STATE OF PRACTICE FOR AUTOMATED INCIDENT DETECTION

FINAL REPORT

January 27, 2022

ENTERPRISE TRANSPORTATION POOLED FUND STUDY TPF-5(359)

Prepared by:
Athey Creek Consultants

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16. Abstract

Traffic Management Center (TMC) operators need to be alerted of roadway incidents (e.g., crashes, stalled vehicles, slowed or stopped traffic) in a timely manner to initiate response efforts and manage the resulting traffic implications. Commercially available products can provide automated incident detection (AID) functionality with alerts to TMC operators. This project researched the state of practice for commercially available AID systems. The project focused on products and tools that detect multiple types of common roadway incidents (e.g., crashes, stalled vehicles, debris, slow or stopped traffic) and provide alerts to TMC operators. The project objectives were to understand the various AID capabilities offered and to define common user needs for TMC operator use of AID systems. To accomplish the objectives, the project identified 42 common TMC operator user needs for AID that were used to guide seven vendor demonstrations of AID products to document their capabilities. Two transportation agencies also demonstrated platforms developed in-house to assist in AID. Finally, a peer exchange webinar featured seven transportation agencies highlighting their experiences with AID products. The AID systems reviewed for this project vary in detection capabilities, detection coverage, and detection environments. In addition, all products or agency platforms are configurable, provide alerts to TMC operators and can be integrated with an agency's ATMS. The product capabilities documented and the TMC operator common user needs for AID can be used and modified by ENTERPRISE members to identify their agency's specific needs for deploying AID systems.

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The cover page image is courtesy of the Minnesota Department of Transportation.

Project Champion

Dean Beekman and David Karnes from the Wisconsin Department of Transportation were the ENTERPRISE Project Champions for this effort. The Project Champions serve as the overall leads for the project.

ENTERPRISE Members

The ENTERPRISE Board consists of a representative from each of the following member entities.

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- Iowa Department of Transportation
- Kansas Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Ontario Ministry of Transportation
- Pennsylvania Department of Transportation
- Texas Department of Transportation
- Wisconsin Department of Transportation

Project Input

ENTERPRISE would like to thank each of the ENTERPRISE member agencies that participated in a series of webinars to provide input to the TMC user needs for automated incident detection and other aspects of the project. ENTERPRISE would also like to thank the following entities that provided product demonstrations and peer exchange presentations on agency experiences with AID products:

Product Demonstrations

Transportation Agency AID Platforms:

- Colorado DOT
- Pennsylvania DOT

Companies Offering AID Products:

- Bosch
- Citilog
- FLIR
- Navtech Radar
- OptaSense
- TrafficVision
- Waycare (Acquired by Rekor in January 2022)

Peer Exchange Presentations

- Georgia DOT
- Iowa DOT
- Kansas City Scout
- Maryland DOT
- Minnesota DOT
- Ontario Ministry of Transportation
- Virginia DOT

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1.0 Introduction

Traffic Management Center (TMC) operators need to be alerted of roadway incidents (e.g., crashes, stalled vehicles, slowed or stopped traffic) in a timely manner to initiate response efforts and manage the resulting traffic implications. Commercially available products can provide automated incident detection functionality with alerts to TMC operators. This includes stand-alone products equipped with detection capabilities or systems that can be connected to existing agency equipment to perform automated incident detection at a network level.

This ENTERPRISE Pooled Fund Study project, *State of Practice for Automated Incident Detection (AID)*, researched the state of practice for commercially available automated incident detection systems. The project focused on commercially available products and tools that detect multiple types of common roadway incident types (e.g., crashes, stalled vehicles, debris in the road, slow or stopped traffic) and provide alerts to TMC operators. The objectives were to understand the state of practice for commercially available automated incident detection systems and to define common user needs for agency use of these systems.

Project Objectives

- Understand the state of practice for commercially available automated incident detection systems.
- Define common user needs for agency use of these systems.

To accomplish the project objectives, the research team worked with ENTERPRISE agencies to identify 42 common AID user needs that were then used to guide seven vendor demonstrations of AID products to document their capabilities. Two transportation agencies also demonstrated platforms developed in-house to assist in AID. Following the demonstrations, a peer exchange webinar was held where seven transportation agencies highlighted their experiences with AID products.

This report includes the following sections:

- 2.0 Project Approach – Describes the research approach and how information was gathered.
- 3.0 Industry Scan – Documents findings from an online search of traffic AID systems.
- 4.0 TMC Operators' Common User Needs for Automated Incident Detection – Identifies 42 common user needs for AID system from the perspective of TMC operators.
- 5.0 Automated Incident Detection Product Capabilities – Summarizes overall observations from the AID product webinar demonstrations.
- 6.0 Agency Experiences – Highlights agency AID experiences presented during a peer exchange webinar.
- 7.0 Key Project Highlights – Presents a summary of key highlights from each phase of the project.
- Appendix – Provides the Product Demonstration Webinar Summaries.

2.0 Project Approach

To document the current state-of-practice for commercially available AID systems a series of steps was completed. See Figure 1.

- **Step 1: Industry Scan:** An online search was conducted to document commercially available AID systems for use by transportation agencies to detect traffic-related incidents and provide alerts to TMC operators and to identify companies offering AID products.
- **Step 2: Define Common TMC Operator User Needs:** ENTERPRISE member agencies participated in an interactive webinar to define common user needs for AID systems from the perspective of the TMC operator.
- **Step 3: AID Product Demonstrations:** Based on the industry scan (Step 1), selected companies were invited to demonstrate their AID capabilities based on the common user needs (Step 2) via a webinar presentation to the ENTERPRISE members.
- **Step 4: Peer Exchange Webinar:** After the product demonstrations (Step 3) were completed, a peer exchange webinar was conducted to highlight agency experiences with a variety of AID products.
- **Step 5: Draft and Final Report:** The final step was creating this report documenting the information gathered in Steps 1-4. This document provides ENTERPRISE member agencies with the current state of practice of AID systems in addition to providing a framework of user needs that may translate to requirements as agencies procure AID systems.

Figure 1: Project Approach

3.0 Industry Scan

The information in this section reflects findings from an online search of AID systems, input from ENTERPRISE member agencies during project kickoff activities, along with input received during the review of this document from the company's that demonstrated products as part of this project. These findings focus primarily on products or tools that detect multiple types of common roadway incidents (e.g., crashes, stalled vehicles, debris in the road, slow or stopped traffic) and provide alerts to TMC operators. In some cases, these systems offer additional capabilities such as detecting wrong-way vehicles, collecting traffic data such as speeds or vehicle classifications, or other unique capabilities.

This search identified commercially available products but also includes selected agency tools and approaches that integrate external data (e.g., crowdsourced data or third-party traffic data) into TMC systems to improve incident detection capabilities.

The industry scan does not include products that provide other local detections with alerts to drivers on-site (e.g., animal crossings, pedestrian or bicyclist detection, hazardous materials vehicle identification).

The AID products and tools documented for this project are presented in six categories as shown in Table 1. Additional details on each product or tool are noted in the following sections. Selected literature that documents evaluations of AID products and systems are also provided.

