Rural and Small Metropolitan Intelligent Transportation Systems Case Studies

February 2020
Draft Final

Prepared by the National Association of Development Organizations (NADO) Research Foundation for the U.S. Department of Transportation Intelligent Transportation Systems Joint Program Office

Executive Summary

Intelligent transportation systems (ITS) projects include a wide variety of applications where communications technologies are connected to transportation systems. Rural and small metropolitan areas can see benefits to transportation safety, mobility, and operations, but they may experience challenges due to long distances, smaller populations, telecommunications connectivity issues, and funding for transportation improvements. This research combined a review of existing literature on rural and small metropolitan ITS with interviews of transportation professionals and primary source research to identify case studies.

The report presents case studies highlighting the work of state, regional, local, and nonprofit agencies using ITS in rural, small metropolitan, and suburban or exurban places around the United States. Several themes emerged across the cases, including important roles for state, regional, and local agencies in preparing for and investing in ITS; the significance of capacity building for staff on ITS; and the need to invest in rural broadband along with ITS.

About the NADO Research Foundation

Founded in 1988, the NADO Research Foundation is the nonprofit research affiliate of the National Association of Development Organizations (NADO). The NADO Research Foundation identifies, studies, and promotes regional solutions and approaches to improving local prosperity and services through the nationwide network of regional development organizations (RDOs). The Research Foundation shares best practices, offers professional development training, analyzes the impact of federal policies and programs on RDOs, and examines the latest developments and trends in small metropolitan and rural America. Most importantly, the Research Foundation is helping bridge the communications gap among practitioners, researchers, and policymakers. Learn more at www.NADO.org and www.RuralTransportation.org.

This report was primarily authored by NADO Program Manager Rachel Beyerle and NADO Associate Director Carrie Kissel. Many transportation agency staff and others assisted with this project in a variety of ways. We offer deep and heartfelt thanks to all the individuals who have provided information and images, consented to be interviewed, and offered editorial guidance in support of this research. This work is supported by the U.S. Department of Transportation under requisition number HOIT190194PR. Any opinions, findings and conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of U.S. DOT or the NADO Research Foundation.

Contents

Executive Summary 2

About the NADO Research Foundation 2

1 Introduction 5

2 ITS in Rural and Small Urban Areas: Overview of Needs and Concerns 6

2.1 Roadway and Traveler Information ITS Applications 6

2.2 Public Transportation Applications 7

2.3 Automated and Connected Vehicle ITS Applications 7

2.4 Research Results and Conclusions 7

3 Travel Information Case Studies 9

3.1 Weather and Road Condition Information in Georgia 9

3.2 IITS Assists Evacuations in Georgia 12

3.3 Using ITS to Improve Traffic Conditions and Visitor Experiences in the National Parks 13

3.4 Rocky Mountain National Park: Experiences and Lessons Learned from Using ITS for Traveler Information 17

4 Management and Operations Case Studies 20

4.1 Dynamic Message Signs and Speed Radar Detectors Deployed to Address Special Events and Safety 20

4.2 Flood Gate System Improves Road Closure Operations and Public Safety 23

5 Transportation Safety and Health Case Studies 27

5.1 Dynamic Warning Systems Enhance Safety for Cyclists and Vehicles on Scenic Roadways 27

5.2 Sign Technology Affects Driver Behavior at Railroad Crossings 28

5.3 South Dakota DOT Implements Intersection Conflict Warning System 30

5.4 Using Passive Pedestrian Detection for Trail and Roadway Crossings 31

5.5 Adapting Non-Traditional Technology for Bicycle and Pedestrian Uses 33

6 Transit and Mobility Case Studies 36

6.1 Technology Improves Western Iowa Transit Operations 36

6.2 Scheduling and Dispatching Deployment and Broadband Expansion in Rural Ohio 38

6.3 Software Supports Volunteer Transportation 42

7 Preparing for Vehicle Connectivity and Automated Vehicles Case Studies 44

7.1 Using Vehicle Connectivity Technology for Roadway Weather Response 44

7.2 Partnerships Support Rural Technology Deployment Along Wyoming's I-80 Corridor 47

7.3 Testing Vehicle and Infrastructure Connectivity in Marysville, Ohio 49

7.4 Minnesota Plans for Connected and Automated Vehicles 51
Appendix A: Additional Resources 59
Appendix B: Acronyms and Abbreviations 66

1 Introduction

Advances in digital communications, geospatial technologies, and information transfer have increased opportunities to improve user experience, safety, and traveler information across all transportation modes. Over the past decade, intelligent transportation systems (ITS) deployments for highways, public transportation, and bicycle and pedestrian travel have ranged from enhanced lighting and signage pilots at a single location to statewide connected vehicle and weather information systems. In its *Intelligent Transportation Systems Benefits, Costs, and Lessons Learned: 2018 Update Report*, the U.S. Department of Transportation (DOT) ITS Joint Program Office defines ITS as "the integration of advanced communication technologies into the transportation technologies and vehicles. Intelligent transportation systems encompass a broad range of wireless and wire line communications-based information and electronics technologies."[1] Application of ITS technologies has been traditionally associated with urbanized area networks in part due to the planning and engineering resources required. In communities with higher traffic volumes, transit ridership, or predictable congestion patterns, ITS projects have been perceived to have a greater return on investment for the state or local government initiating the project, as documented in *Rural Connected Vehicle Gap Analysis: Factors Impeding Deployment and Recommendations for Moving Forward*.[2] As a result, rural transportation networks have not been viewed as traditional candidates for ITS applications. Because of demands to find new solutions to address rural-specific transportation issues, this view has been shifting over time.

What are examples of rural-specific transportation challenges? Rural areas experience high speed traffic and higher traffic fatality rates. Rural roadways are more likely to be constructed on variable terrain, experience higher levels of interaction between vehicles and wildlife, and are affected by extreme weather conditions across the seasons. Federal agencies, state DOTs, RDO and regional transportation planning organizations (often known as RTPOs or RPOs), and local agencies are exploring ways that technology can address these long-standing issues through safety countermeasures and improved driver awareness. During preparation of *Rural and Small Metropolitan Intelligent Transportation Systems Case Studies*, the NADO Research Foundation reviewed technical resources that focused on ITS implementation in rural areas. A core set of recently written reports provided an overview of how ITS is being applied in the areas of collision deterrence, connected vehicles, general highway safety, and public transportation trip planning and scheduling.

The NADO Research Foundation's work takes these reports a step further by documenting a series of case studies that identify how local and regional agencies are involved in ITS planning or projects, the extent to which applications have made a difference in addressing issues beyond metropolitan area boundaries, and identifiable lessons learned from the transportation professionals who are implementing the projects. The research process included reviewing primary source documents such as transportation plans, project documentation, and agency websites, as well as email, telephone, and in-person interviews conducted with transportation professionals. The case studies reflect a range of ITS deployments that fall into categories that The National Center for Rural Road Safety identified in its 2018 *Rural Intelligent Transportation Systems Toolkit*. The toolkit places ITS applications into seven categories: crash countermeasures, traffic management, operations and maintenance, emergency services, surface transportation and weather, rural transit and mobility; and tourism and travel information.[3] Using these categories as a framework, the NADO Research Foundation examined how these commonly used rural applications are being implemented. The challenges and opportunities involved in implementation are described in the following section summarizing some of the relevant literature.

2 ITS in Rural and Small Urban Areas: Overview of Needs and Concerns

Rural ITS applications improve driver awareness and safety through communications, lighting, and signage. The primary benefits of applying ITS tools in rural areas include improved weather information and warnings, increased safety through road curve signage, high-speed crash prevention, and reduction in animal-vehicle collisions, according to the report *Rural Connected Vehicle Gap Analysis: Factors Impeding Deployment and Recommendations for Moving Forward*. When asked why rural ITS applications have been slow to get off the ground, subject matter experts have posed several reasons why ITS implementation in rural areas has been delayed. Reasons include, but are not limited to, lower traffic volumes than urban areas, a lower tax base to pay for ITS projects, and less predictable congestion patterns, less political clout (over urban areas) to implement and operate transportation technologies."

When congestion does occur in rural areas, it is often due to short-term road construction, special events, or weather. When asked about their top ITS concerns, experts identified the primary issues as return on investment, (versus deploying the same ITS application in a more dense and populous location), difficulty in applying ITS in areas with physical barriers or rugged terrain, and cellular network capacity.[4]

2.1 Roadway and Traveler Information ITS Applications

ITS applications being piloted or permanently deployed in rural areas range from small-scale, single-location projects to large-scale, multi-jurisdictional projects reliant on interconnected communications. Sample single-location projects include the use of standard signs that are enhanced with light-emitting diode (LED) bulbs that flash to alert drivers or vehicle sensor deployments at locations with high crash rates. These advance warning systems, which combine vehicle detection mechanisms, flashing beacons, and signage, are typically piloted in locations where cross traffic is not visible or when speeds are high and gaps in traffic are difficult to predict. Railroad crossing approaches or alternative transportation facility crossings (e.g., bicycle, equestrian, pedestrian, or recreational vehicle paths) are ideal locations for testing these relatively simple and basic ITS technologies.

In other locations where conditions change on a frequent basis, dynamic forms of communication are typical. One example is the variable or dynamic message sign used to communicate information on conditions related to detours, parking, and weather conditions. Federal land agencies and rural communities have increased use of dynamic message signs to post traveler information at a geographic juncture where the driver has time to decide to continue to travel as originally planned or detour to a different route or activity.[5] In some areas, travelers may have the option of choosing a different mode of transportation, but this is not always immediately available in rural places. In addition to physical signs, additional types of dynamic messaging include advisory radio announcements, 511 systems, and social media communication. Within social media communication, Facebook is used to relay information for advance planning, and Twitter is relied on to distribute immediate messages on changing conditions.[6]

2.2 Public Transportation Applications

Public transportation ITS applications are oriented toward operations, security, and customer interfaces. The U.S. Government Accountability Office (GAO) conducted interviews with transportation and transit officials to discuss public transportation ITS deployments in rural areas. Sample deployments include geographic information systems-based General Transit Feed Specification (GTFS) or GTFS-Flex feeds that serve Google Maps and Google Transit or agency-based trip planners. Other intelligent technologies commonly used by public transportation systems include security systems (e.g., audio or video surveillance), computer-aided dispatch, and automated vehicle location. Smaller systems reported using technology for maintenance management, traveler information systems, automatic passenger counters, electronic fare payment, and transit signal prioritization. The results of the GAO interviews mirror an earlier 2005 Transit Cooperative Research Program report on *Strategies to Expand and Improve Deployment of ITS in Rural Transit Systems* in which statewide ITS planning focused on enhanced traveler information, automatic vehicle location, automated dispatch and scheduling, online ride requests, and electronic fare collection.[7]

In separate research conducted in New York State by Scott Altman and Susan Bregman, transit and transportation agency representatives identified the following barriers to rural ITS implementation: limited staff size, limited financial resources, digital capabilities of customers, levels of smartphone ownership, computer usage, and broadband access. Best practices identified by transportation agency managers include knowing customer preferences for receiving information, providing up-to-date maps, schedules and service alerts, and leveraging technology used by larger agencies, such as the statewide 511 system and state DOT technical assistance.[8]

2.3 Automated and Connected Vehicle ITS Applications

In addition to roadway, mobility, and alternative transportation ITS applications, this report includes case studies on vehicle connectivity pilot projects that are aimed at improving highway safety, providing real-time weather conditions for travelers and truck fleets, and coordinating state DOT snowplow operations. Vehicle connectivity is being tested in some rural areas, and even if local jurisdictions are not implementing all of the projects, their regions are affected.

A National Cooperative Highway Research Program report on *Strategies to Advance Automated and Connected Vehicles* touches on the aspect of how automated vehicles and connected vehicles are tied to existing regional transportation planning subject matter such as traffic safety and crashes, congestion, land development, and mobility.[9]

2.4 Research Results and Conclusions

This report expands on prior case studies by addressing the planning and partnerships involved in financing, implementing, and evaluating the impacts of rural ITS applications. Each case study was selected because it involves technology tools that are possible for rural and small urban area agencies to implement within a single jurisdiction or across a larger geographic area when working in partnership with federal, state, or multi-jurisdictional partnerships. These projects address practical transportation network needs, such as safety, traveler information, and accessibility. In addition, the featured projects provide a glimpse at how rural regions are taking steps to build capacity for ITS and are considering technology solutions to address ongoing issues, enhance safety, and make the most of limited human and physical resources.

During the course of research and literature review, several cross-cutting themes were identified that appear in these case studies and during interviews conducted with other transportation professionals. These themes include the roles of state, regional, and local governments and other partners; the significance of capacity building; and the importance of broadband.

State, Regional, and Local Roles

State agencies serve as a critical partner in planning and implementing ITS. States own and operate significant portions of the transportation system, so the ITS that benefits rural and small metropolitan regions and communities is often part of the state's ITS network. States provide an important pathway to state or federal funding either through their state's programming processes or as partners on proposals for competitive funding opportunities. States might provide training to local and regional partners in using ITS or accessing the data from ITS assets.

RDOs, RTPOs, and metropolitan planning organizations (MPOs) play an important role in supporting ITS and transportation more generally in many areas. RDOs, RTPOs, and MPOs often conduct regional transportation planning work with support from their state DOTs and involvement from the local governments they serve. In this role, some of the regional planning organizations are working on transportation plans, including coordinated transportation plans, that align with ITS efforts. Others have purchased technology assets such as dynamic message signs and speed radar trailers that are available to be shared among several local governments as needed, without each rural jurisdiction needing to purchase its own. Regional organizations serve as effective conveners, bringing together elected officials and professional staff from multiple local governments to discuss approaches to common issues.

Local governments are the owners and operators of some roadways, bicycle and pedestrian facilities, and ITS assets, and in some areas are also involved in providing public or human services transportation. As transportation owners and operators, local officials and career staff are in a position to identify challenges that might be addressed through ITS, and they often hear from constituents about transportation concerns.

Other regional and local agencies including transit and ferry agencies, air and water port authorities, bridge and road toll authorities, and utility commissions play an important role in seeking resources and deploying solutions to the transportation challenges most closely related to their organizational missions and the needs of their stakeholders. Area businesses often benefit from improved transportation operations and information resulting from ITS and may be willing to support transportation efforts that align with their interests.

Capacity Building

Professionals who provided information in this research effort emphasized the different types of knowledge needed to support successful ITS deployments. Vendors and software developers know the capabilities of various technologies very well and potential use cases, but they do not have the operational knowledge of transportation owners and operators or the accountability to the public and stakeholders. Transportation agencies often rely on outside expertise to provide or develop technology solutions. That knowledge exchange builds the capacity of each side to support successful ITS efforts. Within transportation agencies and local governments, staff often need to develop new knowledge and skills to be able to fully make use of new information or to adequately maintain ITS technologies. External audiences may also need support or information to best utilize ITS, including riders of public and human services transportation, visitors at tourism and recreation sites or accessing special events, or the traveling public who may see safety or operational improvements from ITS.

Broadband

Many of the ITS case studies included in this research include elements of connectivity via communications platforms. Some investments in ITS occurred concurrently with investments in fiber and wireless broadband. This has been necessary in order to connect the ITS devices to allow them to transmit video feeds, operational signals, and communications. Practitioners report challenges with achieving adequate broadband in some rural places, however, as well as concerns about whether emerging or future technologies will work well in places that are hard to reach with broadband or where there is little demand for residential subscriptions to broadband service.

3 Travel Information Case Studies

3.1 Weather and Road Condition Information in Georgia

A drone pulls a broadband cable to connect infrastructure at Neels Gap, GA. Image courtesy Byron McCombs, Blue Ridge Mountain EMC

Safe travel in winter can be difficult in the mountains of Union County, Georgia, where U.S. Route 19/Georgia 11 serves as an important corridor, connecting the county seat of Blairsville and other parts of the county through Neels Gap to health facilities and other amenities in nearby Gainesville, Georgia, in Hall County or further south to Atlanta.[10] A scenic route where the Appalachian Trail crosses the road, this route is particularly important for public safety, ambulance calls, and anyone needing to access the hospital in Gainesville.[11] A partnership to connect broadband to state- and county-owned ITS assets, including cameras and a road weather information system, will improve access to information about travel conditions for residents and others traveling through the county.

Project Purposes

Union County owns two traffic cameras at Neels Gap that were installed around 2016, and the Georgia Department of Transportation (GDOT) has an additional traffic camera and weather system on-site that records air temperature, roadway temperature, the dew point, and other data.[12] However, this infrastructure was only connected to county and state systems by a cell phone internet connection, which was unreliable in storms or even when the mountain was surrounded by thick, low clouds. The internet connection was so slow that the cameras could only transmit one frame with a vehicle passing through the area, which did not provide any information about how vehicles were traveling. Without reliable technology, Union County Sole Commissioner Lamar Paris, as the county government's chief executive and only member of the county commission, became the travel information system himself. He would drive to the top of the mountain in poor weather, even in the middle of the night, and post updates on Facebook to let the public know about conditions.[13]

In 2019, Union County worked with Blue Ridge Mountain Electric Membership Corporation (EMC), the region's rural electric cooperative, to bring broadband to Neels Gap to connect the ITS assets there and provide a connection to the outdoor sporting store Mountain Crossings, which serves Appalachian Trail hikers and others.[14] Traditional methods for laying fiber would have been cost prohibitive in the mountainous area and would be difficult to navigate from a permitting perspective, going through the Chattahoochee National Forest. However, Blue Ridge Mountain EMC worked with Southern Company Services to fly a drone between ridge tops to place a pull line that would take fiber up the mountain, as shown in the image on page 8. With this process, Blue Ridge Mountain EMC obtained a permit from GDOT to run the cable at the proper height over a state-owned roadway and a permit to run the cable over trees in the national forest. Typically, a project to run fiber along the power lines would require extensive tree cutting under the line to allow access. This would necessitate a much more extensive permitting process in which EMC staff identify the trees to be removed, following which Forest Service staff measure the board feet of those trees. By avoiding impacts to the trees, the paperwork was much quicker for Blue Ridge Mountain EMC to complete and for the Forest Service to approve. The process of placing the fiber took hours to complete rather than weeks that would have been required without use of the drone, a significant cost and time savings.[15]

Outcomes

The new broadband service was connected to Union County's cameras in early 2019, and now the county has much better connection to the video feeds, with up to 100 frames of a single vehicles passing through the area, much closer to a full motion video than the delayed communications previously.[16] GDOT's camera and road weather information system (RWIS) at the location are also being connected to the new broadband connection. This will provide better and more timely information to state and local agencies.[17] (*See "Georgia's Connected Data Platform" for more information on the state's ITS network.*)

The GDOT camera at Neels Gap can be moved remotely to zoom, tilt, and pan and view a larger area, while the county's cameras are fixed in place and pointed toward the roadway. With improved broadband allowing for better quality video transmission, the GDOT camera might become an asset in the future for other public safety purposes, as officials conduct about 10 searches per year for hikers who are lost along the Appalachian Trail in that area.[18]

Resources

For Union County, procuring the cameras only cost about $1,500. Eventually, they will need to be replaced, but they are not expected to have a significant impact on the county's budget. The county pays Blue Ridge Mountain EMC about $50 per month to maintain a broadband subscription to the cameras. County staff anticipate being able to learn more about the information they can access from GDOT's ITS assets at Neels Gap, but other than some staff time provided by GDOT and Union County, that should not require significant resources devoted to training or have an effect on staffing levels.[19]

GEORGIA’S CONNECTED DATA PLATFORM

The state’s Road Weather Information System and CCTV camera at Neels Gap are part of the statewide ITS network. GDOT ITS Supervisor Emily Dwyer reports that the state has a fairly dense RWIS coverage and has worked closely with the National Weather Service, as well as significant transportation demands or risks, to look at locations to deploy weather sensors. With power and communications serving those RWIS sites, it is a logical choice to add a camera in order to confirm conditions on the ground. Similarly, sensors and cameras deployed along the causeway that leads to Tybee Island (population estimated at 3,079, a barrier island east of Savannah, GA) collect data to determine whether travel conditions are safe, and warnings are communicated through dynamic message signs before travelers enter the causeway. It’s important for the state to prepare its own response to weather events and to warn residents about travel impacts that might occur as the result of winter storms, hurricanes, or other events, Dwyer notes.

The data from the state’s ITS assets at Neels Gap, Tybee Island, and elsewhere can be even more meaningful when analyzed together with other data. In 2017, GDOT staff and external partners began to think creatively about ways to improve their ability to bring together separate data sources into one connected data platform to analyze issues and make decisions.

The platform brings together data from four sources, including uptime and reliability data from ITS devices along with safety data from crashes and the state’s partnership with Waze, to allow GDOT staff to make operational decisions based on analysis of all the data points. Dwyer says, “Previously, we made decisions based on tools that we were comfortable with. When we aggregated the data, it shifted the perspective entirely.” As one use case, the agency uses the aggregated data to plan for ITS deployment, expanding the network of cameras and other assets according to performance such as locations with a higher volume of crashes or points along an evacuation route. GDOT knows that every minute of closure of a lane translates into four minutes of delay. When GDOT staff can see the details of what is occurring on a camera, they have better information to dispatch the correct crews to address the source of the delay more quickly than without that data.

