC staff greater levels of situational awareness and filling gaps for areas without ITS instrumentation, where RTMC service patrols are not present. The RTMC at Chipley is not co-located with any emergency response, further adding to the utility of the integrated data systems and electronic messaging, either via phone, radio, or analytics platforms like RITIS as tools to interact and coordinate between TMC operation and law enforcement and other emergency personnel. RITIS tools also assist with audit support, after-action reports with the extensive archive of data collected in real time, and the ability to play the information back in the same manner/sequence as received at the RTMC.

While the data and tools available to the RTMC have grown significantly to detect the onset of major slowdowns and incidents, it is still challenging to assess when traffic conditions return to normal, particularly if the incident occurs during peak periods with recurring congestion. Recent RITIS upgrades have offered a 'return to normal' assessment that compares incident conditions to expected conditions for time of day and day of week rather than to free-flow speeds or travel times. This advancement allows for more accurate 'return to normal' assessment.

RITIS supports performance metrics such as Travel Time Index (TTI) and Planning Time Index (PTI), which are metrics typically used at the FDOT's Central Office for performance reporting. These metrics tend to have more value and meaning for urban rather than rural travel but are available along the corridor. This underscores that many of the metrics and tools initially developed for probe data in urban and metropolitan for traffic congestion management, are less applicable for rural TSMO.

An additional tool that has proven useful for rural freeway management is the integration of Waze Alerts application programming interface (API) with FDOT's statewide GIS system. The Waze API feed allows the RTMC to monitor driver reported events and then assess the speeds reported through the RITIS system at that location to see if the event is causing a slowdown. This Waze data has proven valuable, however the quantity of data from the Waze feed can overwhelm a TMC operator. Filters embedded in FDOT's GIS system allow the user to filter for alerts or events that may induce a lane blockage, while excluding the myriad of other user reported events. This combined with spatial tools such as geofences for a district or specific state route focus help manage the volume of data through Waze. The ability to filter both for content and geography allow the RTMC to create and monitor custom, often temporary, special interest areas (e.g., work zones) without having physical sensors deployed in the corridor. Figure 2.4.2 below depicts the output of the Waze dashboard highlighting events with potential for lane blockages along the I-10 corridor.

Figure 2.4.2: Waze dashboard available through the Florida GIS System
Source: FDOT

Events reported through Waze, but which have not yet escalated to the point of being reported through other means (such as CCTV camera, HERE speed data, or through public radio feeds) are of particular interest to FDOT as it allows for early detection of incidents before they begin to impact traffic flow. The addition of the Waze dashboard has allowed the RTMC to operate more proactively and efficiently with a 30% increase in the number of events that are actively managed (See Figure 2.4.3 below).
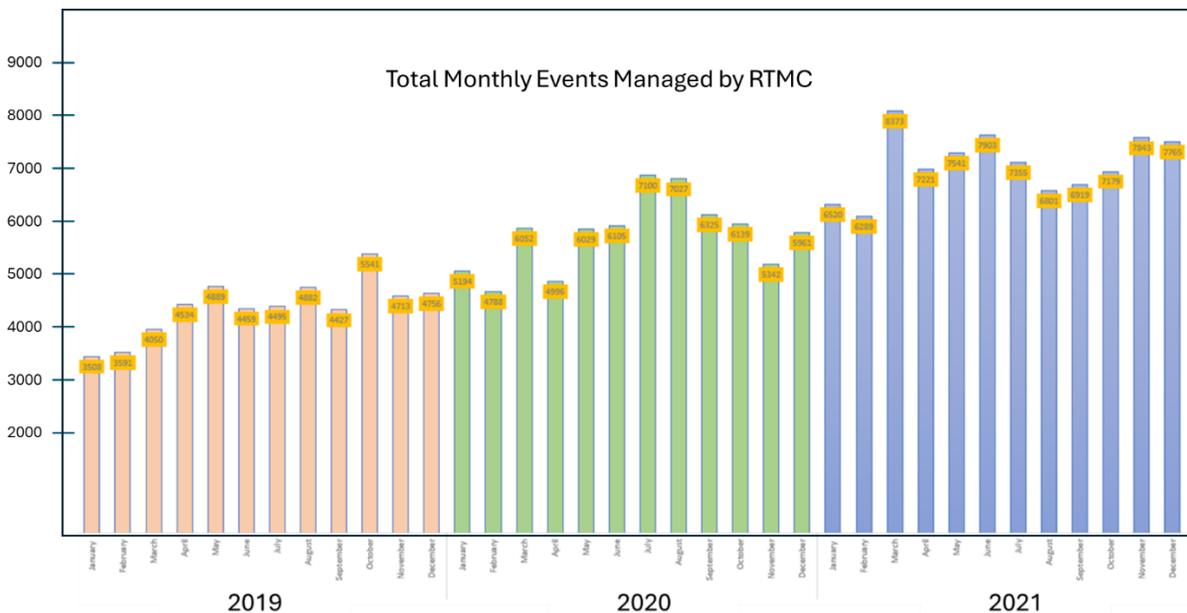
Figure 2.4.3: Total monthly events managed by the Chipley RTMC
Source: FDOT

The TMC has also integrated dash cameras from service patrol vehicles as an additional layer of information in their TMC as well as for responder safety and security. Figure 2.4.4 below depicts an example of the dash cam footage available through the RTMC analytics tools, showing dash cam images verifying reports of debris and other reported road hazards.
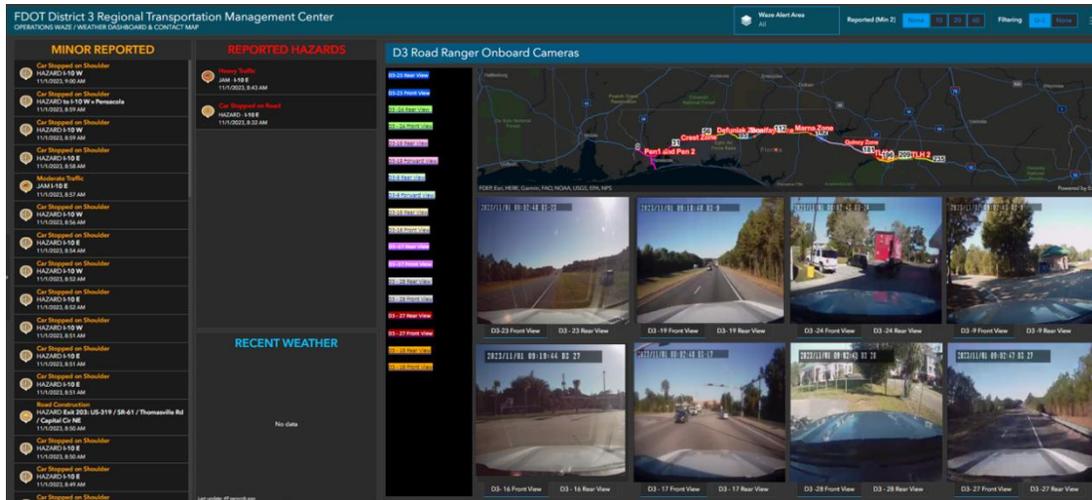
Figure 2.4.4: Dash camera feed from service patrol vehicles integrated into RTMC Dashboard
Source: FDOT

Concerning Wireless Data Infrastructure and Tools …

The commercial wireless infrastructure and cellular data coverage to support cell phones, smartphones, and associated applications along I-10 are adequate to support the RTMC, although there are some known areas of weak coverage. The RTMC relies on commercial cellphone and smartphone connectivity for the majority of their field communications. As this is an interstate corridor, the commercial investment of the major carriers has provided nearly ubiquitous coverage. In areas off the freeway system, connectivity can be significantly less reliable or completely absent.

For field communications with its service operations personnel, the RTMC makes extensive use of the Zello app on smartphones, a 'push-to-talk' audio communications app that simulates the older radio channels. Zello is helpful for roadway management and emergency response as it allows critical personnel to share an audio channel. It is configurable using any cell phone number, provided that all the participants have the app installed. Florida maintains a statewide license for Zello, a testament to its field utility. Zello includes other call management and reporting functions, such as transcription capabilities (voice-to-text), logging, and call dispatch.

FDOT stakeholders also emphasized the difference between urban and rural RTMC operations culture. Although rural RTMCs have less resources, sensors, and data as compared to their urban counterparts, rural RTMCs have the opportunity to be more proactive with respect to emerging situations if the data is received in a timely manner. Urban TMCs, in contrast, are responding constantly to incident calls, resulting in a continuous state of being reactive. Lower traffic volumes, and overall lower incident frequency allow more time flexibility to analyze larger volumes of unconfirmed event notifications, particularly those with potential for a lane blockage, allowing the

opportunity to dispatch response personnel before it becomes a major traffic inhibitor. Also, typically lower overall traffic volumes expands the time window before a minor perturbation (such as a disabled vehicle or roadway debris) escalates to a major traffic impediment, giving rural operations personnel greater opportunity to address the situation proactively.

RTMC staff are looking to embrace future technologies such as connected vehicles, particularly notification systems for freight, since commercial vehicle crashes have the greatest impact on incident clearance times and roadway safety in their region.

2.5   Virginia Department of Transportation – Southwest Region Traffic Operations Center – Salem, VA

The Southwest Virginia DOT (VDOT) Traffic Operations Center (TOC) covers a broad, mostly rural area, as depicted in Figure 2.5.1. Interstate route coverage includes Interstate 81 (I-81) from the southern Virginia-Tennessee state line to just outside of Lexington, Virginia.   It also includes sections of Interstate 77 (I-77) from West Virginia to North Carolina, as well as some shorter sections of I-381 in Bristol, and I-581 in Roanoke (see Figure 2.5.2). VDOT's southwest region is highly rural with rugged terrain as it encompasses the eastern slopes of the Appalachian Mountains. The region also encompasses a few of the state's smaller urban areas including Blacksburg, Bristol, Lynchburg, Roanoke, and Salem.
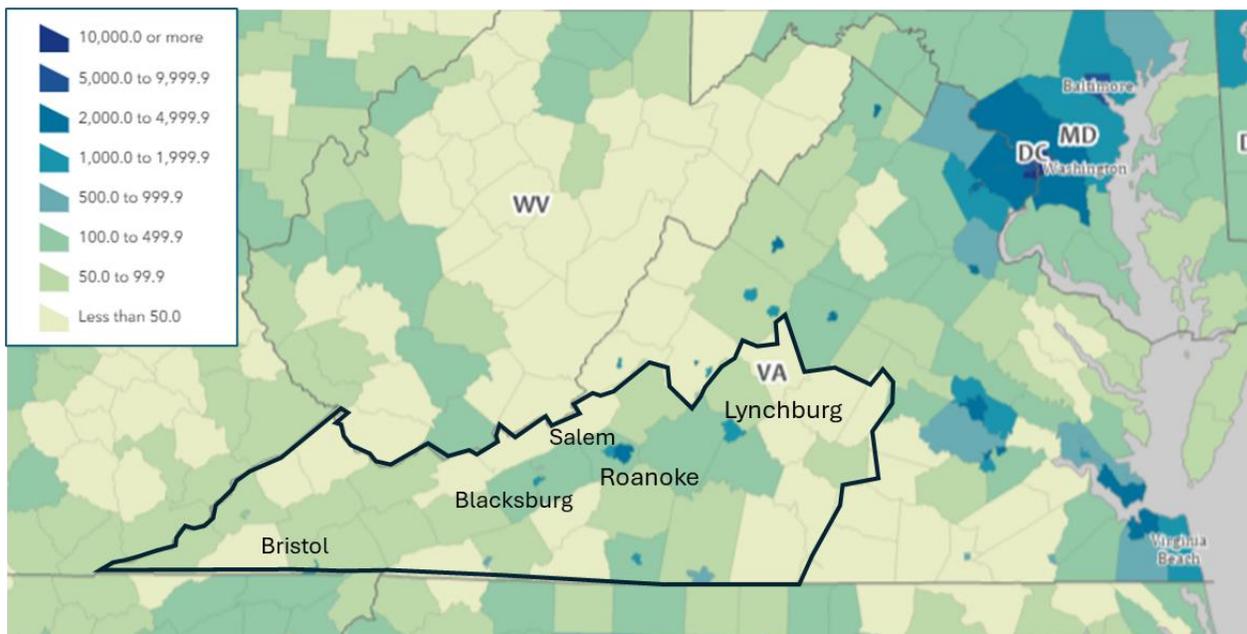
Figure 2.5.1: Population Density of Southwest VDOT Traffic Operations Center
Source: US Census Bureau

The Traffic Operations Center (TOC) for the Southwest region is located in Salem and uses a variety of ITS technologies for monitoring roadway conditions and responding to incidents. This includes the use of fiber optics along freeways for backhaul coverage, wireless telecommunications via traditional cell phone carriers, various types of ITS sensors (particularly for weather events such as mountain fog), cameras, dynamic

message signs, and variable speed limits. The TOC is co-located with the traditional emergency dispatch, including the 911 center with computer aided dispatch (CAD). The TMC receives a large majority of initial incident notifications through their partnerships with emergency response personnel and their associated CAD systems.
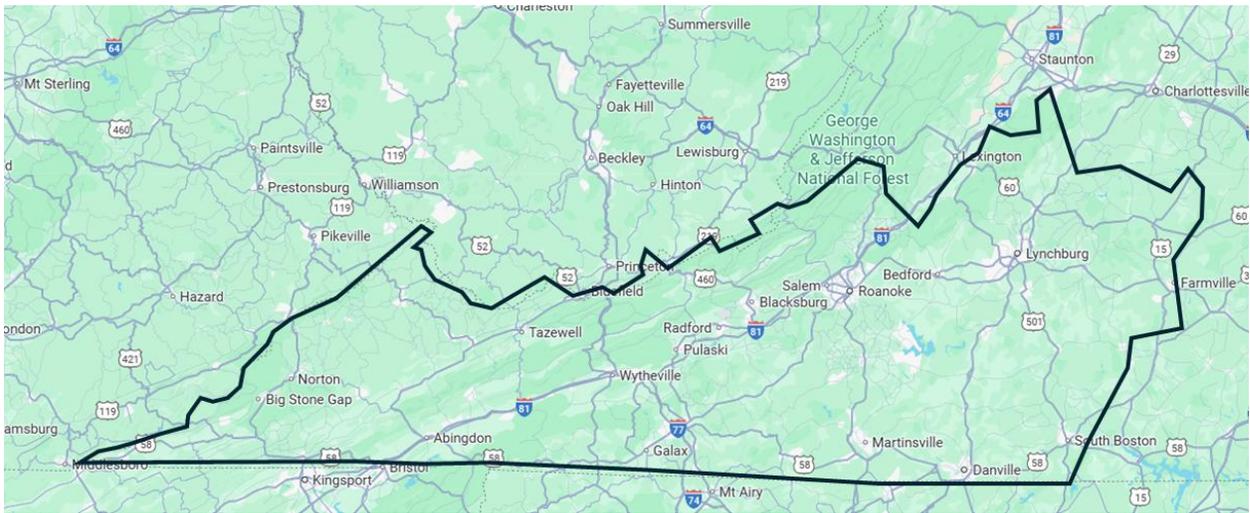
Figure 2.5.2:   Major Routes in SW TOC Region
Source: Google Maps

Telecommunication and ITS Devices:

Within VDOT, traffic operations and traditional traffic engineering collaborate closely and are merging in function and responsibility in many ways. This is particularly true in the Southwest region. As VDOT continues to grow and evolve, the fundamental disciplines of digital devices, data, and communications become more inherent in the workforce as more employees receive information technology/computer/technology training in college or even grew up with the technology as part of the newer generation which tend to be 'digital natives'.

Reliable digital networks are critical to operations. All ITS devices and communication channels are digitally monitored continuously, and their health is reported both centrally to VDOT's network operations center (NOC) as well as through the agency's various regional TOCs. If a communications network or sub-network malfunctions, both the TOC and statewide operations center are notified. If the problem is temporary (e.g., weather or power interruption related), the system monitors the situation and waits for recovery. If the issue is isolated to a particular sensor or device, a technician is quickly dispatched to address the failure.

TSMO in the Southwest region encompasses weather response (fog is a significant issue in the region), incident response, and traffic signal operations. Recurrent traffic congestion, common in urban areas, is rare in this region. However, an incident on an interstate mainline may result in severe backups on adjacent roadways within more populated areas as travelers divert off the interstate routes. In these situations, the SW TOC can alter the local signal timing to prioritize traffic exiting from the major routes to the local streets and facilitate possible detours. This has proven beneficial for interstate/freeway traffic management, though impact on local traffic may be less understood.

The Southwest region utilizes a combination of various communication modes for ITS connectivity including fiber for backbone as well as cellular service from both national and regional carriers. At the time of this writing, VDOT utilizes Verizon's cellular prioritization service (Frontline) for much of their cellular voice and data services. However, they are also investigating T-Mobile's network and priority service due to their recent merger with US Cellular, a prevalent regional carrier in the area. AT&T FirstNet is also being vetted. All three of the national carriers are capable of providing prioritized service for safety and emergency communications (be it data or voice) to emergency and safety personnel in the region. The Verizon Frontline has proven useful for maintaining connectivity to ITS devices during incidents. Prior to prioritized cellular service, an incident resulting in major backup with a queue of travelers could quickly saturate available cellular bandwidth in the vicinity of an incident, eventually causing ITS sensor and electronic signage connectivity to fail. East River Mountain tunnel and Big Walker Mountain tunnel are vital artery interstate paths that are closely monitored for fog events via the Regional TOC and smaller compact control room TOC's within each tunnel facility. These tunnel sites have benefitted significantly from the cellular prioritized service to keep critical sensors and traveler advisory equipment online during incidents.

Robust cellular service remains challenging in southwestern Virginia both due to low population densities as well as the rugged mountainous terrain. Robust communications are needed for reliable connectivity to ITS devices such as dynamic message signs, weather stations, speed advisory signs, etc. Backhaul communications are typically provided by fiber that has been installed through cooperative resource sharing agreements allowing private telecommunications providers to install fiber within the right-of-way, particularly along interstates, in exchange for dark fibers for dedicated use for the DOT. VDOT has and maintains nearly 20 resource sharing agreements in the state related to fiber along the right-of-way (see Figure 2.5.3). Fiber provides longitudinal network bandwidth along major routes with network access points (or HUB
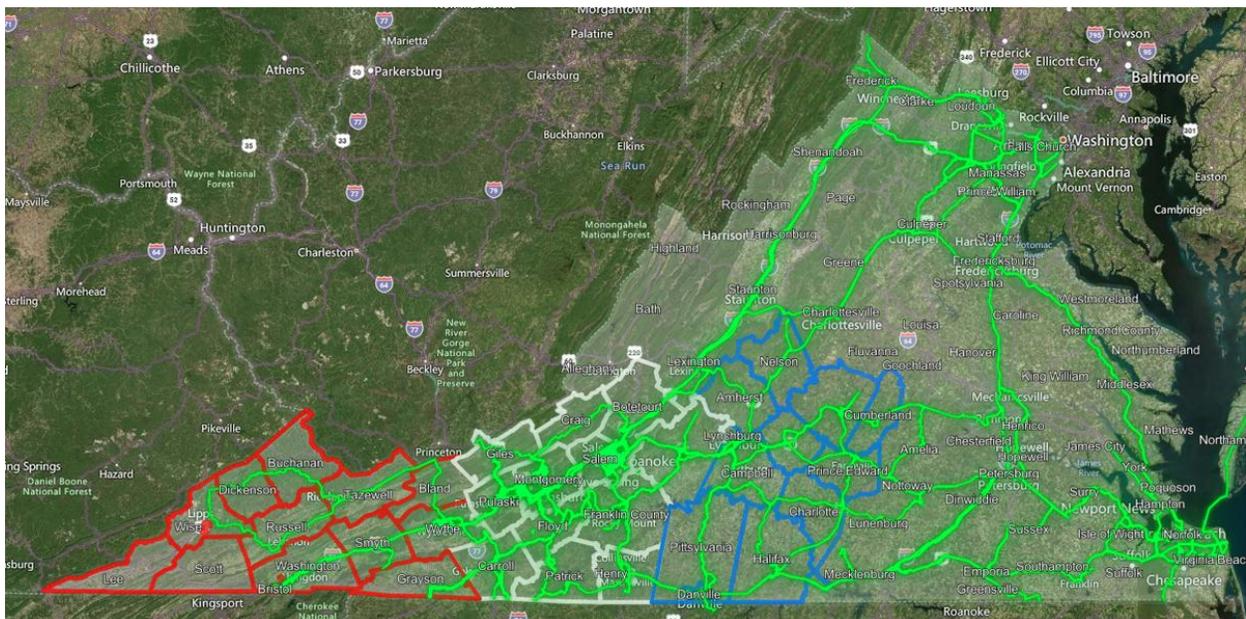
Figure 2.5.3:   VDOT fiber routes in Virginia provided through cooperative resource sharing agreement   Source: VDOT GIS

20

locations that also serve as signal boosters) along the main trunk about 20 to 50 miles apart. Such agreements can result in significant cost savings for the telecommunications companies by having a single entity to negotiate with instead of a large number of individual property owners.   In these agreements, VDOT typically exchanges access to right-of-way for dark (unlit) fiber. VDOT is then provided access to the fiber through a system of laterals off the main fiber trunk. More recently, fiber is being installed in more arterials (non-freeways) to provide high-speed data access to local communities. Not only does this enhance VDOT's network, but rural communities also benefit from these investments, many times progressing from dial up speeds (56K modems) to fiber broadband, without intermediate technologies such as cable modems. Providing full network functionality (voice and data) requires a combination of fiber, cellular, point-to-point wireless devices, and radios to fill in the gaps along the major routes as well as for any lateral connections off the main routes. Power disruptions in rural areas are also an issue, including the availability of power for an ITS device installation (e.g., a fog warning sensors and advisory signs) as well as overall reliability of the power for the installed devices.   In the Southwest region power reliability is notably an issue along I-81 near Christiansburg. Power outages can occur as a result of a weather event, which eventually leads to communications networks going down and subsequently, the eventual disconnection of ITS devices.