Table 1: AID Products and Tools by Category

AID Category	Products and Tools
Video Analytics Systems that Use In-Place Traffic Cameras	• TrafficVision • Citilog (several products) • Southwest Research Institute (SwRI) Active-Vision™ Anomaly Detection • FLIR
Detection-Equipped Traffic Cameras	• Bosch • FLIR
Non-Video Based Products	• Waycare (Acquired by Rekor in January 2022) • OptaSense • NavTech Radar • Bluecity
Agency Tools and Platforms Using External Data	• PennDOT Traffic Alerts Dashboard (Waze and INRIX) • Colorado DOT Traffic Operations Dashboard (Waze and HERE) • Additional agencies integrating Waze into TMC systems (Maine DOT; Lake County, Illinois; Pennsylvania Turnpike; Iowa DOT)
Incident Feeds from Third-Party Traffic Data Providers	• TomTom • INRIX • HERE

Wrong-Way Vehicle Detection Systems	• Citilog Wrong Way Alert System • TAPCO *Wrong-way Alert System* • All Traffic Solutions (ATS) *Wrong-Way Solution™* • MH Corbin *Wrong-Way Detection Solution* • Trafficalm *Wrong Way Warning + Notification* • Carmanah *WW400 Wrong Way Vehicle Detection, Warning and Alert System* • Image Sensing Solutions *Wrong Way Alerting Solution* • Southwest Research Institute (SWRI) *Wrong-Way Driving Solutions* • Cameleon/FLIR Wrong-Way Driving Solutions + Notification • TrafficVision

3.1 Video Analytics Systems that Use In-Place Traffic Cameras

Video analytics systems process video streams from traffic cameras to detect incidents and create real-time alerts. These types of systems process video feeds from in-place traffic cameras to detect incidents and generate notifications.

Table 2 provides an overview of AID systems that utilize video from in-place traffic cameras.

Table 2: Video Analytics Systems that Use In-Place Traffic Cameras

Product	Overview
TrafficVision	Website: http://www.trafficvision.com/ TrafficVision uses a patented advanced computer vision system which was specifically designed for transportation to monitor digitally encoded video streams of traffic cameras on highways to detect incidents and continuously collect real-time traffic data. Types of incidents detected: • Wrong-way vehicle • Stopped vehicle/debris in roadway is stationary for more than the specified threshold • Vehicle congestion if lane occupancy exceeds the specified percentage • Pedestrian in road • Slow speeds if below the specified threshold for specified duration of seconds Special events and other applications: • Monitoring for incidents or collecting data during special events • Construction zones • Problem areas requiring quantified data points such as wrong way drivers, stopped vehicles, volume increases/decreases, or frequent slow downs • Real-time traffic data collection: classifies vehicles as motorcycle, passenger vehicle, truck, and large truck

Product	Overview
Citilog	Website: https://www.citilog.com/solutions/incident-management Citilog solutions turn cameras into Automatic Incident Detection (AID) sensors, creating a broad detection network. Deployed through servers or directly on the edge, within the cameras, the state-of-the-art analytics detect incidents and alert operators in seconds. The CT-ADL (Citilog Applied Deep Learning) leverages the power of deep learning to eliminate false alarms – while maintaining today's high detection rates.
Southwest Research Institute (SwRI) Active-Vision™ Anomaly Detection	Website: https://www.swri.org/industry/intelligent-transportation-systems/active-vision-anomaly-detection Active-Vision™ applies advanced computer vision and Machine Learning Technologies to detect and report actionable traffic condition changes. It can be integrated into a variety of intelligent transportation systems (ITS), using existing traffic cameras to analyze anomalies affecting roadway traffic.
FLIR	FLIR provides in-rack/cabinet modules for AID which use existing hardware.

3.1.1 Selected Literature for Video Analytics Systems that Use In-Place Traffic Cameras

An online literature search located the following selected literature related to video analytics systems that use in-place traffic cameras.

- *Development of Automated Incident Detection System Using Existing Advanced Traffic Management System (ATMS) CCTV* (Chien et al., 2019): The Indiana Department of Transportation (INDOT) has over 300 digital cameras along highways in populated areas of Indiana. ***The main objective of this research was to develop an automatic and real-time system to facilitate the tracking process.*** The Transportation Active Safety Institute (TASI) of the Purdue School of Engineering and Technology at Indiana University-Purdue University Indianapolis (IUPUI) and the Traffic Management Center of INDOT have ***worked together to conduct a one-year research project to develop a system that will monitor the traffic conditions based on the INDOT CCTV video feeds.*** Specifically, the proposed system will perform traffic flow estimation, ***incident detection***, and classification of vehicles involved in an incident. ***The automatic traffic incident detection was not implemented as a part of this project and will be implemented after the traffic flow information is being derived accurately.***
- *Testing and Evaluation of Thermal Camera-based and Video-analytic Systems on Wrong-Way Driving, Stopped Vehicles, and Pedestrians* (Lin et al., 2019): ***This project successfully evaluated the performance of*** a thermal camera-based detection system and ***a video-analytic detection system*** provided by two vendors. The thermal camera-based detection system was deployed at two locations on the Sunshine Skyway Bridge to identify wrong-way driving (WWD), stopped vehicles, and pedestrian events, and the video-analytic system was deployed at six locations on

the Howard Frankland Bridge to detect freeway WWD events. Two performance measures were defined to evaluate the tested systems—detection system accuracy and percentage of false calls. ***Data review and analysis results revealed that*** (1) the thermal-based detection system was able to produce a detection system accuracy of 100% for pedestrian detection, 94.3% for stopped vehicle detection, and 100% for WWD detection; ***(2) the video-analytic system was able to produce a detection system accuracy of 84.6% for WWD detection;*** (3) correct pedestrian detections were triggered by roadway workers or onsite police officers for work; ***(4) correct detection of stopped vehicle events was triggered primarily by vehicles (cars, motorcycles, utility vehicles, etc.) stopped on shoulders and on-duty vehicles (utility vehicles, police vehicles, etc.) stopped in lanes to perform work;*** one potential suicide attempt was detected associated with a stopped vehicle/pedestrian on the Sunshine Skyway Bridge; (5) no actual WWD events were detected at any designated test location; all correctly-detected WWD events were trigged by vehicles in roadway events such as roadwork utility vehicles and on-duty police vehicles driving in opposite direction of traffic in blocked lanes, and vehicles backing upon shoulders; and (***6) the video-analytic detection system configuration may be subject to change due to external environment conditions such as camera vibrations; it is recommended to define appropriate reference points for detection region of interest (ROI) configuration and calibration during the system setup process and to set up alerts when pre-defined ROI is shifted.***

- *Situational Awareness for Transportation Management: Automated Video Incident Detection and Other Machine Learning Technologies for the Traffic Management Center* (Rindt, 2018): ***This report provides a synthesis of Automated Video Incident Detection (AVID) systems as well as a range of other technologies available for Automated Incident Detection (AID) and more general traffic system monitoring.*** This synthesis considered the impacts of big data and machine learning techniques being introduced due to the accelerating pace of ubiquitous computing in general and Connected and Automated Vehicle (CAV) development in particular. To start with, a general background on the history of traffic management was provided. This is followed by a more detailed review of the incident management process to introduce the importance of incident detection and general situational awareness in the Traffic Management Center (TMC). ***Attention was then turned to AID in general and AVID in particular*** before discussing the implications of more recent data sources for AID that have seen limited deployment in production systems but offer significant potential. Finally, the changing role of the TMC and how new data can be integrated into traffic management processes most effectively was considered.