The current effort is likely the beginning of an initiative to put data to work for GDOT. Dwyer is optimistic that more data aggregation and more learning opportunities will be possible in the future. More data sources will likely be added into a connected platform to enhance the information available for planning, operations, and construction projects. Benefits from coordination would arise if more local governments and planning partners will also be using the platform.

Sources: Emily Dwyer and Marc Start (2019). “Connected Data Platform: GDOT’s Solution to the Fire Hose Problem;” personal communication with Emily Dwyer, September 2019

3.2 ITS Assists Evacuations in Georgia

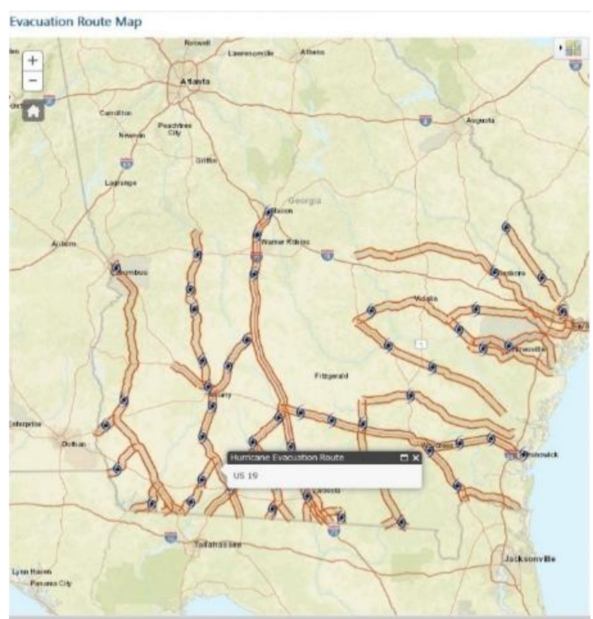
As residents prepare to evacuate when a disaster approaches, they often travel on routes that they are familiar with or use a mapping application to routes that can take them out of harm's way. Those methods direct many drivers onto the best-known routes such as interstates and some arterial routes. GDOT uses contraflow for 125 miles along I-16 from Savannah to the small city of Dublin, Georgia to manage the additional demand when an evacuation event occurs.[20] However, bottlenecks and pinch points are inevitable where contraflow ends and around the state.[21] GDOT uses ITS as part of its tools to support safe and efficient evacuations.[22]

Project Purposes

GDOT has deployed ITS investments throughout the state including closed circuit televisions (CCTV) and dynamic message signs (DMS) that provide beneficial information to transportation professionals and the public for many purposes, including in managing evacuations. Using the CCTV network, staff at GDOT's Transportation Management Center can observe how those major routes are performing as volumes increase.[23] Operators of Georgia's 511 travel information system can also gather information from incoming calls about congestion or incidents.[24] The DMS can display wayfinding messaging to make drivers aware of alternate routes, and the public can find information through 511 by phone or smartphone app.[25] Several social media feeds also communicate travel information, including Facebook and Twitter accounts for the Georgia 511 program and separate Twitter feeds for regions of the state and major corridors.[26]

The ITS network supporting evacuations must cover a significant area since Georgia regularly sees the impacts of hurricanes and tropical storms coming from the state's Atlantic coast or across the panhandle of Florida from the Gulf of Mexico in addition to other major events that may occur around the state. Through the 511 website, called the NaviGAtor, the public can view information on hurricane evacuation routes from the eastern and southern edges of the state, which is helpful for pre-planning potential routes during blue-sky periods or providing information when an evacuation occurs.[27] Maps, such as the image below, show the routes designated as hurricane evacuation routes and can help travelers become familiar with alternatives to the interstates.

Emily Dwyer, GDOT ITS Supervisor, says that because southern Georgia is predominantly rural, travelers evacuating from Florida or elsewhere might not be familiar with those alternate routes, and the information provided by ITS is especially important. GDOT regularly invests in upgrades and expansions to the system, including improvements that have allowed real-time or near real-time traffic information to be shared through the NaviGAtor in many locations throughout the state. In the future, GDOT plans to expand its ITS assets in more locations in southern Georgia to support those evacuations and special events as well as other uses, since there



Evacuation routes from the 2019 Hurricane Dorian are indicated on this map.
Image courtesy GDOT.

currently are not many CCTVs deployed in the area to assist with managing those high traffic events. Dwyer says, "If there will be a lot of cars moving through that area, we want to be able to keep an eye on things and know what's going on. There currently isn't as much data available to back up the operational decisions made in those areas." Prioritizing where to deploy new resources is important to stay within budget constraints, Dwyer adds, "We can identify interchanges or other areas that would be of highest concern."

Outcomes

Dwyer emphasizes that partnerships are essential to GDOT's work. News media is one area where the agency has worked to build and maintain relationships. "We take stories to them, and we want them to get the most accurate information from us," Dwyer notes of the symbiotic relationship that is put to use to communicate information not just about hurricanes and evacuations, but also major projects that have an impact on travel.[28]

Local government partnerships are also critical to GDOT's work. GDOT provides access to its 511 NaviGAtor to local governments, which can use it on their own server or access the information on GDOT's server. "As the local jurisdictions want to use it, they are able to pull up those cameras and the data and see what's going on." In addition to ITS assets providing data to support GDOT's decision making processes about transportation management or future resource deployment, the agency prioritizes local access and cooperative relationships. "If the locals who are making decisions that affect a community can't use [the camera network], then a key piece is missing. They know the [road] systems, breakdowns, and likely failure points. We are better at deploying our resources if we are working closely with them and ask what their needs are," Dwyer emphasizes.[29]

Resources

GDOT's support for safe and efficient evacuations includes a mix of investments in assets such as the state's 511 system, DMS, and CCTVs that are incorporated into the agency's budget on an ongoing basis. However, an important aspect of managing evacuations—close communication with external partners—is embedded in the agency's everyday operations. This includes ongoing outreach to news media who can help to spread the word about the need to evacuate and safe routes to do so. Having close relationships with local governments, who manage their own infrastructure and have regular communication with residents and stakeholders, is also important for GDOT.

3.3 Using ITS to Improve Traffic Conditions and Visitor Experiences in the National Parks

In recent years, the National Park Service (NPS) has encouraged visitors to plan before visiting parks to minimize traffic congestion and conserve resources. The NPS developed a Congestion Management Toolkit in 2014 that includes recommendations for implementing ITS to address vehicle congestion at park entrances and along park roadways, entrance gate delays, and over capacity parking near attractions or trailheads.[30] The NPS has also become more involved in regional initiatives to mitigate traffic issues by coordinating with other federal partners, regional agencies, state departments of transportation, local governments in gateway communities, and chambers of commerce or visitor bureaus. ITS applications in the national park environment include DMS, visitor apps for parking and traffic updates, and use of Twitter for real-time traffic conditions. This case study focuses on use of national park ITS technology in Arizona, Colorado, Montana, New Mexico, Oklahoma, Texas, and

Wyoming. A separate case study examines how ITS is used to provide visitor information at the Rocky Mountain National Park.

Project Purposes

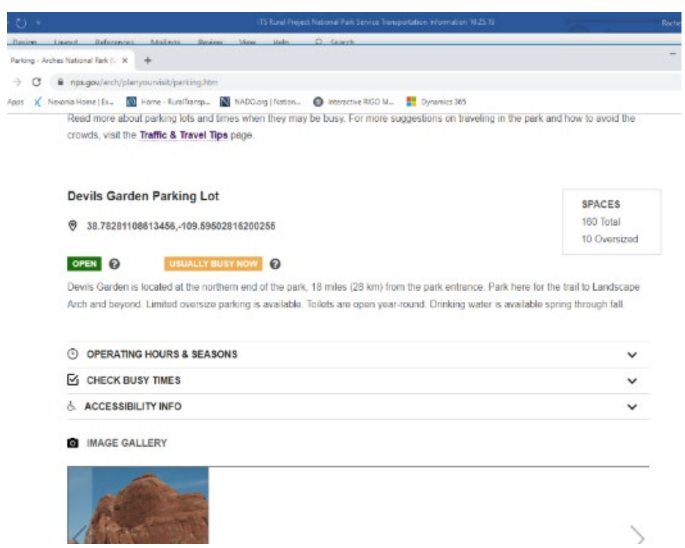
In 2018, the National Park Service recorded over 318 million recreation visits, more than a 15 percent increase from the National Parks' 275 million recreation visits in 2008.[31] All park regions of the U.S. experienced increased visitation, with some individual parks having notable increases. For example, Glacier National Park had a 64 percent increase in visitors in the ten-year period from 2008 to 2018.[32] Modest fee increases were approved in spring 2018 at the 117 parks that charge entrance fees to address $11.6 billion in deferred maintenance at all 417 NPS units.[33] Fees are used to repair infrastructure and respond to increased stress and demand placed on the parks' transportation network. As noted earlier, the National Park Service developed a Congestion Management Toolkit to formally prepare for growing congestion in the parks and to mitigate traffic's effect on air quality and the natural environment. Sample tools recommended to manage congestion include DMS, parking information, expanding transit service, posting information on social media, and expanding bicycle and pedestrian options.

Dynamic Message Signs

National Parks have been using DMS in Colorado to convey information about road closures or traffic since a 2011 pilot between Estes Park, Colorado, and Rocky Mountain National Park. Dynamic message signs relay information at strategic locations to provide visitors the opportunity to enter a park or take the option of detouring or returning to a gateway town if traffic conditions are poor. Glacier National Park is using DMS during peak season at its Many Glacier entrance at the Blackfeet Reservation near Browning, Montana. The park also used DMS during the Going-to-the-Sun Road rehabilitation project from 2007 to 2019 during peak season. Montezuma Castle National Monument, located in Coconino National Forest in Arizona, has coordinated with a federal partner, the National Forest Service, to place a DMS on its entrance road to relay parking information. The National Park Service has leased or borrowed signs and place them in coordination with a state DOT, adjacent county, or as mentioned, with a non-Department of Interior federal agency. The NPS unit takes responsibility for updating sign messages.

Apps and Websites

Western parks are taking visitor messaging a step further by providing real-time information to visitors as part of the NPS's emphasis on visitors learning details before they arrive. Information is shared by traditional webpages or by customized apps. Arches National Park near Moab, Utah, uses webcams and parking status web pages to inform visitors of the current wait time at the park entrance. An NPS webcam provides a regularly updated visual of the Arches entrance gate, and a Utah DOT webcam posts



Arches National Park provides parking lot information on its website.
Image courtesy www.nps.gov/arch/

real-time images of photos of U.S. 191 at the park entrance road. Arches National Park's website parking pages, while static, do list lot names, number of spaces, open/closed status, and usage levels.[34]

Glacier National Park has launched a Recreation Access Display (RAD) application that is used during the park's peak season. The app dashboard provides updates on parking, road closures, and vehicle access restriction, as well as information on campground status and weather.[35] Another app example is Bryce Canyon's Shuttle Tracker app, which allows visitors to view stops and the location of the park's transit shuttles along the route network.[36]

At the current point in time, there is no standardized app in use by all national parks. Off-the-shelf apps are being used to provide NPS visitor and transportation information.

Social Media

Individual national parks use social media accounts to provide transportation condition updates. Twitter is primarily used for immediate updates. Facebook is used for general information about expected travel conditions (e.g., holiday weekend travel).[37] Erica Cole, National Park Service Transportation Planner, notes that visitors need to consider that cell phone coverage is not always available in order to access real-time information. Visitors are asked to allow time for unexpected events, pack their patience, and enter parks during off-peak periods (e.g., before 10:00 a.m. or after 2:00 p.m.). The types of information shared by Twitter include road closures, traffic volumes, and weather conditions.[38] Social media is a form of intelligent transportation communication in and of itself, and posts provide a mechanism to highlight the different types of ITS used in the parks. Many parks enjoy very active Friends of the Park private organizations which help supplement the NPS staff with needed support on facility maintenance and traveler information on the Friends' social media pages and accounts.

Rocky Mountain National Park uses Twitter to announce traffic conditions.
Image courtesy @RockyNPS

Partnerships

When working on regional transportation issues, the National Park Service has traditionally participated in conversations about transportation improvements. For gateway communities such as Estes Park, Colorado; Tusayan, Arizona; or Springdale in Utah, local governments, regional agencies, visitor centers, and chambers of commerce are partners when it comes to discussing remedies for national park congestion and parking needs. Jurisdictions in the Grand Valley region of Colorado, home to Colorado National Monument, work together when transportation projects affect the monument and its surrounding communities. A recent Colorado National Monument roadway construction project involved the NPS, Colorado Department of Transportation (CDOT), and local governments—Mesa County, City of Grand Junction, and the City of Fruita. These local jurisdictions' roles change with each project; however, typical support includes providing detour routing, placing information signs, and managing traffic during construction. The partnership includes participating in each other's public meetings and providing outreach. [39] (*More examples of working partnerships between the NPS and neighboring towns are discussed in the Rocky Mountain National Park case study.*)

Parks Projects and Regional Planning

NPS involvement in the regional planning process depends on each park's transportation issue and relationship to surrounding jurisdictions. A recent example of community-level planning is an October 2019 public meeting held in Moab where local residents and other interested parties were invited to learn about efforts to address traffic congestion and improve the visitor experience at Arches National Park.[40] NPS planning efforts have been bolstered through collaboration with the Bureau of Land Management (BLM), the U.S. Fish and Wildlife Service (FWS), and the U.S. Forest Service (USFS). Federal land management agencies in Colorado have been engaging with CDOT to become more involved in regional planning.

Grand Valley once again provides an example of how planning includes both federal and local partners. Federal land managers and federal recreation planners are included in Grand Valley's continuing, cooperative, and comprehensive planning process, and each of the federal land management agencies (i.e., NPS, the BLM Grand Junction Field Office, and the USFS Grand Valley Ranger District) have a representative on the Grand Valley regional transportation plan steering committee.[41]

Outcomes

On an individual park basis, there have been impact and design plans and studies that focus on proposed ITS technologies or transportation projects that incorporate ITS components. ITS inventory reports for the NPS and federal public lands have likewise been produced every five or ten years since the early 2000s The National Park Service has not conducted a cumulative formal, quantitative evaluation of how intelligent transportation systems have affected travel patterns and user experiences in the parks. At this point in time, the impact of ITS and social media messaging is anecdotal.

Resources

Funding for intelligent transportation system applications in the national parks comes from National Park Service operations funds (ONPS) and revenue from fees and pass sales authorized under the Federal Lands Recreation Enhancement Act (FLREA). Federal Lands Transportation Program (FLTP) funding has been used for transit in the parks and technology deployment. Another source of funds is the U.S. DOT Surface Transportation Block Grant (STBG) Program which funds transportation control measures such as intelligent transportation systems projects. Additional information about technology costs can be found in the National Park Service Congestion Management Toolkit.

3.4 Rocky Mountain National Park: Experiences and Lessons Learned from Using ITS for Traveler Information

Rocky Mountain National Park (RMNP) is the third most visited national park in the United States. Similar to other western national parks, Rocky Mountain has experienced a sharp increase in visitation numbers in recent years. RMNP's visitation rate increased 42 percent between 2012 and 2018.[42] Unlike some of the west's "destination" national parks—Yellowstone is an example—RMNP has a high percentage of day visitors due to the park's proximity to the Front Range metropolitan areas of Denver, Boulder, Longmont, Loveland, and Fort Collins. Over 80 percent of visitors enter through RMNP's eastern entrances just outside the gateway community of Estes Park. In response to the growing popularity of the region, both RMNP and the Town of Estes Park have initiated intelligent transportation systems technologies to inform travelers of traffic and weather conditions and to mitigate parking congestion during the park's busiest hours of 9:00 a.m. to 3:00 p.m.

Project Purposes

Dynamic Message Signs, Parking Restrictions, and Shuttle Service

RMNP takes a multi-pronged approach to providing visitors information about transportation. RMNP first piloted dynamic message signs in 2011. As of 2019, there are five portable message signs under the jurisdiction of the park, and the Town of Estes Park has installed permanent message signing outside the park boundary. The national park's DMS are used to announce parking conditions and to post vehicle restrictions. During summer months, vehicle access along the Bear Lake corridor is limited to maintain traffic flow and enable the National Park Service to respond in case of emergency. In general, RMNP follows the practice that once parking lots are full, the park then moves to using satellite park and ride lots where visitors can board shuttles to access park trailheads and campgrounds or travel into town on the Hiker Shuttle. The Town of Estes Park uses its permanent DMS to share parking lot status as well as information about catching the park shuttle. Two town signs along U.S. 36 and U.S. 34 are used to alert drivers of delays and encourage them to use the town's new parking structure or to visit the new Estes Park visitor center.

For visitors who park their vehicles, RMNP operates three shuttle routes within the park's boundaries, including the route into Estes Park.[43] Estes Park runs a free shuttle within the town, and the two entities—RMNP and the Town of Estes Park—have streamlined administration by piggybacking onto a combined vehicle and service contract.

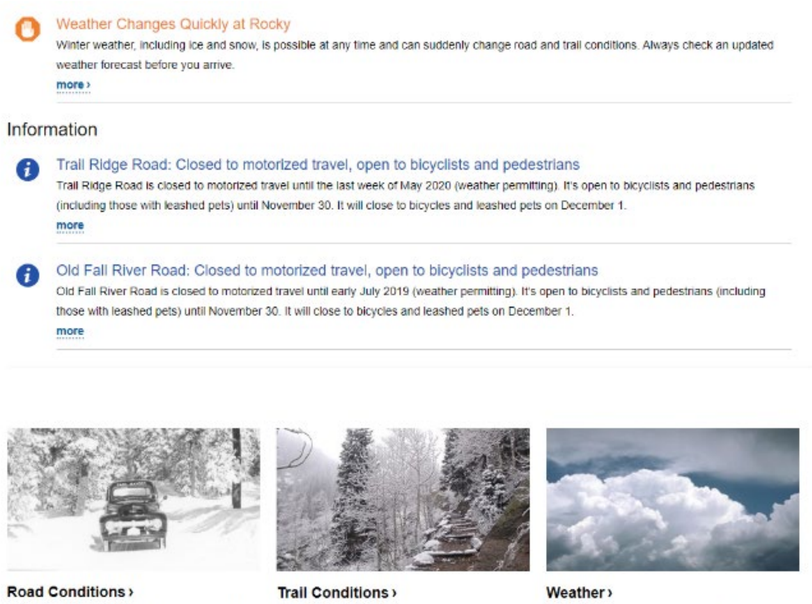
RMNP Public Affairs Officer Kyle Patterson and Management Specialist John Hannon noted that local ability to control DMS content and the ability to update messages when needed have been important to the park. Even with locally controlled messaging, there are still practical factors that have affected RMNP's portable signs. For example, with the current DMS, to remotely control the messages on the signs requires the sign to connect to the cell network. With limited cell coverage within the park, this has influenced the sign locations. A shift to permanent message signs will require more complex infrastructure such as underground cable and more detailed programming. Additionally, Patterson and Hannon stated that as a federal agency, the park must follow federal protocol regarding software and data system protections which presents additional challenges connecting DMS to the NPS network. RMNP has considered pre-timed message schedules, but the practice has not yet been implemented. Not all message updates can be done from a remote location which affects ability to pre-schedule messages. There are occasions where staff have had to plug keyboards into the signs to change messages.

Web Information and Social Media

RMNP uses three primary social media channels: Facebook, Instagram, and Twitter. Facebook and Instagram posts are more for building relationship stories, and Twitter focuses on real-time information. The Estes Park Visitor Center is supportive by re-posting or sharing @RockyNPS tweets. In addition to social media, traditional media outlets along the Front Range also run articles or announce initiatives related to RMNP visitation.

RMNP's website https://www.nps.gov/romo conveys traveler information through webcam images from the Fall River and Beaver Meadow entrance gates. Webcams provide website information on how traffic is flowing (or not) at the entrance lanes. The website has 10 million visits per year, and park representatives indicate that web visitors are likely planning for a future trip.

All National Park websites include an Alert tab to draw immediate attention to situations affecting near-term travel. Alerts are limited in terms of the type of news that can be shared. Examples of approved alerts include fire closures, road closures, and weather information, such as those in the image below.



Screenshot of Rocky Mountain National Park Alerts page.
Image courtesy https://www.nps.gov/romo/planyourvisit/conditions.htm

RMNP staff acknowledge there are considerations to take into account when it comes to implementing new technologies in the parks. Considerations include challenges with app software used for parking or campground status and limited staff resources which affect the prioritization and posting of transportation communication. Twitter is updated for immediate information, whereas website updates are intended for visitors who plan far ahead. Despite all the information available, there will always be visitors who do not research their trip and arrive with little idea of parking availability, road conditions, or traffic levels.

