Using Geofencing to Actively Monitor, Collect, and Share Information

Transportation Management Center (TMC) Pooled-Fund Study

Federal Highway Administration

February 2024

Speakers Notes (1/25)

None.

Issues Faced by State Departments of Transportation (DOTs)

- Travelers need accurate and easily accessible real-time travel and road condition updates that are specific to their route.
- Traditional methods of delivering traveler information (e.g., changeable message sign (CMS), 511 services) often do not provide specific or relevant information for a traveler's route.
- Traditional intelligent transportation system devices used for collecting and disseminating traveler information can be costly and require ongoing services to manage, operate, and maintain.
- New technologies and third-party service providers can support and improve transportation management system (TMS) functions (e.g., geofencing). Integrating these new technologies and methods into a DOT's TMS requires careful planning to realize their full potential.

Speakers Notes (2/25)

- Travelers need accurate and real-time travel and road condition updates that are specific to their route, especially during major incidents or construction activities.
- When an incident occurs on a roadway that severely slows down or even stops traffic for an extended period, the need to get real-time, accurate and relevant traffic related information to travelers is especially important.
- Historically, state DOTs have used changeable message signs (CMS) or dynamic message signs (DMS) as the primary devices to deliver roadway and travel condition information to travelers along specific routes, when available. But DOTs have faced difficulties reaching travelers who may be stuck on the road and not within the vicinity of a CMS.
- To address this, various state DOTs have deployed geofencing technology that allows agencies to collect traffic and incident data and send travel alerts or information to a specific geographic (or geofence) location. Agencies also share information requested by travelers via HAR, websites and traveler information systems (e.g., 511). However, these systems are being used less and less with users migrating to in-vehicle devices or connected mobile devices to receive roadway conditions, travel conditions, or other information (e.g., routing, navigation)
- This topic aims to raise awareness of the geofencing technologies agencies may use to alert travelers of changing roadway conditions in areas outside of their CMS coverage.
- For example, when there is a major slowdown or roadway closure downstream of a traveler's route, the TMC Operator sends a text message alert to all motorist's mobile phones within a geofenced area.

What Is Geofencing?

- Geofencing is the use of Global Positioning Systems (GPS) to create a virtual geographic boundary in software.
- It can be used to trigger a response in the software when a mobile device enters or leaves the geofenced area.
- It can enable an agency to collect traffic and incident data and send travel alerts or information to a specific geographic (or geofence) location.
- It can enable the sending of information to travelers through mobile apps, automated alerts, or CMS.

Speakers Notes (3/25)

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Geofencing Scenarios

- When a road closure occurs downstream of a motorist's travel path, the motorist's mobile device receives an automatic alert if the motorist is within an impacted geofenced area (e.g., a 10-mi radius of the closure).
- When a particular road weather information system (RWIS) station reports inclement weather (e.g., poor visibility), all CMSs within a geofenced area display a message to drivers to slow down.
- When a motorist with a mobile device approaches an upcoming slowdown due to construction activities:
  - An app on the driver's mobile device automatically provides an alert to the driver about the slowdown when the driver enters the geofenced area around the construction site.
  - Maintenance workers at the site receive a warning if the vehicle enters the geofence above a speed determined unsafe for the conditions.

Speakers Notes (4/25)

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Potential Benefits of Geofencing

- Drivers can make informed travel decisions before they reach a slowdown from an incident or closure.
- Drivers only receive relevant alerts that directly impact their specific route.
- Work zone area safety is improved for both construction workers and drivers.
- Agencies can save costs by leveraging third-party service providers for data collection and information dissemination.

Speakers Notes (5/25)

- Proactive alerts provide time for approaching travelers to choose an alternative route. Alerts are sent out without travelers needing to request or search for information sources (such as in the case with traditional 511), allowing drivers to stay focused on the road.
- Alerts only send out to motorists within a geofenced area impacted by a change in roadway conditions so this cuts down on the amount of information thrown at the driver. This ensures that alerts are relevant to the driver.
- By alerting travelers ahead of time of downstream slowdowns, road closures or construction zones, this increases driver awareness and increases safety for both construction workers and drivers.

Desired Outcomes

- Help agencies use geofencing to augment traditional methods to deliver traveler information (CMS, highway advisory radio, 511 services, etc.).
- Support agency TMS functions, including collecting data; actively monitoring travel conditions; and sharing information with agency staff, service providers, and the public.
- Leverage mobile applications and information from third-party service providers to reduce data collection and information dissemination costs.
- Deliver automatic, immediate information to travelers that is directly relevant to their specific trip.