- *Performance Evaluation of Video Analytics for Traffic Incident Detection and Vehicle Counts Collection* (Kim et al., 2017): Current incident detection and traffic monitoring method using closed-circuit television (CCTV) cameras meets with limitations as the coverage of CCTV cameras rapidly expands. In general, traffic operators at the Traffic Operation Center (TOC) have to manage and monitor numerous CCTV cameras deployed on roadways. Thus, many transportation agencies consider the use of a video analytics system to reduce incident detection time and minimize traffic impacts, but they also want to validate the performance of the video analytics system whether it can work with their existing video surveillance infrastructure before procuring the system. To that end, ***a pilot study was designed and conducted to evaluate the accuracy of a video analytics***

product by integrating with CCTV cameras deployed on highways. The pilot study was designed to evaluate the accuracy of video analytics in detecting incidents and collecting traffic counts. ***The test results show that the performance of video analytics is significantly impacted by video quality and other environmental factors such as lighting and weather conditions.***

- Evaluation of Video Analytics for Incident Detection – Pilot Demonstration Houston, Texas (Stevens et al., 2016): To improve incident management while leveraging existing ITS resources, Texas DOT (TxDOT) was interested in evaluating technologies that might enable faster detection of incidents and increase the number of incidents being detected. TxDOT engaged with the video analytics vendor TrafficVision on a demonstration of their video analytics technology. The evaluation ***integrated video analytics software into a subset of existing CCTV cameras with pan, tilt and zoom (PTZ) function without adjusting the camera settings*** to evaluate system viability with the existing CCTV monitored at Houston TranStar. ***Results for incident detection time with TrafficVision when compared to incident detection time with currently used detection tools showed that average detection time for 34 incidents was approximately seven minutes less and for 32 incidents was 14 minutes more than that noted in Regional Incident Management System (RIMS).*** Results for detecting additional incidents using video analytics software showed potential. ***During the 12-week evaluation period, TrafficVision detected an additional 462 stopped vehicle events that were not part of RIMS data.*** This analysis suggests that ***video analytics is a viable incident detection tool that has the potential to increase the number of incidents detected (especially stalled vehicles) even when used with PTZ cameras***.
- Next Generation Traffic Data and Incident Detection from Video (Preisen and Deeter, 2014): This project ***evaluated the accuracy of incident detection capabilities from two commercially available video analytics systems.*** The evaluation compared detection alerts generated by video analytics systems to video clips and still images, compared detection alerts to agency-reported incidents, and gathered observations from TMC operators. ***The best performance result for stopped vehicle/debris in road was 72% alerts validated, 23% alerts not validated (false alarms), and 5% alerts unable to determine. When removing repetitive alerts caused from objects in the camera's field of view, false alerts dropped dramatically for stopped vehicle/debris in the road. The best performance result for detecting slow traffic/congestion was approximately 30% incidents validated, with the remainder being false alarms or not able to determine.*** TMC operators indicated that system-generated email alerts with attached photos of the incident are timely and useful. Sometimes video analytics systems caught incidents that hadn't yet been seen by operators; other times operators already knew about the incident.

3.2 Detection-Equipped Traffic Cameras

Detection-equipped traffic cameras have functionality to detect traffic incidents and create real-time alerts. Detection-equipped cameras can serve multiple purposes for monitoring, incident detection, and other uses. Table 3 provides an overview of commercially available detection-equipped traffic cameras that perform automated incident detection.

Table 3: Detection-equipped Traffic Cameras

Product	Overview
Bosch	ITS Solutions Website: www.boschsecurity.com/us/en/industries/intelligent-transportation-systems-its/ *Automatic incident detection for bridges and tunnels* (brochure): https://media.boschsecurity.com/fs/media/pb/images/industries_2/transportation/app-note_automatic_incident_detection.pdf Detection Capabilities: • Traffic congestion that can delay or prevent emergency response vehicles from access • Stopped or disabled vehicles • Wrong way driver • Debris, objects, or animals in the road • Fire or smoke in hard to see areas • Bicyclists and pedestrians in low light and low visibility conditions • Icicle formations hanging from tunnels
FLIR	Website: https://www.flir.com/traffic/avoid-incidents--traffic-jams-on-roads-highways-and-tunnels/ FLIR's detection solutions can detect: • Stopped vehicles or disable vehicles • Long queues • Slow-moving vehicles (Underspeed but also overspeed (cars moving over a designated maximum)) • Fallen objects/debris • Pedestrians • Wrong Way Driver • Fire • Animals

3.2.1 Selected Literature for Detection-Equipped Traffic Cameras

Following is selected literature related to incident detection for detection-equipped traffic cameras as located through an online literature search.

- *Testing and Evaluation of Thermal Camera-based and Video-analytic Systems on Wrong-Way Driving, Stopped Vehicles, and Pedestrians* (Lin et al., 2019): ***This project successfully evaluated the performance of a thermal camera-based detection system*** and a video-analytic detection system provided by two vendors. ***The thermal camera-based detection system was deployed at two locations on the Sunshine Skyway Bridge to identify WWD, stopped vehicles, and pedestrian events,*** and the video-analytic system was deployed at six locations on the Howard Frankland Bridge to detect freeway WWD events. Two performance measures were defined to evaluate the tested systems—detection system accuracy and percentage of false calls. ***Data review and analysis results revealed that (1) the thermal-based detection system was able to produce a***

detection system accuracy of 100% for pedestrian detection, 94.3% for stopped vehicle detection, and 100% for WWD detection; (2) the video-analytic system was able to produce a detection system accuracy of 84.6% for WWD detection; (3) correct pedestrian detections were triggered by roadway workers or onsite police officers for work; ***(4) correct detection of stopped vehicle events was triggered primarily by vehicles (cars, motorcycles, utility vehicles, etc.) stopped on shoulders and on-duty vehicles (utility vehicles, police vehicles, etc.) stopped in lanes to perform work;*** one potential suicide attempt was detected associated with a stopped vehicle/pedestrian on the Sunshine Skyway Bridge; (5) no actual WWD events were detected at any designated test location; all correctly-detected WWD events were trigged by vehicles in roadway events such as roadwork utility vehicles and on-duty police vehicles driving in opposite direction of traffic in blocked lanes, and vehicles backing upon shoulders; and (6) the video-analytic detection system configuration may be subject to change due to external environment conditions such as camera vibrations; it is recommended to define appropriate reference points for detection region of interest (ROI) configuration and calibration during the system setup process and to set up alerts when pre-defined ROI is shifted.

3.3 Non-Video Based Products

Some commercially available products provide incident capabilities that are not based on video feeds or camera-based technologies. These products vary widely in terms of their approaches and technologies. Table 4 provides an overview of commercially products that do not use video or camera-based analytics to perform automated incident detection.