The park is trying to place information at key decision points so that visitors can decide their own tolerance for traffic congestion. Hannon and Patterson mentioned that several years ago when the park become active in posting traffic information, there were businesses around Estes Park that expressed concern about signage placement and how that might affect their visitation levels because Estes Park is a destination in and of itself. In more recent years, as visitation levels have increased for the entire region, there has been more conversation about congestion and how it affects everyone.[44]

RMNP wants to provide important traveler information while being careful about setting expectations, and that's one reason why the park carefully considers new technology and how useful it will be to visitors. One example is discussing the usefulness of a parking app that indicates number of spaces available. Once a traveler reaches the parking lot, will those spaces still be open? If not, then how useful is the app? Park administration considers these questions as well as infrastructure requirements and costs and staff resources associated with maintaining equipment.[45]

Planning Partnership Between RMNP and Town of Estes Park

RMNP's technology decision making isn't done in a silo. Visitor messaging and transportation service are shared responsibilities of the park and its gateway neighbor, the Town of Estes Park. It's a long-standing partnership that's bolstered by a mutual interest in the preservation and success of the region. RMNP representatives attend the monthly Town of Estes Park Transportation Advisory Board and economic development meetings. In addition, there is close interaction with the Estes Park Visitor Center and Visit Estes Park website https://www.visitestespark.com. The park has been working closely with the town for decades, and current staff were also on board when RMNP first discussed implementing shuttle service based on models used at Acadia National Park and Zion National Park.

Outcomes

RMNP has not conducted a formal evaluation of how the DMS, shuttle service, and social media and web applications are affecting traveler planning and behavior. Park staff has noticed that technology use and awareness is tied to overall changes in behavior as people have gotten used to changes within the park system such as vehicle restrictions. Frequent visitors know they may need to arrive before or after the hours of the restrictions or plan to use the park's shuttle. Visitors' knowledge of the restrictions and a few years to absorb the travel and traffic changes have made a difference in in the patterns of the park.[46]

Resources

RMNP can use funds from National Park Service operations funds (ONPS) and revenue from fees and pass sales authorized under the Federal Lands Recreation Enhancement Act (FLREA). In addition, other federal transportation resources are available depending on project eligibility. Rocky Mountain is one of 17 parks allowed to collect transportation fees for administration. RMNP is looking at funding for permanent DMS down the road. The Fall River entrance will be rebuilt in the next five years with related roadwork in the next few years, so message sign installation is dependent on the timing of the reconstruction.[47] In the Town of Estes Park, sales tax is used to fund shuttle service, and a lodging tax is used for marketing. The town is exploring paid parking in its downtown core to encourage drivers to use the town's free garages, reducing congestion in its inner core.

According to a 2018 *Estes Park News* article on DMS installation, the new permanent signs near U.S. 34 and U.S. 36 the Town of Estes Park, Colorado, received $136,000 in Congestion Mitigation and Air Quality (CMAQ) funding as part of the Upper Front Range Regional Planning Commission and CDOT improvement program.[48] The town government provided local match of $98,000. The funding was used to purchase four permanent signs. According to National Park Service's Congestion Management Toolkit, the estimated capital costs for portable DMS range from $50,000 to $250,000 depending on the number of signs and whether the signs are purchased or leased. Operations and maintenance costs are estimated at $500 to $1,600 per year for a portable sign.[49]

For additional information, view the Rocky Mountain National Park Intelligent Transportation System Pilot Deployment/Evaluation (2011) at https://westerntransportationinstitute.org/research_projects/rocky-mountain-national-park-intelligent-transportation-system-pilot-deploymentevaluation.

4 Management and Operations Case Studies

4.1 Dynamic Message Signs and Speed Radar Detectors Deployed to Address Special Events and Safety

In Missouri, RDOs provide rural transportation planning services in areas not designated as MPOs under a contract from the Missouri DOT to the Missouri Association of Councils of Government. This partnership gives rural-serving RDOs an opportunity to identify transportation concerns and potential projects through ongoing outreach and dialogue among the local, regional, and state levels. In the northwestern part of the state, three RDOs have worked together to advance work in transportation safety across the jurisdictions they all serve.

In 2015, Green Hills Regional Planning Commission (RPC), Mo-Kan Regional Council (Mo-Kan), and Northwest Missouri Regional COG (NWMORCOG) applied together for funding from the Northwest Missouri Coalition for Roadway Safety to acquire a dynamic message sign that is shared among the RDOs (known collectively as RPCs in Missouri) and can be deployed in any of the communities they serve. A speed radar trailer and traffic counters are also available to be used across the three-RDO region, which encompasses 20 counties in northwest Missouri while Mo-Kan serves an additional two counties in Kansas. Recognizing the potential opportunities for DMS, Mo-Kan used a portion of its MoDOT planning grant to purchase an additional LED sign that has also has traffic counting capabilities in 2018.[50]

Project Purposes

Area local governments can request to use the DMS to display notices for any special event or traffic disruption, as shown in the images on page 20. Local governments must complete an agreement to reserve the sign, pay a $250 deposit in case of damage, and pay a $50 maintenance fee and $0.50 per mile travel fee (which is deducted from the deposit upon return of the sign). The fee is waived if the intended purpose is safety or other public benefit. This allows rural, local governments to access an ITS asset with flexible applications for minimal cost. The speed radar trailer is available to local entities within the three-RDO service area under a similar arrangement.[51]

MoDOT or Kansas DOT are often responsible for the roads and right-of-way where local agencies and organizations seek to use the signs or speed radar trailer. As a result, when the RDOs receive a request to deploy one of their ITS assets, they coordinate with the state DOT about placement of the sign, duration, and the wording to be used.[52]

An LED dynamic message sign is a flexible ITS asset available for local governments to communicate information for special events or ongoing issues such as safety in small communities that do not have their own law enforcement. Images courtesy Mo-Kan.

Whether owned by one RDO or jointly by three, having DMS and other assets such as the speed radar trailer available to local communities has been beneficial for a variety of applications. At times, these assets are used to address ongoing challenges, with messages about reducing speed in smaller towns that do not have their own local law enforcement. In other cases, the signs are used to manage temporary events, such as when flooding closed an interstate and trucks and other through-traffic had to pass by an elementary school on a detour route through a small town. For special events, such as the adventure cycling event Bike Across Missouri (BAM), air shows, and the total solar eclipse of 2017, the signs have been used to provide information on parking or amenities or to warn of slow traffic or other roadway conditions related to the events. During May, DMS has alerted motorists to bike-to-work month, with reminders of cyclists in the roadway and for motorists to share the road.[53]

The DMS, speed radar trailer, and traffic counters can be used by themselves or in conjunction with another safety asset developed by Mo-Kan and the St. Joseph Area Transportation Statistical Organization (SJATSO). SJATSO serves as the MPO for the St. Joseph, Missouri urbanized area, which falls within the counties served by Mo-Kan.[54] Together, Mo-Kan and SJATSO applied to Northwest Missouri Coalition for Roadway Safety for funding to develop the region's first Safety and Innovation Mobile Lab to support pop-up safety demonstrations. The Safety and Innovation Mobile Lab trailer (*shown in the image on page 21*) contains materials that local agencies can use for temporary safety installations, allowing them to test out modifications such as traffic configurations such as bike lanes, pedestrian bump outs, or new pavement markings such as crosswalks or "sharrows" before making a major investment in upgrading their infrastructure. The trailer contains roadway grade materials such as caution cones, delineators, pavement tape, chalk paint, and stencils. Permanent paint can be used for installations known to be needed in a location, such as painting a stop bar at a stop-controlled intersection.[55]

The Safety and Innovation Mobile Lab trailer is stocked with materials that local governments can use in temporary safety demonstrations. Image courtesy Mo-Kan.

The DMS, speed radar trailer, and traffic counter owned by Mo-Kan are important tools that can be deployed along with the resources in the Mobile Lab trailer. DMS can be used to inform transportation users that there is a pop-up installation and to expect a change in how they are used to traveling through the area. The sign's data collection capability is useful for pre- and post-event data without being obvious to passing motorists, although the speed radar trailer is also available and provides count, time of day, and speed of passing vehicles, and local police have offered use of a speed radar gun to transportation planning staff. Other information on motorist behavior, such as whether drivers made full stop at stop signs within an elementary school zone where the Safety and Innovation Lab was used to create permanent pavement markings, has been observed and recorded by planning staff seated in a nearby parked car. Technology solutions to capture those data points were not available.[56]

Outcomes

The DMS and speed radar trailer have been useful for addressing recurring conditions, such as speeding, as well as providing safety and information support for non-recurring special events. In addition, these ITS assets, the Innovation Mobile Lab trailer, and observation by transportation staff provide a set of tools for conducting and assessing transportation safety interventions. The first pop-up demonstration project using these tools occurred at Minnie Cline Elementary School, where a pop-up was held in 2018 (*depicted in the image on page 22*). This gave the administration and staff important information to protect students traveling to school. While motorist behavior improved, it was not to the desired level. The project evaluation results guided further interventions such as continuing to use adults as crossing guards (rather than older students helping younger students to cross), high visibility vests for the crossing guards, and a solar-powered flashing stop sign obtained by SJATSO with funding from the Northwest Missouri Coalition for Roadway Safety.[57]

Over time, the RDOs in northwest Missouri and SJATSO hope that use of ITS in conjunction with other tools will result in improved safety outcomes, including protecting bicyclists and pedestrians and reducing speeds where needed in certain zones. These tools can also promote economic activity through improvements in safety leading to improved walkability and resident and visitor access to businesses and services.[58]

Resources

These ITS assets have been acquired at minimal cost to the region. The Northwest Missouri Coalition for Roadway Safety (serving a 20-county section of the state) provided $13,600 for the first DMS purchased jointly by the three RDOs, which is stored in the Green Hills service area. The coalition also provided Mo-Kan and SJATSO with its Blueprint Grant for $4,600 to purchase the trailer and stock it with initial supplies, while Mo-Kan and SJATSO provided approximately $10,000 in supplies, equipment, and the value of staff time, and Buchanan County provides space in its Hazmat building to store the trailer. Mo-Kan used funds from its planning partnership grant with MoDOT to secure the second DMS for $14,700.[59]

On an ongoing basis, user fees offset some of the cost of maintaining and insuring the signs, speed radar trailer, and other equipment. MoDOT's planning partnership grant is an important source to supplement those local funds. In terms of staffing needs, one message sign can be deployed on-site by just one person, while the other DMS is larger and requires two staff. Each time the ITS assets or Mobile Lab are deployed, staff take the time to coordinate not only with the agencies responsible for roadway ownership and maintenance, such as the state DOTs for many area roads, but also emergency management and area stakeholders. Mo-Kan and SJATSO will work together to restock safety supplies in the Innovation Lab trailer as needed.[60]

For more information, visit the RDO and MPO agencies' websites: www.mo-kan.org, www.nwmorcog.org, www.ghrpc.org, and stjoempo.org.

Minnie Cline Elementary School staff and students paint crosswalks and stop bars along with SJATSO and Mo-Kan transportation staff.
Image courtesy Mo-Kan/SJATSO.

4.2 Flood Gate System Improves Road Closure Operations and Public Safety

Washington County, Oregon, is one of six member agencies of TransPort, a subcommittee of Portland Metro's Transportation Policy Alternatives Committee (TPAC) that focuses on transportation system management and operations. Transportation systems engineers from Oregon DOT, Tri-County Metropolitan Transportation District of Oregon (TriMet), Clackamas County, Multnomah County, Washington County, and the City of Portland meet regularly to discuss regional planning for and investment in technologies to support efficient transportation as the members have overlapping responsibility for the road network within the region and want local projects to align with regional initiatives. Washington County, located west of the City of Portland is 726 square miles and had a 2010 population of 529,710.[61] The county's urbanized areas are within the Portland Metropolitan Planning Organization's planning area boundaries, but much of the rest of the county has a rural character. Land use within the county is a mix of urban development, agricultural land, floodplains, and forest. The majority of the county is located in the Tualatin Valley, surrounded by the Tualatin Mountains. Due to topography, Washington County's roadways are affected by periodic flooding, particularly within the 100-year floodplain, and microclimate weather conditions that result in ice, fog, or snowy conditions.

Washington County developed an initial ITS plan in 2005 and updated the plan in 2013.[62] In addition to Washington County department agencies, other regional ITS stakeholders include the City of Beaverton, City of Hillsboro, City of Sherwood, City of Tigard, City of Tualatin, Oregon DOT, Portland General Electric, TriMet, Tualatin Hills Parks & Recreation District, and Tualatin Valley Fire & Rescue. County planning projects that support rural ITS strategies within the purview of Washington County's Traffic Engineering and Operations include a flood gate system, road weather information system, automated snow zone warnings, and speed feedback signage. Some of these ITS projects are still in development; however, the flood gate system is complete. Washington County's flood gate system uses ITS sensors and cameras to assess flood conditions, with a goal of improved public safety and efficient deployment of county and first responder resources.

Project Purposes

A segment of Fern Hill Road south of the City of Forest Grove is a residential and commuter route that's located in the 100-year floodplain and subject to flooding approximately six times per year. Prior to 2018, Washington County Maintenance and Operations staff, in coordination with the City of Forest Grove Fire and Rescue or Tualatin Valley Fire and Rescue, would pre-stage and place mobile barricades across Fern Hill Road and send staff to the field to visually check flooding status. When flooding receded, county staff would return to inspect the roadway for damage, clean the road surface, make any necessary repairs, and manually return signage and barricades to their staging area. The process was costly, time consuming, and posed a safety risk when members of the public chose to physically move the barricades or drive around to enter the closed roadway segment.

To address the ongoing issues, Washington County decided to install fixed, manually lockable gates that are supported by water depth sensors and surveillance cameras. Automated gates were considered; however, terrain constraints, the potential for flood damage, the need for maintenance staff to be able to assess road conditions, the need for emergency personnel to access the road when needed, and infrastructure costs were considerations that affected the decision to install manual gates. While the flood gates rely on county staff for the closing and opening process, what makes the

A Washington County Operations employee opens an arm of the Fern Hill flood gate.
Image courtesy Washington County, Oregon

system notable is the ITS component. With the new system, Washington County can monitor the gates and water levels through cameras and sensors without making multiple field visits to the gates. The real-time status information is then shared at the both the county and state level through the county's transportation information system and Oregon DOT's TripCheck portal.

The gate deployment process works through a series of steps. A U.S. Geological Survey stream gage field sensor alerts Washington County Operations when the gage height reaches 16.3 feet. Staff will monitor Fern Hill Road camera information for roadway conditions. When the stream gage reaches the high field sensor (16.5 feet), Washington County responds to the alert by closing the road segment. The flood gates, which include "Road Closed" signage and flashing red beacons, are manually locked. Pan-Tilt-Zoom cameras posted nearby enable real-time status checks of gate conditions and flooding levels. Gate position sensors transmit road closure information every five minutes to the TripCheck Traveler Information system, the county's communication system, and information service providers such as Waze. Closure information is also shared with the public through https://www.wc-roads.com, the county's transportation information website, and social media (*e.g., Twitter and Facebook, as seen in the image at right*).

Washington County Roads uses Twitter and other traveler information systems to let the public know about road closures.
Image courtesy @Washcoroads

Outcomes

Installation of the flood gate system required coordinated planning between the county's separate Traffic and Operations and Maintenance departments. A portion of the road segment is bounded by Washington County's Clean Water Services and the new flood gates are a technological update to an existing operations practice, so a traditional public involvement process was not used. The gates were installed in November 2017 and first used during the 2017 – 2018 winter season.[63] Washington County Land Use and Transportation engineers report that the gates have worked as projected during flooding. The gates were damaged during their first use by a vehicle driver determined to enter the roadway. The county crews were able to repair the damaged gates, and they had also prepared for this type of situation by ordering a second set of gates at the time that the system was installed.[64]

The flood gate system, along with the county's other planned rural ITS projects, serve the role of improving public awareness and safety, providing a means to monitor road conditions remotely, providing real-time condition information, and decreasing the staff time needed to open and close the roadways.

Fern Hill Road flood gates near Geiger Road in Washington County.
Image courtesy John Fasana

Resources

The Fern Hill Road flood gate system, and its sister project on Susbauer Road, were county-initiated projects. Flood gate system repair and maintenance needs are addressed by the county's overall Operations budget. In Washington County, Oregon, there are a number of funding program options for rural ITS projects including Gain Share revenues, a Major Streets Transportation Improvement Program (MSTIP) funded through county taxes, Metropolitan Transportation Improvement Program (MTIP) funds, federal Congestion Mitigation Air Quality (CMAQ) funding, and county road funds.

In the case of the Fern Hill flood gates, the system was funded through Gain Share, an Oregon-specific program. According to the Washington County Land Use and Transportation website, Gain Share funds consist of a share of the state income tax revenues generated from jobs creation related to Strategic Investment Program (SIP) agreements. SIP "was created to attract job-producing companies by allowing local governments to negotiate alternative taxing agreements with businesses that agree to invest at least $100 million in an urban area or $25 million in a rural area in Oregon."[65] The 2015 Oregon legislature capped the shared amount to $16 million annually for any participating county. The Washington County Board has decided to focus Gain Share funds on one-time projects rather than on-going projects or services.

For more information on Washington County's ITS Plan and the WC-Roads.com Transportation Information website, visit https://www.co.washington.or.us/LUT/Divisions/TrafficEngineering/Programs/TrafficManagement/ITSystem/plan.cfm.

5 Transportation Safety and Health Case Studies

5.1 Dynamic Warning Systems Enhance Safety for Cyclists and Vehicles on Scenic Roadways

Historic and scenic roads on federal lands and in U.S. national parks are enjoyed by both motorists and cyclists. Many of these roads were designed in the early 20th century and were constructed to the design standards of the era. As park attendance has increased in recent decades, so have traffic volumes, and the types of vehicles using the roads now includes recreation vehicles, vehicles pulling trailers, and tour buses. A growing interest in cycling within national parks means more interaction between cyclists and motorists along roads with no shoulders, curves, hairpin turns, and tunnels. In an effort to decrease the number of conflicts and crashes that occur in these locations and remind all road users of safety practices needed to share the road, the NPS is using technology to improve conditions in its units. Colorado National Monument's Rim Rock Drive is one location where a dynamic warning system has been installed to alert drivers that cyclists are on the road. The new system was part of a 2017 – 2018 roadway reconstruction project.[66]

Project Purposes

Rim Rock Drive is a narrow, steep roadway carved out by the Civilian Conservation Corps in the 1930s. The drive is 23 miles long, includes three tunnels, and is considered one of the "most spectacular drives in the United States."[67] The road is used not only by tourists but also by vehicles accessing the town of Glade Park on the western side of the national monument. The NPS reported that the roadway averaged one documented vehicle-bicycle incident per year between 2013 and 2018, and during the peak cycling months of March through October, cyclists make up 10 percent of the traffic on the road. It's during this peak period that the park receives, on average, one complaint per week about a near miss between a vehicle and a bicycle.[68]

The new dynamic warning system has been placed in the uphill lane at two locations along the drive. Newer inductive loop technologies, such as those deployed at Colorado National Monument, are better able to differentiate between bicycles and motor vehicles. The loop detection system triggers a flashing light attached to a sign indicating that a bicyclist is ahead of the vehicle. In addition to serving as an alert for motorists, the warning system also serves the purpose of counting cyclists using Rim Rock Drive.

Dynamic Warning System light and sign on Rim Rock Drive.
Image courtesy National Park Service, Colorado National Monument

Outcomes

Data collection for the Rim Rock Drive warning installations will be part of an evaluation of the safety outcomes of the project. Vehicle and bicycle counts, counts of how often the system is triggered, how well the system differentiates cyclists in mixed traffic, and the number of vehicle-cycle incidents will be monitored. Surveys will evaluate driver and cyclist opinions about the system as well as operations and maintenance experiences. Reducing driver speeds and increasing the awareness of drivers are two goals of the project.[69]

Resources

The detection warning system was funded through Federal Highway Administration (FHWA) Coordinated Technology Implementation Program funds and was part of a roadway reconstruction project in Colorado National Monument. The exact cost of the warning system is not known; however, a system to warn motorists of cyclists or pedestrians in the Knapps Hill Tunnel near Chelan, Washington, is estimated at $16,000 for installation, according to the National Center for Rural Road Safety ITS Toolkit.[70]

5.2 Sign Technology Affects Driver Behavior at Railroad Crossings

Federal Railroad Administration statistics from 2018 indicate that the year closed with over 2,200 collisions, 265 fatalities, and more than 800 injuries during highway-rail incidents at railroad crossings.[71] As of September 2019, over 1,600 highway-rail incidents had been reported, 225 casualties, and 575 non-fatal incidents for 2019.[72] Railroad companies, state departments of transportation, and local jurisdictions are exploring proactive solutions to reduce the number of vehicles that stop on railroad tracks in congested traffic to help prevent future incidents. One example is a 2019 pilot lighting and signage project in Massachusetts to test whether intelligent signage would affect driver behavior around railroad crossings. The U.S. DOT John A. Volpe National Transportation Systems Center (Volpe Center) tested flashing LED-equipped warning signs in early 2019 at the request of the Massachusetts Bay Transportation Authority (MBTA) after several recorded injuries and a fatality at the Brighton Street railroad crossing in the town of Belmont. The installation of new R8-8 “DO NOT STOP ON TRACKS” signs enhanced with LED lights is a small-scale ITS pilot that can be replicated at rural or small town

Brighton Street southbound approach to rail crossing in 2018 before the LED-enhanced signs were installed. The Fitchburg Cutoff Bike Path is on the left side of the photo. Image courtesy Google Maps crossings where congestion is created during peak times due to construction, employment center work shifts, school traffic, freight train schedules, and special events.