Speakers Notes (6/25)

None.

Challenges With Implementing Geofencing

- Deciding how much information is too much so that travelers are not overloaded.
- Determining the cost-benefit ratio. Compare the cost of a third-party service versus an agency providing hardware, software, and information.
- Establishing uniformity in policies, procedures, and standards:
  - Difficulty integrating new data formats into existing TMS.
  - Uniformity of alerts and messages.
- Customizing alerts to drivers based on travel directions and specific routes.
- Sharing incident information between agencies in neighboring States.

Speakers Notes (7/25)

Provide periodic updates to drivers who are not near DMS or do not have mobile apps downloaded, without being overwhelming

What is the cost-benefit ratio? What would be the costs of purchasing data from third party providers, software installation, any hardware equipment

Uniformity of data formats between third party into existing state DOT infrastructure. Uniformity of alerts sent out?

Enabling Technologies and Methods

- Application programming interfaces enable geofencing:
  - Allow seamless data transfer between different types of software and sources.
  - Allow agencies to share information directly with service providers or travelers.
- Travelers receive relevant information when they travel through the geofenced area, including proactive, automated alerts:
  - Drivers pay closer attention.
  - Drivers do not need to search for relevant information.
- Alerts are typically provided audibly using hands-free technology:
  - Audible alerts are nondistracting and safer.
  - In-vehicle technology is required.

Speakers Notes (8/25)

Things to consider

- Methods and/or technologies
- Accessing feasibility
- Planning and procurement
- Design and implementation
- Testing and initiation
- Day-to-day operation and evaluation of results
- O&M costs

Planning and Procurement

- Agencies have successfully developed geofencing tools in house or partnered with third-party service providers to develop them:
  - In-house tools require ongoing operations and maintenance staffing and resources.
  - Service providers require a contract with ongoing costs.
- It is important to know your agency's information technology (IT) policies and procurement requirements to know what information is considered sensitive and should be guarded from public domain.
- IT staff should be included in planning and procurement activities.

Speakers Notes (9/25)

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Examples of Agencies Using Geofencing

- California DOT (Caltrans): QuickMap.[1]
- Pennsylvania DOT (PennDOT): 511PA, Advanced Traffic Management System (ATMS) Integrated Queue Detection.[2,3]
- Colorado DOT (CDOT): COTrip Planner.[4]
- Virginia DOT (VDOT): 511, vehicle-to-everything (V2X) smart work zone.[5,6]
- New Jersey DOT (NJDOT): 511NJ.[7]
- Florida DOT (FDOT): Smart Work Zone.[8]

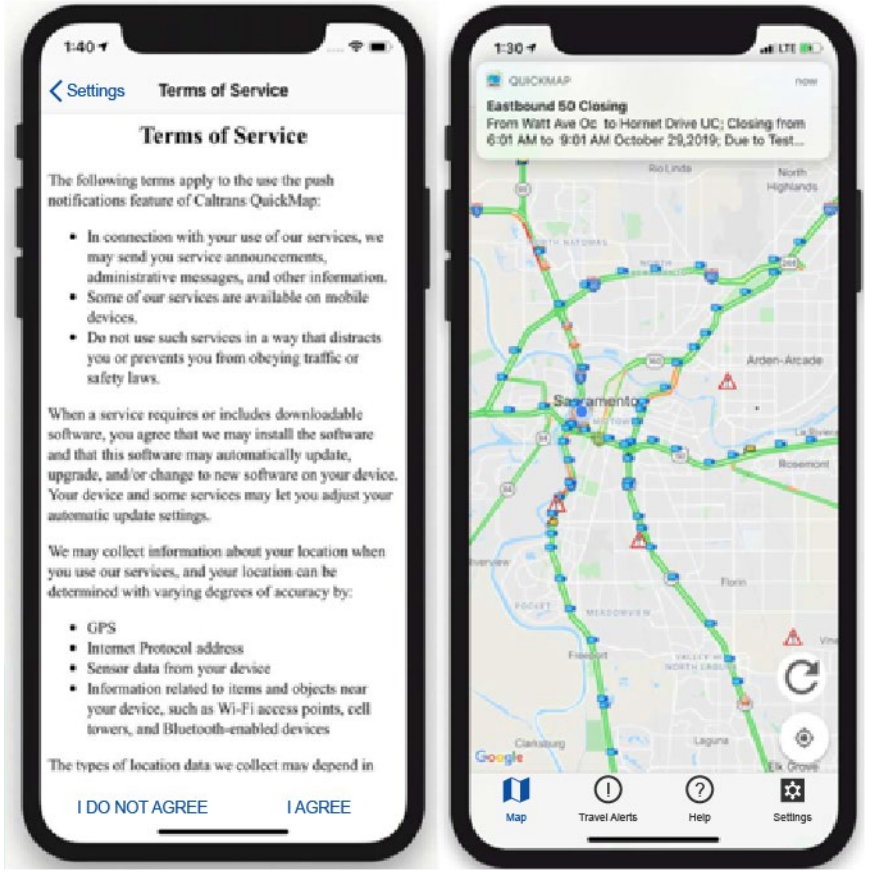
Speakers Notes (10/25)