Table 4: Non-Video Based Products

Product	Overview
Waycare (Acquired by Rekor in January 2022)	Website: https://waycaretech.com/solutions/ Waycare aggregates, synthesizes, and analyzes data from existing transportation infrastructure, in-vehicle data, and other crowd sourced information to provide a shared, cloud-based platform unlocking key real-time and predictive operational insights about roads. Waycare partners with a wide range of data providers to collect information from connected vehicles, navigation apps, and public weather and event services. ***Waycare processes this data to identify and predict incidents and congestion, storing these insights in a Data Warehouse.*** Waycare *Smart Connect* is designed with Traffic Management Operators' needs in mind. An intuitive layered map interface provides users with a real-time outlook of road conditions: ***congestion, risk zones, stalled vehicles, debris, traffic stops, major events, etc.*** Users can input incident activity and memo descriptions that are instantly accessible to other agencies such as First Responders, Maintenance, and more.
OptaSense	Website: https://optasense.com/transportation/road-monitoring/ The OptaSense Traffic Monitoring Solution ***converts existing fiber-optic cable into an array of intelligent sensors*** which deliver timely and accurate traffic monitoring and incident detection information from the entire monitored route.

	The OptaSense Traffic Monitoring Solution delivers the following real-time traffic monitoring applications: • Average Traffic Speed: Measured every 50-meter section and updated every second. • ***Congestion Detection:*** Automatically generated notifications for moderate and severe incidents of congestion. • ***Queue Detection:*** Automatically generated notifications for queuing traffic. Dynamic tracking of queue location and length. • Journey Times: Estimated journey times between set locations. • Traffic Count and Flow Rate: Vehicle counts and flow volume estimates.
NavTech Radar (ClearWay)	Website: https://navtechradar.com/explore/automatic-incident-detection/ Designed for smart cities, highways, tunnels, open roads and bridges, each ClearWay's automatic incident detection (AID) radar covers wide areas up to 1,000 m. Incident Types: • Stopped vehicle • Slow or fast vehicle detection • Vehicles going the wrong way • Pedestrians or animal detection • Debris detection Detection Conditions: • Fog, snow, and rain • Fire, smoke, and hot gasses • Water and spray • All levels of light, from darkness to sun glare
Bluecity / Velodyne Lidar	Bluecity website: https://bluecity.ai/ • Bluecity combines artificial intelligence (AI) and lidar to better understand and adjust smart city mobility. Bluecity uses AI-based traffic data insights to improve mobility and the progression of traffic so congestion is reduced. Lidar technology provides data-based decision-making, so better management of urban growth and travel times during major construction becomes a reality. • Bluecity's technology provides easy-to-install and reliable traffic data with enhanced metrics, ***such as real-time incident detection, warning messages***, real-time accident prediction, hotspot identification and more. Velodyne/Bluecity: https://velodynelidar.com/automated-with-velodyne/blue-city-technology/

3.4 Agency Tools and Platforms Using External Data

Agencies are increasingly using data from external sources to improve incident detection capabilities. For example, the use of crowdsourced data from third-party navigation mobile applications (e.g., incident alerts from Waze) and third-party probe data providers (e.g., incident feeds) can supplement incident information received through traditional methods such as 911 calls or by viewing traffic cameras. Agencies may integrate this data into existing TMC systems such as ATMS or build new platforms to view and sort the data. Agencies using this type of data for incident detection report benefits such as faster incident notifications, decreased incident response times, and improved situational awareness.

Table 5 provides an overview of agency tools and platforms that use external data (e.g., third-party probe data and incident feeds, crowdsourced data) to convey incident detections.

Table 5: Agency Tools and Platforms Using External Data

<table>
<tr><th>Tool/Platform</th><th>Overview</th></tr>
<tr><td>Pennsylvania DOT
Traffic Alerts Dashboard</td><td>Source: Traffic Alerts Overview. Slide presentation. PennDOT TSMO Operations and Performance Section. (PennDOT, 2020)

The Traffic Alerts Dashboard provides PennDOT Traffic Operations staff with a tool that allows for early identification, verification, situational awareness and management of events on PennDOT’s Core Roadway Network. The dashboard utilizes data from third-party sources (WAZE and INRIX) data for incident detection.

Data Sources:
• Waze: Waze Alert Information, Waze Confidence Score
• INRIX: Speeds, Speed Overlay, INRIX Alerts and Severity
• PennDOT Road Condition Reporting System (RCRS) Event Information
• Google map layer
• TSAMS – Camera locations, Changeable Message Sign (CMS) locations

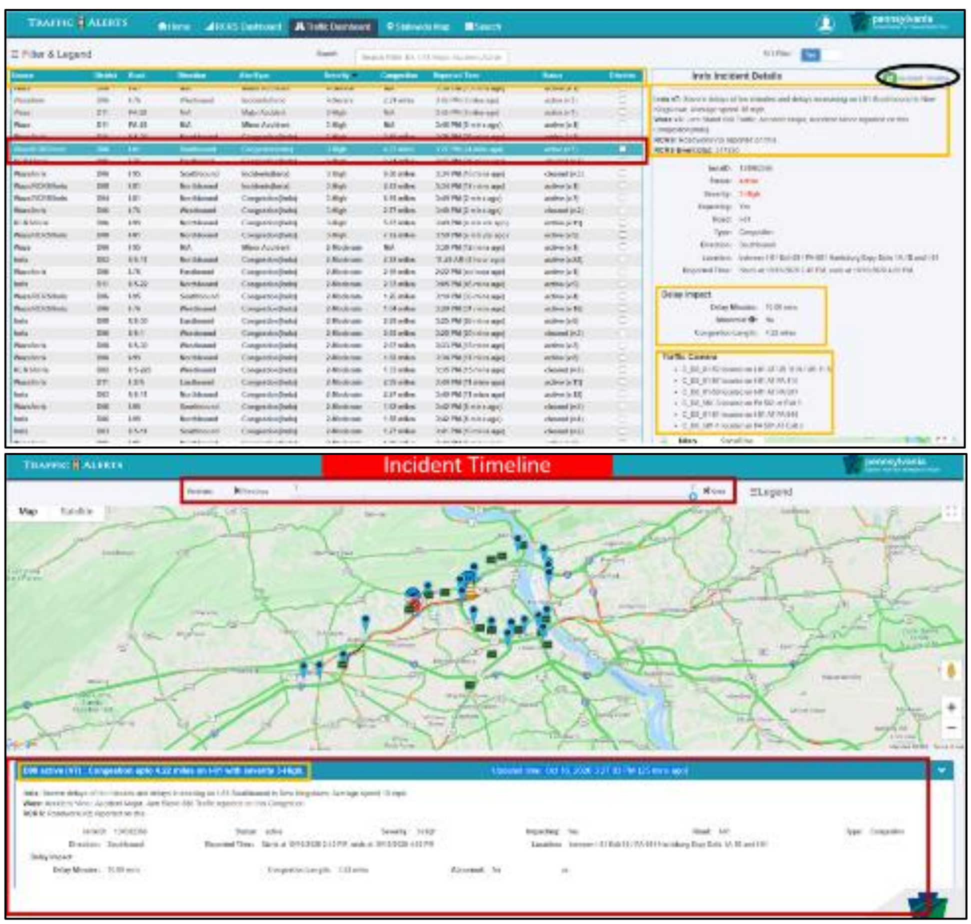

Figure 2: Screenshots of PennDOT Traffic Alerts Dashboard</td></tr>
</table>

Tool/Platform	Overview

	Source*: [Transportation Systems Management and Operations Performance Report 2018Q2 Edition]* (PennDOT, 2018):
	• A year-long pilot used crowdsourced information (INRIX, Waze) to assist with incident identification, validation, and the response process.
	  – Together, TMCs, Waze, and INRIX had situational awareness on 96% of all reportable crashes.
	  – INRIX and Waze combined detect incidents first on approximately 84% of all crashes and high congestion crashes.
	  – Although Waze and INRIX data are not the only sources for incident identification and verification, they can provide valuable information to help TMCs identify incidents and improve situational awareness.