Project Purposes

Brighton Street in Belmont is a two-lane road, and the area adjacent to the MBTA rail crossing includes school and business land uses, left-turning traffic, bus stops, crosswalks, and a bicycle/pedestrian trail that runs parallel to the tracks.[73] The Belmont grade crossing includes flashers, roadway gates, and pedestrian gates. R8-8 signs are posted on both directional approaches, along with grade crossing advance warning signs, and pavement markings including "Do Not Block the Box" lettering that was painted on the approach roadways in 2017.

The technology that the Volpe Center tested consists of 6-volt, solar-powered battery lights that frame the "DO NOT STOP ON TRACKS" sign. During the test period, the lights were set to flash constantly. Once the signs were in place, Volpe analyzed the effect the signage had on driver behavior and whether drivers were more apt to stop in non-dangerous sections of the roadway versus moderately dangerous to very dangerous zones, including the track area itself.

TAPCO R8-8 sign with flashing LED lights. Image courtesy www.tapconet.com

Outcomes

The Volpe Center analyzed driver stopping behavior before and after the enhanced sign installation. Prior to installation, 1,065 vehicles stopped in one of the identified violation zones for both northbound and southbound directions during the week of March 18, 2019. Of this total, 29.6 percent of northbound vehicles stopped in the most dangerous zone—the track zone—and 30.1 percent of southbound vehicles stopped in the track area.

After the new signage was installed, 20.9 percent of northbound vehicles stopped in the track area, and 20.4 percent of southbound vehicles stopped in the track area. With the LED signs, the percentage of vehicles stopping on the railroad tracks was reduced to just over 20 percent of vehicles stopped. For southbound motorists alone, there was about a 42 percent reduction in vehicles stopping in the most dangerous zone. One practice of Brighton Street drivers that continued, regardless of signage, is that northbound drivers had to stop on or near the tracks at times to let pedestrians or bicyclists who were on the bike path cross Brighton Street. In these incidences, the drivers were rarely stopped on the tracks for long.[74] Overall, the flashing LED signs have been effective in reducing the number of vehicles stopping on the tracks at the Belmont location.

Resources

The cost of the LED-enhanced signs depends on manufacturer. The Volpe Center tested signs from two companies, TSC and TAPCO. An LED-enhanced sign with mounting brackets from TSC cost $1,740 and TAPCO's sign was approximately $1,600. A sign with a pole and base cost approximately $3,300 for the Belmont, MA signage project. A copy of the full project and analysis report is available through the U.S. DOT's National Transportation Library at https://rosap.ntl.bts.gov/view/dot/41694.

5.3 South Dakota DOT Implements Intersection Conflict Warning System

Looking for a solution to reduce conflicts between vehicles at rural intersections, the South Dakota DOT implemented a Rural Intersection Conflict Warning System in 2017. The system is based on warning technology used by the Minnesota DOT to reduce right-angle crashes and reduce traffic injuries and fatalities.[75] South Dakota's warning system project has been implemented in two locations: the junction of Highways 46 and 37 in Bon Homme County in southeastern South Dakota and at the intersection of U.S. Highway 281 and SD 20 near Mellette in Spink County.[76]

South Dakota DOT's Conflict Warning Sign.
Image courtesy South Dakota DOT, Andy Vandel

The warning system consists of vehicle detector loops on the side roads of these rural intersections. The loop detection triggers a flashing light and electronic board sign with a message indicating that traffic is approaching on the side road. The lights and sign remain off when there is no side-road traffic approaching the main highway. The specific messaging triggered by traffic on SD 20 is "Traffic Entering When Flashing" and the traffic sign on U.S. 281 reads "Traffic Approaching When Flashing."[77]

Project Purposes

The first conflict warning system in South Dakota is located where two rural two-lane highways intersect. This intersection has a long history of crashes. Between 2006 and 2017, the intersection of SD 46 and SD 37 had experienced nine injury crashes and one fatal crash. Different safety techniques have been deployed over the years to address the issue. A South Dakota DOT engineer had heard about Minnesota DOT installing warning systems and decided to try a similar pilot. South Dakota DOT hired Minnesota-based SRF Consulting to do the design, using concepts and advice from both Minnesota and Iowa projects. In the end, South Dakota wanted a system that was based on those concepts but was tailored to work for South Dakota's conditions.

Outcomes

Minnesota DOT recently completed an analysis of the intersection conflict warning system installations in their state and have found that there have not been clear crash reductions in the past three to five years, although minor reductions indicate the potential for reduction of right-angle crashes.[78] A separate usability study conducted by the University of Minnesota suggests that drivers might behave differently depending on the warning system's design, including wording on the sign and how to use electronic components to indicate the sign is on and when traffic is approaching.[79] Both Minnesota and South Dakota DOTs plan to continue to evaluate its existing locations before installing the system at additional intersections. South Dakota also plans to monitor its pilot locations before adding more intersections. There has been one crash at the SD 46 and SD 37 intersection since 2017's warning system installation. There is not enough data available at this point to draw conclusions about effectiveness of either of South Dakota's warning projects.[80]

Resources

The cost of the warning system infrastructure at the SD 46 and 37 intersection was approximately $170,000 including design. The second intersection at U.S. 281 and SD 20, where a divided four-lane highway intersects with a two-lane highway, cost $214,000 including design. Design includes detection type, loop or video sensors, and determining the amount of delay between the time a vehicle is detected and the light is triggered. Design also includes setting up the type of sign messaging.

In terms of maintenance, South Dakota DOT staff state that the intersection conflict warning system is similar to maintaining a traffic signal but on a smaller scale. Maintenance includes repairing damaged loops, restoring lost power, and maintenance specific to the technology. Maintenance is conducted by South Dakota DOT.

Public outreach about the intersection projects included news releases shared through South Dakota News, media articles, and the South Dakota DOT has posted video of the intersection warning systems on the South Dakota DOT YouTube channel.[81]

5.4 Using Passive Pedestrian Detection for Trail and Roadway Crossings

The Florida DOT District 7 office, working in coordination with regional agencies, is piloting the use of passive pedestrian detection at the intersection of one of the state's long-distance, multi-use trails, the Fred Marquis Pinellas Trail, and Skinner Boulevard (S.R. 580) in Pinellas County. The multi-month project will test how technology can serve the dual purpose of improving pedestrian and bicyclist mobility and safety as well as collect pedestrian and cyclist counts.

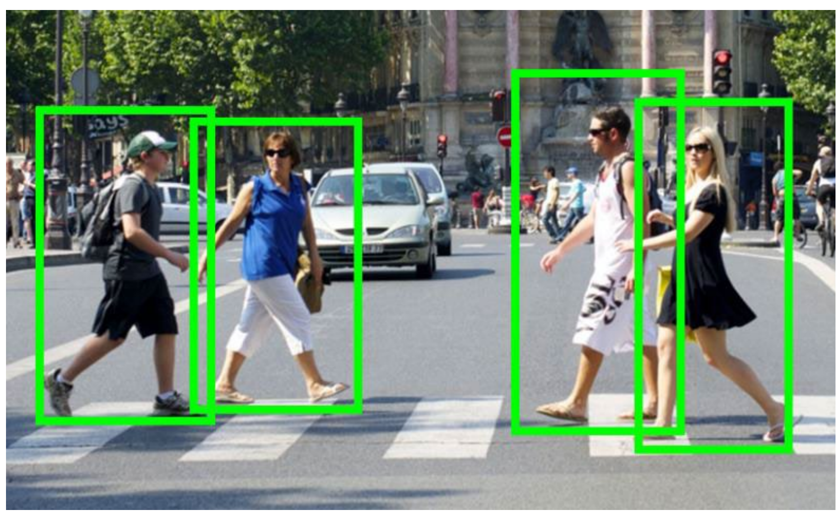
Four agencies are partnering to conduct the pilot: City of Dunedin, Florida DOT, Forward Pinellas (the Metropolitan Planning Organization), and Pinellas County. Each organization took on a role in project planning and implementation. Florida DOT proposed the detection sensor system and connected technology vendors to the local agencies. In addition, Florida DOT has the responsibility of conducting a before and after evaluation. Forward Pinellas had the role of coordinating planning and engineering among the project parties. Pinellas County financed the purchase of a new Rectangular Rapid Flashing Beacon (RRFB) and provided the personnel to install the equipment, including the camera detector purchased by the City of Dunedin.

Project Purposes

As background, the first segment of the Fred Marquis Pinellas Trail opened in 1990. Federal and state funds, along with funding from a local option sales tax, have supported completion of the trail. As of 2019, the facility is approximately 50 miles long, running north-south along former CSX railroad right-of-way.[82]

New crossing detection system in place at Pinellas Trail and Skinner Boulevard. Image courtesy Whit Blanton, Forward Pinellas

Skinner Boulevard (S.R. 580), a principal arterial, is currently two lanes each direction with striped on-street bicycle lanes. The Pinellas Trail crossing at the pilot location includes a ladder crosswalk, a median refuge area, and push button signals. According to trail counts, the average daily crossings consist of 65 percent pedestrians and 32 percent bicyclists, yet, a higher percent of pedestrians than cyclists (80 percent) actuate the signal at the Skinner Boulevard crossing. The location was selected in part because of the bicycle and pedestrian crossing volumes, and the solar power conducted at the crossing had inadequate battery storage capacity for the passive detection system and flashing lights integral to a RRFB planned for the crossing.[83]



Passive detection tracks bicyclist and pedestrian movements. Detectors are capable of adjusting signal timing.
Image courtesy Florida DOT District 7 presentation

Passive detection does not require trail users to push a crossing button. Detectors track movement and are linked to signal timing. In addition to facilitating crossings, detectors can be used to conduct counts, clock speed, and identify direction of travel. Thermal energy emitted from cyclists and pedestrians trigger sensors linked to an installed RRFB that includes yellow rectangular lights that flash. According to the FHWA's Safe Transportation for Every Pedestrian (STEP) Countermeasures, RRFBs can reduce pedestrian crashes by 47 percent. RRFB installation ranges from $4,500 to $52,000 with an average installation cost of $22,250 per site.[84]

Florida has the nation's highest levels of pedestrian fatalities, and the state is focusing on efforts to reduce pedestrian risks. Florida DOT's Strategic Highway Safety Plan includes emphasis on using a

"…systematic approach to identify locations and behaviors prone to pedestrian and bicycle crashes and implement multi-disciplinary countermeasures" and creating "urban and rural built environments to support and encourage safe bicycling and walking."[85] In the case of the Pinellas Trail and Skinner Boulevard crossing, the location was the site of 11 bicycle crashes and six pedestrian crashes between 2011 and 2019, making it a key location for the state's safety improvement plans. Funding support for the cyclist and pedestrian detection system came through a combination of city and county funds with other agencies providing personnel support for installation, maintenance, and evaluation. Pinellas County will maintain the camera detection and RRFB system according to a master agreement signed between the county and Florida DOT. Florida DOT arranged for the technology vendors to provide installation and usage training during project implementation.[86]

Outcomes

As the Pinellas Trail crossing is part of a pilot test, results and evaluation of the new crossing detection have not yet been finalized. An evaluation report is expected to be available in early 2020. According to Florida DOT district engineering staff, initial results have been positive per trail user feedback.

5.5 Adapting Non-Traditional Technology for Bicycle and Pedestrian Uses

Intelligent thinking can lead to the creative application of non-transportation technology in a transportation environment. In the case of Allentown, Pennsylvania, an existing construction industry technology was exactly what the city needed for a new walking program. In 2016, the city decided to expand an existing senior walking program pilot to create a healthy walking initiative. The city's Health Bureau is the recipient of U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Million Hearts funding through the Pennsylvania Department of Health and administrator of the walking program called "Million Clicks for Million Hearts." Million Clicks is free to all registrants. Upon registering, participants receive a key tab to click in at a time clock to mark that they've completed a certain number of walks on local paths. Time clocks are typically used by workers who need to punch in and out of a job site, but in this case, Million Clicks registrants are punching in to record their walking patterns. By doing so, they become eligible for prizes such as gift cards.[87] In addition to the federal funding, Allentown's program is supported by private partners and national associations including the Aetna Foundation, the American Public Health Association, and the National Association of City and County Health Officials.

Project Purposes

The CDC Million Hearts program is a national health initiative to prevent heart attacks and strokes. According to federal statistics, one in three deaths in the United States is due to cardiovascular disease.[88] Million Hearts funding recipients across the U.S. have designed local programs to encourage healthy living and reduce the risk of heart attacks and strokes. The City of Allentown looked for a creative way to promote physical activity to reduce heart disease. Time clocks and tracking software document the walks people are taking. The weather-resistant time clocks are positioned on wooden posts along with a sign indicating that walkers can "Click, Walk & Win!" Walkers register with the City of Allentown Health Bureau, which assigns them a key tab and participant number. Participants also receive a Million Clicks newsletter, and they become eligible for monthly drawings.

Million Clicks for Million Hearts is promoted by the Allentown Health Bureau and Parks and Recreation Department as well as community partners such as local hospitals, businesses and schools.

Outcomes

Allentown's walking program had 3,400 participants as of December 2019. The city averages approximately 500 new registrants per year. Participants can easily go to a City webpage to register. When asked if key tabs are ever reassigned due to relocation or other life events, Allentown Health Bureau staff said that some key tabs have been turned back in, and the city has been accommodating about replacing lost key tabs although there is a limit on replacements because of the costs.[89]

Because Million Clicks is state grant funded, the city reports number of participants, number of clicks, email newsletter recipients, and social media interaction on a quarterly basis.

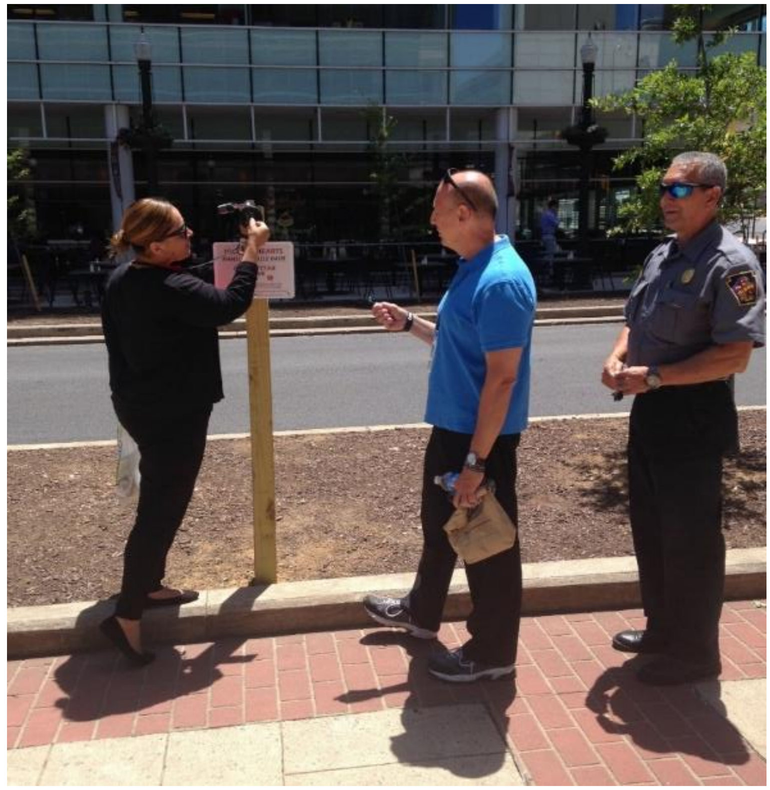
Million Clicks Million Hearts signpost on Lehigh Parkway walking path in Allentown, PA.
Image courtesy City of Allentown/Alexandra Kleintop

Finally, when asked if trail development and pedestrian improvements have increased due to the Million Clicks program, city staff acknowledged that trail development is happening through transportation and recreation funding, and the increased interest in walking options was happening even without the Million Hearts funding; however, the initiatives intersect and complement each other.[90]

Resources

The City of Allentown has received an extension to its state funding to continue its Million Clicks walking program through 2023. The Million Clicks for Million Hearts program has been so successful in Allentown that even if state funding is not continued beyond that point, the city would consider securing funding through a private funder or foundation to continue the program.[91]

The costs of implementing the time clock and key tab technology includes registration system software start-up at $1,000 per year for one computer license and the cost of key tabs, which are normally $10 each, but bulk purchasing provides discounts. Each time clock costs approximately $500. The City of Allentown supports sign and post maintenance through its Public Works and Parks and Recreation offices. Allentown Health Bureau staff noted that the company that provides the city's Million Clicks time clocks is moving to a cloud-based software and that may alter pricing in the future. A training session was provided by the time clock supplier, and the supplier provides software and equipment technical support. Clocks have been sturdy and have worked well. Batteries are replaced by city employees on a regular schedule.



Using key tabs to click in at a Million Clicks Million Hearts time clock in Allentown, PA.
Image courtesy City of Allentown/Alexandra Kleintop

Learn more about Allentown's Million Clicks for Million Hearts and the time clock system at https://www.allentownpa.gov/Health-Bureau/Million-Clicks-for-Million-Hearts and http://walkingsummit.org/click-to-walk-in-allentown-pennsylvania.

6 Transit and Mobility Case Studies

6.1 Technology Improves Western Iowa Transit Operations

Western Iowa Transit (WIT) is a program of the Region XII Council of Governments (COG), an RDO that serves six counties and 56 cities with a total regional population over 74,000.[92] WIT was formed in 1977 and has grown to 60 vehicles and a transit division staff of 39, who provided 158,000 rides and over 1.1 million revenue miles in 2018. WIT operates two commuter routes as well as demand response transportation scheduled by calling the main office or submitting an online rider form with contact information, origin, destination, and the time of the client appointment. Transportation to congregant meals is provided, as well as special services such as transportation from a senior center to a grocery store each week, general public transportation, and non-emergency medical transportation.[93] Historically, WIT had used a variety of methods to communicate between dispatching staff and drivers, from posts on bulletin boards to phone, fax, cell phone, and two-way UHF radio, even at times tracking down drivers by calling their favorite area restaurant to let them know of a change in their schedule. In 2017, WIT began to research options and initiate procurement for needed communications upgrades.[94]

Western Iowa Transit staff member John Shymanski checks the schedule on one of the agency's tablets. Image courtesy Region XII COG.

Project Purposes

The two-way radios that provided the backbone of communication with drivers were comfortable for staff. However, they only worked in about 60 percent of WIT's rural service area. The analog radio system provider notified WIT that it would stop supporting that system, so a change needed to occur. WIT switched to a cellular-based system (*shown in the image to the left*), installing Samsung tablets in each vehicle to use for automated vehicle location (AVL), to share manifests, and to communicate with drivers.[95]

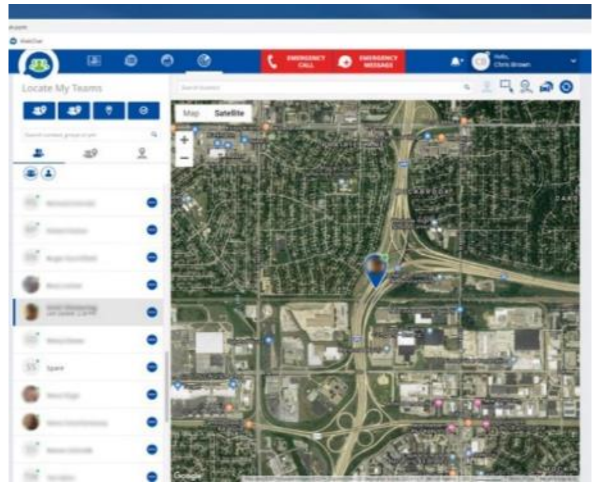
WIT had started using the software ParaPlan around 2016 for scheduling, which eliminated paper manifests. Along with the tablets, WIT adopted Team on the Run software for dispatching and geolocation. The two software companies worked with WIT to feed scheduling data from ParaPlan into Team on the Run for dispatching. This software combination provides several features that improve transportation operations over using the old two-way radios.[96] In the Region XII COG office, the WIT director can track drivers' location and speed, as well as whether clients have been picked up. Drivers can receive dispatch messages and enter data such as rider timing or whether the rider paid. Previously, drivers were sometimes unsure who needed to pay at the time of the ride, but now drivers can see whether a rider is self-pay or if the trip is funded through a contract or other mechanism. Drivers also have access to information such as scheduled pick-up time, a client's appointment time, name, whether they use a wheelchair or are ambulatory, and where they will need to return each rider rather than relying on memory, relayed messages, or handwritten notes.[97]

Having the tablets and on-board software is helpful to map trips. WIT provides medical transportation and Job Corps transportation into neighboring regions and states, so drivers are not always familiar with the route and destination. AVL adds a measure of comfort, since the WIT director can check on a driver's location on an out-of-state trip to see whether the driver is still in service, shown in the image below.