Current practices using geofencing technology to collect and share traffic related data were gathered based on online search and outreach conducted to identify any applicable third-party vendors and agencies using geofencing. Discussions with selected agency and vendor representatives were conducted to gather study data for geofencing technology that is currently being used and how they are evolving its use. Studies were documented for each agency or vendor's technology, including decision factors, day-to-day operations, benefits, and public feedback. The intent of the research was to gather diverse examples of geofencing technology for the purpose of identifying common needs, decision factors, and tools across various agencies throughout the nation. These studies were reviewed, and similar methods and tools were grouped together into the following categories:

- Travel condition notifications based on location
- Direct messaging based on location
- Integrated Queue Detection System
- Work zone locations and traffic conditions

Caltrans QuickMap (Enabled by Geofencing)[1]

- QuickMap partners with a location services provider to determine when a driver is within the geofence. QuickMap was developed by the Caltrans IT department and is operated by TMC staff.
- Travelers may use either a website or mobile app to sign up for customized alerts.
- The TMC operator generates geofences and customized messages, which are sent to drivers within the geofence.
- QuickMap integrates with Caltrans TMS' Lane Closure System (LCS):[9]
  - QuickMap receives closure information from Caltrans LCS.
  - QuickMap automatically notifies app users within a geofenced area 30 min prior to a lane closure start as well as during the closure.
  - Quickmap sends updates to the navigation app every 5 min.



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Speakers Notes (11/25)

Traveler information mobile apps are offered by many transportation agencies, developed in-house or by third-party providers, to share travel times, road-weather conditions, incidents, road construction, route options and other relevant information. Many of these apps rely on location information from the user's cellphone and permission from the user to use that information.

In 2018, Caltrans District 10 experienced an emergency state highway closure that caused significant travel delays and left many stuck on a bridge for hours. Due to a lack of CMSs on the bridge, the district did not have any means of communicating incident updates to the drivers, leaving them with little information. As a response, executive management sought to equip their existing mobile app, QuickMap, with the ability to send traveler information or warning messages to travelers who are approaching the area of a full state highway closure. The IT department developed the software in-house and since then, Traffic Operations HQ and TMC staff utilize it daily to view and manage notifications across the state. Internal authorized staff can create geofences and send customized messages to drivers. Their location services provider then uses the driver's location to determine if it is within a geofenced area to send out the notification. The app requests for permission from the user to keep accessing location data for geofencing, to ensure the push of only relevant notifications.

Apart from unplanned events, QuickMap also aggregates planned closures from Caltrans's Lane Closure System which can be updated by authorized personnel including DOT staff, approved contractors and TMC operators. App users are notified of planned closures 30 minutes prior to start as well as during the closure for anyone within a set proximity using geofencing.

PennDOT—511PA (Enabled by Geofencing)(2)

- Developed by a third-party service provider.
- Sends travelers alerts based on GPS data from their mobile phones:
  - Travelers can elect to receive alerts within a 1- to 500-mi radius in all directions or just the direction of travel.
  - The system is unique because it allows travelers to tailor the alerts based on geolocation.
- Includes major roadways in neighboring States of New Jersey and West Virginia.

IVR = interactive voice response.