For additional robustness and reliability, VDOT utilizes dual subscriber identity module (SIM) modems statewide that can access multiple carriers including US Cellular, Verizon, AT&T, and T-Mobile.   The dual SIM devices allow the user or device to take advantage of whichever carrier has better coverage, as well as allow for redundancy in the event one vendor's tower experiences outages, allowing ITS devices to maintain coverage.

Virginia has begun migrating toward a "pay for performance" type of contracting for digital infrastructure with service level agreements (SLAs). If a device or network is not working, there is a monetary penalty to the vendor. Previous contracting mechanisms specified "uptime", but had no enforceable penalty other than failure to comply with the contract. With the changes in contracting for digital infrastructure, the vendor loses revenue if a device is not operating, providing a monetary incentive for uptime and responsiveness. The health of the ITS system is assessed through monitoring the various devices and communications network as previously described, and is the basis for validating SLAs with technology vendors. The associated vendor's invoice then becomes a record of the reliability of the various parts of the system, as uptime is tracked down to the second, providing visibility into any reliability issues.

TOC service patrols also make use of the STARs network, a state-wide dedicated radio system operated by the Virginia State Police. This is a traditional multi-band radio system for emergency responders for voice communications. VDOT's service patrols have access to the STARs network for voice connectivity, however, maintenance personnel and contractors do not. The STARs network is similar to other legacy dedicated statewide emergency response systems, and is typically a low-bandwidth system, limited to voice.

With respect to data …

The Southwest TOC, which is co-located with traditional emergency dispatch, is also integrated into the Virginia State Police's CAD system, from which 80-90% of incidents

are initially reported to the TOC. Safety service patrols are sometimes the first to report, but these 'first to notify' reports from safety service patrols tend to focus on non-traffic related issues, such as stalled vehicles and roadway debris. Occasionally, TOC operators are the first to notify of incidents through monitoring of cameras.

In the Southwest region, there are over 300 traffic cameras in operation (see Figure 2.5.4), which allow operators to monitor the scene of an incident; however, there are too many camera feeds for constant monitoring by personnel. To help with this concern, VDOT may one day consider the use of artificial intelligence (AI) technology to better utilize the camera feeds, but there are no deployments or demonstrations currently planned.
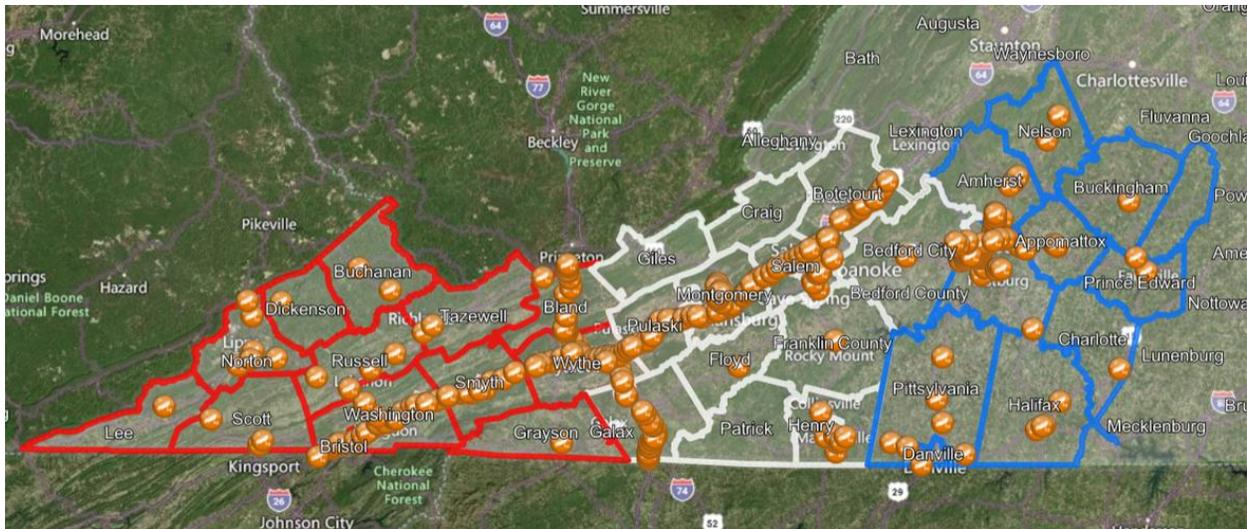
Figure 2.5.4:   VDOT Southwest TOC Region Traffic Camera locations
Source: VDOT GIS

VDOT has access to probe data and associated dashboards through INRIX, which is displayed on a large monitor in the SW TOC in Salem. The data and associated display maps are used for overall situational awareness of the flow of traffic in the region. Probe data is typically not the primary data source for any particular incident response, but rather maintains observation of overall flow of traffic in the TOC southwest region as well as inform traffic flow impact for any given incident.

The TOC also makes extensive use of ITS weather systems in the mountainous areas where fog is a significant issue. A sensor will detect fog and automatically activate warning signs for travelers. Many of the signs are simple alerts warning drivers of the danger. In some areas, it is more sophisticated, with the fog detection data used to adjust variable speed limit signs, automatically informing drivers to reduce their travel speeds in areas with low visibility. Parts of the region also have fog illumination where lights line the road on either side to assist drivers with navigation in addition to message signs and cameras.

Future capability …

Looking to the future, distributed acoustic sensing (or DAS) is beginning to be tested by VDOT. DAS technology is a linear sensor that makes use of available dark fiber along a major freeway that monitors traffic longitudinally along the roadway. The closer the

fiber is to the travel way, the more effective it is as a traffic sensor. Heavy commercial vehicles as well as incidents can be detected through disturbances in the light conducting properties of the fiber. DAS technology is fairly new with only a couple known deployments around the world. VDOT is planning for a pilot demonstration to assess its effectiveness and potential uses within the agency.

3.0 In-Depth Data and Telecommunications Topics for Rural TSMO

The following section provide greater detail and discussion of solutions identified by stakeholders.

3.1   Confidence and Accuracy of Probe Data in Rural Areas

'Big data' has been used for decades in areas with higher traffic volumes, typically associated with major population centers. The TDM has provided evidence of the data quality in these areas by validating data accuracy on how well it reflects slowdowns on roadway links with a high frequency of recurring congestion during a two week test period. Although the TDM data has been tested in rural areas, the lack of recurring congestion due to lower volumes in rural areas typically defeats validation efforts whose entire premise is to compare reported speed to observed speed during times of congestion. A typical validation test consists of recording speed data using re-identification technology on ~20 segments over a period of two weeks. Slowdowns observed in these two weeks would be compared with vendor provided data to assess performance. However, in all but one validation test, the two weeks of data collection produced primarily an archive of free-flow data, and rarely captured any significant congestion events. In February of 2023, the TDM validation effort was able to successfully observe slowdowns in rural Vermont associated with a busy ski weekend at a popular ski destination near Stowe, VT. This location and time were chosen because of its history of congestion in previous ski seasons during this three-day holiday weekend. In essence, it was similar to urban probe data validation exercises due to the expected slowdowns over the busy ski weekend. The probe data performed well during this exercise, with the results available in the Coalition's validation archive.[4] Since then, Vermont has also independently tested its probe data feed during the construction season at work zone locations where known roadway maintenance and paving operations occurred.

> The ability to detect slowdowns at rural work zones using probe data was observed as early as 2008, when Maryland initially purchased statewide vehicle probe data. The Traffic Management Center in Maryland observed a slowdown in their probe data feed in a rural Maryland location, and doubted its veracity since congestion is highly unusual on rural roadways. However, as a follow up activity, the Maryland State Highway Administration (SHA) looked into the reported slowdown and discovered that it coincided with a planned roadway maintenance activity. Though not a planned validation activity, this experience bolstered confidence in probe data for Maryland SHA.

The concerns of probe data validity and usefulness in rural areas stem from fundamental differences in rural roadway networks versus urban and suburban networks. The reason for these concerns include:

- Lower traffic volume flows in rural areas offer less opportunity to capture data from probe vehicles. Traffic data validity typically scales with the number of samples (or probes). A probe data source with 5% penetration rate on an urban roadway with 100,000 annual average daily traffic (AADT) has about 5000 probe

vehicles traversing the roadway on any given day. A rural roadway of 1000 AADT with the same probe penetration rate, however, results in only 50 observations. The fidelity of summary insights for travel time, delay, volume, etc. would be therefore subsequently diminished.

- Penetration rate of probe vehicles is less in rural areas than in urban and metropolitan areas. While this may have been accurate in the early years of probe data (though not enough literature could be obtained to verify) recent evidence suggests that they are now on parity if not greater in penetration rate. [8,9,10]. Reasons for this perception may include:
  - Lower smartphone and GPS device usage: Rural populations tend to have fewer connected vehicles and mobile devices contributing to probe data sets.
  - Sparse infrastructure and traffic: Fewer vehicles and less frequent travel reduce the volume of data collected.
  - Limited commercial data coverage: Many probe data and telematics providers prioritize urban networks where demand and density are higher.
  - Data networks in rural areas can be sparse due to limited broadband/cellular coverage. These areas have a higher likelihood of having older cellular technology with less data bandwidth. Gaps in coverage can prevent real-time data reporting of roadway bottlenecks or closures (e.g., a rural construction zone) from probe vehicles.

The growth of cellular networks and near ubiquity of smartphones has nullified the validity of these inferences, which may have been accurate in the early years of probe data reporting. From discussion with industry, even if cellular coverage in rural areas is sparse, probe data and/or telematics data (a major contributor to probe data) is typically stored locally, and reported as soon as network connectivity is restored.

In addition to travel time and speed, each probe data feed includes a *confidence score*. The *confidence score* is a required metric within the speed and travel time core data specification within the TDM. The confidence score provides evidence of the availability of sufficient vehicle probes from which to estimate traffic speeds. It is thus an indication of base data quantity, and provides insight into the quality of data supplied, be it rural sections of roadway or the metropolitan roadway network. The form of the confidence score varies by vendor. The confidence score for travel time and speed delivered from the probe data vendor in Vermont is defined as:

  - 30 = Real-Time Data
  - 20 = Historical Average
  - 10 = Reference Speed

The confidence score was introduced at the onset of the TDM when it began in 2008. At that time probe data was emerging as a new technology to assess traffic congestion on major roadways. During these early years, probe data was typically available and valid during peak travel times, but as volume decreased during off-peak periods there may not be enough vehicle probes to accurately report speed and travel time. As a result, the Coalition required vendors to include a confidence score to indicate times when enough probes were present to trust the reported speeds versus times when insufficient probes vehicles were available, and the vendor reported either a historic

speed, or a free-flow travel speed. This measure was critical during the first decade of proliferation of probe data to support urban and metropolitan TSMO efforts. For example, probe data would be used to display travel time on changeable message signs only if the confidence score was above a certain threshold. Although confidence score has remained a required metric in TDM, its importance has diminished over time in urban and metropolitan areas as the penetration rate of probe data escalated. Currently valid travel time and speed in urban areas are typically available from probe vehicles for all but the most least traveled over-night periods. However, this confidence score reflects sufficient probe data for estimating traffic on any roadway, and so it is now critical to provide evidence of probe data quality for rural areas.

Assessment of the confidence score across different geographies and times within Vermont helped bolster confidence in the use of probe-based traffic data for a primarily rural state. An example of confidence scores in Vermont are shown in Figure 3.1.1 reflecting high-confidence real time probe data (Score = 30) for both major and minor roadways (indicated in green) during evening hours. Some yellow exists (indicating a confidence of 20), but the high majority is confidence score of 30.
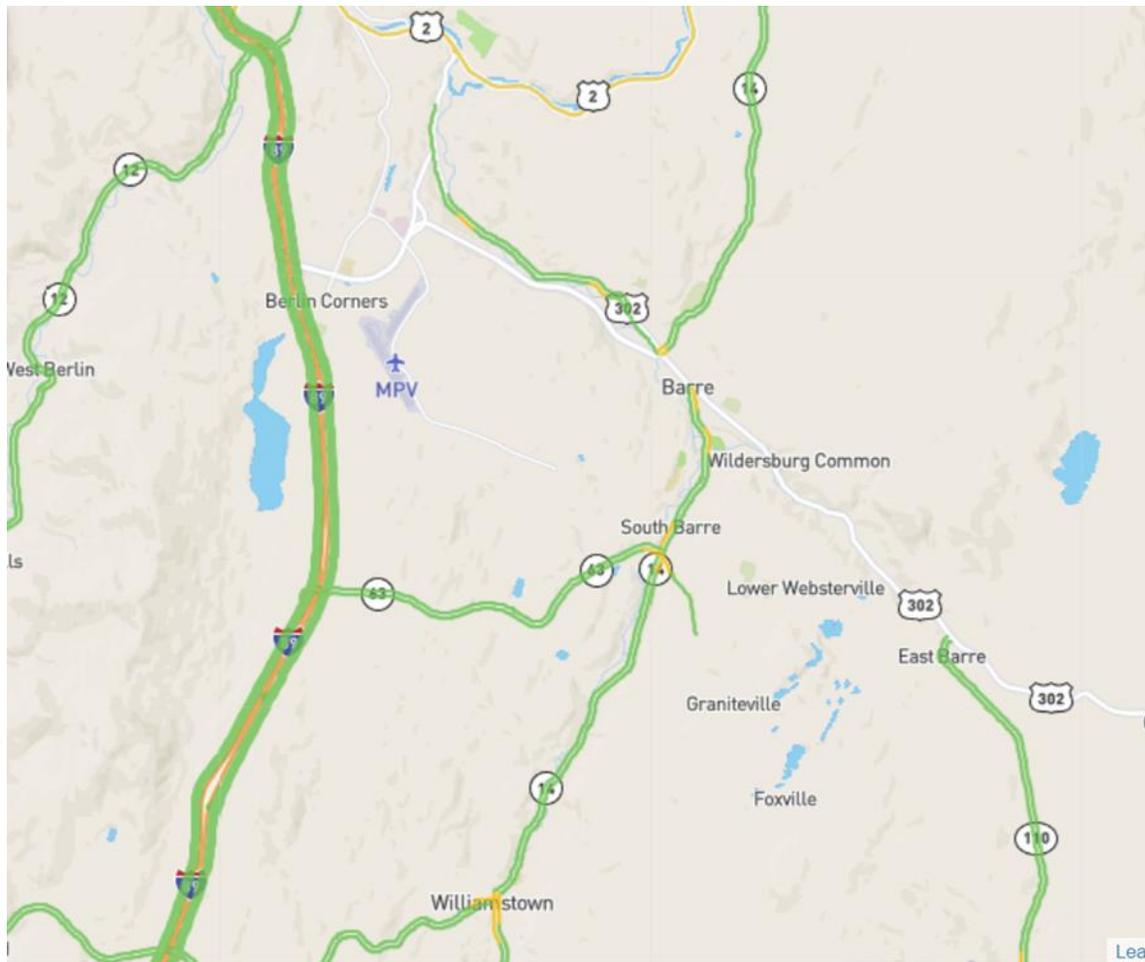
Figure 3.1.1:   Confidence scores of probe data for a portion of rural highway network near Barre, Vermont (Green reflects real-time data, yellow is historic average) 6:40 PM on Tuesday, 11/29/22
Source: INRIX

26

In 2024, the confidence score assisted Vermont to assess the impact of the loss of a major data provider to their travel time and speed information systems. When Wejo ceased operations in 2023, confidence scores were used to assess the overall impact on data quality to their speed and travel time provided by INRIX. This was a major concern since Wejo data was a significant contributor to the INRIX data panel. An extensive review of the impact of the loss of Wejo data is provided in Appendix C.

The loss of Wejo data resulted in confidence scores dropping from 30 to lesser values (20 and 10) sooner during off-peak periods in the evening, and later in the morning hours as traffic approached morning peaks in the state of Vermont as illustrated in Table 3.1.1. For example, with the Wejo data, the confidence score would transition to a preponderance of confidence scores equal to 30 (an indication of real-time data) sometime between 6 and 7 AM as volumes escalated with the normal, diurnal cycle of traffic. After the Wejo data was removed, that transition would be delayed until after 7 AM. Both the magnitude and time pattern resulting from the loss of Wejo data is reflected in the averages for 2023 prior to the loss of Wejo data (Jan-May) and after (June-Dec) at the bottom of the table.

Table 3.1.1:   Confidence score assessment in Vermont before and after loss of Wejo data

Vermont (Time of Day)

TMCs = 1856
Records = 974M

Month	Overall	Percent of 1-minute records with confidence score = 30 (real-time)																						
		Hour 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	78	49	40	35	37	45	65	80	89	93	95	95	95	96	95	95	96	96	95	94	91	87	81	69	59
Feb	78	49	39	34	36	45	66	81	90	94	95	96	96	94	94	95	96	96	96	94	92	88	83	70	61
Mar	79	49	40	35	37	47	67	82	91	94	95	95	96	96	96	96	96	96	96	94	92	88	83	70	60
Apr	77	44	35	31	34	44	64	80	88	93	95	95	96	96	96	96	95	96	95	93	90	87	81	66	55
May	78	45	34	29	33	45	66	83	91	94	95	96	96	96	96	96	96	96	96	95	92	90	84	69	58
Jun	55	22	17	15	16	21	37	51	63	71	75	77	78	79	79	79	79	79	78	76	70	62	55	47	34	27
Jul	54	22	17	16	16	20	34	47	59	67	72	76	78	79	79	79	79	79	78	75	70	62	55	48	35	28
Aug	54	20	16	14	15	20	35	51	63	71	74	77	79	79	79	79	79	79	76	71	63	55	47	34	26
Sep	52	16	13	12	12	18	33	47	60	68	72	75	77	77	77	77	77	77	75	69	61	52	43	30	23
Oct	52	16	12	11	13	18	34	48	61	69	73	75	78	78	78	78	78	78	75	69	60	51	42	29	22
Nov	51	17	13	12	13	19	33	47	60	69	72	74	76	77	75	75	75	75	72	66	57	48	39	28	22
Dec	52	19	15	12	13	19	31	44	58	67	72	74	76	77	77	77	76	76	73	69	61	52	44	32	25
Avg Jan-May	78	47	38	33	36	45	66	81	90	94	95	96	96	96	96	96	96	96	96	94	91	88	82	69	59
Avg Jun-Dec	52	19	15	13	14	19	34	48	60	69	73	76	77	78	78	78	78	77	75	69	61	52	44	32	25
Diff	-26	-28	-23	-20	-21	-26	-32	-33	-29	-25	-22	-20	-18	-17	-18	-18	-18	-19	-21	-25	-31	-36	-38	-37	-34

The loss of Wejo data impacted any state whose data vendor incorporated Wejo as part of their data panel, and thus many states in the Coalition region were impacted. The state of Maryland has procured probe data since 2008, and thus has a significant history of archive probe data. Archive probe data from Vermont was only available from ~2022 forward. Figure 3.1.2 depicts the average confidence since 2013 for a representative county in Maryland. The percentage of confidence scores equal to 30 is graphed from 2013 through 2024. As probe data evolved, and more probe data sources were added to the data panel, this percentage increased. In 2023, prior to the loss of Wejo data, the confidence score averaged over 80% across all roadways and time periods. For freeways and Interstates, classified by FHWA as functional road class

1 (FRC1) this average was well above 90%.   After the loss of Wejo data, this metric fell to about 60% for all roadways, and had negligible impact on FRC1. Confidence scores after loss of Wejo data were approximately equal to confidence score before Wejo was introduced prior to 2021. Note that the average confidence score for freeways and Interstates were above 90% throughout the entire time period of historical data from 2013 through 2024. The lower roadway classifications (FRC2 and below) were measurably impacted, each in proportion to their relative volume.