Colorado DOT *Traffic Operations Dashboard*	Source: National Operations Center of Excellence (NOCoE) webinar: *Adventures in Crowdsourcing: Business Case for Crowdsourced Data* (October 22, 2020)
	• Colorado DOT "Traffic Operations Dashboard" (partnered with ESRI to develop)
	  – Dashboard uses HERE Live Traffic Data and Waze Traffic Alerts.
	  – Use of crowdsourced data has resulted in a significant decrease in incident response times, improved situational awareness for operations and maintenance staff, and more accurate and timely traveler information.
	
	
	Figure 3: Screenshot of Colorado DOT Traffic Operations Dashboard

Agencies Integrating Crowdsourced Data into TMC Operations	Source: NOCoE webinar *Adventures in Crowdsourcing: Business Case for Crowdsourced Data* (October 22, 2020)
	• Maine DOT:
	  – Using Waze data in the TMC for operations
	• Lake County, Illinois:
	  – Waze data integrated into ATMS

	Source: NOCoE webinar *Adventures in Crowdsourcing: Incident Management Tools* (October 10, 2019) • Pennsylvania Turnpike: – Integrates Waze data into TMC operations and systems (e.g., Early Warning Detection Tool, Waze Operational Dashboard)

Tool/Platform	Overview
	– Incident Management Dashboard: Waze alerts received 3 to 4 minutes before calls
	Source*: [Adopting and incorporating crowdsourced traffic data in advanced transportation management systems]* (Amin-Naseri, 2018) • Iowa DOT: – This research quantified the potential additional coverage Waze can provide to existing sources of the Advanced Traffic Management System (ATMS). – One year of Waze data was compared with the recorded incidents in the Iowa's ATMS in the same timeframe. ***Overall, the findings indicated that the crowdsourced data stream from Waze is an invaluable source of information for traffic monitoring with broad coverage (covering 43.2% of ATMS crash and congestion reports), timely reporting (on average 9.8 minutes earlier than a probe-based alternative),*** and reasonable geographic accuracy. Waze reports currently make significant contributions to incident detection and were found to have potential for further complementing the ATMS coverage of traffic conditions.

3.5 Incident Feeds from Third-Party Traffic Data Providers

Third-party probe traffic data providers may offer incident information via data feeds such as Application Programming Interfaces (APIs), for possible integration into TMC systems, web applications, or mobile applications. These services and data feeds likely require software development to integrate into existing agency systems and platforms.

Table 6 provides an overview of third-party traffic data services that offer incident feeds.

Table 6: Incident Feeds from Third-Party Traffic Data Providers

Product	Overview
TomTom *Traffic Incidents API*	Website: https://developer.tomtom.com/traffic-api/traffic-api-documentation/traffic-incidents The Traffic Incidents service is a ***suite of web services designed for developers to create web and mobile applications around real-time traffic***. • These web services can be used via RESTful APIs. • The Traffic Incidents APIs are based on real-time traffic data from TomTom Traffic™. TomTom's Traffic Incident RESTful API: • Is updated every minute with very latest traffic incident and delay information. • Returns detailed ***information about traffic jams and traffic related incidents. Details include: start-location, end-location, road-name, type of delay, length (in time) of the delay, significance, and distance***. • The Incident Tile API provides traffic incident and delay information for display on your map view.

Product	Overview
TomTom *Traffic Incidents – Intermediate Service – DATEX II*	Website: https://developer.tomtom.com/intermediate-traffic-service/intermediate-traffic-service/tomtom-traffic-incidents-intermediate-service-datex-ii The TomTom Traffic Incidents - Intermediate Service – DATEX II is based on DATEX II v1.0. DATEX II is a standard for information exchange between traffic control centers, service providers, and application developers. – The Service provides the latest real-time information about traffic incidents, their causes and impacts on travelers. ***Typical traffic incidents include accidents, road construction projects, traffic jams, travel weather warnings, road closures, and any other road-related situation that could potentially cause a delay.*** – TomTom offers traffic incident data to customers. ***In the basic configuration,*** TomTom ***provides customers information on traffic congestion and other roadwork related traffic events*.** Each traffic incident is represented in a DATEX II event, and we add an Alert-C event code with the same meaning.
INRIX *INRIX Incident Service*	Website: http://docs.inrix.com/traffic/xdincidents/ ***The INRIX Incident Service provides information on incidents that can impact traffic***, including: – Accidents (Incident Type 4) – Events (Incident Type 2) – Construction (Incident Type 1) – Road Weather (Incident Type 5) – Congestion alerts (Incident Type 3) – User reported alerts - various incident types – Police - User reported alerts (Incident Type 6) The main usage scenarios are: – Displaying incidents on a map – Creating routes that avoid incidents – Creating alerts for upcoming incidents
HERE *Traffic API (Incidents and Incidents 6.2)*	Website: https://developer.here.com/develop/rest-apis Whether providing truck routing for fleets or navigating users through the city with different transport modes, ***HERE REST APIs*** provide users with everything needed to put location at the heart of your app: maps, weather information, batch geocoding, comprehensive routing and more. Additional advanced location features include geofencing (entry and exit notifications), custom and private roads, speed limits, traffic lights and road curvature. *Traffic API:* Add real-world context to your application by integrating real-time and historical traffic information about accidents, congestion, construction and more. *Incidents and Incidents 6.2:* These resources are responsible for handling requests for ***traffic incident information for a geospatial area***. The delivery formats are either XML or JSON.

3.6 Wrong-Way Vehicle Detection Systems

This section provides an overview of systems that detect wrong-way vehicle movements, primarily for site-specific applications (e.g., ramps). These are typically specialized, local deployments at problematic areas and may or may not include alerts to TMC operators. Because the focus of this research is to document systems that provide alerts to TMC operators, the systems noted in this section have this capability. Some are commercially available solutions, while others are agency-specific systems.

Note that some of the individual products documented in previous sections may be capable of detecting wrong-way vehicles (e.g., systems that process video from existing cameras) or may be components of the systems documented in Table 7 (e.g., detection-enabled cameras that are part of a TAPCO solution.)

Table 7 provides an overview of wrong-way vehicle detection systems with alerts to TMC operators.