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Speakers Notes (12/25)

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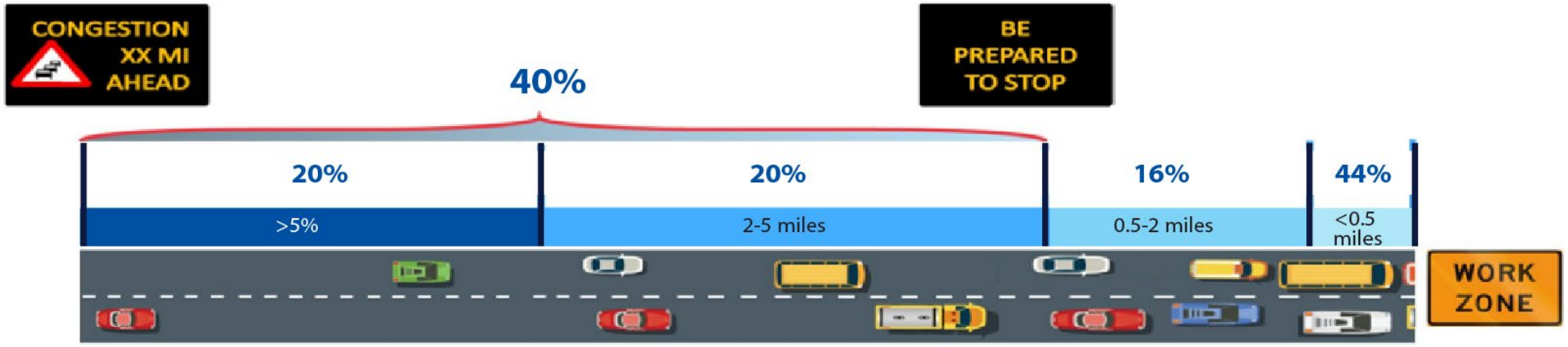
In 2014, PennDOT released their mobile app 511PA to provide real-time, hands-free traffic advisories along every PennDOT roadway and for major roadways in neighboring state of New Jersey and West Virginia. The app is based on Information Logistics' Open Microphone Platform, which is a queue-driven, voice-streaming technology used in combination with the GPS location from user's phones. Users can select to receive alerts within a one to 500-mile radius from all directions or just the direction of travel. PennDOT is looking to evolve their system further by incorporating geofenced push notifications as a driver enters an impacted area.

In 2016, several hundreds of vehicles were stranded along a dozen miles of the Pennsylvania Turnpike for more than a day during a snowstorm. There were no DMS within the vicinity of the incident and PennDOT was unable to get information to drivers. Shortly after, PennDOT transportation officials partnered with Information Logistics to develop the 511PAConnect system, a trapped-traveler emergency communications tool that allows incident response teams to interact with stranded motorists using geofencing technology.

PennDOT—ATMS Integrated Queue Detection System (Enabled by Geofencing)[3]

- The virtual queue detection function is integrated as a standalone subsystem within the PennDOT TMS.
- The system has been implemented in more than 10 corridors to detect slowdowns (i.e., speeds <30 mph).
- TMC operators assign CMSs to geofences within the TMS software.
- The TMS sends a message to be displayed on all CMSs within that geofence when it detects a slowdown.