Drivers can use an emergency button to quickly indicate an urgent problem to staff in the office. The data also assist WIT with conducting driver safety evaluations, using trip information such as speed to support evaluations and training.[98]

Outcomes

The new cellular-based system provides 80 to 90 percent coverage of the six-county service area, much higher than the two-way radio coverage.[99] A focus on ease of use has been key, to ensure that drivers are comfortable with the tablets and knowing how to access manifests and enter rider information. This transition has been successful, with the new software providing many benefits at a lower cost than upgrading the two-way radios would have been.[100]



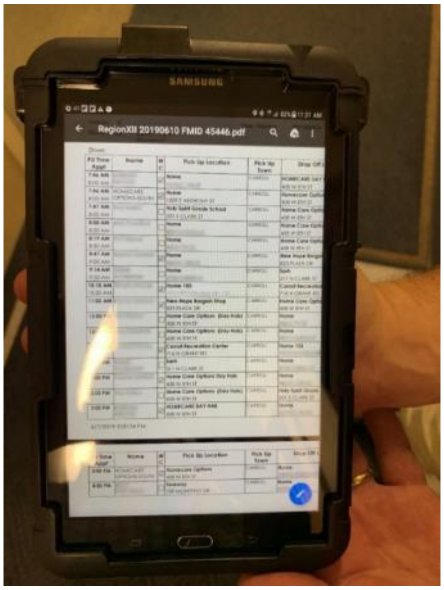
A screenshot of the geolocation view available to staff in the WIT office.
Image courtesy Region XII COG.

Overall, communication and reporting have significantly improved with the technology upgrade. A remaining challenge is that software solutions examined by Region XII COG are set up to track trips by vehicle. In contrast, WIT develops its scheduling by driver, and the most efficient dispatching might include a driver providing a trip, returning to the office, and switching to a different vehicle (such as a wheelchair accessible van) based on the number of riders and their needs.[101]

Resources

The upfront cost for a ParaPlan license was $25,400, half of which was supported through a grant from Iowa DOT. After the fifth year of the license, WIT pays an annual maintenance fee of $1,400 and cloud fee of $2,500 keep the software up to date.

In addition, other associated costs total less than $1,000 in a typical month. This includes a shared monthly cellular data plan of $160, connection fees of $10 per line for up to 40 tablets, and $35 per line for four staff smart phones. The tablets are provided for free by the cellular provider, U.S. Cellular. Team on the Run licenses are charged at $6 per driver per month. WIT acquired headsets for the drivers from another vendor at $20 – 30 per set. The monthly cellular fees represent a significant cost savings over upgrading the two-way radio system, which would have cost $3,500 per month and provided less functionality and coverage.[102]



The tablet used by WIT drivers displays manifest of clients and trip information. Image courtesy Region XII COG.

The two software applications in use, ParaPlan and Team on the Run, are developed by different companies and did not automatically link up. However, the two companies were willing to work together to find a way for ParaPlan scheduling data to feed into Team on the Run dispatching.

With some time spent on orientation and training on the new procedures, staff are now using the tablets (*shown in the image to the left*) and new software comfortably.[103] The acquisition of ParaPlan by a larger company, Passio, will lead to new software features.[104] Support for Android and updates to billing and reporting may offer new functionality to WIT.[105]

For more information on WIT, visit http://www.region12cog.org/public-transit/.

6.2 Scheduling and Dispatching Deployment and Broadband Expansion in Rural Ohio

In 2015, the Ohio Department of Transportation (ODOT) and project partners were selected to receive $6.8 million for a project called Transit Tech Ohio (T2O) in federal funding to improve rural transportation through the Transportation Investment Generating Economic Recovery (TIGER) VII competitive grant program. The funding supported the state's efforts to work with rural transportation providers for software access and to improve rural broadband. Without connectivity across their service area, transportation providers cannot get the full benefit of software.[106]

Project Purposes

ODOT assessed the transportation services and software of each partner rural transportation agency and the availability of broadband within its service area to assist with developing estimates of the need. Some agencies had scheduling software already, but many did not. Several areas were found to have insufficient broadband access. Most rural transit agencies provide demand response service, but two provide fixed route service.[107]

To minimize the burdens on individual rural transportation systems for procuring new technology, ODOT developed a set of minimum standards for hardware such as tablets and GPS, software for scheduling and dispatching, and services such as installation, maintenance, and training. ODOT then issued an invitation to bid (ITB) to select approved vendors who meet those standards as well as federal procurement requirements, from which rural systems could choose to procure services through the project.[108] A similar ITB was developed to select vendors to provide software to support fixed route service.[109]

To maximize the benefit of acquiring new software, ODOT worked with Connect Ohio, a subsidiary of Connected Nation operating as a nonprofit to expand broadband in Ohio.[110] Connect Ohio mapped broadband speeds in the counties served by participating rural transportation agencies. This was achieved by conducting drive tests with a cell phone in a car that was used to test connection speeds on the major cellular networks in the state. The project also identified state- and other publicly owned assets such as water towers or land where wireless broadband towers could be placed. The asset data were overlaid with locations identified through the drive tests as having no signal.[111] This allowed Connect Ohio and ODOT to identify that there were several locations where towers could be placed on public land or facilities to improve broadband access. Connect Ohio and ODOT issued an ITB for wireless broadband service; however, it has been more difficult than anticipated to incentivize private partners to invest in wireless broadband infrastructure in rural areas of Ohio, even with subsidy and the use of public facilities such as water towers to install the wireless infrastructure.[112]

The T2O project has supported transportation providers' licenses to access the software offered by the vendors who met the requirements through the ITB and contracting process for demand response and fixed route. It also supported the agencies' access to mobile routers that provide cellular connectivity to two cellular providers, which the transportation agencies were able to choose based on coverage that had been mapped in their service area.

DEMAND-RESPONSE SOFTWARE SPECIFICATIONS

The required minimum standards developed by ODOT and the T2O steering committee included data elements that the software application would need to collect about clients and trips, communication ability to update manifests and connect drivers and the base, real-time tracking, hardware requirements for in-vehicle tablets, and reporting. Certain software functionalities were listed as necessary in the specifications, such as auto-scheduling demand-response trips, editing records, and calculating pick-up times and fares. In addition to the software requirements, the standards addressed a minimum amount of initial and annual training to be provided by the vendor, maintenance including software upgrades and technical support.

Source: ODOT ITB 142-17: Transit Scheduling and Dispatching Software

Outcomes

Some rural transportation providers around Ohio already had been using ITS to support scheduling and dispatching, but the T2O project has opened new opportunities for many agencies. South East Area Transit (SEAT), one of ODOT's rural transit partners in the T2O project, serves Muskingum, Guernsey, and Noble Counties and went live with CTS software, obtained through the T2O project, to support its demand-response service in January 2018. New staff hired in mid-2017 brought in prior knowledge of other software with similar functionality, which was of benefit to the agency in making the transition from older software.

SEAT Operations Director Andrea Dupler credits the progress SEAT has made to work in the months leading up to going live with new software: "Our success with CTS is because we prepared for the software, cleaned out old data, and spent months with Executive Director Howard Stewart to really get to know the business. That allowed us to know what we wanted, so when CTS techs were on-site, we could tell them what we wanted to customize and knew what to ask for help with.”

SEAT Dupler and Stewart analyzed the agency’s operations and goals. This led to new operational decisions about where and how to deploy the agency’s own vehicles for fixed route and demand response trips, which locations would work better contract out the trips, as well as how to better coordinate trips to maximize efficiency. Once the software was live, SEAT staff relied on trial and error for a few months to set up parameters within the software, being willing to change their approach in order to use the software as fully as possible to improve scheduling, dispatching, communications, data validation, reporting, and other functions.[113]

Riders receive reminder calls notifying them of an upcoming transit pick-up with SEAT’s demand response software.
Image courtesy SEAT

Together, the changes that SEAT underwent along with adopting CTS have led to significant transportation outcomes. Prior to using the new software, SEAT was scheduling 2,300 trips per month. By December 2019, SEAT scheduled 9,300 trips per month, more than a 400 percent increase in two years. Over the same time period, SEAT’s passenger per hour rate increased from 1.6 to 5.3, and the operational cost per passenger decreased by $2 per passenger. Previously, most calls for demand-response trips came in 72 hours in advance, but now SEAT can accommodate same-day requests. No-shows for trips have decreased from 17 percent to 2 to 3 percent.[114]

SEAT has shared its successes with other agencies, having conducted outreach and trainings to about two dozen other rural transportation agencies to share lessons learned such as analyzing business operations in order to determine priorities for using new software, and using block scheduling rather than open scheduling.[115]

Tuscarawas County Mobility Manager Shannon Hursey has identified several promising outcomes from launching CTS with Horizons Rural Public Transit, including wayfinding and customer service. “Some people don’t have mailboxes, or they might live on a dirt road with little signage, so GPS has been very welcomed by the drivers.” Hursey continues, “It’s very helpful that clients are getting alert calls the night before or morning of a scheduled ride to know when their pick-up times are. If they call in to check on their ride, they are getting the most up-to-date information. You can see exactly where the driver is.” Being able to use farecards that the drivers can scan has also simplified the need to have exact cash for certain riders using transit for employment, education, or other institutions.[116]

Hursey, Dupler, and Stewart all identified a lesson learned for other rural regions considering a similar transition of identifying training opportunities to better align software capabilities with transit operations. The agencies all received training in how to use the software but felt training provided by individuals with transit operations experience could have helped to optimize their use of CTS early on. Initially, some drivers did not find the system intuitive for tracking trips, so data validation became a large task until everyone became comfortable with the new processes.[117]

Rural transportation agencies have had varying degrees of success with using the auto-scheduling function of the software. SEAT has seen major efficiency gains from using auto-scheduling, particularly with rides provided on the agency's buses, which carry more passengers than many of their vendors' vehicles and are used most heavily in Zanesville, Ohio, a city of 25,000 that serves as a regional hub.[118] In contrast, Horizons Rural Public Transit has not used the auto-scheduling feature as extensively. Hursey describes that Horizons Rural Public Transit sees many clients needing non-emergency medical transportation to destinations outside of Tuscarawas County. With a small fleet, it has been more difficult for the auto-scheduler to handle from an operations perspective to manage the number of vehicles on longer trips at the same time and the number of miles traveled.[119]

Ohio continues to prioritize broadband expansion through ODOT's work, and a state broadband strategy adopted in 2019, but there are still gaps in coverage. These gaps in coverage cause hiccups in the agencies' use of new technology, Hursey says, but the vehicles' tablets do catch up when signal is restored.[120]

Despite these challenges, opportunities to increase mobility are continuing to grow. SEAT staff outreach to area medical offices has encouraged many to also begin using CTS to schedule their patients' transportation, a major change from an earlier survey where health partners indicated a lack of knowledge about transportation options. Dupler says, "I was on a mission. If someone said transportation didn't exist, I was going to prove them wrong." With a new focus on mobility as part of the medical offices' business model, Stewart says, one facility has even purchased four vehicles and plans to partner with SEAT to deploy them, and other medical offices have begun to pay for clients' trips if they are not eligible for other funding support.[121]

Hursey notes that mobility managers across Ohio have seen their partners become much more open to possibilities to improve transportation outcomes. Not all of the changes are tied to accessing new software, but accessing ITS solutions have been part of the change.[122] Tuscarawas County, the three counties served by SEAT, and several other neighboring counties are all part of a regional coordinated transportation planning pilot program conducted by the area's RDO, Ohio Mid-Eastern Governments Association (OMEGA), funded by ODOT.[123] ODOT's support of this and other related mobility pilot projects such as a regional call center pilot project partnership between SEAT and Tuscarawas County Mobility Management Program and other rural efforts enhances transportation providers capacity to learn from peers and innovate. At the state level, efforts are underway to harmonize requirements across state agencies and simplify the process of providing transportation.[124]

Resources

ODOT and its partners received $6,839,860 in federal funds to support the project and used $466,000 of state funds. Local match of $34,000 statewide included a $1,000 paid by each rural transportation agency to access the software.[125] The grant funds and state match provided the remaining support for software licenses, hardware installation, data subscriptions for mobile routers on the vehicles, and other expenses related to procuring the software and accessing broadband. Where trips have increased, many of the additional trips are eligible for non-emergency medical transportation (NEMT) funding through Medicaid or other public and private sources, which supports operational costs. Ongoing efforts are being made by state and local governments, as well as their RDO partners, to secure additional capital funding for rural broadband from multiple sources.[126]

6.3 Software Supports Volunteer Transportation

Volunteer transportation management is fundamentally different from managing volunteers who are contractors or employees, says Volunteer Transportation Center Inc. (VTC) Executive Director Sam Purington.[127] VTC provides essential mobility services in Northern New York and in New Hampshire using only volunteers. VTC is a nonprofit leader in its coverage area, breaking down transportation barriers for the most vulnerable populations, having completed 5.7 million miles driven on over 158,000 one-way trips in 2018. A staff of 29 individuals manage a mission-driven volunteer team of over 350. VTC provides two categories of transportation, (1) contracted trips that are arranged and reimbursed by an agency or insurer (Fidelis, Nascentia, Medicaid, and others), and (2) trips funded by the donations of the local communities the volunteers serve. Volunteers use their own vehicles and receive reimbursement for miles traveled.[128]

Project Purposes

Off-the-shelf software exists for tracking rides, but it does not account for the human interaction and social capital needed for volunteer management. Without a readymade software solution, VTC brought two developers on board in 2017 to create software built for volunteer centric transportation options.[129] The software tracks origins, destinations, and times for the trips, along with volunteer availability and assistive route design to coordinate trips and maximize efficiency. The software also records the funding source for each trip. Important for VTC's mobility model, the software also includes volunteer credentialing controls (such as tracking background checks and vehicle inspections, vehicle registration, completed orientation, signed handbook, and any training that the volunteer needs to complete). For example, VTC's trips include transporting children in foster care, so volunteers that transport children must attend training on installing and using car seats among other classes. In addition to tracking information about trips and volunteers, the software also alerts clients when their ride is approaching. Alerts can be delivered by text or email to clients themselves or others who book transportation for clients, such as a case manager at an assisted living facility.[130]

As of mid-2019, 240 volunteers are using the new software application, which may grow as funding allows and as volunteers become more comfortable shifting away from using paper records. VTC has issued tablets to most of these volunteers, but volunteers who have a smartphone and an adequate data plan (typical usage is 500 mb per month) can add the app to their own personal device.[131]

Usability was central to the software development project from the start. VTC hired two individuals as developers who already had some transportation experience. They used site visits and phone calls to learn the requirements, terminology, and business practices of providing volunteer transportation in rural areas in order to build an application that addressed compliance and privacy, tracked the right indicators, and maintained human interaction with the volunteers rather than automating all of the dispatching functions.[132]

A VTC volunteer assists a rider from the vehicle to the door of their destination.
Image courtesy VTC

Volunteers not only provide rides but are also critical data collectors, responsible for tracking the rides they provide to clients. The average age of the VTC volunteer pool is about 60, with some individuals who are eager technology adopters and many who are less comfortable with new technologies. VTC reached out to the volunteers least interested in transitioning away from paper records to guide the development of the app. This focus on user experience has been successful; engaging volunteers who might otherwise be reluctant to change helped to ensure that they would have a user-friendly interface to report information about their rides and receive reimbursement. "Now, people will move from paper to digital and never want to go back. In fact, our bigger challenge in communicating with volunteers is using email effectively, not the app," says Purington.[133]

In addition to the software's ability to simplify information management about trips and volunteers, VTC is testing additional functionalities that will be deployed over time. For example, a feature being tested in 2019 would use algorithms to automate volunteer assignment, matching up volunteer location with the trip location, as well as the type of vehicle needed (such as wheelchair accessible) and the days and hours of the week that a volunteer is available. Assistive route design is a software feature, with the option to fully automate volunteer assignment once that feature is rolled out. This is expected to help with trip coordination, but it would not replace the work of VTC's dispatch staff in connecting with volunteers by phone. Purington says, "Streaming an assigned trip directly to the tablets is not the right way to work with our volunteers. Automating volunteer assignments will allow our dispatchers do things in a more efficient way. Then dispatchers can spend time on phone interactions that build the connection volunteers have to the organization, so that volunteers are willing to provide a ride when asked. Volunteer management is based on knowing each other." Once the person has accepted a request from a dispatcher to provide a ride, they can receive trip information through the app.[134]

Outcomes

The new software is already improving some metrics and is expected to help improve others as it becomes more fully implemented. With the features in use so far, volunteers are reporting that the app is easy to use and simplifies their recordkeeping role. For VTC staff, the app streamlines data tracking and compliance. Over time, VTC will track additional metrics using the software regarding efficiency and effectiveness. These include deadhead miles driven without a client on board (volunteers are reimbursed for mileage to and from their home), missed appointments, and near misses when a client barely arrives in time to keep their appointments.[135]

VTC conducts outreach to other regions and organizations looking to create a volunteer transportation program. The "VTC in a Box" program provides tools for running a volunteer transportation program; guidance during development and implementation; training for program staff, transportation coordinators, and volunteers; as well as access to its proprietary software.[136] "VTC in a Box" has been provided to other areas of New York and other locations where there is interest in improving mobility through volunteer transportation. VTC is also working with the non-profit MOVE in Stanislaus County, California, to develop a volunteer program in the rural Central Valley area of the state. Once it is implemented, the volunteer program will be brought into a mobility app that integrates public transportation, volunteer transportation, and other available services to allow clients to request rides. The app is being developed by professionals at the University of California-Davis.[137]

Resources

Beginning several years prior to software development, Purington says that VTC negotiated a higher rate for its transportation contracts, working with funders to explain that transitioning to digital recordkeeping would require effort and expense. VTC was able to build up enough of a fund balance to support the development, testing, and deployment of the app.[138] Having developers on the VTC team will not be a long-term situation. Although new functionality and support over time will be needed, the developers will spin out the software as a social enterprise after it is deployed more fully by VTC. That way, the social enterprise can provide the software to other volunteer transportation programs at a low per-ride fee. This future process will enable nonprofits and other organizations with minimal budgets for transportation can access the app without large upfront investments in purchasing a license or an expensive subscription model. VTC can continue to focus on its mission of providing mobility and avoid having developers on staff permanently, without spending time marketing or supporting other organizations' use of the software.[139]

Training for volunteers and administrative staff can be incorporated into orientation procedures without much additional time investment. Case managers or others booking rides can access a user-friendly website to book trips with minimal training needed. Riders receive email or text communications about their rides via the app. There is no current need for riders to interface directly with the app itself, although that may change in the future.[140]

The tablets issued to volunteers cost about $100 to acquire, including needed accessories such as a protective case, charger, and all associated cords. In addition, VTC pays about $12 per month for each tablet to have a cellular data plan. Some volunteers use their own smart phone and have an adequate data plan, increasing the number of volunteers using the app without additional cost to VTC.[141]

For more information on the VTC, visit https://volunteertransportationcenter.org.

7 Preparing for Vehicle Connectivity and Automated Vehicles Case Studies

7.1 Using Vehicle Connectivity Technology for Roadway Weather Response

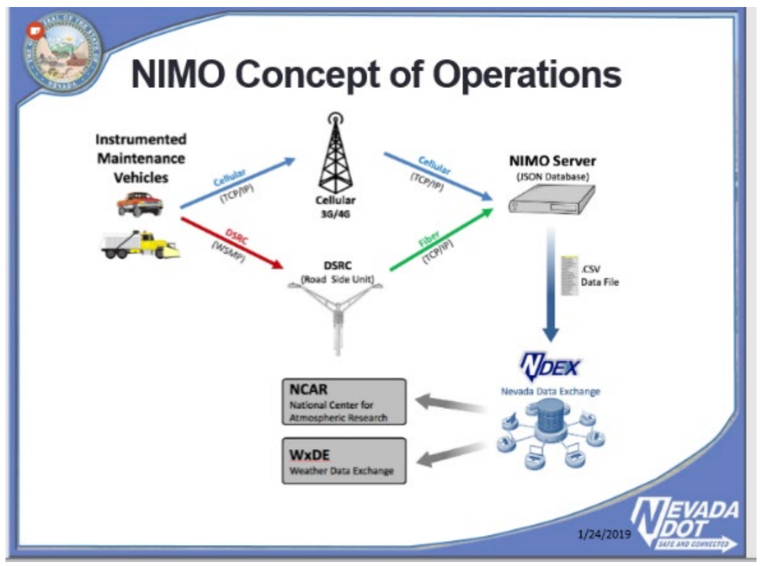
In an effort to improve safety, roadway conditions, and motorist advisory warning information during winter weather, the Nevada DOT recently launched a pilot to test dedicated short-range communications (DSRC) to improve the collection of weather condition data from snowplow vehicle and roadside units along the I-580 corridor between Reno and Carson City. The pilot is the third in a series of Integrated Mobile Observations (IMO) projects that Nevada DOT first launched in 2011. According to the

FHWA, the IMO applications "promote the collection of mobile, weather, road, and vehicle data from agency fleets to improve situational awareness of road conditions."[142] The DSRC application builds on a foundation Nevada DOT set with using Enhanced Digital Access Communications System radio for communication and cellular connectivity capabilities.