The impact of the loss of Wejo data in Vermont (and other states in the Coalition region) was primarily exhibited in the availability of probe data (confidence score = 30) during the transition from non-peak periods to peak periods, and vice-versa. As traffic volumes escalated in the morning hours, transition to the majority of real-time data with confidence score = 30 was delayed, and the opposite effect was observed in the evening hours. The loss of Wejo data did not substantially dimmish the value of vehicle probe travel and speed data for traffic management in Vermont – as high confidence data continued to be available during the core roadway traffic hours.

Figure 3.1.2:   Historical percent confidence score = 30 for travel time and speed data for Frederick County, MD
Source: INRIX

Overall, the critical finding was that the confidence score which was introduced in the TDM in 2008 due to concerns of data adequacy in the early years of probe data technology was equally applicable and valuable to assess the adequacy of probe data coverage for rural areas. The complete analysis of the impact to confidence score resulting from the loss of Wejo data is contained in Appendix C of this report.

3.2 Assessment of Wireless Telecommunications Infrastructure

A consistent theme of the interactions with Coalition stakeholders was the criticality of the telecommunications system, particularly the public cellular network, as a major component of the success of rural TSMO. Review of the five case studies all had elements that reflected on this aspect. The growth and reliance of cellular networks to communicate both voice and data has grown steadily over the past two decades, first with the introduction of smart phones, and most recently with the COVID pandemic. Overall bandwidth consumption expanded 40% during the first year of the pandemic (2020) as more people stayed home for work and school.[11] Monitoring the quality of wireless cellular either for broadband, ITS device connectivity, smartphone navigation apps, or even traditional voice, is growing increasingly important as wireless cellular continues to play a larger role in the overall system architecture for rural TSMO. This section provides additional detail on the state of Vermont internal initiative to measure and characterize cellular service. Appendix B also provides additional material and representative output of the assessment findings.

In addition to 'big data' adoption in Vermont, the state was also proactive in measuring the effectiveness of existing wireless data networks to serve its citizens. This was summarized in a December 2022 report in which Vermont's Department of Public Service (PSD) contracted for a drive test to determine the extent of mobile wireless coverage along all primary roads in the state.[12] As per the report, *"PSD partnered with the Vermont AOT whose road maintenance staff conducted the driving. The PSD retained the services of a company that provides broadband and mobile internet performance assessment".*

The full report is available from the state of Vermont [12], and contains information on 5G access, as well as AT&T FirstNet performance. A couple of examples reflecting the nature of the assessment of the Vermont effort are included below. The first example is an assessment of each major carriers' ability to establish and convey voice and wireless data connectivity, summarized across the entire state. The assessment reflects the availability of the major carriers as well as AT&T FirstNet service to serve Vermont state government and its citizens. The speed test results for mobile data are reflected in the sample output below in Figure 3.2.1. The full report provides even greater detail, as well as separates out voice versus data connections.

Speedtest Performance

	All Carriers	AT&T	Firstnet	T-Mobile	USCell	Verizon	Vtel
■ Not on Drive Routes	78,520	78,520	78,520	78,520	78,520	78,520	78,520
■ Not Tested Carrier	-	6,410	7,047	6,440	6,486	5,886	5,636
■ No Completed Tests	28,628	51,974	49,880	75,687	72,127	101,480	87,588
■ > 100 Mbps	5,190	24,511	32,853	15,112	258	9,668	719
■ 25 Mbps - 100 Mbps	142,613	111,354	104,106	73,595	3,741	72,140	79,647
■ 5 Mbps - 25 Mbps	51,727	35,669	36,433	38,949	11,223	38,525	56,332
■ 256 Kbps - 5 Mbps	5,159	4,605	4,223	20,880	2,868	6,230	4,620
■ < 256 Kbps	1,225	19	-	3,879	137,839	613	-

Figure 3.2.1   Statewide Average Carrier Specific Performance Results
Source: State of Vermont [12]

The second example is the summary map in Figure 3.2.2. The color-coded hex-bin map reflects the effectiveness and connectivity of cellular service across state, but limited to the primary highway routes where the tests were performed. This map provides a top-level view of the extent of coverage (composite across all providers) based on location. Note the test results in hexbin format provide a view of the Vermont roadway system, as the tests were conducted by the Vermont AOT with equipment mounted on their vehicles as they traversed the state as part of their normal duties. Additional carrier specific maps are available here.

This approach provides a possible template for other states (particularly states with large rural areas) to independently assess the capability and capacity of their wireless infrastructure within their regions. Vermont intends to continue monitoring the capacity of wireless telecommunications periodically, with the next test scheduled for 2024. At the time of this report, the results from the 2024 test were beginning to be published, and are likely currently available.
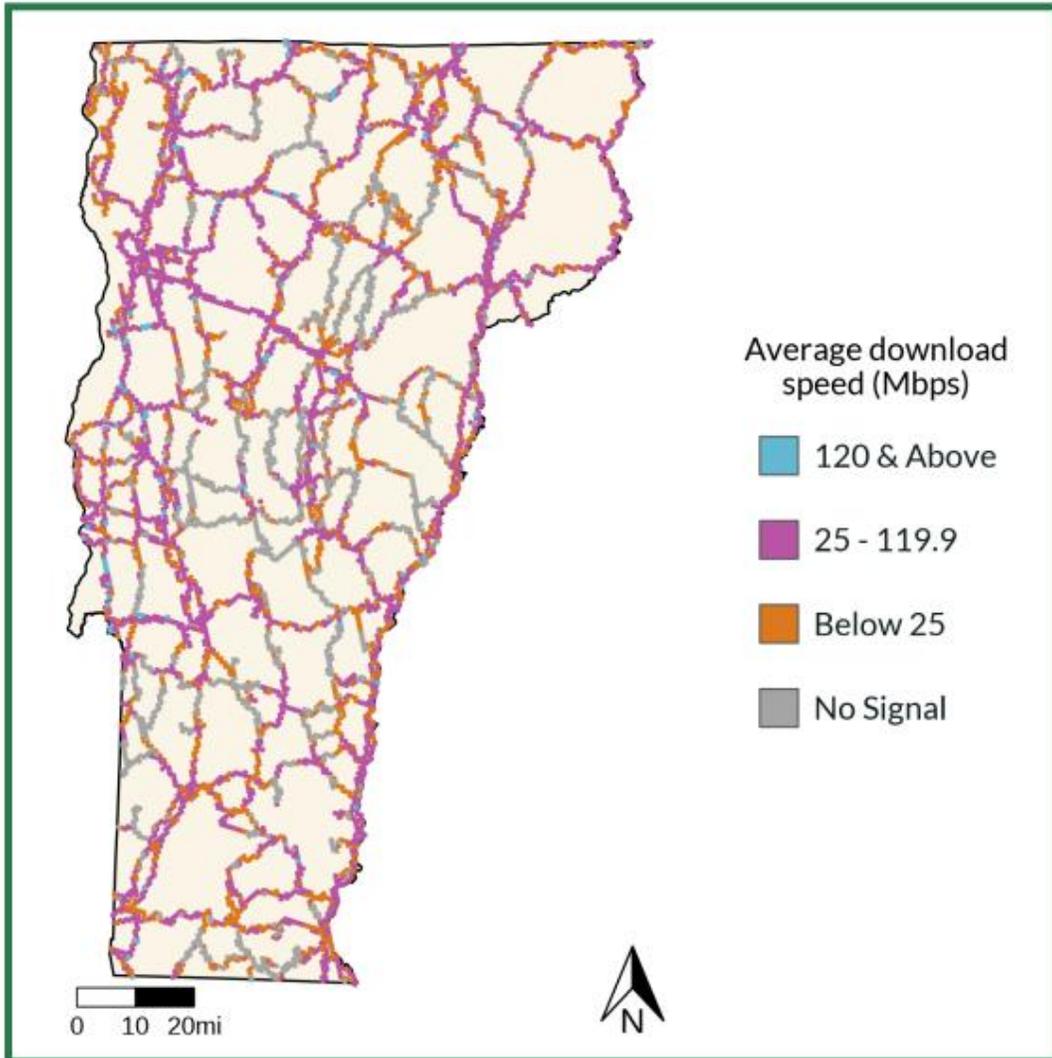
Figure 3.2.2: Average mobile data wireless download speeds – 2022
Source: State of Vermont [12]

3.3 Emerging Technologies to Assess Telecommunications Robustness

GeoTab is a core data provider to the TDM, particularly with respect to freight information. In late 2024, Geotab released a white paper titled *"North Carolina and Florida hurricane use case: Using commercial vehicle data to understand the impact of extreme weather events".* This whitepaper illustrated possible uses of their fleet telematics data to monitor the physical roadway network *as well as the wireless telecommunication network*, comparing their performance immediately before, during, and after a hurricane. Although this information represents the impact of a severe weather use case, the concepts presented in this white paper are reflective of the needs for rural TSMO in that they reflect aggregate conditions of roadway "passability" as well as wireless network capacity and health. Excerpts from the white paper are provided below as reflective of rural TSMO needs. The full white paper is available from GeoTab upon request with a [web version](#) also available.

The purpose of the Geotab white paper was to explore possible new use cases of the data derived from the company's telematics services. Use cases included assessing the severity and longevity of extreme weather events such as hurricanes, understanding the impact of hurricanes on specific geographies, and understanding the impact of these incidents on the telecommunication systems. The examples herein illustrate the impact on western North Carolina resulting from flooding conditions that resulted from Hurricane Helene, a Category 4 storm that struck in the fall of 2024.

The southeastern United States was impacted by back-to-back hurricanes in late 2024, leading to severe flooding, widespread power outages and all-around disruptions to normal life. For fleets, severe weather events can pose a logistical challenge, as it is difficult to plan around unknown obstructions to "business as usual". Geotab's commercial fleet data ([Geotab's Altitude](#)) can assist fleets in understanding if they can fully resume normal operations, providing insight into storm severity and longevity of disruptions.

Geotab explored three different metrics to understand the impact of Hurricane Helene and its resulting flooding in North Carolina, with an emphasis on the area around Asheville in the western part of the state. The full white paper also contains example metrics for Hurricane Milton, a category 5 hurricane that impacted Florida, with an emphasis on the area around Tampa. The metrics explored in both cases include:

- **Telecommunications Impact** - Measures the mobile telematics connectivity lag time and the amount of time it takes for a Geotab telematics device to communicate its data to central processing for logging and analysis.

- **Roadway Vehicle Volumes** - Measures how many vehicles (specifically fleet vehicles with GeoTab telematics) are traveling on roadways as a percentage of maximum observed volume during normal conditions.

- **Travel Hot Spots** - Measures how many vehicles are visiting small geographic areas as a percentage of maximum observed vehicle counts during normal conditions.

Metric #1: Telecommunications Impact

Vehicles equipped with 'Geotab GO' telematics devices' (GO device) have their driving activities recorded and then sent electronically to a server periodically. The amount of time it takes for data to be sent from a GO device to a server functions as a proxy for the health and performance of the cellular network. When this time is very short (e.g., 30 to 60 seconds), the GO device is likely in a location with good cellular coverage. Conversely, when this communication takes a longer amount of time (e.g. 3 minutes or more), it is indicative of poor cell service. Even under normal circumstances, some geographies have poor cellular service. This is often true in very rural locations. However, when power is interrupted due to inclement weather, locations that typically have good or moderate cell service may suddenly experience worsening connectivity both from power outages and excess demand due to emergency conditions.

Under normal circumstances, it takes less than 30 seconds for a GO device's data to be recorded to a server. The maps below in Figure 3.3.1 show the aggregate proportion of GO devices that took three minutes or longer to record data (i.e., six times longer than normal) before, during, and three days after Hurricane Helene. Yellow areas indicate that very few devices have a slow connection, while purple indicates that a high concentration of devices have a very slow connection. The maps show that prior to the weather events, very few areas have high concentrations of devices that take three minutes or longer to transmit their data. However, under extreme weather conditions, the geographies that are most severely impacted show higher concentrations of slow connection times. The areas most impacted correlate closely with highly rural areas of the state.

The three maps reflect the concentrations of GO devices with a connection time of three minutes or longer. The first map, which shows the overall lowest concentration of devices with a slow connection, covers September 25-26, 2024, prior to the hurricane. The second map covers September 27-28, which were days of intense flooding in the western part of the state. The map shows that the area around Asheville, in the far western part of the state, had a very high concentration of slow connections. The third map covers September 30 through October 1, indicating that even several days after the most intense flooding had subsided, the area around Asheville continued to have relatively poor connectivity, whereas areas in the mid to eastern portions of the state had improved to nearly pre-hurricane conditions compared to the days prior to the hurricane.
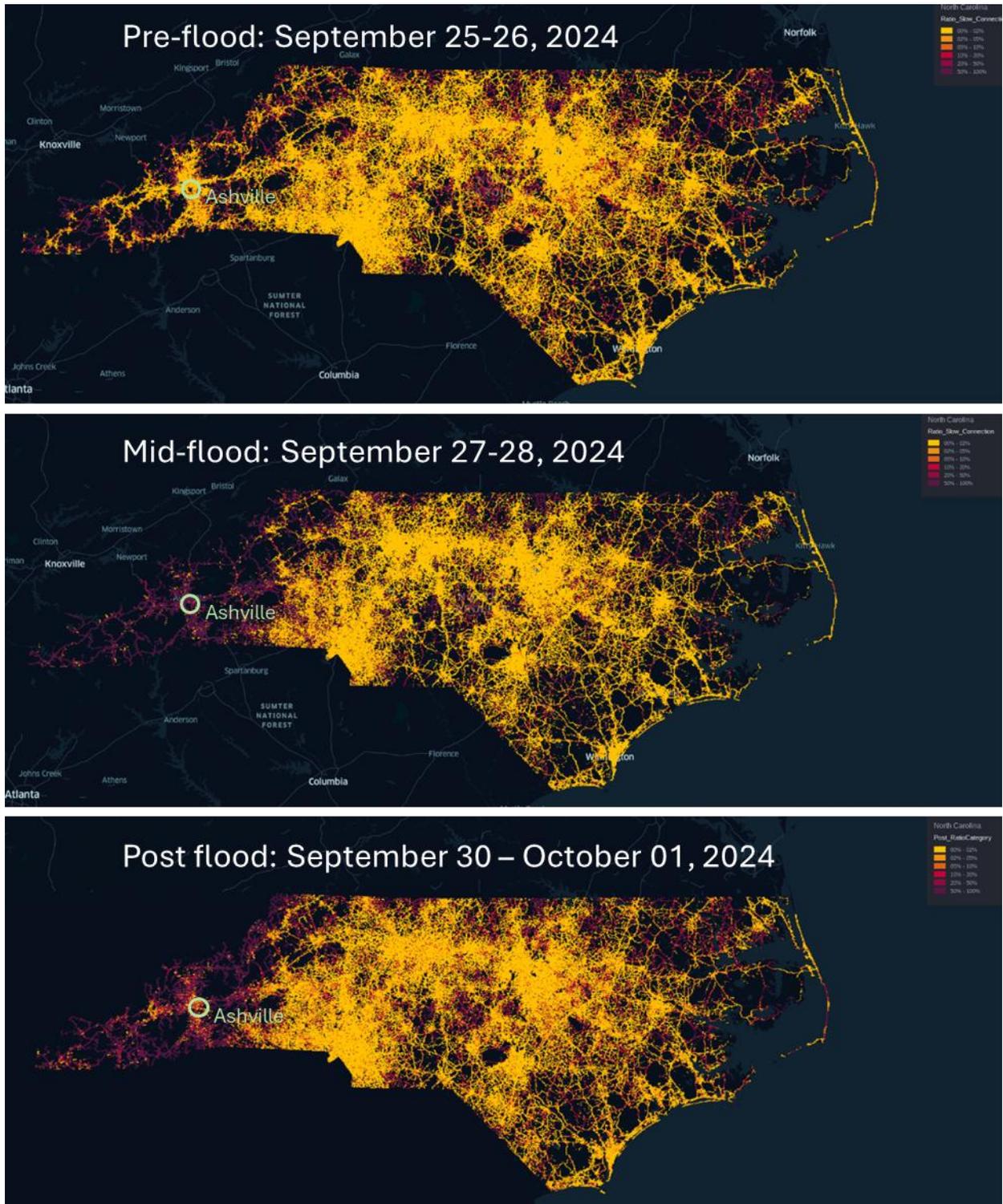
Figure 3.3.1:   Cellular network performance before, during, and after hurricane flooding
Source: Geotab

Such data reflects:

- Normal condition of cellular networks prior to the storm (expected connectivity in rural regions relative to more populus regions).

- The relative impact to the cellular connectivity as compared to 'business as usual' as a result of the hurricane.

- The greater amount of time it took for rural western portion of North Carolina to recover robust cellular coverage compared to the rest of the state.

This proposed metric (not yet in production) provides assessment of the telecommunications network as a function of telematics operations. This is unique in the probe vehicles have the capability of not only assessing traffic metrics, but in this instance can assess performance of telecommunications concurrently.

Metric #2: Relative Roadway Vehicle Volumes

Relative vehicle volumes on roadways over time can illustrate how roads are used on different days during major storms. In this example, GeoTab shows vehicle volume as a percentage of maximum observed volume to assess the impact of the hurricane. These volume ratios can be used to understand how travel patterns vary in anticipation of impending severe weather; how limited travel becomes during the severe weather; and how many days after the event normal operations resume.

The maps below in Figure 3.3.2 depicts relative vehicle volumes as a percentage of maximum observed vehicle volume. The four images show relative traffic volume on the day leading up to severe flooding in Asheville (September 25), the peak flood day (September 27), as well as immediately after (September 29), and a few days after (October 01). The maps indicate that a roadway going around Asheville to the southeast (the Blue Ridge Parkway) remained closed even after the majority of roads in the area reopened, which is further verified in this article. Note these were derived based on percent of vehicles observed in the Geotab telematics system, with no attempt to reference or report absolute volumes on the roadway.
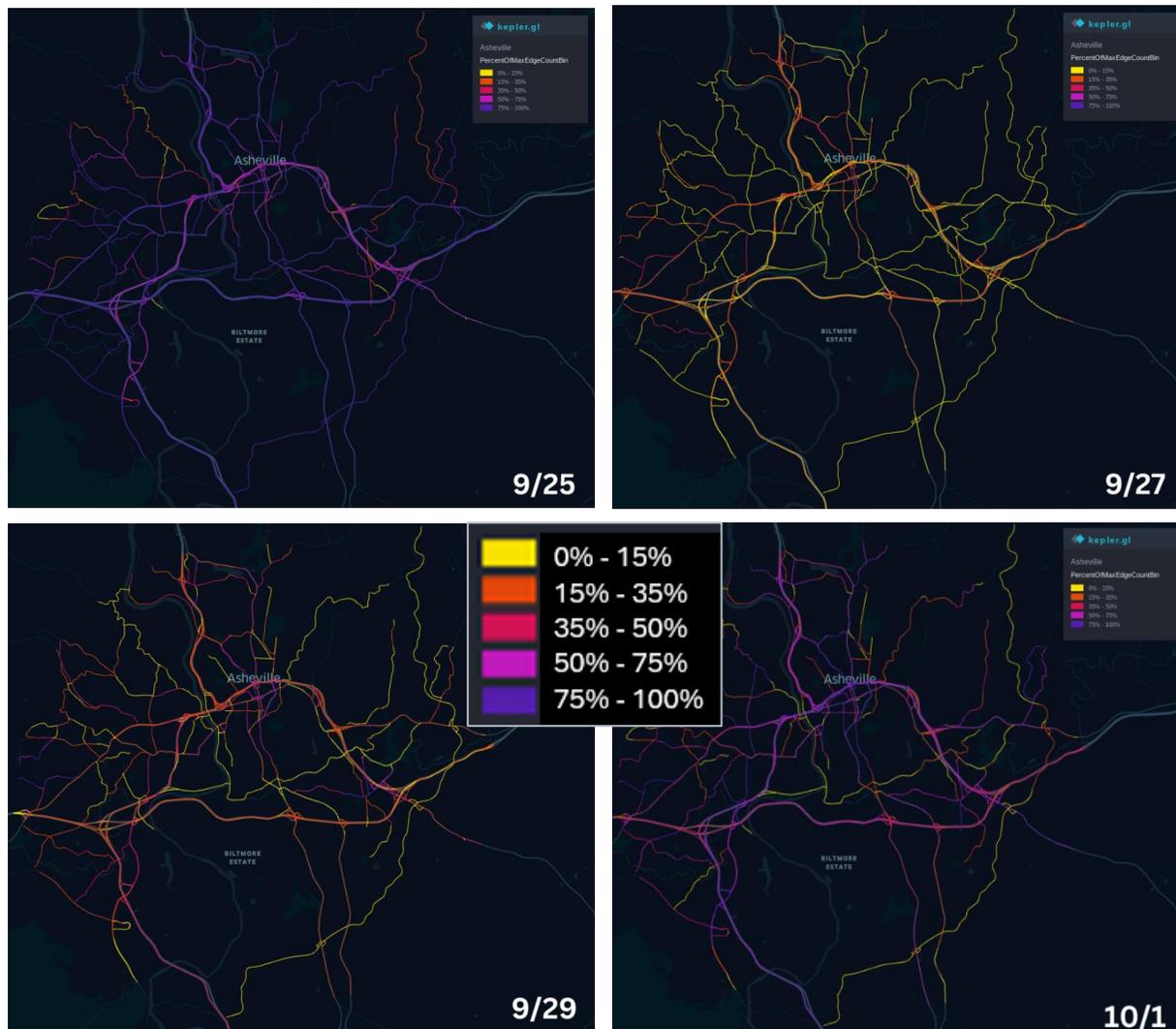
Figure 3.3.2: Relative vehicle volumes in Asheville, NC before, during and after hurricane conditions
Source: Geotab

Metric #3: Travel Hot Spots

Vehicle travel hot spots show how travel patterns change across a large geographic area in response to a major event. GeoTab counted the number of fleet vehicles that visited each sub-geography (using hexagonal units covering ~98 square miles) and calculated the ratio of vehicles on a given day to the maximum number of vehicles that visited the same area on similar days (for example, Wednesdays were compared with Wednesdays). The maps in Figure 3.3.3 show regional travel trends over time from 9/24 through 9/29. These trends indicate the preparation prior to severe weather (9/24 – 9/25), limited movement in areas affected immediately preceding and during the severe weather events (9/26 – 9/27), and increased travel following the events (9/28 – 9/29). These are similar to relative volume, but reflect areas served or visited as a percentage of 'business as usual', rather than relative volume of a roadway.