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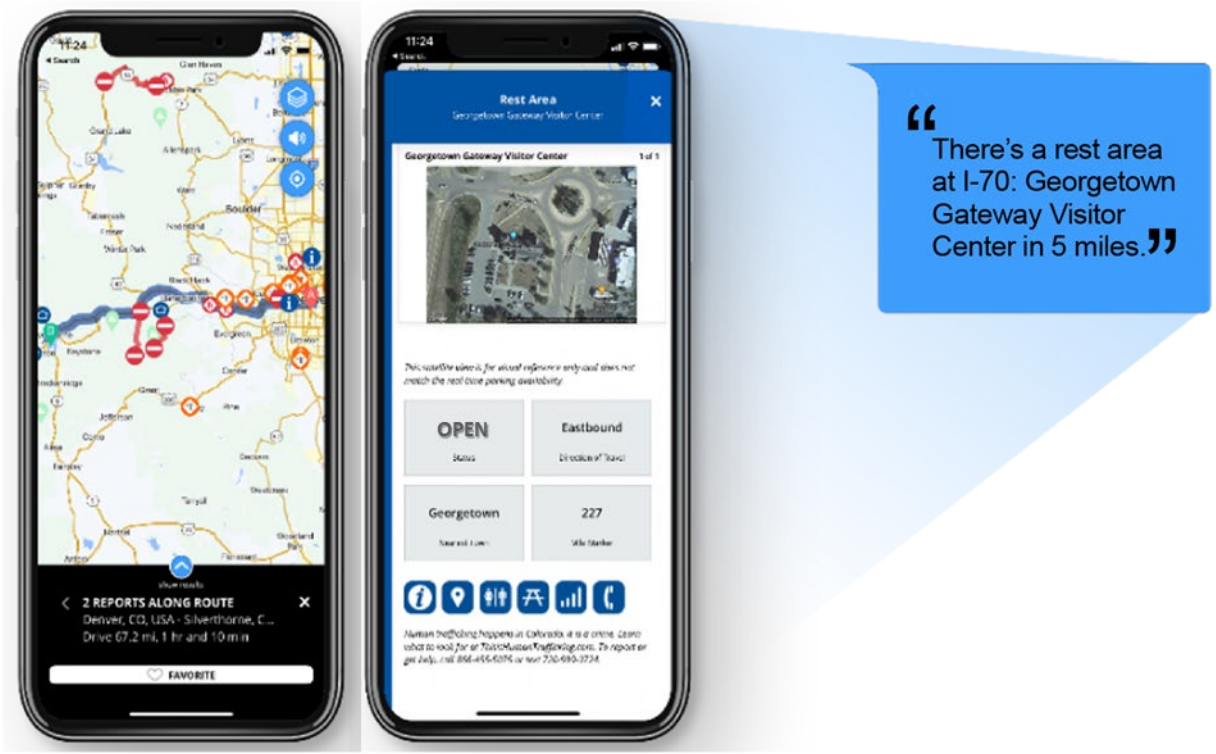
Speakers Notes (13/25)

In 2021, PennDOT integrated a virtual queue detection module into their ATMS for over 10 corridors that uses crowd sourced speed data from INRIX to detect slowdowns along specific sections of a corridor. PennDOT operators have developed a streamlined process to create geofences in their ATMS and link any DMS within the vicinity of each geofence. When speeds drop below 30 mph, the built-in algorithm will automatically display predetermined messages to each DMS based on calculated slowdown times. The messages on the DMS extend to variable speed limits, winter weather, and notice of white out conditions within a 15-mile geofence.

CDOT—COtrip Planner (Enabled by Geofencing)[4]

- Developed by a third-party service provider and operated by CDOT TMC operators.
- Includes a feature that detects a user's location and immediately provides a summary of relevant traffic incidents from TMS.
- Identifies a traveler's direction and speed from the mobile phone's GPS and sends alerts specific to the vehicle's travel path within a 5-mi radius.
- Integrated into the State's TMS. TMC operators generate customized messages sent out to all travelers in a geofenced area.



© CDOT.

Speakers Notes (14/25)

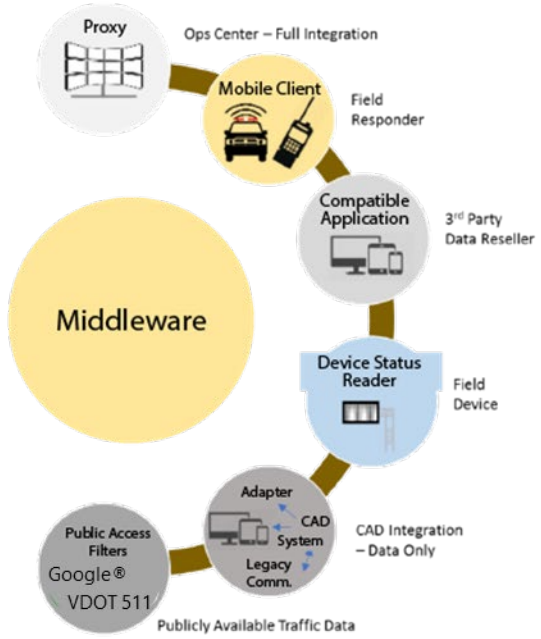
In 2021, CDOT released their COtrip Planner mobile app that provides statewide, real-time traffic information. The app includes a feature called TellMe, developed by Castle Rock, that detects a user's location and immediately provides a summary of traffic incidents within a 5-mile radius upon activation. As the user begins their trip, the app will identify the vehicle's direction of travel, speed, and automatically announce more focused alerts along the vehicle's path. If the user inputs their destination, the app provides alerts specific to the route. To support this service, CDOT traffic operators generate customized messages through their Advanced Transportation Management System (ATMS) which then get aggregated and sent out to the public via the TellMe feature.