Project Purposes

In the Phase III snowplow connectivity project, roadside units, cellular signals, and on-board instruments are used by nine snowplow vehicles and one service patrol vehicle to provide real-time road and atmospheric condition data that will assist Nevada DOT's Enhanced Maintenance Decision Support System (EMDSS) for roadway treatment. In addition to Nevada DOT's internal use of the data, the information is used to inform the state's 511 system and other traveler information software.

The flow of communication between the sensor equipment mounted in Nevada DOT's vehicles and Nevada's data exchange is illustrated in the graphic below. How does the information flow from the vehicle-mounted units to the state's server and data exchange? As a first step, roadway and atmospheric weather conditions are read by sensor equipment in the vehicles. The sensor records the date, time, location, speed, altitude, air temperature, barometric pressure, humidity, dew point, road temperature, wiper status, and spread rate of treatment material. In the second step, the conditions report is relayed using cellular or roadside units that communicate with a central server.

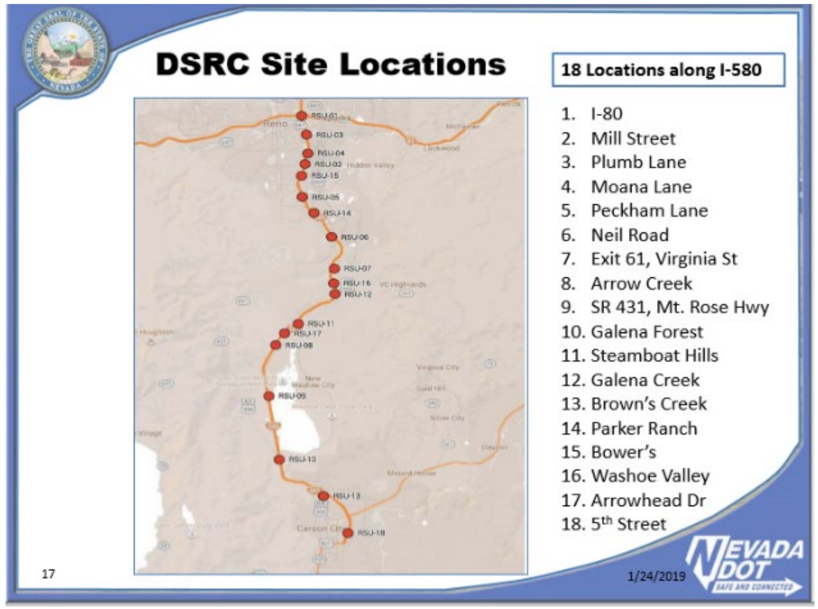


Nevada DOT Integrated Mobile Operations
Image courtesy NDOT

Once the data is received by the Nevada IMO server, the server exports a CSV file. Data in the CSV file is then sorted through the Nevada Data Exchange where the information is shared with weather and road condition providers (e.g., Nevada 511, Waze). The data generated is also used by Nevada DOT for dynamic message signs, highway advisory radio messages, and the EMDSS.

The on-board vehicle sensors update conditions data every eight seconds. There are 18 DSRC systems locations along Nevada's I-580 corridor between the I-80 interchange in Reno to 5th Street in Carson City, indicated in the map below. DSRC is used along I-580 and cellular coverage is used between the I-580 corridor and Lake Tahoe. DSRC have an effective range of 300 meters (less than one-quarter mile) at highway speeds, which can lead to longer caching times and delays in information exchange. In areas where DSRC, Wi-Fi, and cellular are not available, data is stored on the vehicle until communications are reestablished.[143]

Nevada's Integrated Mobile Operations system meets the standards of the National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP), Society of Automobile Engineers (SAE), and the National Marine Electronics Association (NMEA)—all incorporated through the Institute of Transportation Engineers (ITE) utilizing the Traffic Management Data Dictionary (TMDD). This TMDD data standard provides rules for communicating and vocabulary needed to permit electronic traffic control equipment from different manufacturers to operate with each other.



A map of the I-580 corridor indicates the locations of Nevada DOT's Dedicated Short-Range Communications Systems roadside units.
Image courtesy NDOT

Outcomes

Even though the primary purpose of the snowplow data collection is to inform the state's operations and maintenance practices, other users who benefit from the data are cities and counties, Nevada DOT's 511 system, the www.nvroads.com website, the Nevada Highway Patrol, and WAZE. This IMO project has already been integrated with the National Center for Atmospheric Research and FHWA's Weather Data Environment.

Nevada DOT staff have stated that the technology has helped to standardize how operations staff are trained for weather-related road treatment—important in an environment where staff turnover requires training for new employees.[144]

Resources

Stakeholders involved in the technology applications and development include the University of Nevada-Reno, University of Nevada-Las Vegas, University of California-Davis, and the Desert Research Institute. The cost of implementing the Phase III snowplow sensor project was over $4,000 each vehicle. The initial roadside equipment (i.e., radio and GPS/weather sensor) cost over $5,500 but was paid for during earlier phases of the Nevada project. In addition to one-time capital costs, the project has recurring data plan costs of $15 – $35 per month per vehicle. Additional information about costs and lessons learned are available in the Nevada DOT's Integrated Mobile Observations 3 Final Project Report prepared for the U.S. DOT.[145]

7.2 Partnerships Support Rural Technology Deployment Along Wyoming's I-80 Corridor

The Wyoming DOT is one of three agencies that was selected in 2015 by the U.S. DOT to pilot vehicle connectivity technologies. The two other agencies selected for pilots are the New York City DOT and the Tampa-Hillsborough Expressway Authority. Wyoming DOT is using ITS to improve safety along the I-80 corridor, which runs east-west through the southern portion of the state between Evanston and Pine Bluffs. Drivers who travel along that 402-mile segment of I-80 experience high winds throughout the year, and white-out conditions are possible during snowstorms. The state's Connected Vehicle Pilot (CVP) addresses weather and traffic through communication of messages and warnings signaled from roadside sensor units and onboard vehicle units. Both Wyoming DOT service vehicles and commercial carrier fleets are hosting onboard units as part of the pilot. Wyoming's CVP is considered critical to improve travel safety and reduce road closures due to vehicle collisions or blow overs. According to a U.S. DOT fact sheet on the CVP Deployment program, there were 1,237 reported blow overs from 2006 to 2016, and from October 2015 to September 2016, there were more than 1,600 crashes on I-80 resulting in 18 fatalities and 271 injuries. It is calculated that for the 2015 – 2016 period, the affected segments of I-80 were closed for over 1,500 hours.[146]

Project Purposes

Wyoming 511 public service outreach.
Image courtesy Wyoming DOT

Due to limited alternate routes, I-80 truck volumes can reach 50 to 70 percent of overall traffic during seasonal travel peaks.[147] As noted, the primary purpose of the CVP is to improve travel safety and reliability and reduce crashes and delays by improving road weather information, alerting drivers to emergency situations, and providing up-to-date information about travel speeds, detours, and truck parking availability. Vehicle-to-vehicle and vehicle-to-infrastructure interconnectivity is reliant on DSRC between the 75 roadside units and 400 vehicles with on-board units. The use of short-range communication and vehicle units will enable faster information sharing in conditions when there is not enough time for road and condition messages to be relayed from Wyoming DOT's Transportation Management Center.

Interconnectivity extends beyond the technology itself. Partnerships within Wyoming DOT divisions and with external partners from the public and private sectors are driving the CVP project forward.

The CVP's systems engineering phase was completed in 2016. Design, build, and deployment testing took place between 2016 and 2019 with maintenance and operation of the pilot occurring after fall 2019. The second phase of design and deployment involved working with the Wyoming Trucking

Association, third-party intermediaries, and commercial fleet partners who sign a memorandum of understanding with Wyoming DOT to participate and test the connected vehicle technology. Participating trucking fleets vary in size from small to medium regional operations (e.g., Dooley Oil, Inc.) to national fleet operators (e.g., Crete). Participants agree to have their truck cabs equipped with on-board units so that drivers and/or the units receive and relay data through one of the five onboard applications.[148] The five applications are: distress notification, forward collision warning, situational awareness (e.g., speed restriction, parking availability), spot weather impact warning, and work zone warning.

Truck fleets that participate in the pilot are expected to drive the Wyoming stretch of I-80 about three or more times per week and to continue with the pilot for a 12-month evaluation period. On-board units are purchased by Wyoming DOT and funded through the U.S. DOT. Fleet partners must agree to install on-board equipment using their own contractors with guidance from the Wyoming pilot team. Pilot fleets do not need to return the equipment. Drivers are expected to participate in periodic project surveys.[149]

As part of the partnership with commercial fleets, the University of Wyoming is providing truck simulator and online training for fleet operators. Training is required to ensure that drivers are informed about the system and its capabilities. The driver training consists of several modules that can be completed in a single training at the university's facilities in Laramie or on a computer at any location.[150]

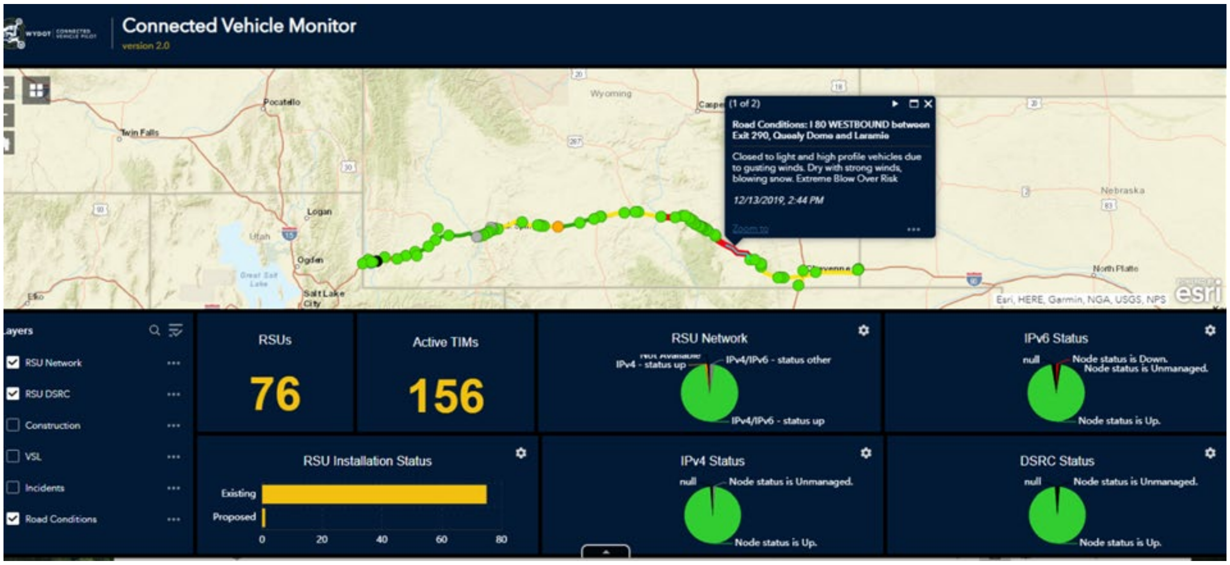
Outcomes

Real-time status of roadside units and road conditions along I-80 in Wyoming is visible on the Connected Vehicle Monitor. As depicted in a screenshot of the monitor taken on December 13, 2019, 76 roadside units are in place and 156 Traveler Information Messages (TIMs) were being shared at that moment. Segment colors indicate the quality of driving conditions and whether the road section is closed. Details identify exact conditions. An example message is "Closed to light and high-profile vehicles due to gusting winds. Dry with strong winds, blowing snow. Extreme Blow Over Risk." Winter 2019 through 2020 will be an opportunity for Wyoming DOT, I-80 travelers, pilot participants, and partners such as the Wyoming Trucking Association to determine how traveler information is being accessed and the extent to which drivers are making travel decisions sooner than in prior years.

Resources

The U.S. DOT awarded more than $45 million in funding for the three CVPs in Wyoming, New York, and Florida.[151] The U.S. DOT has funded small, mid-size, and large CVP projects. By the Department's definition, small projects are in the $2 million to $5 million range, medium-sized projects are in the $5 million to $12 million range, and large projects, such as the I-80 CVP, range from $12 million to $20 million.[152] For large-scale projects such as the Wyoming CVP, the U.S. DOT provides detailed technical assistance guidance.

Wyoming DOT has a documented plan for each phase of the project from conception to implementation, including plans for stakeholder outreach, partnerships (i.e., fleet partners, training agreements with the University of Wyoming), and project evaluation. The content and format of these plans can be used as models for other rural ITS projects, no matter their size. Plans can be scaled to match small, localized technology partnerships and local memoranda of understanding or can be expanded for regional deployments. A downloadable list of technical assistance documents and project plans is available at https://www.its.dot.gov/pilots/technical_assistance_events.htm#t2.



A screenshot of Wyoming DOT's Connected Vehicle Monitor.
Image courtesy https://wydotcvp.wyoroad.info/CVM/

7.3 Testing Vehicle and Infrastructure Connectivity in Marysville, Ohio

Union County, Ohio (population of 52,300 in 2010), and its county seat, the City of Marysville (population of 22,094) are testing vehicle and infrastructure connectivity in real-world conditions.[153] Along the U.S. 33 corridor, this area and neighboring counties are home to automotive manufacturers and research and development entities, making the area ready for innovation. Drive Ohio, the state's multi-agency partnership to advance smart mobility, and the local jurisdictions are working together with Honda and other partners to deploy roadside DSRC, on-board units in vehicles, and other technologies through connected intersections within the City of Marysville and along the U.S. 33 corridor, which connects Marysville to destinations such as Columbus to the southeast and to the Transportation Research Center in East Liberty to the northwest.[154]

Project Purposes

Connected Marysville

The City of Marysville, Ohio, has launched Connected Marysville, a project that has equipped all 27 traffic signals with DSRC that will enable communication between the signals and more than 500 planned connected vehicles in the community. This will enable the city to serve as a rural, smart mobility test site and provide automotive companies, government agencies, and academia an opportunity to develop and test connected vehicle technologies in a real-world environment.[155]

At the first intersection to receive cameras and DSRC to support connectivity (*shown in the image below*), downtown buildings at each corner of the intersection block the driver's view, reducing their opportunity to react safely to another vehicle running the red light, an approaching emergency vehicle, or even a pedestrian crossing. These applications, along with signal phase and timing messages, will alert drivers through their on-board units to the possibility of conflict so that they can react in time.

The city hopes that up to 5 percent of traffic will ultimately be equipped with on-board DSRC units, giving a large enough sample size to study how connected vehicles and intersections work together and how technology can support the goal of reducing fatalities. The vehicles with DSRC units include city and state vehicles such as government fleets and law enforcement vehicles, as well as volunteers interested in participating and local Honda employees.[156]

The city has worked with key partners to move the project forward. Significant funding has been provided through the U.S. DOT. Drive Ohio has provided funding through ODOT, technology, and technical assistance in the project. Honda has provided research, technology, and equipment, and has recruited employees to have their vehicles equipped with on-board units. Union County-Marysville Economic Development provides communications and marketing throughout the community, including in connection to other smart transportation projects, and supports the Northwest 33 Council of Governments who have partnered on the 33 Smart Mobility Corridor.

City of Marysville Director of Public Service shows visitors the connected signal cabinet interior. Image courtesy NADO Research Foundation

33 Smart Mobility Corridor

The 33 Smart Mobility Corridor is a 35-mile stretch of connected highway with on-the-road infrastructure that allows for the development and testing of vehicle connectivity technologies in a real-world, open and closed, all-weather environment. The corridor includes 94 roadside DSRC units and more than 175 smart signals, including those in Marysville as well as other jurisdictions along the corridor. The project allows for testing in rural, exurban, suburban, and urban environments.

The City of Marysville, Union County, and Union County-Marysville Economic Development have been players in the 33 Smart Mobility Corridor as well as in the Connected Marysville project. Since the 33 Smart Mobility Corridor spans a larger geography, other key partners have included the City of Columbus, City of Dublin, National Highway Traffic Safety Administration, Transportation Research Center, The Ohio State University and Center for Automotive Research, Honda, ODOT and Drive Ohio, JobsOhio, Battelle, and Logan County. The Mid-Ohio Regional Planning Commission has played a role in convening partners and supporting the project as a benefit to the entire central Ohio region, as the staff to the area's MPO and the Central Ohio Rural Planning Organization. These entities work together either as members of the Northwest 33 Council of Governments or as external partners, and together have focused the efforts of working groups on infrastructure, vehicles, smart network, engagement, and funding and finance.[157]

Outcomes

Innovation in transportation technologies is emerging around Ohio in a variety of rural, suburban, and urban locations, and in various types of technologies and applications across modes. The data and information gathered from both Connected Marysville and the 33 Smart Mobility Corridor will be important for research, manufacturing, transportation planning and operations, and more. So far, lessons learned from the rollout of these projects include the amount of time and engagement needed for volunteers to sign on to install on-board units in their vehicles and receive the benefits of intersection conflict warnings and other alerts. Project participants also had not anticipated the pace of change of technology and adaptations that need to be made over time, even as some locations for roadside units needed to install adequate power supply.[158]

These and other investments in advanced transportation technologies have also sparked interest in workforce development. A Smart Workforce Committee has been established including state and local government partners, educational institutions, and private sector partners. With a significant presence in the region of automotive and other advanced manufacturing as well as research sites, Union County-Marysville Economic Development anticipates future growth in jobs and investment made in the area. A program has been created to train high school students in this field, with local private sector partners offering the students hands-on experience through internships.[159]

Resources

The ability to test out new technologies in Marysville and Union County has been the result of significant investments by multiple partners. The NW 33 Innovation Corridor Partnership was the recipient of a $5.9 million grant from the U.S. DOT in 2016.

ODOT recently funded the installation of a fiber network at a cost of approximately $15 million in support of the investments along the corridor, along with local public match of $400,000. Local public and private sources have matched these state and federal investments with nearly $3.5 million. Another $45 million has been invested to establish a dedicated connected and automated vehicle testing facility at the Transportation Research Center, which is an enclosed vehicle proving ground situated along U.S. 33 in East Liberty, Ohio.[160]

Maintenance and operation costs for the connected infrastructure roadside units and signals should be minimal. Typically, the cost to install a roadside unit at an existing traffic signal ranges from $5,000 to $10,000 including installation. On-board units to retrofit vehicles that are not currently connected cost $5,000 including installation. For more information about these projects and others around Ohio, visit https://www.33smartcorridor.com/ and https://drive.ohio.gov.

7.4 Minnesota Plans for Connected and Automated Vehicles

Emerging technologies such as connected vehicles (CVs) and automated vehicles (AVs) raise significant questions in the statewide and regional planning processes. In order to address the uncertainties, the Minnesota Department of Transportation (MnDOT) Office of Connected and Automated Vehicles (known as CAV-X) developed a Connected and Automated Vehicle (CAV) Strategic Plan to guide the state's planning processes and investment decisions with respect to technology change.[161] This built off earlier work such as the state's CAV Advisory Council, research projects, and demonstrations and public outreach. During months of research and outreach to stakeholders through regional workshops and other methods, CAV-X gathered as much information as possible on the future of vehicle technologies and public sentiment.[162]

Project Purposes

The CAV Strategic Plan was developed to address future directions for Minnesota's capital investment, research and development, partnerships, regulation and policy, transportation system operations and maintenance, staffing, interactions between modes of transportation, external communications to decisionmakers and the public, and long-range planning.

To address the various issues on MnDOT impacts and processes, CAV-X conducted a multi-step planning process. This began with a scan of the industry to identify gaps where Minnesota could develop research and investment. A strategic visioning workshop with partners around the state led to the development of an overarching vision for the future of transportation technology. An online survey was distributed to RDOs, cities, counties, and other local and regional entities to assess whether they had begun to plan for vehicle connectivity and AVs. Less than 5 percent of respondents had, making the next phase of regional workshops an important one for communicating information about vehicle connectivity and AVs as well as gathering feedback to use in the planning process.[163]

Recognizing the wide amount of uncertainty about evolving technologies, the pace of change, roles of public and private sector partners, and adoption by the public and fleet owners, MnDOT chose to present scenarios of possible future directions. CAV-X staff used four scenarios with a 20-year time horizon, based on six scenarios developed by the FHWA but tailored to Minnesota's demographics. These scenarios were shared at workshops around the state in the next phase of data collection. Eight workshops were held in smaller cities and rural communities around greater Minnesota, and an additional four workshops were held in the Minneapolis-Saint Paul metropolitan area.[164] The staff and members of MPOs and RDOs attended workshops held in their areas, and the regional planning partners also assisted MnDOT by inviting regional stakeholders to participate. Attendees included practitioners in the transportation industry and local decision-makers such as mayors and county commissioners, as well as some consultants.[165]

Each workshop began with a CAV 101 presentation intended to set the context for the planning process, work from a common set of ideas about transportation technologies, and dispel assumptions. The attendees divided into four groups that each discussed one scenario, with a series of facilitation questions around the potential benefits of the scenario occurring, steps to achieve those benefits, potential risks, and steps to mitigate those risks. Attendees often reacted to the uncertainty of the future by asking questions outside of their assigned scenario, but trained facilitators used guided questions to bring attention back to the variables of that scenario. After the breakout group discussions, the entire group of attendees gathered to report back for a synopsis from each group.[166] Workshop attendees were very supportive of the fourth scenario, which assumed that CVs and AVs were the dominant mode of transportation and mobility was highly shared. However, rural residents, in spite of their support for the scenario's ideals, expressed doubts about implementation due to a comparative lack of broadband connectivity and other challenges.