By using data from commercial vehicles to understand the impact of Hurricane Helene in western North Carolina, GeoTab demonstrated how device connectivity lag time, relative roadway volumes, and travel hotspots (or cold spots) can be used as key metrics in understanding roadway conditions and travel patterns before, during and after extreme weather events. Hurricane Helene had significant impacts to the regions in which they made landfall. This data demonstrates that telematics data may serve TSMO purposes to plan, monitor, and respond to major incidents such as hurricanes.
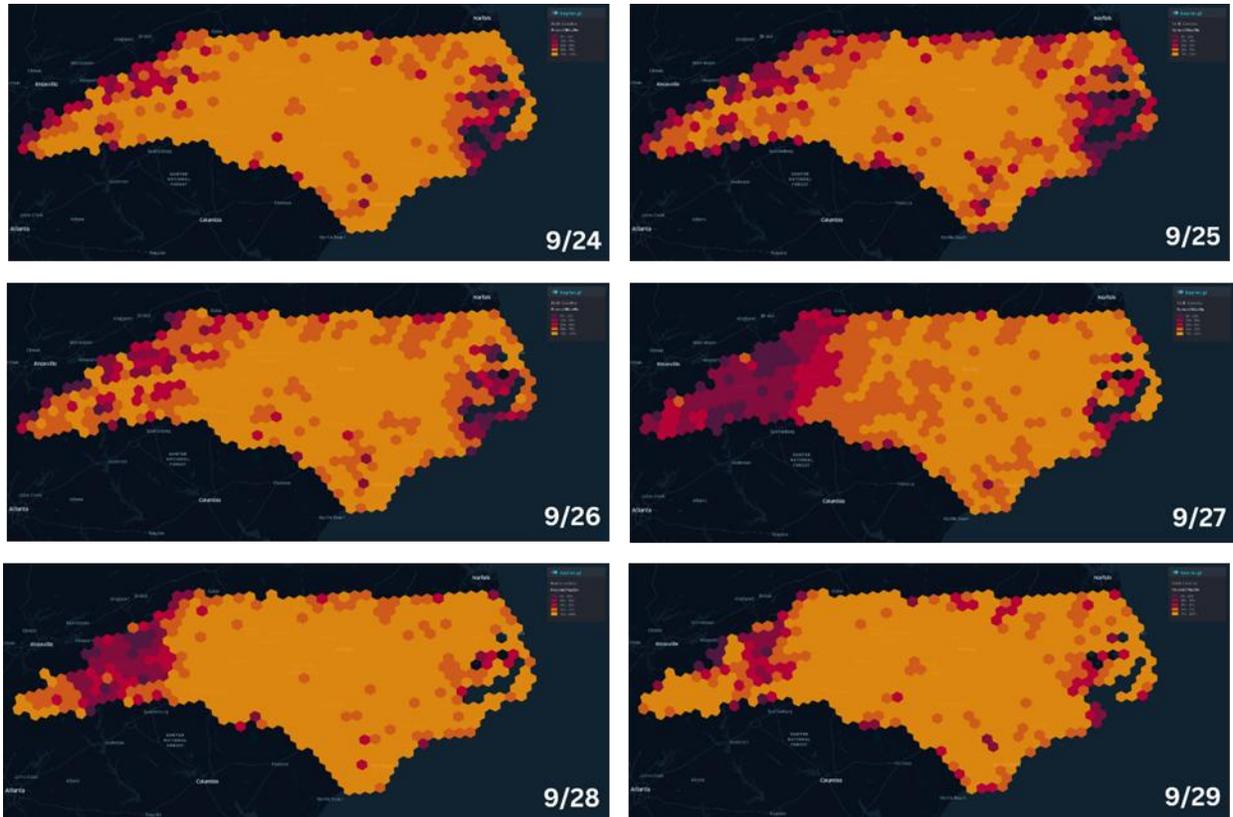
Figure 3.3.3:   Relative vehicle volumes in Asheville, NC before, during and after hurricane conditions
Source: Geotab

4.0 Summary and Recommendations for the Eastern Transportation Coalition

4.1 Summary of Challenges and Best Practices as Revealed through Stakeholder Engagement

Stakeholder engagement from representatives from Kentucky, Vermont, Pennsylvania, Florida, and Virginia included many common themes that spanned data, telecommunications, and rural DOT culture, as well as best practices as summarized below.

Rural Traffic Data: The MUSTANG initiative began with a focus on 'big data' for rural transportation. Data was a major point of discussion with each stakeholder, but each stakeholder had unique challenges and perspectives. 'Big data' many times played a supporting role to other sources of data in the theater, providing overall situational awareness of the network, while ITS specific sensors, or other data systems informed on initial incident detection. A major theme in the data space is the benefits from close coordination with law enforcement officials (LEOs) and other emergency response. In Florida, their RITIS analytics platform has a specialized module that monitors all LEO and emergency response radio channels in the region, providing their TMC direct access to incidents as they are reported. Florida as well as Virginia reported that most initial incident detections (>90%) were derived either from co-location with emergency response and dispatch (i.e. VDOT), or tight integration with their data systems (i.e. Florida).

The analytics provided by most probe data systems are typically speed, travel time, queuing, and other aspects most commonly associated with the concerns of recurring congestion in urban and metro areas. Although the Coalition's Transportation Data Marketplace (TDM) data has been tested in rural areas, efforts to validate the data typically have failed to locate any slowdowns in traffic during the typically two-week test period over the past two decades, with one exception from Stowe, Vermont in which slowdowns associated with a busy ski weekend were analyzed (which could be argued was a recurring congestion event). Validation methods currently centered on recurring congestion events need to evolve to reflect accuracy and value of data for rural TSMO. One such method is to analyze and validate data following a major weather event that impacts roadway access such as flooding or a winter snow storm. Another effective method was to monitor the 'confidence indicator' in each vendor's data stream, a metric initially introduced over concerns of accurate reporting during off-peak hours now informs on quality of coverage in rural areas.

Whereas urban probe data is often used to detect and monitor the myriad of recurring and non-recurring congestion events in a metropolitan area, rural incidents are typically first reported through traditional emergency dispatch. However, one aspect of rural TSMO data needs for which probe data may provide benefit is that of monitoring the roadway for 'passability' in addition to speed and congestion. The ability to assess and monitor when a road can no longer be safely traversed during floods or winter storms (as well as the converse of when the facility returns to normal operation after such events) is of equal (or perhaps greater) importance for rural TSMO as compared to speed data that reflects demand related congestion. In addition to TSMO, such data

was reported to save rural states a considerable amount of time and resources in updating its transportation resilience plan, adding to the return on investment. Although existing data and tools incubated in metropolitan regions may be able to infer insight for such various purposes, current transportation data analytics tools may not be directly designed for such functions to support rural TSMO. Both Vermont and Florida worked with their analytics providers for solutions that met their unique rural TSMO needs.

With respect to emerging 'big data' sets, Florida noted that the availability of WAZE data through the state's GIS data system has had a significant impact on their ability to respond to minor incidents before they began to impact traffic flow such as disabled vehicles and roadway debris. Although managing these large data sets is challenging, modern analytics tools have allowed them to filter extraneous information, and find user reported minor incidents that have potential for roadway restrictions and lane blockages, allowing their response crews to proactively address minor incidents before they escalate to major traffic impacts.

Kentucky reported that a primary data concern was not data input, but rather sharing critical roadway conditions with commercial navigation providers such that they route travelers and freight appropriately when primary routes are blocked, an area that the Coalition may provide benefit through unified collaboration with industry.

Effective strategies, tactics, and technologies for rural TSMO data include:

- Close coordination and integration with traditional emergency response typically provides the majority of initial incident detections. Either tight data system integration or co-location of the TMC with emergency dispatch is recommended.
- In rural areas, probe data provides overall situational awareness across the network, showing the larger scale consequences of major incidents. However, the lower traffic volumes in rural areas typically results in higher latency, and so it typically lags other data sources for incident specific detection and information, as such probe data may play a supporting role to other forms of detection such as ITS detectors or direct field observations, particularly for crash related incidents.
- Rural TSMO may be able to capitalize on emerging 'big data' such as WAZE to detect and respond to small incidents (i.e. disabled vehicles or roadway debris) before they escalate to major traffic impacts. Though management and filtering of these emerging 'big data' feeds can be challenging, Florida DOT has enabled constructive use of the data feed through central systems and appropriate tools to manage the volume of information.
- Data needs of rural regions fundamentally differ from urban and metropolitan regions where probe data matured for traffic management. Working directly with probe data providers for metrics and analytics appropriate to the rural context is essential. Probe data analytics tools as well as validation methodology for probe data need to evolve to meet the needs of rural TSMO accordingly.
- TSMO data needs are highly context specific. For example, traveler safety in southwest Virginia is highly impacted by fog in mountainous areas. Accurate detection of fog formation, and prompt notification to drivers to reduce speed is critical. This currently requires dedicated ITS devices for detection and notification, something that probe data or 'big data' currently has no capability to address, however, probe data can indicate the extent to which traffic flow responds to such warnings.
- Transportation data, be it for operations or planning, is less abundant in rural areas, and funding is minimal to acquire such data. As outsourced data continues to grow and evolve, wholistic procurement approaches at the state level that provide both state-wide data sets, as well as GIS, data science, and other analytics resources to leverage 'big data' are needed.

Wireless Communications Infrastructure: Although MUSTANG started with an emphasis in data, most conversations had a strong parallel emphasis on the critical role of modern telecommunications infrastructure, and its challenges and solution paths. Public wireless communications connectivity (3G, 4G and 5G voice and data services), which are typically taken for granted in urban and metropolitan areas are much less robust in rural areas. Cellular coverage is typically available in small towns, but can be highly susceptible to outages either from weather or over-subscription (too many people

trying to use it at the same time). Coverage between populated places can be sparse or non-existent in some areas – particularly in regions with rugged terrain. Stakeholders all commented that cellular coverage as well as broadband internet have improved (many noting additional investment due to the impact of COVID) and is anticipated to continually evolve and improve, however it continues to lag its urban and metropolitan counterparts. Even so, the cellular telecommunications network remains a critical tool for rural TSMO. All stakeholders in some fashion monitored cellular coverage closely to understand its strengths and weaknesses, as well as to leverage cellular service to maximize rural TSMO investments.

Outages of wireless network communications can impact data collection from ITS devices and the ability to communicate with travelers either through agency assets (such as 511) or consumer navigation smartphone applications. Over the past decade, the proliferation of priority cell service from national carriers has brought benefits to traffic management, first responders and other safety critical applications, resolving issues related to over-saturation of the network during emergencies and major incidents.

Cellular communications is just one component (though a major player) in the overall telecommunications network employed by DOTs. These typically also include fiber connectivity (many times from shared resource agreements) and dedicated wireless data communications devices to reach the 'last mile' to ITS devices. It can also include legacy dedicated radio systems to provide primarily voice communications across vast rural areas as a final fallback connecting law enforcement, emergency response and roadway operations personnel.

Effective strategies, tactics, and technologies for rural TSMO within the telecommunication space include:

- Use prioritized cell service – in the past decade prioritized wireless connectivity for public safety has emerged and is currently available from all national carriers. Use of these prioritized services for either voice or data has proven effective to maintain critical communications during incidents that would normally saturate (and subsequently block) wireless rural cellular connectivity.
- Remain knowledgeable and independently monitor the robustness of the telecommunications networks within the coverage region. For example, Vermont independently assessed cell coverage bandwidth and availability statewide for all carriers. Virginia continuously monitors its ITS network to both understand its vulnerabilities and respond swiftly to outages. Kentucky is aware of the various national and regional carriers, and their potential to complement and 'fill in the gaps' within their region.
- Leverage redundancy, such as multiple carriers, dual-sim cards, and use of traditional (older) dedicated radio networks as available.
- Investigate resource sharing agreements which allow a DOT to negotiate to obtain telecommunications infrastructure (dark fiber) or services in exchange to access to public right-of-way. These can provide a high bandwidth backhaul to central ITS services.

Culture: Stakeholder feedback from Coalition members with rural operations responsibilities consistently brought to the forefront that the culture and resource constraints associated with rural roadway operations differ greatly from their urban or metropolitan counterparts. Constraints include limited staffing with many staff members serving in multiple roles allowing less time to specialize or become familiar with emerging data, tools, and resources at their disposal. Vermont addressed these constraints with one-on-one launch sessions for staff starting to use RITIS, small group training sessions, highlighting Vermont use cases at staff-run quarterly workshops, and working with its Bureau of Innovation, Learning, and Development.

Additionally, traffic congestion due to excess demand at rush hour is rare in rural roadway network operations. Demand related congestion is primarily limited to seasonal recreational periods, holidays, or major events. The primary concerns of rural traffic operations are crashes, inclement weather, and construction and maintenance activities. Many of the modern data tools came of age to address congestion concerns in urban and metropolitan areas, and although useful for rural TSMO, they have yet to fully evolve to directly meet rural needs.

Florida shared that another important difference is that due to lower traffic volumes, rural TSMO typically has greater opportunity to be proactive than their urban counterparts. Due to the sparseness of traffic, rural operations typically have a larger time window to address a developing incident (disabled vehicle or roadway debris) before it grows to a significant traffic disrupter if notification is received in a timely fashion.

Virginia commented that though rural TSMO has lagged with respect to the adoption of technology, this is changing quickly as ITS and information technology education proliferates in the workforce such that knowledge and expectation of advanced technology solutions grow yearly.

> **Effective strategies for leveraging the unique culture and challenges of rural TSMO:**
>
> - Partnerships are critical to integrate 'big data' and technology into a resource constrained environment. The multiple areas of responsibility of a rural TSMO professional limits their ability to focus on emerging data tools or analytics, and funding constraints typically limit specialized positions for data science or GIS experts. Expertise either from central DOT, or through partnership with a local or regional university provides pathways to leverage existing data and technology expertise and tools.
> - Rural TSMO tends to be geographically isolated, creating less opportunities for professional networking and knowledge sharing. Central champions for advanced data and technology, as well as creating venues (both virtual and physical) to share knowledge and lessons learned are critical to overcome the rural isolation and resource limitations.
> - The fundamental data skills needed to leverage transportation 'big data' as well as advanced technology are becoming more abundant through training and education, as well as a result of 'digital natives' integration into the workforce.

4.2   Recommendations to the Eastern Transportation Coalition:

Based on conversations with Coalition stakeholders, industry data providers, along with a review of available literature, the MUSTANG project developed the following recommendations for the Coalition moving forward:

- **Emphasize the needs of rural operations and other applications in future evolutions of the Coalition's Transportation Data Marketplace (TDM)**

  Operations staff in rural states should consider using archived operations data for various other purposes such as after-action reports and planning activities. They would benefit their state at that point of bringing more people along for their local big data community of excellence and funding support. Expanding the user base for local big transportation data also expands the community of excellence and funding support. As the TDM continues to evolve along with its data validation efforts, additional emphasis on the use, specifications, and products for rural TSMO are needed. While much of the current data, products and nature of outsourced traffic data was born and nurtured in urban and metropolitan areas, continued growth in the market to address the unique needs of rural areas is needed. This includes both ex-urban and highly rural areas where demand related congestion is less of an issue, and connectivity and throughput related to incidents, crashes, work zones and weather events tend to dominate. It also include not just data but tools so they become more useful to

light users in urban areas as well as address needs in rural areas. Rural users may have less time and less solid data but deal with increasing numbers of severe weather events to manage.

- **Enhance emphasis on rural operations within Coalition working/user groups focused on tools, data, and communications issues.**

  Rural TSMO data analytics (data tools targeted at rural operations) require focused attention. This includes reporting tools that reflect 'passability' of the roadway network – such as 'time since last probe vehicle passage' as well as dashboard tools appropriate for low volume rural work zones, and after-action reporting templates. Such tools need not be a completely separate toolbox, but extensions and evolutions of existing dashboards, and may also prove useful in a more urban context to indicate if an incident has completely blocked a road for some reason. Rural big data users need data tools to be simple and straight forward (tools, dashboards, and trainings). Such and tools need to help TSMO professions tell the story easily and well. Many current visualizations and analysis tools are too complicated for people doing this work a small fraction of their time. Whether it is a subgroup of the Coalition's RITIS user group or a stand-alone group that provides feedback to commercial data providers and the analytics industry, increased emphasis on rural operations probe data and associated tools would result in continued evolution of the TDM, RITIS and the industry to better meet the needs of rural operations and planning.

- **Complement existing TDM data validation practices with methods that reflect data quality in rural areas.**

  Much of the TDM data validation in rural areas has attempted to use methods and reporting that was developed for urban and metropolitan regions where demand-related recurring congestion are common, and easy to capture in a periodic two-week long validation exercise. This recommendation is not to cease current validation work that serves the millions of drivers and TSMO needs in larger, more populous urban areas, but to mindful of the differences in application and context of traffic concerns in rural areas, , using methods that capture data quality concerns in less populated and lower traffic areas. Continued exploration and guidance from a rural focus committee could guide this effort.

- **Increase emphasis on rural wireless data communications.**

  Since the effectiveness of rural highway operations are closely linked to the availability and robustness of wireless voice and data communications, it is recommended that the Coalition rural TSMO emphasis explore or partner to assess and benchmark the coverage and robustness of rural wireless telecommunications. Knowing telecommunications capabilities and limitations during major incidents is critical. Data to monitor and assess the quality of wireless telecommunications services may be available from other groups engaged in the telecom world, or (if not) should be considered for inclusion in the TDM in the future.

Rural Transportation Management and Operations is not just an implementation of the disciplines learned from urban and metropolitan counterparts, but presents challenges

and demands solutions tailored and refined to the rural context, culture and resource environment. This MUSTANG report examines rural TSMO through stakeholder engagement with five primarily rural Coalition member regions, and shares the insights, best practices, and resulting recommendations to the Coalition with respect to rural TSMO data and wireless telecommunications environments.

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MUSTANG: Measurement Utilities for Sensing Transportation Activity in Non-Urban Geographies

Rural Data and Operations Challenges and Recommendations for the Eastern Transportation Coalition

Final Report - APPENDICES

11/06/2025

Prepared by: The Eastern Transportation Coalition

This report characterizes the unique challenges of rural highway operations including available data, resource constraints, and telecommunications in contrast to urban highway operations. The report makes recommendations resulting from stakeholder feedback across the coalition and with vendors supporting transportation operations.