Table 7: Wrong-Way Vehicle Detection Systems

Product/ System	Overview
Citilog *Wrong-Way Alert System*	Website: https://www.citilog.com/products/citilog-ct-im-analytics Wrong-way detection is a key function of the Citilog CT-IM analytics suite. This suite can operate on a server-base using existing cameras or on edge-based inside a camera. The Edge-based solution is more common for wrong-way detection since time is of the essence. Using open protocols (https, xml…) the CT-IM analytics onboard the camera can easily interface with a Dynamic/Variable message sign positioned downstream to alert wrong-way drivers. The wrong-way alerts can be viewed and archived on CT-Center-Client, a central GUI that enables reviewing video recordings of incidents.
TAPCO *Wrong-Way Alert System*	Website: https://www.tapconet.com/product/wrong-way-alert-system#product-selection Uniquely engineered to fit any ramp configuration, TAPCO Wrong-Way Alert Systems detect wrong-way drivers, immediately activate LED-enhanced flashing alerts and send real-time wrong-way event notifications. • Activation options include thermal detection, radar, inductive loop detectors, detection-enabled cameras. • BlinkLink® cloud-based software application collects real-time data and ***sends out voice, email and Short Message Service (SMS) alert notifications to pre-determined recipients.*** – Access on any web-enabled device – Easily program and view the status of every system – Analyze system activation trends and gain insight to problem areas – ***Keep your whole team informed through activation alert notifications*** – Generate custom activation reports

Product/ System	Overview
All Traffic Solutions (ATS) *Wrong Way Solution™*	Website: https://www.alltrafficsolutions.com/solutions/wrong-way-solutions/ Brochure: https://www.alltrafficsolutions.com/wp-content/uploads/2019/10/WrongWay-SpecSheet-100719.pdf • ATS Wrong Way Solution™ uses Lidar or radar to sense wrong-way drivers. • Multi-channel Notification System alerts the driver with flashing messages and beacons, telling them to stop and turn around, ***notifies designated authorities immediately via email or text message (both with links to video when available),*** and optionally can alert other drivers of the wrong way vehicle via dynamic messages on variable message signs, via 511 systems, TMC and/or social apps. • Notifications sent using ATS TraffiCloud cloud-based software, ***provides real-time wrong way alerts with accompanying video via email or SMS message to predetermined contacts***. Alerts can be sent to as many recipients as desired. • Secure "Anywhere" Access: – Fully hosted web-based remote management service is always available – Uses Lidar at multiple points to sense and verify wrong-way vehicles – Access system from anywhere from any Internet-connected device – ***Accessible via API to inform other systems*** – Password-protected with three levels of user access
MH Corbin *Wrong-Way Detection Solution*	Website: https://mhcorbin.com/Solutions/Wrong-Way-Detection • Every customized solution from MH Corbin can confirm the overall presence of a wrong-way driver—from the moment of infraction to a potential full merge onto a highway. The solutions can leverage a single camera or a combination of inputs to track complete driver behavior, reducing false positives. • The Connect:ITS Roadside Controller operates primarily as an edge computing device, but gathered data can also be sent to and stored in the Cloud. Destinations: Highway Advisory Radio, Dynamic Message Signs, Variable Speed Limit Signs, ***Email/Text Alerts***, and In-vehicle alerts via Dedicated Short Range Communication (DSRC).
Trafficalm *Wrong Way Warning + Notification*	Website: https://trafficalm.com/wwa/ • Retrofit install to existing signs, with four Basic Components: Flashing LED Sign Rings, Controller, Collaborators, Radar Detectors • If notification is desired, the existing controller can be reconfigured to act as a Collaborator, making this a zero-waste upgrade. ***4g Cell technology integrates for easy access to rapid notifications for law enforcement or traffic safety personnel via our secure cloud interface or email.*** Notifications deliver in less than 15 seconds of the event.
Carmanah WW400 *Wrong Way Vehicle Detection,*	Website: https://carmanah.com/product/ww400-wrong-way-vehicle-detection-warning-and-alert-system/ • The WW400 is an advanced system that detects wrong-way drivers on highway off-ramps, warns them of their error with high-intensity flashing lights, and alerts local traffic management centers (TMC) of the event. • Includes two types of units: detector unit and warning sign units.

Product/ System	Overview
Warning and Alert System	• The radar unit detects the incoming vehicle and simultaneously triggers the LED warning lights and activates the cameras and video analytics. The system then uses advanced image-processing algorithms to process the video. ***When the cameras confirm the wrong-way event, the WW400 automatically sends an alert notification and event package containing a configurable sequence of images, video and other data to the local TMC.***
Image Sensing Solutions (ISS) *Wrong Way Alerting Solution*	Website: https://www.imagesensing.com/solutions/wrong-way.html • The Wrong Way Alerting solution is an all-in-one system that provides reliable wrong way detection on ramps. This module is a side-fire sensor that can detect vehicles traveling the wrong way on ramps. • The wrong way module detects wrong way vehicles and ***sends an automated message alert with an image snapshot via E-mail or short message service (SMS).*** The system also provides a 30 second video of the event, allowing traffic operators to visually confirm the wrong way vehicle and provide emergency officials the details of the vehicle.
Southwest Research Institute (SwRI) Wrong-Way Driving Solutions	Website: https://www.swri.org/technology-today/righting-wrong-way-driving-problem • One solution ***pairs thermal cameras with perception algorithms SwRI developed*** for driverless vehicles and the manufacturing industry. The perception algorithms process visual inputs from a video camera, ***classifying patterns to isolate a wrong-way driver from other objects and backgrounds in the visual field***. • The second solution uses connected-vehicle technology that enables communication between vehicles, infrastructure and transportation agencies to warn the wrong-way driver as well as other motorists in the vicinity. The system also identifies and helps track wrong-way motorists.
Cameleon/ FLIR Wrong-Way Driving Solutions + Notification	Website: https://www.flir.com/browse/public-safety/traffic-sensors/?application=1073742569 • FLIR TrafiBot HD combines field-proven video detection algorithms with advanced camera optics and powerful processing technology in a single box camera. TrafiBot HD (with 1920 × 1080 resolution) provides superior image quality, embedded AID analytics, as well as multi-stream encoding. TrafiBot HD’s advanced processing unit ***generates traffic data and incident detection information*** and thus supports traffic operators with alerts on stopped vehicles, ***wrong-way drivers***, pedestrians, lost cargo, smoke, and traffic flow data. • FLIR TrafiSense2 Dual combines best-in-class thermal and visual imaging technology with advanced video analytics to provide vehicle and bicycle presence detection at signalized intersections, day and night. Thermal imaging lets traffic operators see in total darkness and inclement weather. The daylight camera ***offers additional visual verification for such incidents as wrong-way drivers*** and animal crossings. In addition, FLIR's analytics capture accurate traffic data, making FLIR TrafiSense2 Dual ideal for real-time traffic management in urban environments.