CAV SCENARIOS

MnDOT CAV-X staff used four scenarios to present possible futures for CV and AV technology adoption. The scenarios included:

- **Advancing technology:** Today's technology advances slowly and becomes more common. Advanced automation is uncommon. Few vehicles are connected, automated, electric or a part of a shared fleet.
- **Connected infrastructure:** Connected vehicle technology advances more rapidly than automation. The public sector makes significant investments in connected and electric vehicle infrastructure because automated vehicle technology has lagged. Little focus is on shared transportation.
- **Private automation:** Automated vehicles are common, but not all benefits are realized. Automated vehicles rapidly multiple with a mix of privately owned cars and competing mobility providers. Congestion is common in urban areas as cooperation and sharing lag.
- **Integrated mobility:** Connected and automated transportation is integrated, affordable, and serves everyone. Car ownership drops and shared rides are common. Fleets are highly connected, automated and electrified.

Source: CAV Strateaic Plan

Outcomes

The workshops were an effective way to gather professionals with a role in transportation and other disciplines, including city and county planners and engineers, MPOs and RDOs, local transit agencies, non-profits, social services, and MnDOT staff. More than 1,750 comments were collected from the workshops conducted in the Twin Cities area and across Greater Minnesota, providing a significant amount of qualitative information to MnDOT.[167]

MnDOT is already taking next steps to work with local and regional partners to prepare for CAVs. In August 2019, MnDOT published a report through the Local Road Research Board titled *How Locals Need to Prepare for the Future of V2V/V2I Connected Vehicles*, developed by the Minnesota Traffic Observatory at the University of Minnesota.[168] This report provides a background on vehicle and infrastructure connectivity, potential applications, types of communication and hardware required for vehicle connectivity systems, and general guidance to local road owners to prepare for vehicle connectivity.

MnDOT CAV-X is also working on a strategic communications framework, so that all of the agency's staff and partners work from a common set of language and concepts when discussing transportation and vehicle connectivity and AVs with stakeholders around the state. The framework will also lay out demonstrations, events, workshops, and listening sessions throughout Minnesota to provide information to the public and stakeholders about transportation issues, as well as to receive input from them. CAV-X is also conducting research on telecommunications and undertaking an effort to identify corridors needing traffic signal upgrades (including rural corridors), which will be cost-effective system upgrades regardless of the pace of technology change and adoption.[169]

Research and innovation are major themes of the CAV Strategic Plan, so that the deployment of new technologies is well understood in Minnesota's climate and context, such as automated technology needing to operate in cold weather conditions. The University of Minnesota continues to be an important partner for conducting research that benefits MnDOT's planning and operations, and the state looks to its neighbors for lessons learned and to avoid duplicating similar research occurring elsewhere.[170]

CAV-X staff also hope to have additional resources developed for local partner audiences that can provide answers to some of their questions. Going forward, the CAV Strategic Plan will be tied into other plans developed by the agency, including modal plans as they are updated.[171]

For more information on the work of CAV-X at MnDOT, visit http://www.dot.state.mn.us/automated.

---

[1] U.S. Department of Transportation, ITS Joint Program Office (2018). Intelligent Transportation Systems Benefits, Costs, and Lessons Learned: 2018 Update Report, https://rosap.ntl.bts.gov/view/dot/36236
[2] U.S. DOT, Intelligent Transportation Society of America (2017). Rural Connected Vehicle Gap Analysis: Factors Impeding Deployment and Recommendations for Moving Forward, https://rosap.ntl.bts.gov/view/dot/34723
[3] National Center for Rural Road Safety (2018). Rural Intelligent Transportation Systems Toolkit, https://ruralsafetycenter.org/resources/rural-its-toolkit
[4] U.S. DOT, Intelligent Transportation Society of America (2017)
[5] U.S. Department of Interior, National Park Service (2014). Congestion Management Toolkit, https://www.nps.gov/orgs/1548/upload/NPS-CMS_Toolkit.pdf
[6] U.S. DOT, John A. Volpe National Transportation Systems Center (2011). Intelligent Transportation Systems in the National Parks System and Other Federal Lands, https://rosap.ntl.bts.gov/view/dot/9554
[7] United States Government Accountability Office (2016). Intelligent Transportation Systems: Urban and Rural Transit Providers Reported Benefits but Face Deployment Challenges, https://www.gao.gov/assets/680/677919.pdf
[8] Altman, S. & Bregman, S. (2019). Reaching Rural Transit Riders, Presentation at ITS America, June 14, 2019, https://static1.squarespace.com/static/5b44befeb98a780957982bf3/t/5d274f28a9a3290001b6c9ef/1562857256318/16627_Presentation.pdf
[9] Transportation Research Board, National Cooperative Highway Research Program (2017). NCHRP Research Report 845 Briefing Document: Strategies to Advance Automated and Connected Vehicles, https://www.nap.edu/catalog/24873/strategies-to-advance-automated-and-connected-vehicles
[10] Cash, Cathy (2019). Co-op Fiber and Drone Capability Improve Safety on a Georgia Mountain Pass, National Rural Electric Cooperative Association, www.electric.coop/georgia-co-op-broadband-fiber-drone-improves-safety
[11] Personal communication with Lamar Paris, June 2019
[12] Personal communication with Lamar Paris, June 2019, and Emily Dwyer, September 2019
[13] Personal communication with Lamar Paris, June 2019
[14] Personal communication with Lamar Paris, June 2019
[15] Cash (2019); personal communication with Daniel Frizzell, March 2020
[16] Personal communication with Lamar Paris, June 2019
[17] Personal communication with Emily Dwyer, September 2019
[18] Personal communication with Lamar Paris, June 2019
[19] Personal communication with Lamar Paris, June 2019
[20] GDOT (nd). Hurricane, http://www.dot.ga.gov/DS/Emergency/Hurricane

[21] GDOT (nd). Hurricane Information – Contra-Flow Lanes: The I-16 One-Way User's Guide, http://www.511ga.org
[22] Personal communication with Emily Dwyer, September 2019
[23] Personal communication with Emily Dwyer, September 2019
[24] Wells, Bill (2016). Transportation Management Center, Georgia Intelligent Transportation Society, www.itsga.org/transportation-management-center
[25] GDOT (nd). 511: FAQs, http://www.511ga.org
[26] GDOT (nd). General Information: Twitter Feeds for Traffic Alerts, http://www.511ga.org
[27] GDOT (nd). Hurricane Information: Evacuation Routes, http://www.511ga.org
[28] Personal communication with Emily Dwyer, September 2019
[29] Personal communication with Emily Dwyer, September 2019
[30] National Park Service (2014). Congestion Management Toolkit, https://www.nps.gov/orgs/1548/upload/NPS-CMS_Toolkit.pdf
[31] National Park Service (2018, 2008). Annual Visitation Summary Reports, https://irma.nps.gov/STATS/Reports/National
[32] National Park Service (2018, 2008). Annual Visitation by Park or Region, https://irma.nps.gov/STATS/Reports/National
[33] National Park Service (2018). National Park Service Announces Plan to Address Infrastructure Needs & Improve Visitor Experience, https://www.nps.gov/orgs/1207/04-12-2018-entrance-fees.htm
[34] National Park Service, Arches National Park, https://www.nps.gov/arch/planyourvisit/directions.htm
[35] National Park Service, Glacier National Park, https://www.nps.gov/applications/glac/dashboard/
[36] http://www.brycecanyonshuttle.com
[37] National Park Service, Montezuma Castle National Monument Facebook account, https://www.facebook.com/MontezumaNPS/posts/2309650859086507
[38] National Park Service, Rocky Mountain National Park Twitter account, https://twitter.com/RockyNPS?ref_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwgr%5Eauthor
[39] Personal communication with Dean Bressler, November 2019
[40] National Park Service, Arches National Park (2019). https://www.nps.gov/arch/learn/news/news100119.htm
[41] Personal communication with Dean Bressler, November 2019
[42] Personal communication with Kyle Patterson and John Hannon, November 2019
[43] Rocky Mountain National Park (2019). Shuttle Bus Routes, https://www.nps.gov/romo/planyourvisit/shuttle_bus_route.htm
[44] Personal communication with Kyle Patterson and John Hannon, November 2019
[45] Personal communication with Kyle Patterson and John Hannon, November 2019
[46] Personal communication with Kyle Patterson and John Hannon, November 2019
[47] Rocky Mountain National Park (2018). Decision Reached on Fall River Entrance Improvements in Rocky Mountain National Park, https://www.nps.gov/romo/learn/news/decision-reached-on-fall-river-entrance-improvements-in-rocky-mountain-national-park.htm
[48] Town and contractors begin installation of Dynamic Message Signs (2018). *Estes Park News,* http://www.estesparknews.com/featured_articles/article_f9ffc188-52d9-11e8-bced-8b255674d0b1.html
[49] National Park Service (2014). Congestion Management Toolkit, https://www.nps.gov/orgs/1548/upload/NPS-CMS_Toolkit.pdf
[50] Personal communication with Rebecca Thacker, March 2019
[51] Northwest Missouri Regional Council of Governments (nd). Transportation, https://nwmorcog.org/programs/transportation
[52] Rebecca Thacker (2019). Presentation to the National Regional Transportation Conference
[53] Rebecca Thacker (2019). Presentation to the National Regional Transportation Conference
[54] Personal communication with Rebecca Thacker, March 2019
[55] Rebecca Thacker (2019). Presentation to the National Regional Transportation Conference
[56] Rebecca Thacker (2019). Presentation to the National Regional Transportation Conference
[57] Rebecca Thacker (2019). Presentation to the National Regional Transportation Conference
[58] Personal communication with Rebecca Thacker, March 2019
[59] Personal communication with Rebecca Thacker, March 2019
[60] Personal communication with Rebecca Thacker, March 2019

[61] U.S. Census Bureau (2018). Quick Facts, https://www.census.gov/quickfacts/washingtoncountyoregon
[62] Washington County, Oregon (2014). Washington County ITS Plan Executive Summary, https://www.co.washington.or.us/LUT/Divisions/TrafficEngineering/Programs/TrafficManagement/ITSystem/upload/WaCo-ITS-Plan-Executive-Summary-2014-2.pdf
[63] Washington County Oregon (2018). Fern Hill Road Closed Due to High Water; Gates in Place, https://www.co.washington.or.us/LUT/News/fernhillflooded012718.cfm
[64] Personal communication with Stacy Shetler and John Fasana, October 2019
[65] Washington County, Oregon (nd). Department of Land Use and Transportation: Gain Share Funding, https://www.co.washington.or.us/LUT/TransportationFunding/gain-share-program.cfm
[66] Western Transportation Institute, Montana State University (2018). Dynamic Warning System to Alert Motorists to the Presence of Bicyclists, https://westerntransportationinstitute.org/wp-content/uploads/2016/09/CNMBikeWarningOverview4-18.pdf
[67] National Park Service (2017). Historic Rim Rock Drive, https://www.nps.gov/colm/planyourvisit/historic-rim-rock-drive.htm
[68] Hamilton, Amy (2018). Safety Upgrades at Monument. *The Daily Sentinel,* https://www.gjsentinel.com/news/western_colorado/safety-upgrades-at-monument/article_dfef337e-7056-11e8-96c8-10604b9f1ff5.html
[69] Western Transportation Institute, Montana State University (2018). Dynamic Warning System to Alert Motorists to the Presence of Bicyclists, https://westerntransportationinstitute.org/wp-content/uploads/2016/09/CNMBikeWarningOverview4-18.pdf
[70] National Center for Rural Road Safety (2018). https://ruralsafetycenter.org/wp-content/uploads/2018/03/CC3.pdf
[71] Operation Lifesaver. Collisions & Casualties by Year (2019). https://oli.org/track-statistics/collisions-casualties-year
[72] Federal Railroad Administration Office of Safety Analysis (2019). https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/gxrtally1.aspx
[73] U.S. DOT, Federal Railroad Administration (2019). Effectiveness of LED-Enhanced Signs in Reducing Incidents of Vehicles Stopping on Tracks, https://rosap.ntl.bts.gov/view/dot/41694
[74] U.S. DOT, Federal Railroad Administration (2019).
[75] South Dakota State News (2017). New Intersection Warning System South of Tripp, https://news.sd.gov/newsitem.aspx?id=22314
[76] Traxler, Marcus (2018). At key intersection, rural alert system working well so far. *Agweek, https://www.agweek.com/news/traffic-and-construction/4492524-key-intersection-rural-alert-system-working-well-so-far*
[77]South Dakota State News (2018). New Intersection Warning System in Spink County, https://news.sd.gov/newsitem.aspx?id=23574
[78] Maranatha Hayes and Derek Leuer. Minnesota DOT (2019). A Study of the Rural Intersection Conflict Warning System, https://www.dot.state.mn.us/trafficeng/safety/docs/ricws-report.pdf
[79] Disi Tian, Nichole Morris, and David Libby (2018). Rural Intersection Conflict Warning System Evaluation and Design Investigation, Center for Transportation Studies, University of Minnesota, https://conservancy.umn.edu/handle/11299/198534
[80] Personal communication with Andy Vandel, September 2019
[81] South Dakota DOT (2017). SD 46 and SD 37: https://www.youtube.com/watch?v=bg8raRtKins; U.S. 281 and SD 20: https://www.youtube.com/watch?v=V_IX4lsFZDE
[82] Pinellas County, Florida (nd) Parks & Conservation Resources, https://www.pinellascounty.org/trailgd/
[83] Florida DOT presentation (2019). Forward Pinellas Bicycle Pedestrian Advisory Committee Meeting – June 17, 2019, http://forwardpinellas.org/wp-content/uploads/2019/06/BPAC-June-17-2019-Agenda.pdf
[84] U.S. DOT (2018). Rectangular Rapid Flashing Beacon Safe Transportation for Every Pedestrian Countermeasure Tech Sheet, https://safety.fhwa.dot.gov/ped_bike/step/docs/TechSheet_RRFB_508compliant.pdf
[85] Florida DOT (2016). Florida Strategic Highway Safety Plan, https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/safety/safety/shsp2016/fdot_2016shsp_final.pdf?sfvrsn=3c118f35_0
[86] Personal communication with Peter Hsu and Whit Blanton, October 2019

[87] Personal communication with Alexandra Kleintop and Tina Amato, February 2020
[88] U.S. Department of Health and Human Services (2019). Million Hearts Costs and Consequences, https://millionhearts.hhs.gov/learn-prevent/cost-consequences.html
[89] Personal communication with Alexandra Kleintop and Tina Amato, February 2020
[90] Personal communication with Alexandra Kleintop and Tina Amato, February 2020
[91] Personal communication with Alexandra Kleintop and Tina Amato, February 2020
[92] Region XII Council of Governments (2019). http://www.region12cog.org
[93] Chris Whitaker (2019). Regional Mobility & Intelligent Transportation Systems, presentation developed with Tom Feldman, Region XII COG, and presented at the 2019 National Regional Transportation Conference
[94] Personal communication with Rick Hunsaker, March 2019
[95] Whitaker (2019)
[96] Personal communication with Rick Hunsaker, June 2019
[97] Whitaker (2019)
[98] Whitaker (2019)
[99] Whitaker (2019)
[100] Whitaker (2019)
[101] Personal communication with Rick Hunsaker, June 2019
[102] Whitaker (2019); personal communication with Tom Feldman, March 2020
[103] Whitaker (2019)
[104] Personal communication with Kyle Archer, September 2019
[105] Personal communication with Rick Hunsaker, September 2019
[106] ODOT (nd). Transit Tech Ohio Overview, http://www.dot.state.oh.us/Divisions/Planning/Transit/Pages/Tiger-Grant.aspx
[107] ODOT (2016). Invitation to Bid 142-17: Transit Scheduling and Dispatching Software
[108] ODOT (2016). Invitation to Bid 142-17: Transit Scheduling and Dispatching Software
[109] ODOT (2017). Invitation to Bid 405-18: Fixed Route CAD/AVL, Real-Time Passenger Information
[110] Connected Nation (nd). About Connected Nation Ohio, https://connectednation.org/ohio/about
[111] Chuck Dyer (2019). Presentation at the 2019 National Regional Transportation Conference, June 2019
[112] Chuck Dyer (2019). Presentation at the 2019 National Regional Transportation Conference, June 2019
[113] Personal communication with Howard Stewart and Andrea Dupler, January 2020
[114] Personal communication with Howard Stewart and Andrea Dupler, January 2020
[115] Personal communication with Howard Stewart and Andrea Dupler, January 2020
[116] Personal communication with Shannon Hursey, December 2019
[117] Personal communication with Shannon Hursey, December 2019, and Howard Stewart and Andrea Dupler, January 2020
[118] Personal communication with Howard Stewart and Andrea Dupler, January 2020
[119] Personal communication with Shannon Hursey, December 2019
[120] Personal communication with Shannon Hursey, December 2019
[121] Personal communication with Howard Stewart and Andrea Dupler, January 2020
[122] Personal communication with Shannon Hursey, December 2019
[123] Personal communication with Sean Sammon and Kevin Buettner, March 2019
[124] Personal communication with Shannon Hursey, December 2019
[125] ODOT (nd). Transit Tech Ohio Overview, http://www.dot.state.oh.us/Divisions/Planning/Transit/Pages/Tiger-Grant.aspx
[126] Chuck Dyer (2019). Presentation at the 2019 National Regional Transportation Conference, June 2019
[127] Personal communication with Sam Purington, September 2019
[128] Sam Purington (2019). Volunteer Transportation Center, Inc., presentation given at On the Road to Prosperity Virtual Peer Exchange #5: How Transportation Technologies Are Meeting Mobility and Economic Development Needs in Rural America
[129] Purington (2019)
[130] Personal communication with Sam Purington, September 2019
[131] Personal communication with Sam Purington, September 2019
[132] Personal communication with Sam Purington, September 2019

[133] Personal communication with Sam Purington, September 2019
[134] Personal communication with Sam Purington, September 2019
[135] Personal communication with Sam Purington, September 2019
[136] Purington (2019)
[137] Personal communication with Sam Purington, September 2019
[138] Personal communication with Sam Purington, September 2019
[139] Personal communication with Sam Purington, September 2019
[140] Personal communication with Sam Purington, September 2019
[141] Personal communication with Sam Purington, September 2019
[142] Pisano, P. (2019). Are Your Roads Weather Savvy? FHWA Research and Technology, https://www.fhwa.dot.gov/publications/publicroads/19spring/03.cfm
[143] FHWA (nd). Weather-Savvy Roads - Leveraging Multiple Communications Systems for Vehicle-Based Data Sharing: Nevada Department of Transportation Case Study, https://ops.fhwa.dot.gov/publications/fhwahop18030/fhwahop18030.pdf
[144] Nevada DOT (2019). Presentation at 2019 NADO Annual Training Conference
[145] U.S. DOT (2018). Nevada DOT's Integrated Mobile Observations 3 Project Final Report, https://collaboration.fhwa.dot.gov/dot/fhwa/RWMX/Documents/Nevada%20DOT%20IMO%203%20Final%20Report.pdf
[146] U.S. DOT, ITS Joint Program Office. (nd) Wyoming Connected Vehicle Pilot Deployment Program, https://www.its.dot.gov/factsheets/pdf/WyomingCVPilot_Factsheet.pdf
[147] State of Wyoming, Wyoming DOT (2017). WYDOT Connected Vehicle Pilot project website, https://wydotcvp.wyoroad.info/index.html
[148]Phoenix Contact USA. Connected Vehicle Pilot Deployment Overview – Deepak Gopalakrishna. (2018). https://youtu.be/9ScWtawAbJc
[149] Personal communication with Vince Garcia, November 2019
[150] Personal communication with Vince Garcia, November 2019
[151] U.S. DOT (nd). Connected Vehicle Deployment Program: Wyoming, https://wydotcvp.wyoroad.info/assets/promotion/WyomingCVPilot_Factsheet_v2_020817.pdf
[152] U.S. DOT (2016, 2018). Connected Vehicles Pilot Deployment Program, https://www.its.dot.gov/pilots/technical_assistance_events.htm#t2
[153] Census 2010, http://data.census.gov
[154] Union County-Marysville Economic Development/CIC (2020), https://www.33smartcorridor.com/
[155] Personal communication with Mike Andrako, June 2019
[156] Drive Ohio (2019) "Connected Marysville," https://drive.ohio.gov/wps/portal/gov/driveohio/know-our-projects/projects/07-connected-marysville
[157] Personal communication with Mike Andrako, June 2019
[158] Personal communication with Mike Andrako, June 2019
[159] Personal communication with Mike Andrako, June 2019
[160] Union County CIC (2020). "Smart Mobility," https://www.33smartcorridor.com/mobility
[161] Personal communication with Kristin White and Keith Mensah, September 2019
[162] MnDOT (2019). Connected and Automated Vehicle Strategic Plan
[163] Personal communication with Kristin White and Keith Mensah, September 2019
[164] Personal communication with Kristin White and Keith Mensah, September 2019
[165] Personal communication with Kristin White and Keith Mensah, September 2019
[166] Personal communication with Kristin White and Keith Mensah, September 2019
[167] MnDOT (2019). Connected and Automated Vehicle Strategic Plan
[168] Hourdos, John (2019). How Locals Need to Prepare for the Future of V2V/V2I Connected Vehicles, Local Road Research Board, MnDOT, http://www.cts.umn.edu/Research/ProjectDetail.html?id=2018025
[169] Personal communication with Kristin White and Keith Mensah, September 2019
[170] Personal communication with Kristin White and Keith Mensah, September 2019
[171] Personal communication with Kristin White and Keith Mensah, September 2019

Appendix A:
Additional Resources

The research, guides, toolkits, and other resources summarized below contain additional information on ITS applications in rural and small metropolitan areas.