Appendix A: The Vermont Big Data Story

The following material was gleaned from the Vermont Agency of Transportation (AOT) presentation during the 2025 Transportation Research Board (TRB) annual meeting as part of the session titled "Data Analytics for Optimizing Rural Transportation Performance". Vermont AOT's presentation titled "How Vermont is Using Big Transportation Data" (TRB 2025 Reference Number P25-20574) is available in presentation slide format through the TRB. A synopsis of the issues and concerns of their highly rural transportation network paraphrased from their presentation at TRB is provided below.

- **Big Transportation Data in Vermont**

  Over the past 24 months (with reference to January 2025), Vermont AOT (VAOT) has entered the Eastern Transportation Coalition (TETC) Transportation Data Marketplace (TDM), procuring travel time and speeds, estimated volumes, origin-destination data, and conflation services. VAOT participates in the RITIS analytics suite for analysis, visualization, and communication. As a byproduct of the procurement through the TDM, public partners (such as cities, counties, and MPOs) have access to the TDM procured transportation data free of charge. VAOT also participates in the TDM validation activities through the TDM Validation Technical Advisory Committee (TAC) and takes advantage of various collaboration opportunities with other Coalition members.

  VAOT, acknowledging that a large majority of the state is rural, has concerns with probe-based traffic data, along with special needs unique to Vermont's geography. Those concerns included:

  - Transportation probe data quantity and quality given vehicle probe density and low vehicular volumes
  - Sparse cell phone coverage and its impact on available data
  - The need to socialize this new capability within the agency, and the need for a data 'champion'
  - Special issue: cross-border analysis:
    Vermont shares a border not only with adjoining states, but also with Canada. The ability to use the data and perform analysis with bordering states and countries was needed.
  - Staff Capacity: Staff bandwidth to engage and assimilate the new data and tools was a concern. As a rural state, most staff and engineers have a broad array of concerns and responsibilities, leaving little time to devote to new data and tools.

- **Who Uses It**
  Over 125 staff at Vermont AOT, plus 11 other state agencies, the regional planning commission, municipalities, and related organizations have access to the data and can login into the RITIS platform for data access and analysis. In order to build a community of excellence, Vermont AOT proactively provides the following opportunities.

  - Hosts staff presentations to small groups

- o Convenes a quarterly Vermont Big Data Workshop

- o Works 'one-on-one' launch sessions with organizations

- o Uses a Vermont AOT Microsoft Teams site, and makes content available to all users

- o Collaborates with TETC, UMD CATT Lab, INRIX (its primary data provider), and others

- Overview of Use Cases

  Probe data procured through the TDM provides Vermont AOT with traffic 24-7-365 on their Federal Aid System plus some local roads on a minute-by-minute basis. They also have historical data for analysis. Templates have been developed to tell the story for after action reporting of significant events, along with take-aways for future improvement.

  - o **After Action Reporting:** The graphic in Figure A1-1 documents the traffic on I-89 during a crash on October 31 (Halloween), resulting in significant slowdowns. The Vermont AOT TMC staff developed and used this template for the first time (VTrans after-action template), as shown in the Figure below. This template is now in routine use.

Figure A1-1 After action RITIS template in use at Vermont AOT
Source   Vermont AOT

  - o **Work Zone Use Cases:**

    Work Zones are common, and in some respects more impactful in rural areas than compared to urban areas due to the need for either detours or pilot car operations. Vermont AOT uses the WorkZone Performance Monitoring App (in RITIS) to:

    - ▪ Document the speeds before, during and after the project

    - ▪ Assess any formal or informal detours associated with the project

▪ Develop alerts that are shared statewide for speed drops in work zone (s)

An example output of the WorkZone monitoring app is shown in Figure A1-2.
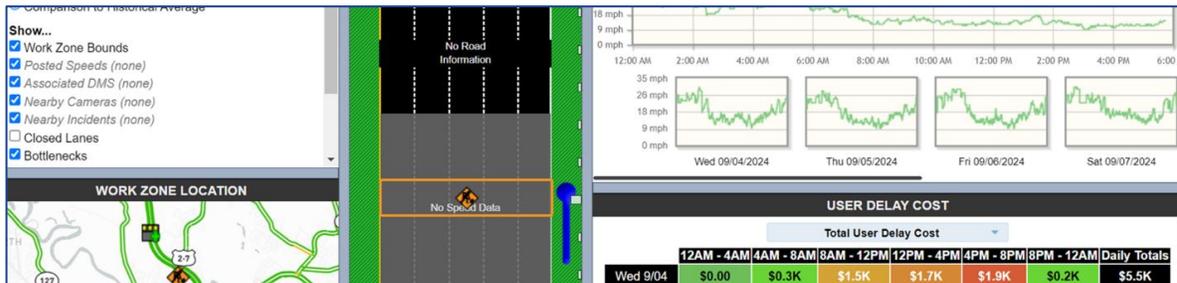
Figure A1-2 RITIS WorkZone monitoring app as deployed at Vermont AOT
Source   Vermont AOT

The WorkZone tool can be used to scope projects more efficiently, assess where cars and trucks that pass through the work zones come from and their destination (O-D), monitor congestion in the work zone and its associated causes (weather, time-of-day, incidents, local or regional events), and monitor conditions on either formal or informal detours (as shown in the image in Figure A1-3). The tools allow for fine-grained analysis by either segments or routes.

Figure A1-3 Vermont AOT work zone traffic conditions as monitored in RITIS
Source   Vermont AOT

o **Planning Use Cases:**
The use cases for planning are many and varied. Within VAOT, the probe data has been used to improve quality and reduce cost of analysis. Applications include corridor studies, new project summaries (i.e. has a new crosswalk slowed drivers), updating the Rail Plan, Freight Plan, Long-Range Transportation Plan, Reducing Repeat Damage to Roads and Structures (MAP-21 Part 667) and resilience planning. Data is also used to update the travel demand model for the state, as well as to help understand the relationship between speed, congestion, weather, crashes, wildlife crossing corridors, and other matters.

• Big Data Accuracy and Confidence in a Rural State

Big data has been used for decades in states with higher traffic volumes. The TDM validation has provided evidence of the data quality in urbanized areas around cities. The Confidence Score within the data feed also provides evidence of the base data quantity (and thus quality) on rural road networks. The confidence score for travel time and speed in Vermont (as provided by INRIX) is defined as:

- o 30 = Real Time Data
- o 20 = Historical Average
- o 10 = Reference Speed

Assessment of the Confidence Score across geography and time within Vermont helped bring confidence to the application of probe data for rural Vermont. An example of confidence scores in Vermont are shown in Figure A1-4 showing high-confidence real time probe data for both major and minor roadways (indicated by green). Some yellow exists (indicating a confidence of 20), but the high majority is confidence score of 30.
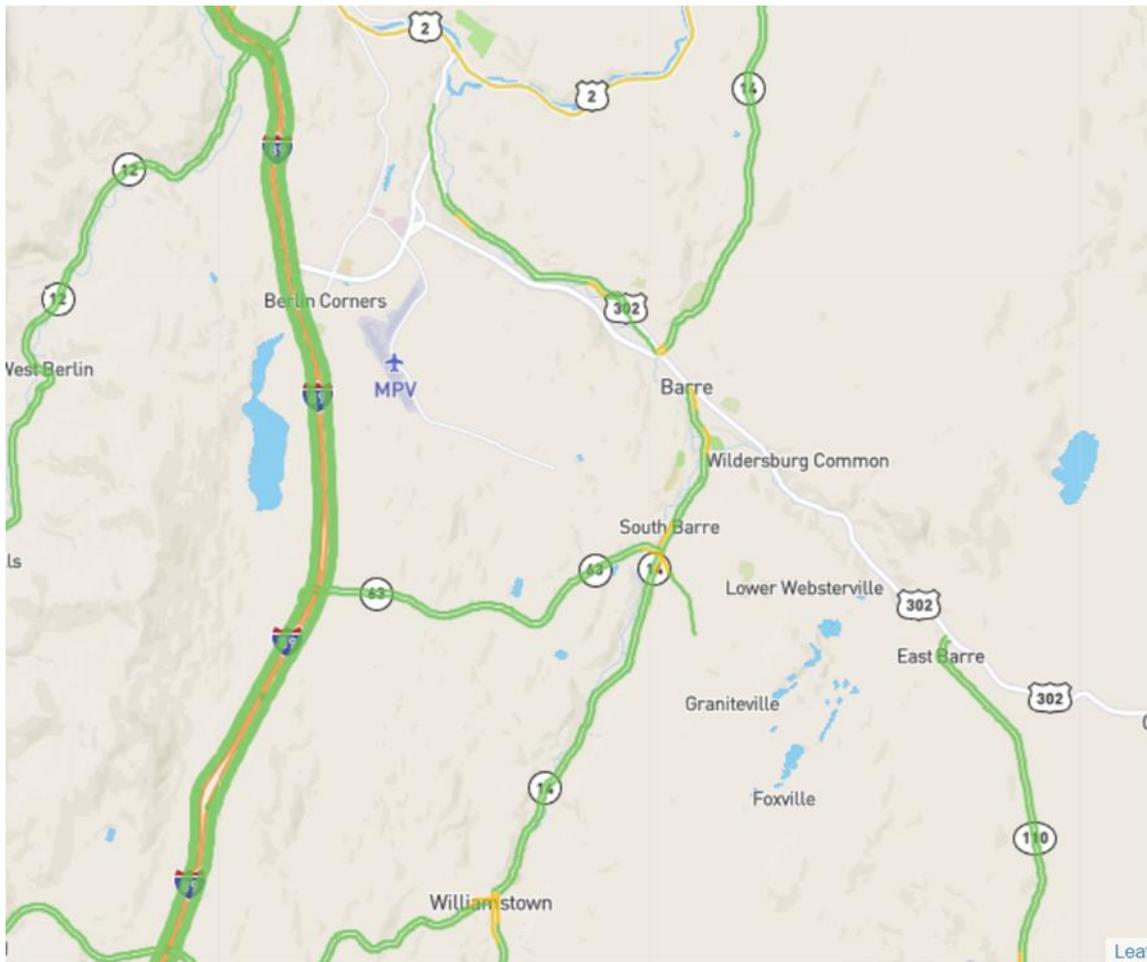
Figure A1-4 Map of Confidence Scores near Barre, VT, 6:40 PM on Tuesday, 11/29/22
Source   Vermont AOT

A tactic for the effective use of probe data in rural areas (or anywhere where the volume fo traffic is significantly lower) is to use a longer time averaging period to account for the sparsity of data. For example:

- o Consider increasing time granularity from one minute to 15-minutes or one hour
- o Consider time ranges such as a day, week, or month when comparing traffic conditions over longer periods.

Vermont AOT has developed guidance for both its internal and external users for exploring and applying big data for uses within the state. The reader is referred to VAOT for further information.

- Sample of Technical Explorations
  - o Visualizing traffic at a popular tourist destination

    Figure A1-5 is a congestion scan of VT 108 from Stowe (a popular tourist destination) on a short northbound section. It explores speed along the road from noon to 3:00 PM by five-minute intervals, on Sunday, July 2nd, 2024 on VT 108.
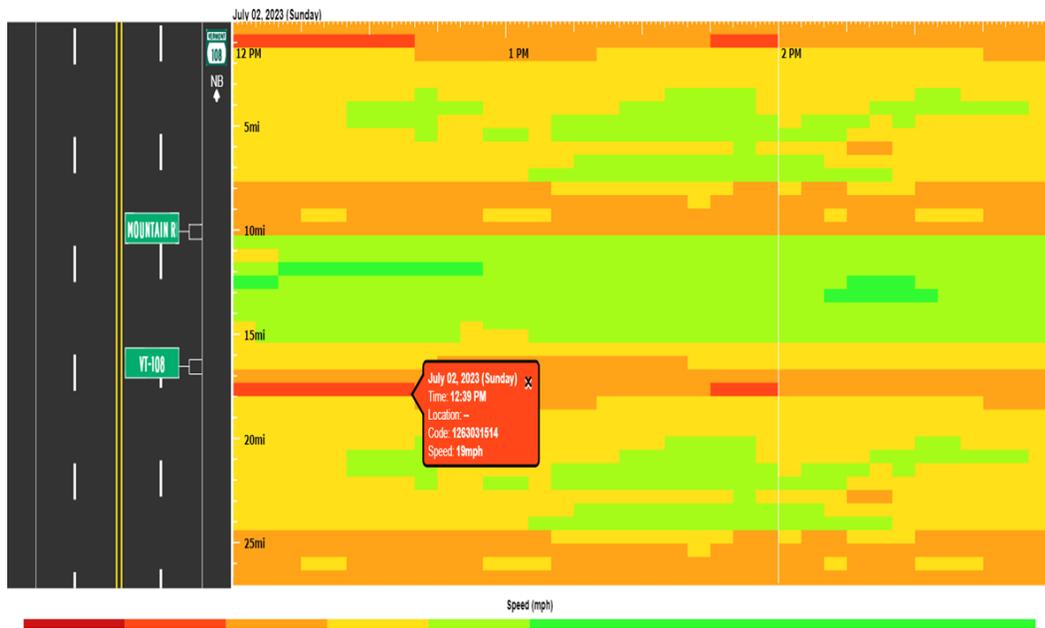
Figure A1-5   Congestion scan of northbound VT 108 during July 4th weekend 2024
Source   Vermont AOT

  - o Conditions on a rural Interstate Highway during flooding
    On Monday, July 10, 2023, flooding occurred near Barre, VT. Figure A1-6 provides a visualization of the impact of the flooding on the I-89 corridor

between Barre and VT 100 as flooding spread through the region.
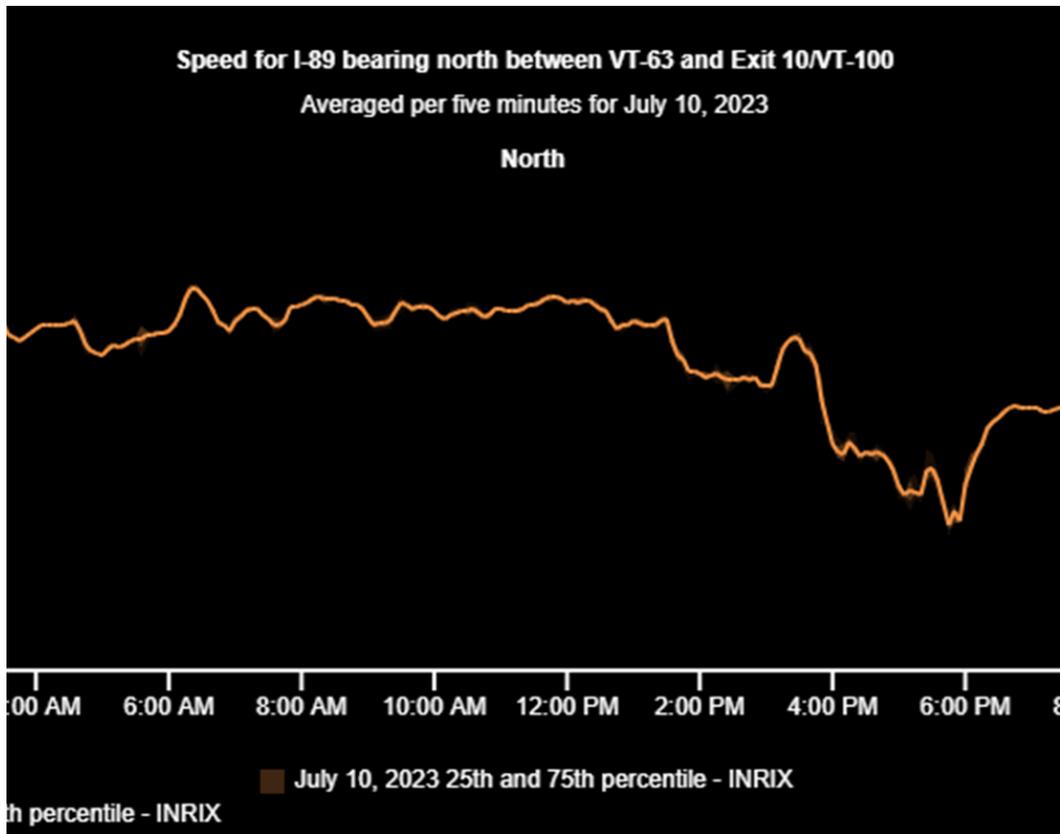
Figure A1-6   Impact on I-89 near Barre due to flooding in July of 2023
Source   Vermont AOT

Further analysis (drilling down) shows the time and location specific details of the slow down. This example reflects that a tool developed initially for incidents and congestion in urban areas can be effectively repurposed for weather related impacts in rural areas
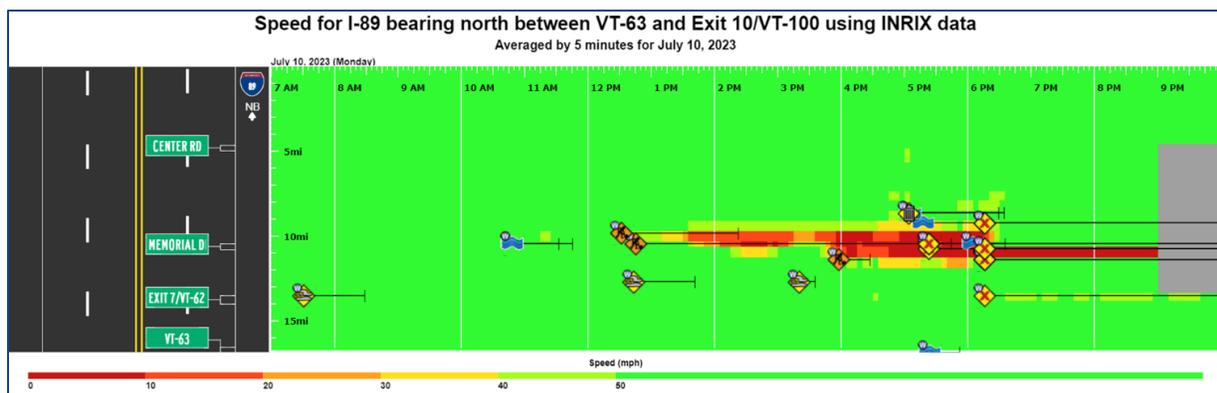
Figure A1-7   Location and time details of the I-89 flooding in July of 2023
Source   Vermont AOT

Appendix B: Mobile Wireless and Broadband Coverage in Vermont

The following contains excerpts, summaries, and paraphrased material from the report: Mobile Wireless Coverage in Vermont,[12] December 2022 as well as the state wide telecommunications plan issues in 2024 [14].

In Dec 2022, the State of Vermont Department of Public Service (PSD) released a report reflecting the quality of mobile wireless cellular connectivity throughout the state. PSD contracted for a drive test to determine the coverage and bandwidth of mobile cellular service along all primary roads in the state. PSD partnered with the Vermont Agency of Transportation (AOT) whose road maintenance staff conducted the driving. The PSD retained the services of a company that provides broadband and mobile internet performance testing, to provide the software and technical support for the project. The project employed a handset-based testing and monitoring solution to collect performance metrics along the routes. Smartphone devices with mobile wireless service were supplied by the six facilities-based carriers offering cellular service in Vermont: AT&T, FirstNet, T-Mobile, US Cellular, Verizon, and VTel Wireless.

The test protocol consisted of both voice call test as well as wireless data network performance test, which included download speed, upload speed, latency, and jitter. The smartphone devices conducted this repeating test protocol automatically while the Vermont AOT driver navigated the planned routes. The drive test included over 6,500 miles of planned routes which included all routes managed by the AOT, as well as over 1,500 miles of additional roads managed by towns. The drive test was conducted between July 1 and September 15, 2022.

The results of these tests provided performance data for the entirety of the state. Vermont followed the FCC's use of H3 resolution 8 hexagons ("hexcells") to evaluate mobile wireless and broadband deployment, with each hexcell having an area of roughly one square kilometer. Although performed by driving the roadway system, the results were transformed by overlaying the quantity of buildings in each tested hexcell, which allowed for the estimation of wireless performance for the general population.

The project identified voice and data performance for 10,946 hexcells. These tested hexcells include 62% of the 19,744 Vermont road miles. Of the 313,062 business and residential buildings in the state, 75% were within the tested hexcells.

Additionally, as part of the state overall telecommunications 10 year plan released in June of 2024 [14], information from broadband carriers (both wireless as well as cable, landline, and other) as well as survey results from users were assembled and reported.