Product/ System	Overview
	FLIR Cameleon ITS is a central software platform for transportation monitoring and management that allows for the control of ITS-specific devices, including cameras, DMS signs, detector stations, gates, signal heads and incident detection.
TrafficVision	Website: http://www.trafficvision.com/ TrafficVision offers wrong way detection using both new and existing categories and can apply this feature across a series of cameras. Currently Florida DOT is testing TrafficVision Wrong Way Detection with existing cameras. The system activates signs and flashing lights as well as sends alerts including both snapshots and video of the Wrong Way Driver to their ATMS -all in real-time. In addition to detecting a Wrong Way Driver, the TrafficVision software also continuously collects data providing the agency with more than just a wrong way detector. Also, Wrong Way Detection can be added to any camera within an agency's existing network of cameras within minutes giving an agency the flexibility of applying any of the TrafficVision features. Traffic Vision's wrong Way detection solution can operate as a stand-alone turn-key solution or as a feature turned "on" within an agency's network of cameras.
Examples of Agency Deployments	*Countermeasures for Wrong-Way Driving on Freeways* (Athey Creek Consultants, 2016): • ***10 agencies deployed wrong-way detection with alerts to TMCs:*** Arizona DOT, Central Florida Expressway Authority, Florida DOT, Iowa DOT, Missouri DOT, Ohio DOT, Rhode Island DOT, Harris County Toll Road Authority (Texas), Texas DOT, and Wisconsin DOT. • Primarily at freeway ramps. Mostly using radar detection, often with cameras for verification. Some mainline detection using radar. • ***Nearly all deployments include on-site warnings to alert drivers, plus notifications to TMCs and/or other entities.*** • Equipment vendors or solution integrators are not documented. ***Rural Intelligent Transportation System (ITS) Toolkit: Wrong Way Driver Detection & Warning System*** (n.d.) https://ruralsafetycenter.org/wp-content/uploads/2018/03/CC5.pdf – Examples of wrong-way detection systems implementation: New York State Thruway Authority, Texas DOT Lonestar software, Texas DOT San Antonio, Florida DOT SunGuide software, Arizona DOT, Rhode Island DOT. ***Florida DOT Wrong-Way Driving (WWD) Initiative*** (n.d.) https://www.fdot.gov/traffic/its/projects-deploy/wrong-way-driving – FDOT has also been exploring various WWD countermeasure systems for warning wrong-way drivers, verification of the wrong-way vehicles and sending alerts to Regional Transportation Management Center (RTMC)/ Traffic Management Center (TMC) upon detection of wrong-way vehicles. ***Rhode Island DOT Safety and Traffic Engineering - Wrong Way Crash Avoidance*** (n.d.) http://www.dot.ri.gov/safety/wrong_way_safety.php – Detection systems sense if a driver has entered a highway off-ramp and activate a series of flashing signs.

Product/ System	Overview
	– It will also notify the Rhode Island State Police that someone is driving the wrong way on the road, take a picture of the vehicle, and display a message on overhead signs to warn drivers heading in the opposite direction. ***Southern Nevada pilot program aims to deter wrong-way drivers*** (December 2019) https://www.reviewjournal.com/traffic/southern-nevada-pilot-program-aims-to-deter-wrong-way-drivers-1906043/ – The system will be tied into the Southern Nevada traffic command center so that first responders can be dispatched immediately. ***CDOT testing wrong-way detection technology in reversible express lanes*** (November 2019) https://www.9news.com/article/traffic/wrong-way-vehicle-detection-system-tested-denver/73-19b29f00-2e61-41f4-868f-1abc80bfd28f – The technology alerts drivers when they are traveling the wrong way by using sensors which detect thermal energy from an approaching vehicle. An electronic 'Wrong Way' sign is activated if wrong-way movement is identified by the system. ***North Texas Explores New Wrong-Way Driver Detection, Alert System*** (October 2019) https://www.nbcdfw.com/news/local/north-texas-considers-new-wrong-way-driver-detection-alert-system/2078069/ – “The technology that's used to connect vehicles detects the wrong way driver, sends a message to a traffic management center, alerts the wrong way driver and alerts right-way drivers using in vehicle messages," Texas Transportation Institute (TTI) Research Engineer Melisa Finley explained. ***Ohio DOT Installing Wrong-Way Driver Detection System*** (July 2019) https://aashtojournal.org/2019/07/26/ohio-dot-installing-wrong-way-driver-detection-system/ – When the system is activated, light-emitting diode or LED lights around the edge of several “wrong way” and “do not enter” signs begin blinking, while an alert is sent to the Ohio DOT’s Traffic Management Center in Columbus. ***This Week at NCDOT: Wrong-Way Vehicle Detection System*** (January 2019) https://www.ncdot.gov/news/press-releases/Pages/2019/2019-01-18-this-week-ncdot.aspx – With this technology, State Traffic Operations Center staff and State Highway Patrol are notified more quickly of the vehicle’s location. **Wisconsin DOT: *Wrong-way driver detection devices being added to roadways in Milwaukee area (December 2016)*** https://www.fox6now.com/news/wrong-way-driver-detection-devices-being-added-to-roadways-in-milwaukee-area – The system triggers an alert to the Statewide Traffic Operations Center, to identify or locate the vehicle traveling the wrong way and contact the Milwaukee County Sheriff's Office.

3.6.1 Selected Literature for Wrong-way Vehicle Detection Systems

Following is selected literature related to wrong-way vehicle detection systems video as located through an online literature search.

- *Interstate 17 Wrong-Way Vehicle Detection Pilot Program* (Arizona DOT, 2020): The ADOT Interstate 17 Wrong-Way Vehicle Detection Pilot System became operational in January 2018. The pilot system, which covers a 15-mile stretch of I-17 between I-10 and State Loop 101, is the first in the nation to track wrong-way vehicles in real time. ***The system uses thermal cameras for primary detection of wrong-way vehicles along exit ramps and at other potential points of entry onto the freeway's mainline lanes***. Video clips generated by the cameras allow ADOT dispatchers and Arizona Department of Public Safety troopers stationed in ADOT's Traffic Operations Center (TOC) in Phoenix to visually verify and track wrong-way vehicles. ***The ability to dispatch law enforcement quickly and effectively has been the most significant benefit of the wrong-way detection pilot program***. In 2018, the detection system resulted in more than a threefold increase in wrong-way vehicle detections in the pilot area compared with traditional means (911 calls) alone. ***Of the detected incursions that were also reported to 911, the detection system reported the incursion much faster—an average of 1 minute, 38 seconds before a 911 call was received.***
- *Wrong Way* Driver *Mitigation* (Slonaker, 2020) - Caltrans
  - Deployments:
    - Sacramento: 6 Ramps: Signage with TAPCO detection and alerting systems
    - San Diego: 4 Ramps: Signage with TAPCO detection and alerting systems; 2 Ramps: Signage with TraffiCalm detection and alerting systems
  - The TAPCO Systems activated their flashing signs, thus warning wrong-way drivers locally, for 64.3% of the video based site monitoring (VBSM)-detected WWD events. However, the TAPCO Systems only sent alerts to the TMC for 30% of the VBSM-detected WWD events.
  - The TraffiCalm Systems activated its flashing sign, thus warning wrong-way drivers locally, for 50% of the VBSM-detected WWD events. However, the TraffiCalm Systems sent alerts to the TMC for 100% of the VBSM-detected WWD events.
- *Testing and Evaluation of Thermal Camera-based and Video-analytic Systems on Wrong-Way Driving, Stopped Vehicles, and Pedestrians* (Lin et al., 2019): ***This project successfully evaluated the performance of a thermal camera-based detection system*** and a video-analytic detection system provided by two vendors. ***The thermal camera-based detection system was deployed at two locations on the Sunshine Skyway Bridge to identify WWD, stopped vehicles, and pedestrian events,*** and the video-analytic system was deployed at six locations on the Howard Frankland Bridge to detect freeway WWD events. Two performance measures were defined to evaluate the tested systems—detection system accuracy and percentage of false calls. ***Data review and analysis results revealed that (1) the thermal-based detection system was able to produce a detection system accuracy of 100% for pedestrian detection, 94.3% for stopped vehicle detection, and 100% for WWD detection;*** (2) the video-analytic system was able to produce a detection system accuracy of 84.6% for WWD detection; (3) correct pedestrian detections were triggered by roadway workers or onsite police officers for work; ***(4) correct detection of stopped***