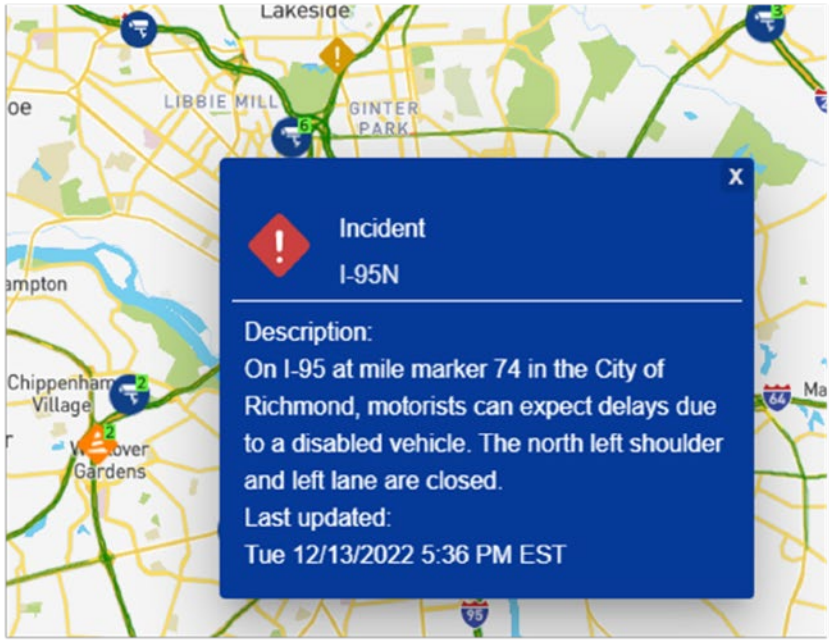
In 2012, VDOT introduced their 511 mobile app in partnership with Information Logistics. The app detects a user's location and receives an alert when the vehicle enters a geofenced area. Currently, the app alerts drivers of upcoming reduced speed and tolling booths.

VDOT is in the process of improving the data available to the traveling public and other agencies through data partnerships, and website and app improvements. VDOT is partnered with 17 agencies, and connected to field devices, public and 3rd party data, CAD, and field responders through their Public Safety Access Point Program. The program aims to improve incident management and provide relevant partner route incident data to the public. The website and app improvements include route/region specific information as filtered by the user, like alerts for incidents and planned events, weather advisory.

VDOT—511 (Enabled by Geofencing)(5)

- Mobile app developed in partnership with a third-party service provider.
- The app detects a user's location and provides an alert when the user is in a geofenced area:
  - Pulls incident data from TMS.
  - Alerts drivers of upcoming reduced speeds, incidents, and toll booths.
- VDOT is enhancing the data available through partnerships and website and app improvements.
- The goal is to improve incident management and provide relevant data to the public.





Source: VDOT.

Comm = communications; CAD = computer-aided dispatch; Ops = operations.

Speakers Notes (15/25)

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VDOT—V2X Smart Work Zone Pilot (Enabled by Geofencing)[6]

- VDOT partnered with Virginia Tech Transportation Institute and a third-party service provider.
- A cellular-V2X base station generates the geofences and serves as the primary processing unit.
- Workers can update work zone location data in realtime simply by moving connected cones.
- Workers receive audible and tactile alerts when they approach the edge of a geofence or if a vehicle is approaching.
- Connected vehicles receive advanced travel information when they enter the work zone geofence.

Speakers Notes (16/25)

VDOT partnered with the Virginia Tech Transportation Institute (VTTI) and GeoStabilization International to deploy a fully functional V2X smart work zone system along U.S. Route 23. The dynamic and wireless system is designed to protect roadside workers by quickly informing workers and connected vehicles of potential work zone dangers. The system includes four components: wearable smart vests that accurately monitor the location of workers, smart cones that create digital boundaries based on GPS locations, a single C-V2X base station that generates the geofences and serves as the primary processing unit, and the Work Zone Builder app that identifies all construction zones and possible hazard areas. Workers can update work zones in real-time simply by moving cones and will receive audible and tactile alerts when they approach the edge of a geofence or if a dangerous vehicle is approaching. Connected vehicles will receive advanced travel information when they are approaching the work zone.