Voice Performance

The chart in Figure B1 depicts voice call completion performance for each service provider. Each section of the bar depicts the portion of buildings in the state that are within hexcells with the indicated level of call completions. Voice calls were treated as successfully completed if they were connected and sustained until disconnected by the handset. In the legend below, "Not on Drive Routes" indicates the quantity of buildings

not within tested hexcells and "Not Tested Carrier" indicates the quantity of buildings in hexcells that were tested, but where no results were recorded for that specific provider.

Voice Call Completions

	All Carriers	AT&T	FirstNet	T-Mobile	US Cellular	Verizon	Vtel
Not on Drive Routes	78462	78462	78462	78462	78462	78462	78462
Not Tested Carrier	0	6422	6764	6927	5888	6383	5419
All Completed	36214	172885	164560	127679	148482	80582	115581
More than half	163195	25834	30742	50783	43784	61041	67730
Less than half	25399	8309	12292	19059	11734	36869	19319
None Completed	9792	21150	20242	30152	24712	49725	26551
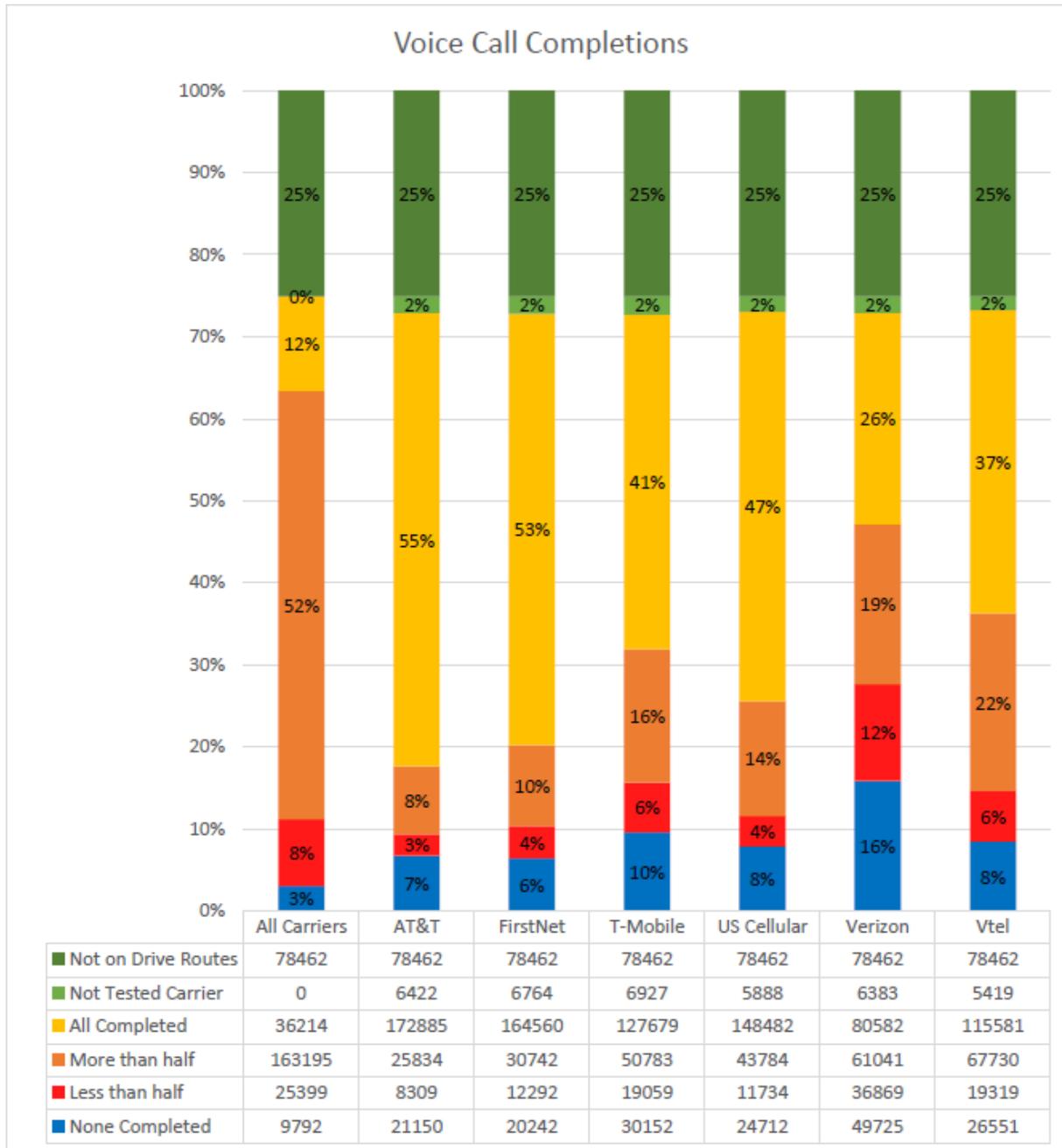
Figure B1   Voice call completion results from Vermont statewide cellular assessment
Source   Vermont PSD

Speed Test Performance

The chart in Figure B2 depicts Speed Test performance for each service provider. Each section of the bar depicts the portion of buildings in the state that are within hexcells with the indicated level of performance. For instance, in the yellow portion of the bar for AT&T, the chart indicates that 36% of buildings in the state (111,354 buildings) are within hexcells where the average recorded download speed was between 25 Mbps and

100 Mbps. An Ookla Speedtest was successfully completed only if all components of the test were completed. In the legend below, "Not on Drive Routes" indicates the quantity of buildings not within tested hexcells and "Not Tested Carrier" indicates the quantity of buildings in hexcells that were tested, but where no results were recorded for that specific provider.

Speedtest Performance

	All Carriers	AT&T	Firstnet	T-Mobile	USCell	Verizon	Vtel
■ Not on Drive Routes	78,520	78,520	78,520	78,520	78,520	78,520	78,520
■ Not Tested Carrier	-	6,410	7,047	6,440	6,486	5,886	5,636
■ No Completed Tests	28,628	51,974	49,880	75,687	72,127	101,480	87,588
■ > 100 Mbps	5,190	24,511	32,853	15,112	258	9,668	719
■ 25 Mbps - 100 Mbps	142,613	111,354	104,106	73,595	3,741	72,140	79,647
■ 5 Mbps - 25 Mbps	51,727	35,669	36,433	38,949	11,223	38,525	56,332
■ 256 Kbps - 5 Mbps	5,159	4,605	4,223	20,880	2,868	6,230	4,620
■ < 256 Kbps	1,225	19	-	3,879	137,839	613	-
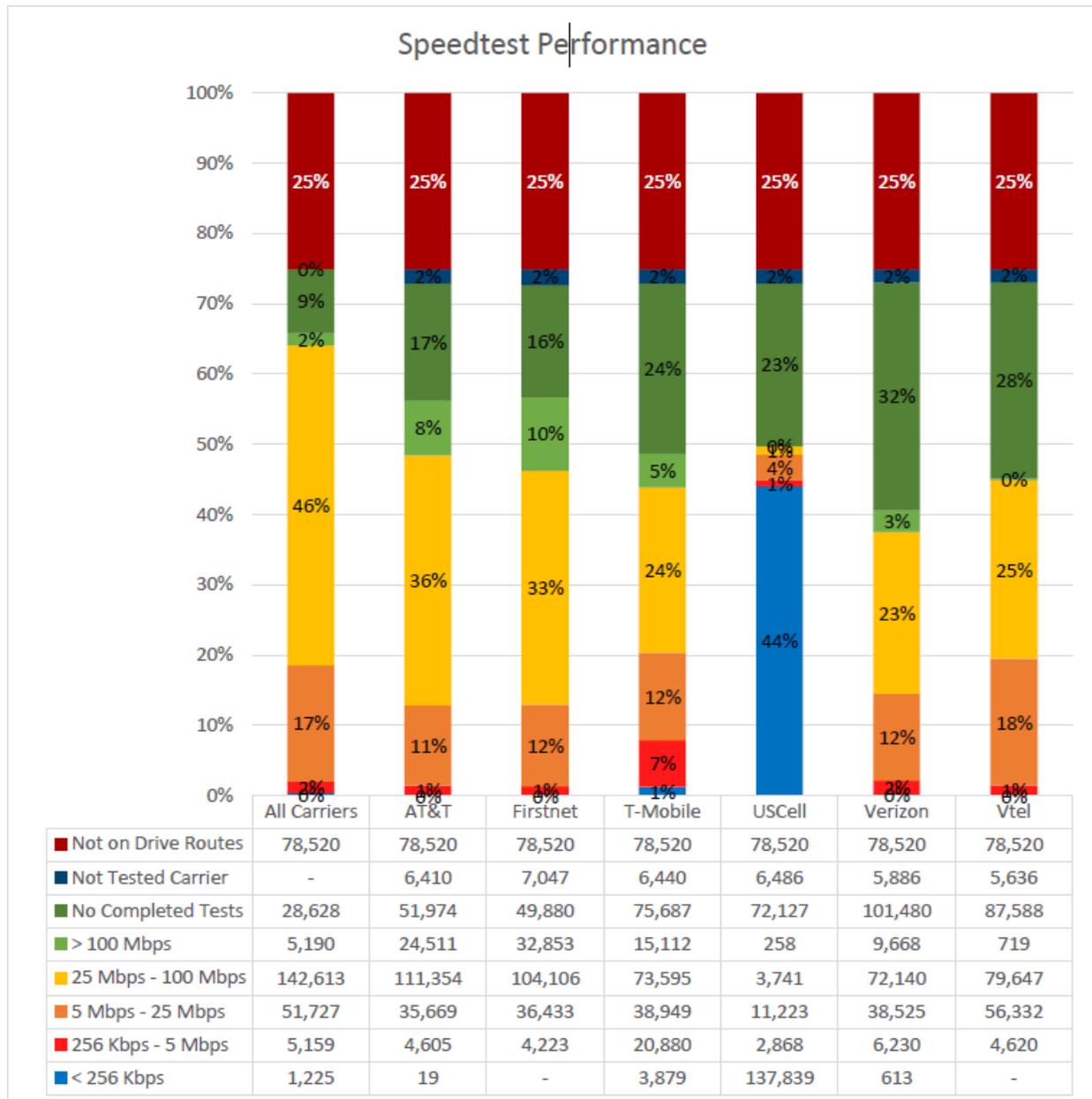
Figure B2 Data speed test performance from Vermont statewide cellular assessment
Source Vermont PSD

Roadmile Analysis

There are 19,744 identified road miles in the state of Vermont. Of these, 12,144, or 62%, are within tested hexcells, while 7,600 are not. The chart in Figure B3 depicts the proportion of road miles within tested hexcells for each class of road. A hexcell is

determined tested successfully if an individual speedtest or voice test call was initiated within that hexcell. Not all roads in each tested hexcell were driven.

Tested Road Miles

	Interstate Highway	US Highway	State Highway	Forest Highway	Town Highway Class 1	Town Highway Class 2	Town Highway Class 3	Town Highway Class 4	Legal Trail/Private	Other
■ Not Tested	2	1	5	218	1	20	4,504	1,050	1,748	52
■ Tested	710	610	1,752	98	144	2,628	4,146	284	1,759	12
Total	712	611	1,756	317	145	2,648	8,651	1,334	3,507	64
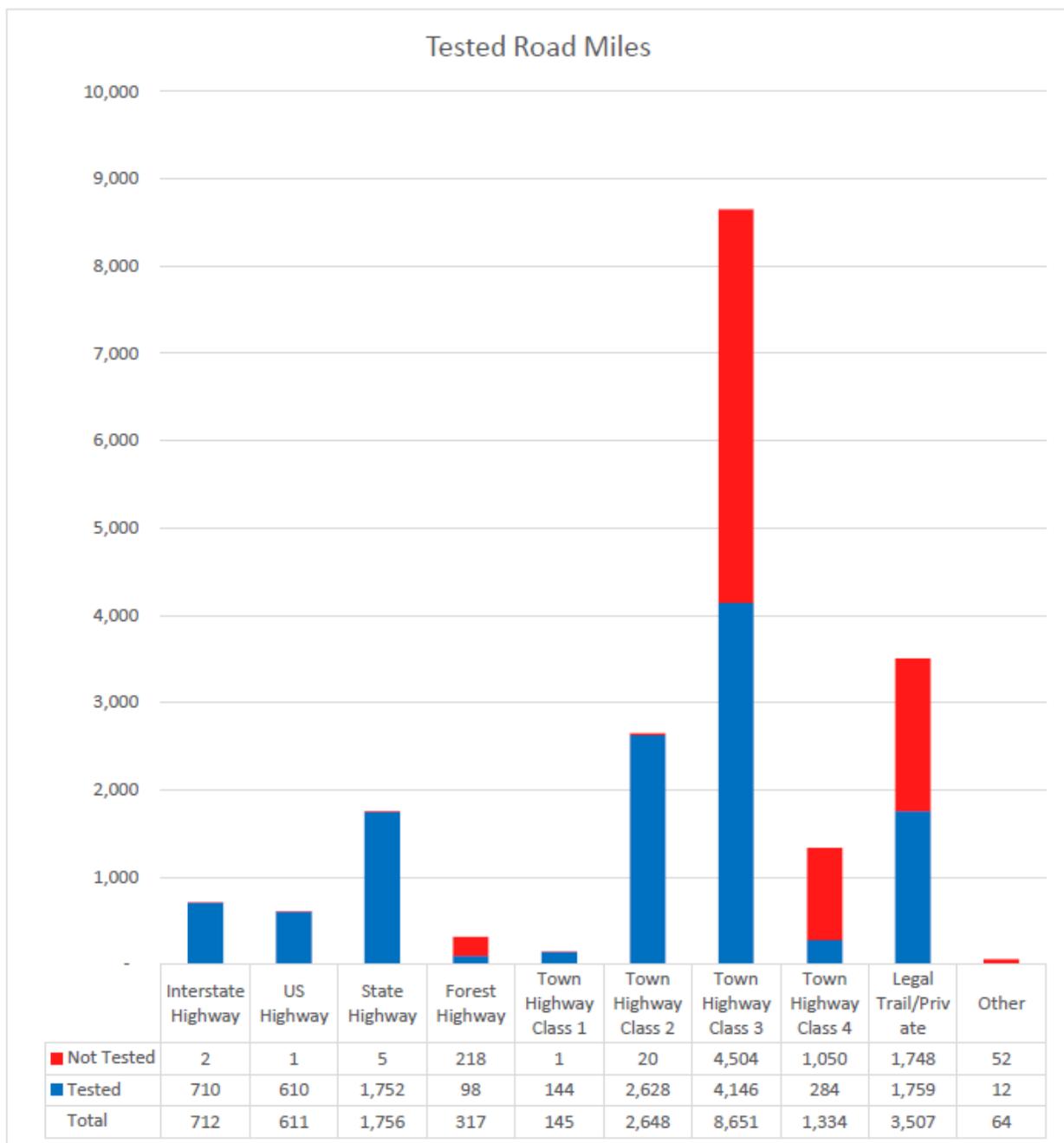
Figure B3   Proportion of roadway miles tested in Vermont statewide cellular assessment
Source   Vermont PSD

5G performance
The use of the term "5G" in the wireless industry is complicated. The term is sometimes used to indicate the use of specific frequency bands, such as the millimeter wave 30 GHz band. The mobile wireless industry standards body's 3rd Generation Partnership

Project (3GPP) defines 5G as any wireless service that employs "5G New Radio" signaling protocol, regardless of frequency band. The drive test identified 2,055 of the 10,946 tested hexcells where this signaling protocol was detected. Table B1 below depicts the quantity of hexcells by provider:

Table B1 Number of hexcells thatin which detected "5G New Radio" signaling protocol

Provider	Hexcells
AT&T	68
FirstNet	62
T-Mobile	1923
USCC	157
Verizon	70
Vtel	0

FirstNet Band Class

FirstNet has access to a special spectrum frequency range called Bandclass 14. The chart in Figure B4 depicts the extent to which the tests determined deployment of this spectrum.
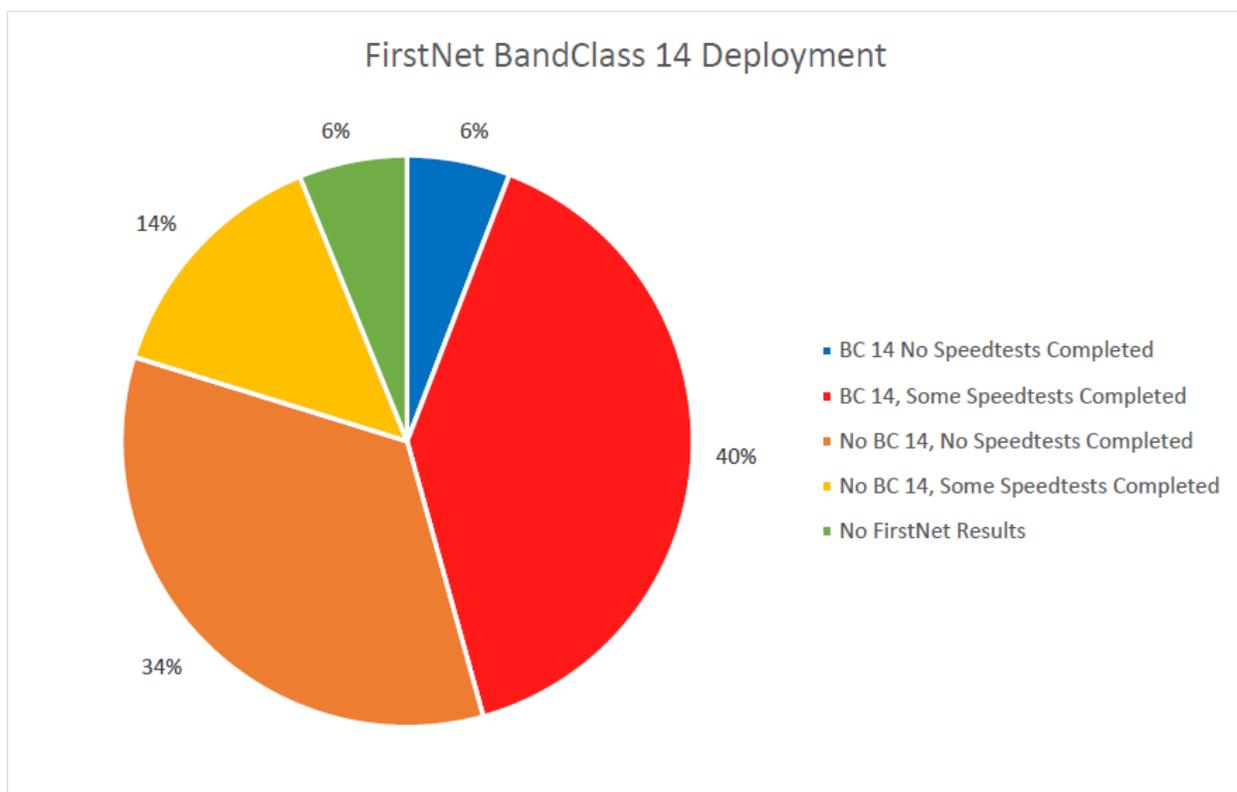
Figure B4   Percentage of detected FirstNet BandClass in Vermont statewide cellular assessment
Source   Vermont PSD

Statewide Broadband and Wireless Access

The raw data from all the statewide assessment as well as data from broadband carriers (both wired and wireless) were used to developed a series of GIS visualizations from which select examples are provided below, which are referenced to the Vermont