Multimodal ITS Applications

National Center for Rural Road Safety. (2018). ***Rural Intelligent Transportation System Toolkit*****.**
https://ruralsafetycenter.org/resources/rural-its-toolkit/

The toolkit includes fact sheets on 42 types of ITS technology. Fact sheets outline the technology, partners or jurisdictions involved, components involved in installing the technology, examples of how the technology has been implemented, considerations, resources, and capital and operations costs.

U.S. Department of Transportation, ITS Joint Program Office. (2018). ***Intelligent Transportation Systems Benefits, Costs, and Lessons Learned: 2018 Update Report.***
https://rosap.ntl.bts.gov/view/dot/36236

The report contains summaries of applications in the areas of crash prevention and safety, accessible transportation, mobility on demand, and information management, connected vehicles, and automated driver assistance. The report includes overviews of U.S. DOT-funded Connected Vehicle Pilots in New York City, Wyoming, and Tampa. The Wyoming DOT Connected Vehicle Pilot is a safety and weather information project that incorporates V2V and V2I technology through roadside units and onboard communications units along rural segments of I-80. Specific applications within the pilot pertain to forward collision warning, infrastructure-to-vehicle situational awareness (e.g., weather alerts, parking and road closures), work zone warning, and spot weather impact warning. Other projects identified in the report include a Vermont statewide trip planner that incorporates alternative modes and a section on truck platooning through V2V connectivity.

Rural Highway ITS Applications

U.S. Department of Transportation, Intelligent Transportation Society of America. (2017). ***Rural Connected Vehicle Gap Analysis: Factors Impeding Deployment and Recommendations for Moving Forward*****. https://rosap.ntl.bts.gov/view/dot/34723**

This document is based on interviews with subject matter experts. One-on-one interviews were conducted with 11 state DOT, federal, university, or consultant representatives who work in rural transportation. In addition, 20 rural emergency response and ITS practitioners were interviewed at the National Rural ITS Conference in 2015. Rural-specific issues discussed include lower traffic volumes, lower tax base, and less funding to support projects. Rural areas do experience a higher level of fatal crashes. Extreme weather conditions, severe vehicle crashes, and a lack of operational data about roadways are other areas of concern.

Interviewees noted that there can be misconceptions about connected vehicle technologies in rural areas. The perceived primary benefit is addressing rural crashes and related factors of high speed, roadway curves, weather conditions, and animal collisions. Interviewees mentioned that rural congestion is difficult to predict and is often the result of crashes, stalled vehicles, road construction, weather, tourism, and special events. Limited alternative routes mean it may take longer to clear congestion or provide effective emergency response times. These are issues that could be addressed by connected vehicle technology, yet, rural areas have concerns about the clear demonstration of benefits and return on investment; lack of funding to implement projects; and physical barriers of rugged terrain, extreme weather, and the environment. Other areas of concern mentioned include backhaul capacity (connection from node/vehicle to central network) and cellular capacity. Rural areas have lower smartphone ownership and internet use combined with a higher percentage of older and low-income residents. Interviewees mentioned that rural residents may raise more concerns about government intervention through technology applications.

Recommendations from the interviews include developing a connected vehicle sustainability plan that uses data from pilots to demonstrate technology usability and to encourage future deployments, deploying freight supply chain movement projects, exploring innovative funding beyond traditional grant programs, and conducting outreach and public engagement programs as well as identifying champion agencies or individuals who can support projects and promote their use in rural areas.

U.S. Department of Transportation, ITS Joint Program Office. (n.d.) *Rural Safety Initiative: The Approach*. https://www.its.dot.gov/research_archives/rural/rural_approach.htm#co

The U.S. DOT awarded Rural Safety Innovation Program (RSIP) funding to nine agencies in 2008 to develop 11 projects. ITS elements include the use of changeable message signs and smart work zone cones that track vehicle speed in California, use of augmented LED lighting in the U.S. 160-Wolf Creek Pass tunnel in Colorado, and installation of speed-actuated truck tip-over warning signs on U.S. 50 in Colorado. In Illinois, safety countermeasures include vehicle detection before curves that triggers LED-flashing beacons to warn drivers. Illinois also implemented flashing beacons to warn drivers of an upcoming two-way stop. Iowa established a web-based Traffic and Criminal Software program to improve accuracy and completion of traffic crash data and load data into the statewide crash report system. Kansas DOT entered a partnership with the Prairie Band Potawatomi Nation to deploy ITS at intersections that provide access to the reservation. The technologies include a roadway weather information system station, a closed-circuit television camera, portable DMS, flashing beacons, and traffic queue detection at two other locations along U.S. 75. Minnesota DOT implemented a speed measuring device tied to a DMS with a message “Slow Down” to address the statistic that 27 percent of crash fatalities in the state between 2001 and 2005 were along rural curves. Variable speed limit signing was implemented in South Carolina to reduce speeds in wet conditions on U.S. 25 in the mountainous region of the state near.

Additional funded projects include development and implementation of driver feedback signs that use vehicle detection technology and display vehicle speeds. The Wisconsin DOT used RSIP funds to implement a Rural Intersection Collision Avoidance System (RICAS). The RICAS technology provides real-time warnings to drivers to help prevent [vehicle] gap selection errors for drivers attempting to turn at unsignalized medians. The 2010 pilot location for the project was the intersection of U.S. 53 and State Trunk Highway 77 west of Minong in Washburn County, Wisconsin. In the RICAS implementation, sensors are used on U.S. 53 to determine the lane of travel, position, and speed of vehicles approaching the intersection. Loop detectors installed in the intersection median activate a Driver Infrastructure Interface (DII) that relays alerts and warnings to the vehicle attempting to turn from the intersection median. The DII sends its alerts through a variable message sign alerting the crossing driver that a vehicle is approaching. When a vehicle is not sensed, the alert system remains inactive. *[Note: Wisconsin DOT is no longer using this technology at the pilot location.]*

Rural Public Transportation ITS Applications

Shared-Use Mobility Center. (2019). ***Case Study: Vermont Flexible Trip Planner: Bringing Fixed and Flexible Transit Together on a Single Platform.***
https://learn.sharedusemobilitycenter.org/casestudy/vermont-flexible-trip-planner-bringing-fixed-and-flexible-transit-together-on-a-single-platform/

The Vermont Agency of Transportation (VTrans) has developed an online trip planning tool that includes all available options including flexible ride and dial-a-ride. Funded as a Mobility-on-Demand Sandbox project, the tool increases access to traditional fixed-route transit and alternative transportation. A project case study is available on the Shared-Use Mobility Center website. The case study explains that in 2014, all of Vermont's transit agencies adopted the Google Transit platform that publishes their public transit data; however, the Google Transit platform shows fixed-route transit and does not include dial-a-ride, hail-a-ride, and deviated fixed-route services. Responding to the issue, open-source software developers created GTFS-Flex providing information about flexible services. At that time, the Shared-Use Mobility Center's case study was completed, and Google Transit could not consume the GTFS-Flex information. VTrans applied to the 2016 Federal Transit Administration Mobility-on-Demand Sandbox opportunity in order to create mobile and desktop versions of OpenTripPlanner.

In spring 2018, the Go! Vermont Trip Planner was launched for statewide use. With the Trip Planner, travelers could see hail-and-ride stops, deviated fixed-route transit, and ADA-accessible transportation. The platform is also capable of listing carpools, hotel shuttles, and ride sourcing. In 2019, the planner was updated to include carpooling and vanpooling services. The trip planner platform is owned and managed by VTrans. To increase usage by the general public in addition to call center staff, VTrans scheduled a marketing campaign for 2019. State associations and departments that serve individuals who are blind or who have disabilities were engaged in testing the trip planner for accessibility. Transportation agency contact information is provided as appropriate; however, the planner does not include eligibility details or trip-booking/ticket purchasing capabilities.

United States Government Accountability Office. (2016). ***Intelligent Transportation Systems: Urban and Rural Transit Providers Reported Benefits but Face Deployment Challenges***
https://www.gao.gov/assets/680/677919.pdf

To prepare this report, the U.S. Government Accountability Office (GAO) reviewed DOT's ITS deployment data and ITS studies, interviewed U.S DOT officials and public transit stakeholders, conducted three site visits to Pittsburgh, Pennsylvania; Portland and Eugene, Oregon; and Tampa and Orlando, Florida. GAO interviewed 31 transit providers from across the country. For rural and small urban areas, GAO used a web-based survey that received 233 responses. The sample excludes transit systems with 10 or fewer vehicles.

The report includes a background overview of the types of transit service provided in urban and rural areas and the general types of ITS applications (e.g., communications, GIS and data management, maintenance management, and weather information systems). In 2016, small urban and rural transit agencies were primarily using four ITS-related technologies: security systems, computer-aided dispatch, automatic vehicle location, and GIS. If smaller systems were not using a specific ITS technology, it is was due to costs or perceived lack of need. The most commonly used applications for smaller systems were maintenance management systems, traveler information systems, automatic passenger counters, electronic fare payment, and transit signal prioritization. The top five benefits of ITS that small and rural operators identified are: improvements in record keeping, enhanced safety, more efficient scheduling and routing, improvements in one-time performance and schedule adherence, and increased customer satisfaction. Interviewees indicated that the indirect benefits of ITS such as operator satisfaction and improved marketing are difficult to quantify. Technical expertise and connectivity were two challenges identified by the rural and small urban providers interviewed.

The final section of the report explores the extent to which local transit systems use federal resources, training, or funding, especially resources of the U.S. DOT's ITS Joint Program Office, to implement ITS systems.

Transportation Research Board, Transit Cooperative Research Program. (2005). ***TCRP Report 84, e-Transit: Electronic Business Strategies for Public Transportation Volume 6 Strategies to Expand and Improve Deployment of ITS in Rural Transit Systems.*** **https://www.nap.edu/catalog/23315/strategies-to-expand-and-improve-deployment-of-its-in-rural-transit-systems**

The report summarizes interviews with rural agencies who had implemented or were planning to implement rural ITS strategies. The agencies are the Kansas DOT, Community Action Partnership of Mid-Nebraska, Iowa DOT, California DOT (Caltrans), and Oregon DOT. Each agency had a similar goal: to reduce the time to schedule trips and streamline the process of planning trips.

Kansas had a statewide ITS plan in place that focused on traveler information, and KDOT wanted to enhance traveler information, automatic vehicle location (AVL), and increased dispatch to driver communication. Mid-Nebraska focused on automated dispatch and scheduling, online ride schedule and ride request for travelers, and use of global positioning systems (GPS) for vehicle deployment and tracking. Iowa DOT had a statewide ITS plan in place with the goal of improving transit service. Iowa wanted to establish a statewide architecture for ITS and recommendations for the transit agencies related to fleet management systems, operational software and computer-aided dispatching, electronic fare payment systems, advanced traveler information systems, and transit intelligent vehicles. Caltrans' focus was on identification and field testing of potential low-cost rural transit technologies. Technologies explored include AVL and GPS, DMS for real-time information, dispatch software and real-time web maps for bus locations, silent alarms for emergencies, radio frequency modems, driver mobile data terminals (MDTs), and card reader inputs. Oregon DOT wanted to use ITS to address the needs of transportation users who are identified as transportation disadvantaged. Oregon, in coordination with Washington State DOT, decided to deploy a regional trip planning website. The service—which still exists as www.tripcheck.com—allows users to schedule trips in rural and urban areas using a variety of modes.

The report emphasizes that web-based technologies are just part of ITS infrastructure. Other technologies that play a role in the systems discussed include wireless communications, computer-aided design (CAD), AVL, MDTs, accounting and reconciliation, online customer service centers, and electronic fare collection. The Analysis of Solutions section of the report identifies funding and levels of staff technical expertise as barriers to rural ITS implementation. Barriers may be overcome by partnering with a state DOT and other agencies within the state to deploy a seamless, comprehensive system.

Altman, S. & Bregman, S. (2019). Reaching Rural Transit Riders, Presentation at ITS America, June 14, 2019.
https://static1.squarespace.com/static/5b44befeb98a780957982bf3/t/5d274f28a9a3290001b6c9ef/1562857256318/16627_Presentation.pdf

Scott Altman and Susan Bregman researched the challenges that rural transit agencies have in providing up-to-date information to transit customers and best practices that can improve the timeliness of the information shared. Their ITS America presentation is based on interviews with transportation agency managers in Chemung County, Clinton County, and Suffolk County, New York, and C Tran in Elmira, New York.

According to the authors' research, providing real-time information is affected by whether a transit schedule is published in the GTFS so that Google Transit and third-party apps can list the data. In rural areas, types of services can include a mix of fixed route, ADA-complementary service, fixed-route service with flag stops, and on-demand service. These services may have published schedules. The agencies interviewed notes that limited staff and financial resources, the digital capabilities of customers, and procurement processes affect the ability to share information about transportation services. Staff members have limited time to update websites and social media posts or must rely on county IT staff to update travel or weather information. Customers may not use social media to receive updates. Transit agencies interviewed in New York mentioned continued use of flyers or newspaper notices to reach customers. Agencies expressed concern about inflexible procurement processes that affect agency ability to update technology. In addition, agencies noted that a lack of research and data to illustrate that technology-based improvements will bring in revenue to offset the cost of investment surfaces in discussions and affects decisions to invest in technology.

Best practices recommended for rural systems include thinking like a customer and providing up-to-date schedule and service information by a variety of media; knowing the customers and how they prefer to receive information; leveraging existing technology to provide at a minimum static schedules, maps, and service alerts; using forward thinking for technology systems by watching trends in technology (e.g., rise in smartphone ownership); and leveraging existing technology where its available (e.g., statewide 511 network or state DOT assistance or consultant support to upload schedules into GTFS format).

Vehicle Connectivity and Automated Vehicles

U.S. Department of Transportation, Federal Highway Administration. (2018). *Effects on Intelligent Transportation Systems Planning and Deployment in a Connected Vehicle Environment*.
https://ops.fhwa.dot.gov/publications/fhwahop18014/fhwahop18014.pdf

This report provides an overview of what ITS technologies are, explains connected vehicle technology and automated vehicle technology, and describes U.S. DOT categories of ITS. The ITS categories listed are traveler information, freeway management and arterial management, archived data management, public transportation, emergency management strategies, construction and maintenance strategies, construction and maintenance management, other types of traffic management, vehicle safety, and connected vehicle technology. A chapter highlights how connected vehicle technology may impact core ITS functions and direct delivery of traveler information into vehicles. Several case studies related to connected vehicle technologies are identified including a Maricopa County, Arizona, mobile pedestrian signal system that activates extended cross times and the Wyoming DOT Connected Vehicle Pilot. Connected vehicle impacts on peripheral ITS are addressed (e.g., electronic toll collection, truck parking information systems). The report concludes with key findings and recommendations. The technologies discussed may be deployed in rural areas or involve the participation of rural agency stakeholders.

Transportation Research Board, National Cooperative Highway Research Program. (2017). ***NCHRP Research Report 845 Briefing Document: Strategies to Advance Automated and Connected Vehicles.*** **https://www.nap.edu/catalog/24873/strategies-to-advance-automated-and-connected-vehicles**

This document summarizes the key findings of *NCHRP Research Report 845: Advancing Automated and Connected Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies* and is designed to help decision makers identify and leverage policy tools they have in place and consider how to align with emerging automated vehicle and connected vehicle technology. The document outlines how vehicle technology is tied to existing transportation planning issues: traffic crashes, congestion, pollution, land development, and mobility. The report identifies strategic goals tied to addressing these issues through implementation of vehicle connectivity projects and provides a menu of strategies for policy makers to consider based on the outcomes they want to achieve. Outcomes may include mitigating safety risks through testing, training, and public education; encouraging shared automated vehicle use; addressing liability issues that may impact market development; enhancing safety, congestion, and air quality benefits by influencing market demand. An example strategy under the Encourage AV Use outcome is “subsidized shared AV use.” For each strategy, there is an overview page with assessment or rating of a viability, including how the strategy has geographic impact statewide or in urban, suburban, and rural areas. Other viability criteria include effectiveness, efficiency, political acceptability, operational feasibility, geographic impact, level of government affected, and hurdles or barriers to implementation.

Federal Lands

U.S. Department of Interior, National Park Service. (2014). ***Congestion Management Toolkit*****.** **https://www.nps.gov/orgs/1548/upload/NPS-CMS_Toolkit.pdf**

The Congestion Management Toolkit provides a list of congestion mitigation solutions or tools that can be applied to address specific congestion problems and issues in National Park Service settings. Key features include implementation considerations, cost and financial information, examples of where these tools have been used, and expected outcomes based on previous applications. The toolkit contains an overview of the congestion and the specific steps that can be taken to address the issue. The tools that can be used are broken into five categories: additional capacity to existing system and infrastructure, intelligent electronic systems, public transportation, traffic operational improvements, and visitor demand management that can include electronic systems. Other features of the toolkit include a chart with a comprehensive list of tools, strategies that can be achieved by each tool, physical locations and emphasis areas where tools should be deployed, estimated capital costs for the tool, and timing to implement the project (e.g., near term to long term). The toolkit offers an extended profile of each tool including a description, photo, a list of where the tool can be used, which strategies it achieves, the pros and cons of implementation, whether the tool requires partnerships, estimated time for implementation, examples of where the tool is currently being used, suggested performance measures, and additional resources. The last section of the toolkit is an index list of tools categorized by the locations where they are used within a national park.

U.S. Department of Transportation, John A. Volpe National Transportation Systems Center. (2011). ***Intelligent Transportation Systems in the National Parks System and Other Federal Lands.*** **https://rosap.ntl.bts.gov/view/dot/9554**

This report discusses the state of ITS deployments on federal lands through 2011 and updates an earlier 2005 report. In 2011, use of DMS was continuing to increase, and social media to provide traveler information was experiencing the most growth activity among ITS applications. The report covers considerations and challenges surrounding deployment of ITS in rural locations and rugged terrain. Types of technologies evaluated include travel and traffic management, incident management, park or facility entry management, and public transportation management. The five technologies that the Volpe Center found as having promising results in 2011 are DMS, highway advisory radio, 511 system integration, traffic counters and loop detectors, and social media tools. Volpe provides ITS implementation recommendations for the park of federal land unit level and the national level and technology-deployment guidance. The report appendices offer a detailed inventory of ITS technology in use for each park and technology-deployment guidance that charts the type of ITS recommended for each park or federal land area.

Appendix B: Acronyms and Abbreviations

AV – Automated Vehicle

BLM – Bureau of Land Management

CAV – Connected and Automated Vehicles

CCTV – Closed-Circuit Television

CDC – Centers for Disease Control and Prevention

COG – Council of Governments

CV – Connected Vehicle

CVP – Connected Vehicle Pilot

DMS – Dynamic Message Sign

DOT – Department of Transportation

DSRC – Dedicated Short-Range Communication

EMDSS – Enhanced Maintenance Decision Support System

FHWA – Federal Highway Administration

FTA – Federal Transit Administration

FWS – United States Fish and Wildlife Service

GAO – Government Accountability Office

IMO – Integrated Mobile Observations

ITB – Invitation to Bid

ITE – Institute of Transportation Engineers

ITS - Intelligent Transportation Systems

LED – Light-Emitting Diode

MBTA – Massachusetts Bay Transportation Authority

MDT – Mobile Data Terminal

MPO – Metropolitan Planning Organization

NADO – National Association of Development Organizations

NMEA – National Marine Electronics Association

NPS – National Park Service

NTCIP – National Transportation Communications for Intelligent Transportation System Protocol

RAD – Recreation Access Display

RDO – Regional Development Organization

RMNP – Rocky Mountain National Park

RPO – Rural Planning Organization

RRFB – Rectangular Rapid Flashing Beacon

RTPO – Regional Transportation Planning Organization

RWIS – Road Weather Information System

SAE – Society of Automobile Engineers

SEAT – Southeast Area Transit

T2O – Transit Tech Ohio

TMDD – Traffic Management Data Delivery

TPAC – Transportation Policy Alternatives Committee

Tri-Met – Tri-County Metropolitan Transportation District of Oregon

USFS – United States Forest Service

V2I – Vehicle to Infrastructure

V2V – Vehicle to Vehicle

VTC – Volunteer Transportation Center

WIT – Western Iowa Transit