NJDOT—511NJ (Enabled by Geofencing)[7]

- Emergency alert system created by a third-party service provider and developed in coordination with the New Jersey State Police.
- Agencies send out a Wireless Emergency Alert message (like an AMBER Alert) during prolonged roadway closures to all drivers within a geofence location defined by a radial distance from the incident:
  - Message is broadcast to all cellphones.
  - The user does not need to download an app or register.
- Drivers can also download an app and opt to provide their location to the system, providing NJDOT more data on traffic speeds and lengths of traffic queues.

Speakers Notes (17/25)

Some agencies have partnered with third-party vendors to provide emergency alerts through a text message system or emergency alert system, as opposed to or in some cases, in addition to, a mobile app. These services do not require users to download a separate app or pre-register to participate.

In 2019, NJDOT proactively launched their 511NJConnect system, which uses the same technology and data source as 511PAConnect. 511NJConnect was developed in coordination with the New Jersey State Police with the intent to inform immobilized motorists on New Jersey's Interstate highways, the New Jersey Turnpike, the Garden State Parkway, or the Atlantic City.

Both agencies' systems utilize the Highway Emergency Linked Platform (HELP) Alerts system created by Information Logistics, with data provided by INRIX. During prolonged roadway closures, the agency's incident team will activate their respective system to send out a Wireless Emergency Alert (WEA) message, similar to an Amber Alert. The message is sent to all drivers within a defined radius of the incident area and drivers can opt in to provide their location to the system. This allows the incident team to get a better picture of the backlog of trapped vehicles and exactly where they are located.

FDOT—Smart Work Zones (Enabled by Geofencing)[8]

- Developed in partnership with a third-party service provider.
- Deployed an app that shares work zone travel condition information:
  - Information includes the specific roadway, number of lanes open to traffic, temporary speed limit, and whether the work zone is active.
  - Data follows the standard Work Zone Data Exchange format.[10]
- Creates and updates geofence locations using GPS-enabled devices installed in the field (e.g., connected cones).
- Validates the status of the work zone by the presence of connected field devices.
- Sends information to navigation apps to disseminate back to the traveler.

Speakers Notes (18/25)

Geofencing is also being applied as validation and safety layers for active construction zones, referred to as smart work zones. The USDOT's Data for Automated Vehicle Integration (DAVI) initiative identifies that improving access to work zone data is one of the top needs. These smart work zones rely on several sources of data and represent one of many tactics that agencies are utilizing as the use of connected vehicles increases.

The system takes low quality input data and standardizes it to a Work Zone Data Exchange (WZDx) format that can be sent out to third party navigation apps such as Waze and Google. It will then validate the data within a geofence around the work zone area using the location of channelization devices, any maintenance vehicles, reduced speed limit areas, connected vehicle images, and in some cases, construction workers.

Florida DOT’s Construction division, supported by OneNetwork, deployed an app with real-time standardized information on work zones. Historically, work zone information available to the public only identified the roadway and general starting and ending points. To improve upon this, Florida DOT uses the WZDx interface that standardizes work zone data to include specifics like lane number and temporary speed limit. OneNetwork integrates data from around 150 public sources and has partnership with navigation apps like Waze and Google Maps. The status of the work zones is validated by geofencing the construction crew’s location, using Waze and Google data, and via connected vehicle data. Additionally, work zones are geofenced using devices like connected cones. Ultimately, OneNetwork pushes this information back to the navigation apps to disseminate back to the traveler.

Summary of Geofencing Benefits

- Travelers receive proactive, accurate, relevant, and continuous updates.
- Travelers can make informed decisions and stay informed during incidents.
- Geofencing enables automated TMS processes that result in faster incident response times.
- Users of location-based apps can become mobile data sources:
  - Users must agree to allow their location information to be shared.
  - Systems enable traffic information to be collected in a wide area without installing and maintaining sensors.
- Geofenced construction work zones help both drivers and workers:
  - Information generated by GPS-enabled field devices and geofencing allows agencies to provide accurate work zone information to motorists.
  - The time required for agencies to provide real-time work zone data to the public is reduced.
  - Automated alerts to workers of motorists entering geofence improve worker safety.

Speakers Notes (19/25)

- Allow Agencies to detect incidents in areas where other surveillance technologies are not currently deployed and facilitate faster response to incidents.

Agencies have successfully developed in-house or partnered with service providers to develop apps that are free to the public to receive traveler information and allow agencies the ability to collect traffic condition information. These apps include hands-free operation that do not distract drivers and automatically provide targeted information to drivers to ensure they are receiving important updates that may directly impact their trip. These apps are also meant to be user friendly and easy to use as drivers no longer need to sift through various sources to receive traffic information.