[10-Year Telecommunications Plan](#) released in June of 2024. These reflect not only roadway coverage, but general availability of telecommunications, particularly for broadband access, across the state. Figure B5 reflects the quality of broadband internet in the state of Vermont, with areas highlighted not having the minimum (25/3 BPS or better) as the minimum threshold for broadband as defined by the FCC. This minimum threshold has since been raised. Note the Vermont cellular assessment was motivated by economic and equity concerns, which received additional emphasis due to the increased demand for broadband for home schooling and work from home activities as a result of the COVID pandemic. Both broadband as well as wireless data connectivity for the broader population was a consistent peripheral theme in stakeholder engagement. Mobile cellular connectivity for TSMO was related and intertwined with overall improved telecommunications access for any rural area.
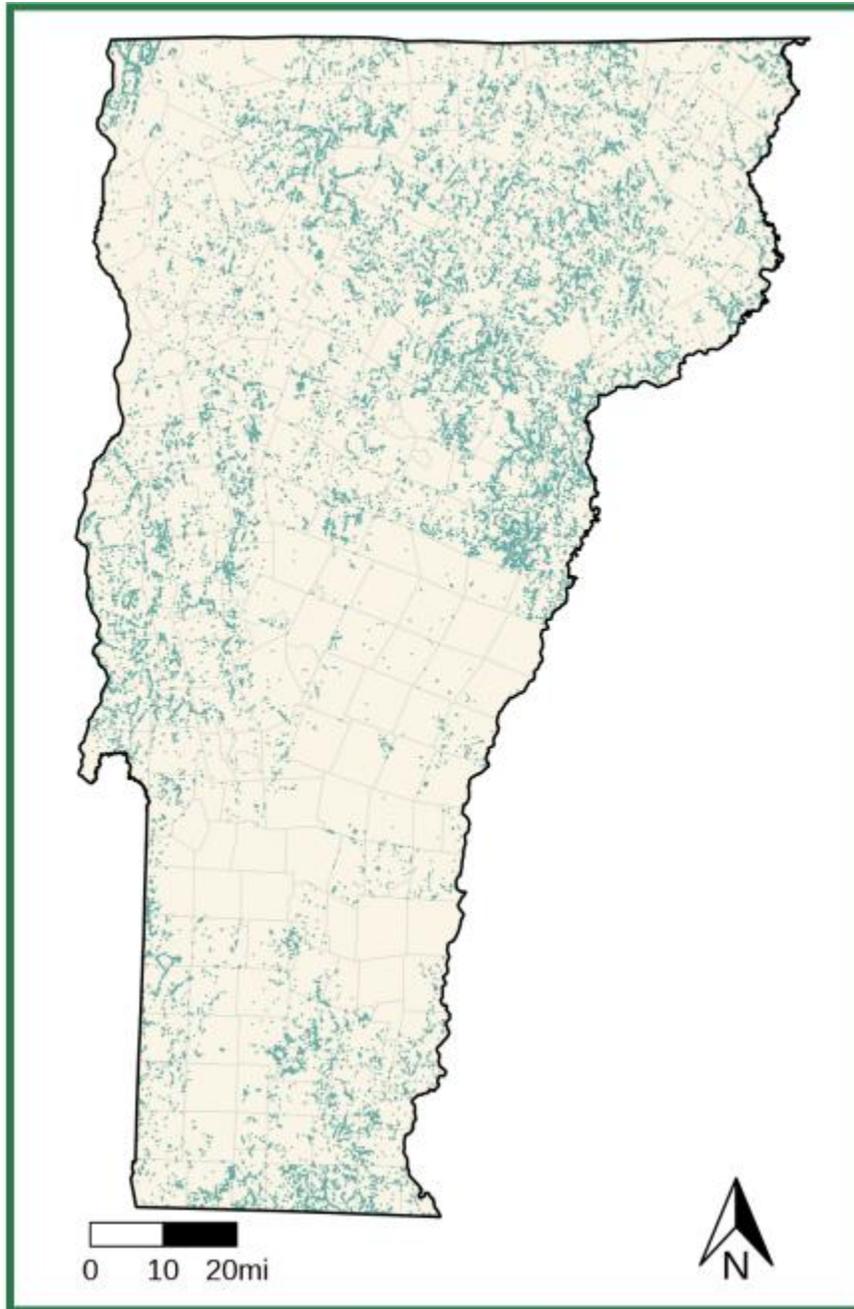
Figure B5   Vermont premises currently unserved or underserved by broadband (not having speeds of 25/3 Mbps or better) Source: Vermont PSD (Dec 2023) [14]

Figure B6 further disaggregates broadband access for premises by level of service.
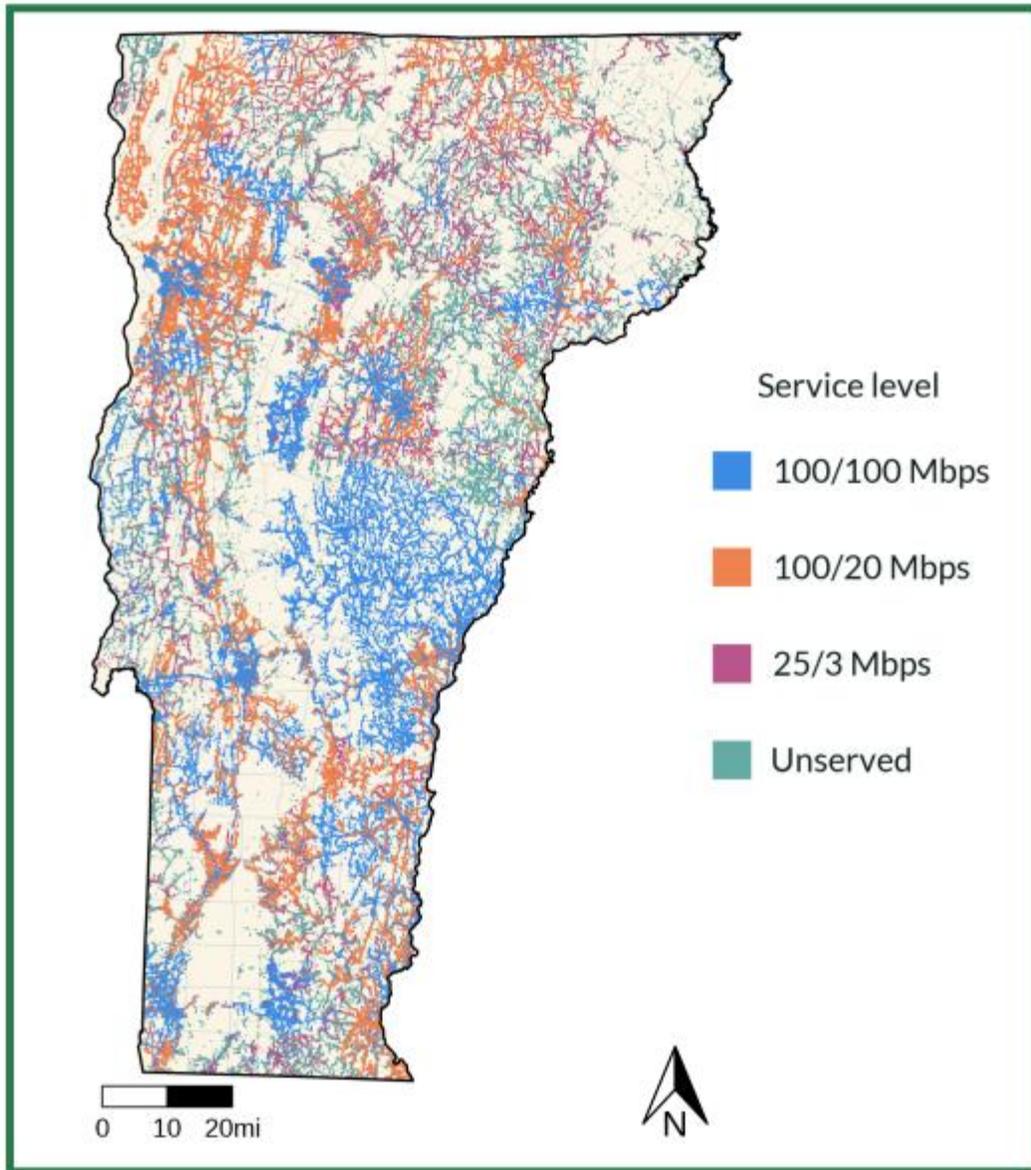
Figure B5   Premises in Vermont by broadband service area
Source: Vermont PSD (Dec 2023) [14]

Specific to roadway use, Figure B6 provides average wireless download speed for all tested providers on Vermont roadways in 2022, a depiction directly applicable to rural TSMO.
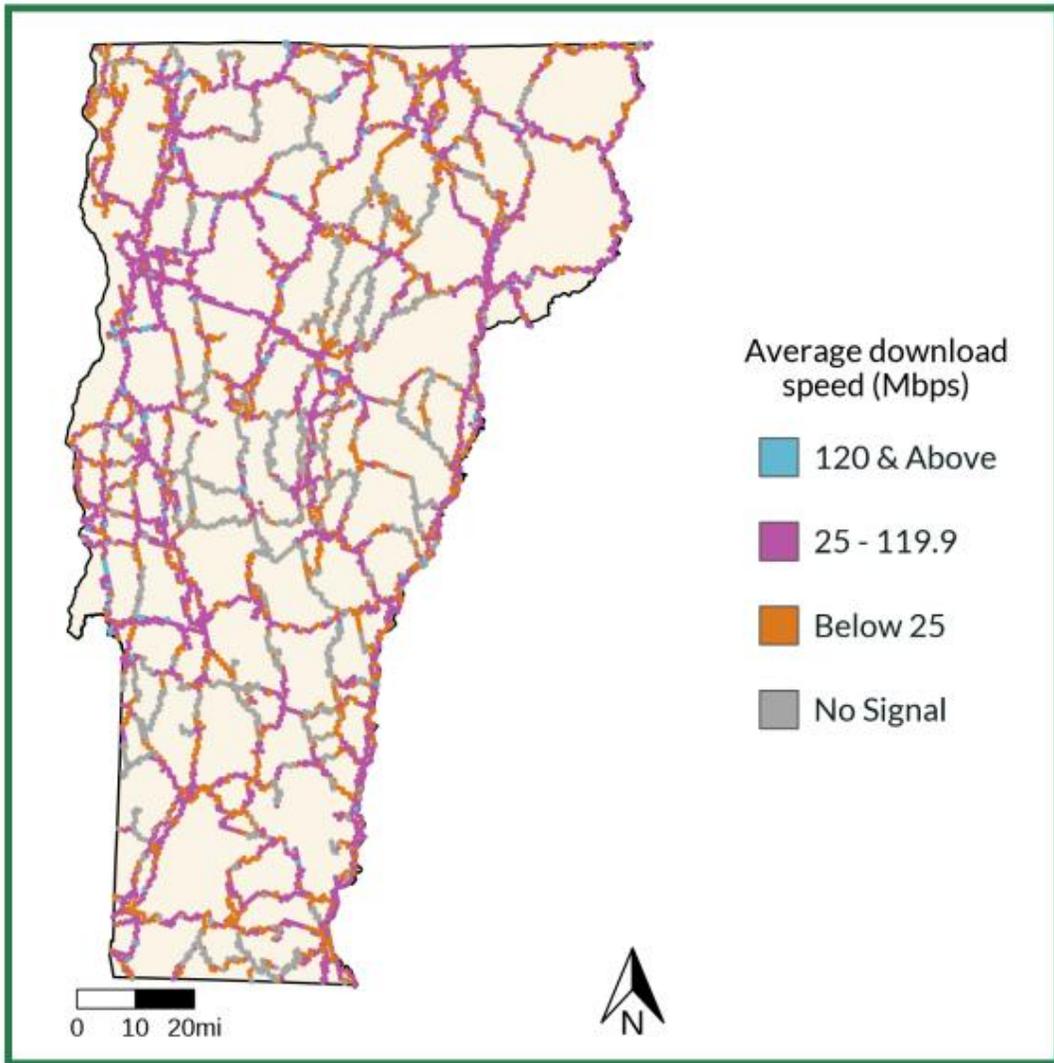
Figure B6   Average mobile wireless download speeds for all tested providers on Vermont roadways in 2022
Source: Vermont PSD (Dec 2023) [14]

Mobile wireless coverage is further disaggregated by carrier in Figure B7.
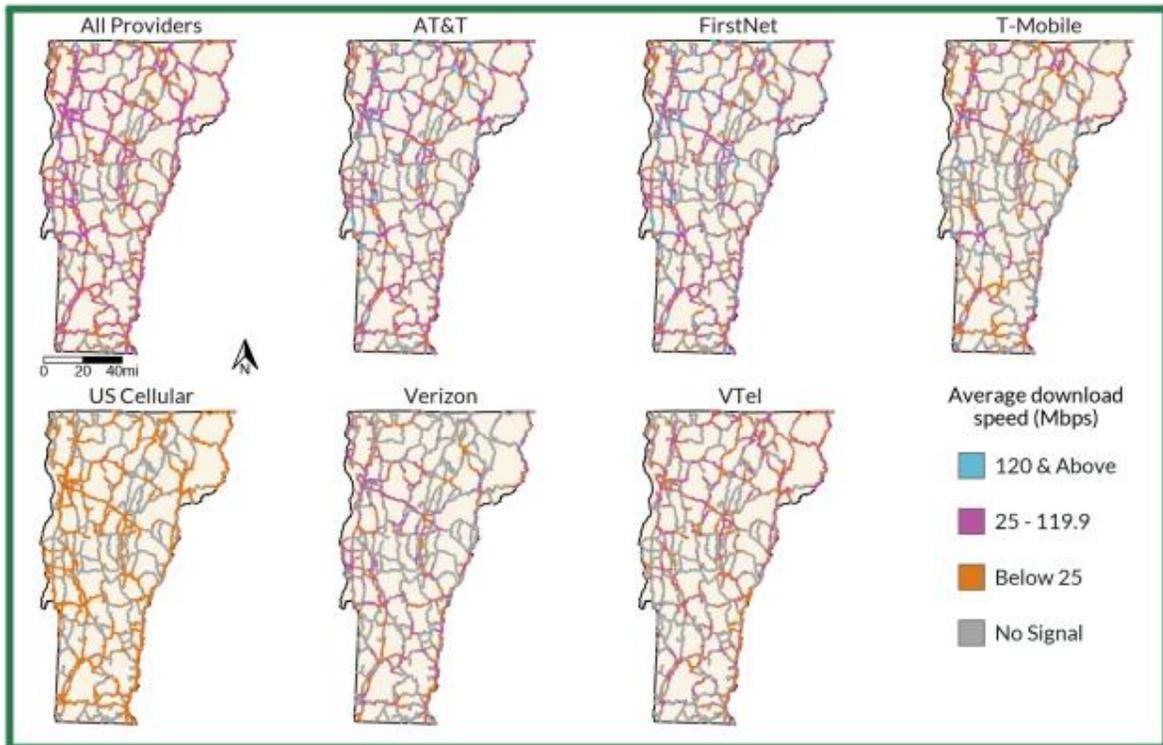
Figure B7   Average mobile wireless download speeds on Vermon roadways in 2022 by provider
Source: Vermont PSD (Dec 2023) [14]

Additional information concerning in depth provider performance, improvements in coverage from 2018 till 2022, and results of a user satisfaction survey of the wireless carrier are available from Vermont [14].

The final map in Figure B8 depicts both broadband data access combined with the wireless cellular assessment providing a valuable perspective of the spatial coverage of data access throughout the state.
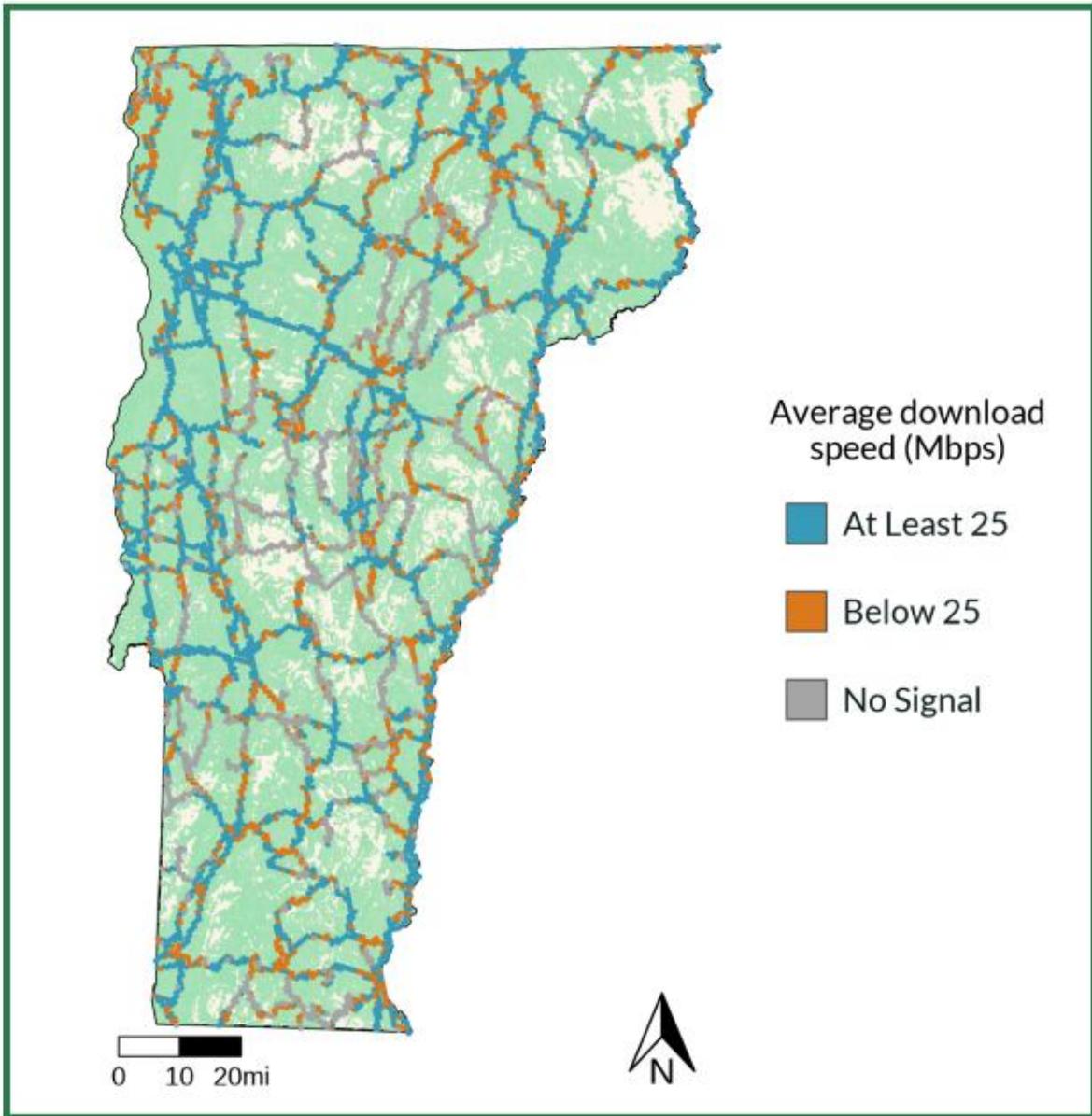
Figure B8   Estimated mobile broadband coverage and average mobile wireless download speeds
on Vermont roadways in 2022
Source: Vermont PSD (Dec 2023) [14]

Appendix C: Use of Confidence Scores for Vermont Coverage Assessment

In 2023, as Vermont was beginning its procurement and use of vehicle probe data, concerns were raised when one of the major industry data supply chains was disrupted. Wejo, which provided connected vehicle data from a major OEM, went bankrupt. Wejo had previously provided highly detailed data reflecting the position of vehicles within its fleet once every three seconds. This data was available for approximately 2% of all vehicles on the roadway based on comparisons between Wejo reported probes and volume counts at continuous count stations. The Wejo data had been integrated into a number of value added data resellers by this time. Most probe vehicle data vendors source data from multiple providers within the supply chain, so as not to be overly dependent on any one provider, which in turn allowed for resilience from disruptions in any one supply chain link. The probe data vendor under contract to Vermont Agency of Transportation (AOT), included Wejo as one of its supply chains of probe data, from which various data tools and products were being provided to Vermont AOT. Vermont AOT wanted to know and better understand the extent to which the loss of Wejo data would degrade the accuracy and availability of probe vehicle data for the state of Vermont. Being primarily a rural state, a loss of a major data provider may have significant impact.

The Eastern Transportation Coalition (TETC) Transportation Data Marketplace (TDM) staff performed several analyses to characterize the impact of the loss of Wejo data using the *'confidence score'* embedded in the data feed. A confidence score is required for any core data vendor providing travel time and speed within the TDM. Each vendor can define the technical form of the confidence score metric, but the confidence score must reflect whether travel time and speed data is derived directly from observations, or whether a default value based on either assumed freeflow conditions, speed limit, or historical average is used when real-time observations are not available. The vendor (INRIX) providing travel time and speed data to Vermont AOT defines confidence score as follows:

- 30 = Real Time Data
- 20 = Historical Average
- 10 = Reference Speed

If there is sufficient data to accurately report travel time and speed, the confidence score from INRIX is equal to 30. If the amount of real-time probe data is insufficient, the score may be either a 20 or a 10. Other probe data vendors use various methods to report confidence, many using a scale between 0 and 100, with 100 being high confidence data based on observations of probe vehicles in real time. As the number of probes diminish, and inferences are based more and more on either a historical average or a reference speed, the confidence score drops accordingly. The drop in confidence score is most notable during overnight, off-peak hours. As traffic diminishes into the night, the volume of vehicles likewise diminishes, such that the opportunity to observe any probe vehicle (a proportion of actual traffic) likewise diminishes. It is typical to observe the confidence score remain near its maximum value until late in the evening, and then gradually diminish, reflecting more and more reliance on historical averages or reference speeds late into the night, and then the confidence score will

quickly escalate from its lowest value to its maximum value at the onset of the AM rush hour.