In the case of direct instant messaging that does not require a mobile app, drivers do not need to download any software or register before their trip. With the use of apps, agencies do not need to install any equipment in the field which may lead to cost savings. So far, agencies using mobile apps based on location have received mostly positive feedback from their TMCs and no negative feedback from drivers about being overloaded with notifications.

The integrated virtual queue detection utilized by PennDOT was developed to automatically detect, assess, and respond to slowed/stopped traffic in a geofenced area of interest utilizing live traffic data. The technology decreases the time to identify and facilitate incident response with emergency service providers and increases situational awareness for both the traveling public and TMC staff. This function was integrated within PennDOT's existing TMS, which allows the data to be consolidated with other sources of information in the data subsystem or database. With over 10 deployments, PennDOT saw signification cost savings in hundreds of thousands of dollars per project.

Providing up-to-date information about traffic conditions in advance of construction work zones can help drivers navigate through work zones more safely and efficiently. Agencies are also testing sending traveler information electronically to approaching CAVs. The use of connected traffic control devices (e.g., arrow boards, channelization devices, etc.) allows workers to update work zone boundaries in real time and that can be immediately transmitted to any oncoming CAVs.

The C-V2X base station that is being tested by VDOT, consolidates information on work zones into a central location. The use of GPS coordinates in the work zone traffic management and control plan reduces the time required for construction crews to set up and tear down the work zone. However, a lack of use of GPS coordinates, data standards, and electronic messages sharing this information makes it difficult and costly for third parties to access and use data between systems, agencies, or service providers.

Lessons Learned

- Geofencing has proven to be a cost-effective option for agencies to improve the quality and relevance of their traveler information.
- Agencies that have used geofencing have given positive feedback so far.
- Agencies are in the very early stages of exploring how to use geofencing technology to support other TMS functions.

Speakers Notes (20/25)

None.

Future Direction (Currently in Planning or Testing Phase)

- Traffic detection:
  - Utilize crowdsourced or third-party data to supplement or replace traffic-monitoring devices.
  - Reduce an agency's need to deploy, manage, and maintain physical infrastructure.
  - Allow the public to report incidents and incident locations using GPS from mobile devices.
- Winter hazard notifications:
  - Create geofences around RWIS stations to detect adverse weather conditions.
  - Send an operator-defined message automatically to nearby CMSs within the same geofence when weather conditions near the RWIS exceed a threshold (e.g., visibility less than 1 mi).
- Snowplow data sharing:
  - Use location data from snowplows to collect and share road-condition information.
  - Share photos or live video from snowplows equipped with dashcams when they are within a geofenced area.
  - Send alerts from TMSs to vehicles within the geofenced area.

Speakers Notes (21/25)

Agencies that have used geofencing are looking to expand the use of the technology, enhancing the capabilities of their existing traveler information apps, researching the feasibility of certain features of these apps, and some agencies are in the piloting stages of using certain types of electronic messages to prepare for a future with CAVs. Currently, agencies are either researching or beginning to implement the following features:

- **Incident reporting (testing)** – The traveling public may report incidents such as rockfall locations that will be sent to the agency's TMC for analysis. Users can easily submit a report by pressing a button or they can choose to submit a report later, when not actively driving, by selecting their GPS location at the incident area.
- **Automated winter hazard notifications (testing)** – Operators will create geofences around RWIS with predefined weather conditions that constitute white outs that may cause a crash. When weather conditions go beyond the threshold, an operator-defined message will be sent to the surrounding CMS.
- **Snowplow data (implementing)** – Some agencies are sharing near real-time locations of their snowplows using Automated Vehicle Location (AVL), especially during snowstorms. The snowplows are also equipped with dashcams that can share photos or live stream videos for the public's reference. Snowplows will only share their locations when they are within a geofenced area.
- **Detection (planning)** – Some agencies are considering utilizing crowd-sourced or 3rd party data to supplement or replace their own field devices to monitor traffic conditions, reducing the agency's investment in physical infrastructure.

Additional Information on Other TMS Practices

- TMS portal.[11]
- TMC PFS website.[12]

Speakers Notes (22/25)

None.

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Speakers Notes (23/25)

None.

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Speakers Notes (24/25)

None.

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Speakers Notes (25/25)

None.