In order to assess the impact of the loss of Wejo as part of the foundational data input to the travel time and speed data delivered from INRIX, the TDM staff first investigated the distribution of confidence score historically for two counties, one in Maryland and one in Virginia. Maryland and Virginia counties were chosen because they have a long history of available data, whereas Vermont historical data is limited to only a couple of years of available data.

The historical data for Frederick County, MD is shown in figure C1 from approximately 2013 through 2024. The percentage of real time data (confidence score = 30) is shown by functional road class (FRC) 1 through 4, and as an aggregate of all roadway segments. The percentage of one minute intervals of reported travel time and speed with a confidence score equal to 30 averaged 40% across all road classes in 2014, and reached as high as 80% by 2023. Interstates (FRC 1), averaged over 90 percent real time data (confidence score = 30) during this entire period. As the roadway class decreases, so does the percentage of real-time data because lower class roadways carry less volume, and have less probability of observing a real-time probe vehicle, particularly during non-peak hours. The overall average confidence score, shown in black, reflects the combined average score by FRC and is weighted by miles of roadway. This average is heavily weighted by the lower functional road classes because there are typically many more miles of lower road classes than higher road classes.

Real time data increased over time, with significant step increases in 2019 and 2020/21 time frames. These correspond to when additional source data was procured and included in the probe data vendor's products. The collection of source data from which a vendor derives information and data feeds is referred to as their 'data panel'. The highlighted area in shaded gray depicts the decrease in real time data in 2023 corresponding to the loss of Wejo connected vehicle data when Wejo went bankrupt and ceased operations. Note that the average level of confidence score decreased to approximately 2020 levels, which corresponds to pre-Wejo integration.

Figure C1   Average confidence score for one minute travel time data in Frederick County, MD
Source: Eastern Transportation Coalition

Similarly, the historical data for Arlington, VA is shown in figure C2. The patterns are similar to that of Frederick, MD above, with the loss of Wejo data highlighted in 2023.

Vermont data could not be assessed in a similar fashion due to lack of historical data.

Figure C2   Average confidence score for one minute travel time data in Arlington, VA
Source: Eastern Transportation Coalition

At the time of the analysis, only one year of travel time and speed data covering January through December 2023 was available within Vermont. The Vermont data was analyzed by time of day and by roadway class for the entirety of 2023.

The results for Vermont by time of day across all covered roadways is shown in Figure C3. This includes over 974 million records corresponding to 1856 defined segments (TMCs), each having 1 minute data records for the year. The general diurnal pattern of real-time data availability is reflected in the chart. From Midnight to early morning, the percent of real-time data is at its lowest, reflecting the low volumes during these overnight periods during which data feeds rely on a surrogate such as freeflow speed, posted speed limit or 85th percentile speed. The percent of real-time data begins to escalate at 5 AM, reach its peak between 9 AM to 10 AM, sustain high percentages of real-time data throughout the day, and then begins to diminish after the evening rush hour about 6 to 7 PM. Note that in June of 2023, the general pattern continues to hold, with the peak of real-time data (average over all segments) just under 80 percent during the busiest times of day, as opposed to above 90 percent prior to losing Wejo data. Similarly, in the middle of the night, the percent of real time data would dip into the teens after losing Wejo, whereas before it was generally 30 to 40 percent even in the middle of the night.

Another impact of losing Wejo data was the change in period of peak coverage. Prior to losing Wejo, peak coverage occurred in the morning at about 7 or 8 AM, and held its value into the evening hours until after 7 PM – with 90% or above segments reporting real-time data (confidence score = 30) during this time. After losing Wejo, peak coverage was reduced to 70% or greater, an the onset peak coverage occurred at 8 to 9 AM, and lasted till 6 PM, at which it began to diminish. The differences in coverage

between January through May (with Wejo data) and June through December (without Wejo data) reflects these trends in Figure C3.

Vermont (Time of Day)

TMCs = 1856
Records = 974M

Month	Overall	Hour 0	Percent of 1-minute records with confidence score = 30 (real-time)																						
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	78	49	40	35	37	45	65	80	89	93	95	95	95	96	95	95	96	96	95	94	91	87	81	69	59
Feb	78	49	39	34	36	45	66	81	90	94	95	96	96	94	94	95	96	96	96	94	92	88	83	70	61
Mar	79	49	40	35	37	47	67	82	91	94	95	95	96	96	96	96	96	96	96	94	92	88	83	70	60
Apr	77	44	35	31	34	44	64	80	88	93	95	95	96	96	96	96	95	96	95	93	90	87	81	66	55
May	78	45	34	29	33	45	66	83	91	94	95	96	96	96	96	96	96	96	96	95	92	90	84	69	58
Jun	55	22	17	15	16	21	37	51	63	71	75	77	78	79	79	79	79	78	76	70	62	55	47	34	27
Jul	54	22	17	16	16	20	34	47	59	67	72	76	78	79	79	79	79	78	75	70	62	55	48	35	28
Aug	54	20	16	14	15	20	35	51	63	71	74	77	79	79	79	79	79	79	76	71	63	55	47	34	26
Sep	52	16	13	12	12	18	33	47	60	68	72	75	77	77	77	77	77	77	75	69	61	52	43	30	23
Oct	52	16	12	11	13	18	34	48	61	69	73	75	78	78	78	78	78	78	75	69	60	51	42	29	22
Nov	51	17	13	12	13	19	33	47	60	69	72	74	76	77	75	75	75	75	72	66	57	48	39	28	22
Dec	52	19	15	12	13	19	31	44	58	67	72	74	76	77	77	77	76	76	73	69	61	52	44	32	25
Avg Jan-May	78	47	38	33	36	45	66	81	90	94	95	96	96	96	96	96	96	96	96	94	91	88	82	69	59
Avg Jun-Dec	52	19	15	13	14	19	34	48	60	69	73	76	77	78	78	78	78	77	75	69	61	52	44	32	25
Diff	-26	-28	-23	-20	-21	-26	-32	-33	-29	-25	-22	-20	-18	-17	-18	-18	-18	-19	-21	-25	-31	-36	-38	-37	-34

Figure C3   Assessment of confidence score by time of day in Vermont during 2023
Source: Eastern Transportation Coalition

A second analysis was conducted by roadway class in Vermont, spanning FRC 1 through FRC 5 and roadways off the National Highway System. The results are shown in Figure C4. The number of segments in each roadway class (roughly proportional to roadway miles in each class) is also shown to the right. The drop in percent of real time data on average is 26%, but with higher roadway classes being less impacted (about 11%), and lower roadway classes having progressively larger impacts, approaching a drop of 30% for the lowest road class segments. These findings are consistent with the trends revealed from historical data from Maryland and Virginia as revealed in Figure C1 and C2.

The same analysis was performed in Washington DC (Figures C5 and C6) as well as for the state of Maryland (Figures C7 and C8) as shown below. In both cases the patterns were similar as those experienced in Vermont as revealed in Figures C3 and C4. Note the data came from the same core data provider and the loss of Wejo created similar patterns in each area.

Vermont (Road Class)

TMCs = 1856
Records = 974M

Month	Percent of 1-minute records with confidence score = 30 (real-time)							# TMC Segments					
	Overall	FRC1	FRC2	FRC3	FRC 4	FRC5	Off-NHS	FRC1	FRC2	FRC3	FRC 4	FRC5	Off-NHS
Jan	78	89	84	86	85	64	73	234	328	49	114	25	1105
Feb	78	89	84	86	85	65	74	234	328	49	114	25	1105
Mar	79	90	85	88	86	66	74	234	328	49	114	25	1106
Apr	77	89	83	86	85	62	72	234	328	49	114	25	1106
May	78	89	84	87	86	61	73	234	328	49	114	25	1106
Jun	55	80	66	66	66	30	45	234	328	49	114	25	1106
Jul	54	80	64	65	64	29	44	234	328	49	114	25	1106
Aug	54	80	66	66	64	27	44	234	328	49	114	25	1105
Sep	52	77	63	63	62	25	42	234	328	49	114	25	1106
Oct	52	77	63	62	61	26	43	234	328	49	114	25	1106
Nov	51	76	62	62	61	26	41	234	328	49	114	25	1106
Dec	52	76	62	62	61	25	42	234	328	49	114	25	1106
Avg Jan-May	78	89	84	87	85	64	73						
Avg Jun-Dec	52	78	64	64	63	27	43						
Diff	-26	-11	-20	-23	-23	-37	-30						

Figure C4   Assessment of confidence score by roadway class in Vermont during 2023
Source: Eastern Transportation Coalition

Washington, DC (Time of Day)

TMCs = 3661
Records = 1.9B

Month	Percent of 1-minute records with confidence score = 30 (real-time)																								
	Overall	Hour 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	91	87	81	76	71	71	78	85	91	95	96	97	98	98	98	98	98	98	98	98	97	96	95	93	90
Feb	91	87	81	75	70	70	78	86	92	95	97	98	98	97	97	98	98	98	98	98	97	96	95	93	91
Mar	91	87	81	75	70	70	79	87	92	96	97	97	98	98	98	98	98	98	98	98	98	97	96	94	91
Apr	90	85	78	71	66	67	75	84	90	95	96	97	97	97	98	98	98	98	98	97	97	96	95	93	90
May	90	85	78	70	65	66	75	84	91	95	96	97	97	97	97	97	98	98	98	97	97	96	95	93	90
Jun	74	59	49	43	39	40	49	62	74	83	87	88	89	89	90	90	90	90	90	89	86	83	80	74	67
Jul	72	58	48	41	37	38	48	59	71	80	84	86	87	88	89	89	89	89	88	87	85	82	78	73	66
Aug	72	54	45	38	34	37	48	62	74	82	86	87	88	88	88	88	89	89	88	87	85	81	77	71	64
Sep	73	57	47	40	35	37	48	60	73	82	85	87	88	89	89	89	90	90	89	89	87	83	79	73	66
Oct	73	56	46	38	34	37	48	61	74	82	86	88	89	90	90	90	90	90	90	89	87	83	79	72	65
Nov	73	56	46	39	35	37	47	60	73	82	86	88	89	89	89	89	90	90	90	88	86	82	78	72	65
Dec	72	57	48	41	36	37	45	58	69	78	83	86	87	88	88	89	89	89	89	87	85	81	77	72	65
Avg Jan-May	91	86	80	73	68	69	77	85	91	95	96	97	97	98	98	98	98	98	98	98	97	96	95	93	91
Avg Jun-Dec	73	57	47	40	36	38	47	60	72	81	85	87	88	89	89	89	89	90	89	88	86	82	78	72	66
Diff	-18	-29	-33	-34	-33	-31	-30	-25	-19	-14	-11	-10	-9	-9	-9	-9	-8	-8	-9	-10	-11	-14	-17	-21	-25

Figure C5   Assessment of confidence score by time of day in Washington DC during 2023
Source: Eastern Transportation Coalition

Washington, DC (Road Class)

Month	Percent of 1-minute records with confidence score = 30 (real-time)							# TMC Segments					
	Overall	FRC1	FRC2	FRC3	FRC 4	FRC5	Off-NHS	FRC1	FRC2	FRC3	FRC 4	FRC5	Off-NHS
Jan	91	-	100	97	95	90	88	-	244	647	290	79	2382
Feb	91	-	100	97	95	91	88	-	244	647	290	81	2386
Mar	91	-	100	97	95	91	88	-	244	648	290	81	2398
Apr	90	-	100	97	95	89	86	-	244	648	290	81	2398
May	90	-	100	97	94	89	86	-	244	648	290	81	2398
Jun	74	-	98	89	85	73	66	-	244	648	290	81	2398
Jul	72	-	98	89	84	71	64	-	244	648	290	81	2398
Aug	72	-	97	88	83	71	64	-	244	648	290	81	2398
Sep	73	-	97	88	83	72	65	-	244	648	290	81	2398
Oct	73	-	97	88	83	72	66	-	244	648	290	81	2398
Nov	73	-	97	88	83	71	65	-	244	648	290	81	2398
Dec	72	-	98	88	83	70	64	-	244	648	290	81	2398
Avg Jan-May	91		100	97	95	90	87						
Avg Jun-Dec	73		98	88	83	71	65						
Diff	-18		-2	-9	-11	-19	-22						

Figure C6   Assessment of confidence score by roadway class in Washington DC during 2023
Source: Eastern Transportation Coalition

Maryland (Time of Day)

Month	Percent of 1-minute records with confidence score = 30 (real-time)																								
	Overall	Hour 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan	88	76	69	64	62	65	77	86	92	95	96	97	97	97	97	97	97	97	97	97	96	95	92	87	82
Feb	88	76	68	62	60	64	76	86	92	96	97	97	97	96	96	97	97	97	97	97	96	95	92	88	83
Mar	88	76	68	62	60	65	77	86	93	96	97	97	97	97	97	97	97	98	98	97	96	95	93	88	83
Apr	87	74	67	60	58	62	75	84	91	94	96	96	96	97	97	97	97	97	97	96	95	94	92	87	82
May	87	74	66	60	57	62	75	85	92	95	96	96	97	97	97	97	97	97	97	96	96	94	93	88	82
Jun	69	48	41	36	35	38	50	63	74	80	83	84	85	86	86	86	86	86	86	83	80	76	71	62	55
Jul	67	46	39	34	32	35	47	59	70	77	81	82	84	85	85	85	85	85	84	82	78	74	69	61	54
Aug	67	43	36	32	31	35	48	62	73	80	82	83	84	85	85	85	86	85	85	82	78	74	68	59	51
Sep	66	41	34	30	28	32	45	59	71	79	81	82	83	83	83	84	85	85	84	82	78	73	67	57	49
Oct	66	41	34	30	28	32	46	60	72	80	82	83	84	84	85	85	86	86	85	83	79	74	67	57	49
Nov	66	42	35	31	30	33	46	60	72	79	82	83	84	85	85	85	85	85	85	82	78	73	67	57	49
Dec	66	44	37	32	30	33	44	57	68	76	80	82	83	84	84	84	85	85	84	82	78	73	68	59	51
Avg Jan-May	87	75	68	62	59	64	76	85	92	95	96	97	97	97	97	97	97	97	97	97	96	95	93	88	82
Avg Jun-Dec	66	43	37	32	30	34	47	60	71	79	82	83	84	84	85	85	85	85	84	82	78	74	68	59	51
Diff	-21	-32	-31	-29	-29	-30	-29	-26	-21	-16	-14	-14	-13	-12	-12	-12	-12	-12	-13	-15	-17	-21	-24	-29	-31

Figure C7   Assessment of confidence score by time of day in Maryland during 2023
Source: Eastern Transportation Coalition

Maryland (Road Class)

right
TMCs = 20,686
Records = 10.7B

Month	Percent of 1-minute records with confidence score = 30 (real-time)							# TMC Segments					
	Overall	FRC1	FRC2	FRC3	FRC 4	FRC5	Off-NHS	FRC1	FRC2	FRC3	FRC 4	FRC5	Off-NHS
Jan	88	100	98	96	95	88	83	939	1512	2433	1890	130	12667
Feb	88	99	98	96	94	88	83	939	1512	2433	1890	130	12667
Mar	88	100	98	97	95	89	83	939	1512	2434	1891	130	13791
Apr	87	100	98	97	94	87	82	939	1512	2434	1891	130	13775
May	87	100	98	97	94	87	82	939	1512	2434	1891	130	13765
Jun	69	99	94	87	79	66	60	939	1512	2434	1891	130	13765
Jul	67	99	94	86	77	63	57	939	1512	2434	1891	130	13763
Aug	67	99	94	85	76	62	58	939	1512	2434	1891	130	13763
Sep	66	99	92	83	75	60	56	939	1512	2434	1891	130	13763
Oct	66	99	92	84	75	62	57	939	1512	2434	1891	130	13767
Nov	66	99	92	84	76	62	57	939	1512	2434	1891	130	13776
Dec	66	99	93	84	75	60	56	939	1512	2434	1891	130	13780
Avg Jan-May	87	100	98	97	94	88	83						
Avg Jun-Dec	66	99	93	85	76	62	57						
Diff	-21	-1	-5	-12	-18	-26	-25						

Figure C8   Assessment of confidence score by roadway class in Maryland during 2023
Source: Eastern Transportation Coalition

A similar analysis was performed in Atlanta, GA as shown in Figures C9 and C10. However, the core data provider for travel time and speed in the state of Georgia was different from previous examples. This vendor did not incorporate Wejo data as part of its data panel. As a result the analysis showed that the percent of real-time data did not experience any impact during June of 2023 as a result of the Wejo bankruptcy. Each core data vendor defines the 'confidence score' metric differently. This vendor uses a number between 0 and 100, with '100' equating to high confidence in the reported travel time and speed based on observing probe vehicles. Each vendor's metric can be used to reflect a relative percentage of real-time data versus times when a surrogate is used for travel time and speed. However, the algorithms used to determine each vendor's confidence score is unique and proprietary. As such the reader is cautioned with respect to direct comparisons of confidence score or percent real-time data.

Atlanta (Time of Day)

Month	Overall	Hour 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
												Percent of 1-minute records with confidence score = 30 (real-time)													
Jan	81	72	64	56	51	49	57	71	81	87	90	91	92	93	94	94	94	95	95	94	92	89	87	85	80
Feb	83	74	65	58	52	50	59	73	84	90	92	93	93	94	94	95	95	95	95	95	94	90	89	87	83
Mar	84	77	67	59	53	50	60	74	85	90	92	92	93	94	95	95	95	96	96	96	94	92	90	88	84
Apr	84	78	70	63	57	52	59	73	84	89	92	92	93	95	95	95	95	96	96	95	94	92	91	88	86
May	84	78	69	61	55	52	59	74	85	90	92	93	93	94	95	94	95	95	95	94	93	90	90	88	85
Jun	84	78	69	61	55	51	59	74	84	89	92	92	93	94	94	94	94	94	95	95	94	91	91	89	86
Jul	84	79	70	61	57	52	58	72	82	88	91	92	93	94	95	95	95	96	95	94	94	91	91	89	86
Aug	84	79	69	60	54	51	60	75	86	91	93	93	94	94	95	95	96	96	96	95	94	92	90	89	85
Sep	85	80	71	62	56	53	60	73	85	90	92	93	94	94	95	95	95	96	96	95	94	93	91	89	85
Oct	85	80	71	63	58	55	61	75	84	90	92	93	93	94	94	94	95	96	96	96	95	93	91	89	86
Nov	83	78	68	58	54	50	59	74	84	89	92	93	94	94	95	95	95	95	95	95	93	90	90	88	84
Dec	83	78	69	61	55	51	57	72	80	86	90	91	93	94	94	94	94	95	95	94	93	91	89	88	84
Avg Jan-May	83	76	67	59	54	50	59	73	84	89	91	92	93	94	94	95	95	95	95	95	93	91	89	87	83
Avg Jun-Dec	84	79	70	61	55	52	59	74	84	89	92	92	93	94	95	95	95	95	95	95	94	92	90	89	85
Diff	1	3	2	1	2	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2

Figure C9   Assessment of confidence score by time of day in Atlanta during 2023
Source: Eastern Transportation Coalition

Atlanta (Road Class)

Month	Overall	FRC1	FRC2	FRC3	FRC 4	FRC5	Off-NHS	FRC1	FRC2	FRC3	FRC 4	FRC5	Off-NHS
	Percent of 1-minute records with confidence score = 30 (real-time)							# TMC Segments					
Jan	81	100	93	96	83	77	78	42	89	175	57	2	1431
Feb	83	100	93	97	85	82	80	42	89	175	57	2	1431
Mar	84	100	93	97	85	85	81	42	89	175	57	2	1427
Apr	84	100	93	97	86	85	81	42	89	174	56	2	1424
May	84	100	94	97	85	84	81	42	89	175	57	2	1427
Jun	84	100	95	97	84	84	81	42	89	175	57	2	1424
Jul	84	100	96	97	84	83	81	42	89	175	57	2	1427
Aug	84	100	95	97	85	85	82	42	89	175	57	2	1427
Sep	85	100	96	97	85	84	82	42	89	174	56	2	1424
Oct	85	100	96	97	85	87	82	42	89	174	56	2	1424
Nov	83	100	96	97	84	84	81	42	89	175	57	2	1427
Dec	83	100	95	97	84	83	80	42	89	175	57	2	1427
Avg Jan-May	83	100	93	97	85	83	80						
Avg Jun-Dec	84	100	96	97	84	84	81						
Diff	1	0	2	0	0	2	1						

Figure C10   Assessment of confidence score by roadway class in Atlanta during 2023
Source: Eastern Transportation Coalition