vehicle events was triggered primarily by vehicles (cars, motorcycles, utility vehicles, etc.) stopped on shoulders and on-duty vehicles (utility vehicles, police vehicles, etc.) stopped in lanes to perform work; one potential suicide attempt was detected associated with a stopped vehicle/pedestrian on the Sunshine Skyway Bridge; (5) no actual WWD events were detected at any designated test location; all correctly-detected WWD events were trigged by vehicles in roadway events such as roadwork utility vehicles and on-duty police vehicles driving in opposite direction of traffic in blocked lanes, and vehicles backing upon shoulders; and (6) the video-analytic detection system configuration may be subject to change due to external environment conditions such as camera vibrations; it is recommended to define appropriate reference points for detection region of interest (ROI) configuration and calibration during the system setup process and to set up alerts when pre-defined ROI is shifted.

- *Testing and Evaluation of Freeway Wrong-way Driving Detection Systems* (Lin et al., 2018): Sponsored by Florida Department of Transportation (FDOT), this project successfully ***evaluated video-analytic freeway WWD detection systems currently on the market from three vendors,*** regarding their capabilities for real-time WWD vehicle detection and Traffic Management Center (TMC) notification. Real-time WWD incident detection and data collection were conducted ***through fixed camera videos streams*** at these locations. A series of performance measures was defined to evaluate the performance of the WWD detection systems from three vendors, including (1) WWD detection system accuracy; (2) percentage of false calls; (3) actual WWD detection accuracy; and (4) percentage of missed calls. In addition, the capabilities of candidate systems on TMC notification were tested by collecting email notification data. ***The system from Vendor 1 showed the best performance at an overall 95% detection system accuracy and 94% actual detection accuracy***, followed by the systems from Vendor 2 and Vendor 3. ***System performance from the three vendors on WWD detection varied significantly,*** indicating that performance of real-time video-analytic freeway WWD detection systems highly depends on the individual vendor's system. Analysis of TMC notification data revealed that ***all three candidate systems were able to send an email notification*** if a WWD was detected.
- *Wrong-Way Driving (WWD) Detection Proof of Concept at I-70/Ward Road* (Marlina, 2020): Colorado DOT evaluated four (4) commercially available wrong-way detection and alert products/solutions: Image Sensing Solutions (ISS), Bosch, TAPCO, TraffiCalm. The objectives were to test different wrong-way detection system capabilities, evaluate the accuracy of the different detections, and provide insights of the operational feasibility of wrong-way detections. Measures of effectiveness included accurate calls, missed calls, false calls, latency, and maintenance efforts. All WWD detection systems had difficulties in detecting WW vehicles traveling fast (35 mph or more), except TAPCO incoming. There is a risk a small car will go unnoticed (covered) by heavy vehicle, if the detection system is only on one side of the roadway. Duplicate notifications create confusion to the operators who reviews the true WW event. Most systems did not detect the second vehicle when two vehicles are going back-to-back in the WW direction. All communication were handled by the vendor using a cellular network; the system would work better (more stable) when it connects to fiber.

4.0 TMC Operators Common User Needs for Automated Incident Detection

This section identifies common user needs for automated incident detection systems from the perspective of TMC operators. These user needs were developed with input from TMC operators and managers from ENTERPRISE agencies, as discussed during an interactive webinar in January 2021 and from input received via email following the webinar.

This documentation of common user needs was completed to:

- Provide guidance for the demonstrations of AID products completed as part of this project and documented in Section 5.0; and
- Establish a framework for user needs that could translate to requirements as agencies procure automated incident detection systems. The list of user needs in this section can be customized by selecting specific needs appropriate for each AID application or use case.

The 42 TMC operator user needs for automated incident detection systems are presented in the following categories:

- Detection Capabilities (Needs 1-12)
- Coverage and Environment (Needs 13-17)
- Alerts, Displays and Configuration (Needs 18-33)
- Integration with Agency Systems and Practices (Needs 34-42)

Tables 8-11 document challenges and issues, with corresponding TMC operator user needs for each of the categories listed above for AID systems.

Table 8: Detection Capabilities Challenges/Issues and Corresponding TMC Operator User Need(s)

Challenge / Issue	TMC Operator User Need
TMC operators cannot manually cycle through all camera feeds to monitor for crashes or collisions. 911 calls or other reports may not identify every incident or may not be reported a timely manner.	***Need #1:*** TMC operators need to receive real-time alerts when a crash has occurred.
Obstructions blocking roadway lanes could disrupt traffic flows or lead to crashes. Operators require a system to flag 'events' for them to examine.	***Need #2:*** TMC operators need to receive real-time alerts of stopped vehicles that are fully or partially blocking one or more lanes of traffic.
	Need #3: TMC operators need to receive real-time alerts of extremely slow vehicles that are fully or partially one or more lanes of traffic.
	Need #4: TMC operators need to receive real-time alerts of debris on the road surface that is fully or partially blocking one or more lanes of traffic.

Challenge / Issue	TMC Operator User Need
Obstructions blocking roadway shoulders are disruptive to vehicles that use the shoulder for bus-only transit operations, emergency response, or as a general purpose lane during temporary shoulder operations (i.e., hard shoulder running.) In addition, vehicles stopped in the shoulder for long periods of time are sometimes struck by oncoming vehicles.	***Need #5:*** TMC operators need to receive alerts of stopped vehicles on the roadway shoulder.
	Need #6: TMC operators need to receive real-time alerts of debris on the roadway shoulder.
Especially in urban, higher-speed roadway settings, unexpected objects or entities on the roadway (including the shoulder) can be distracting to drivers or can result in collisions.	***Need #7:*** TMC operators need to receive real-time alerts of unexpected entities (e.g., pedestrians, animals, other) in traffic lanes.
	Need #8: TMC operators need to receive real-time alerts of unexpected entities (e.g., pedestrians, animals, other) on the roadway shoulder.
Traffic congestion, including slow or stopped traffic, causes delays for travelers and can create unsafe conditions for oncoming traffic. TMC operators cannot manually monitor all congestion and will benefit from early indication that queues are forming.	***Need #9:*** TMC operators need to receive real-time alerts of traffic congestion or slow/stopped traffic conditions.
Traffic queues that form quickly can surprise oncoming drivers. TMC operators can benefit from knowing queue limits and lengths, to initiate messages about queues, expected delays, or alternate routes.	***Need #10:*** TMC operators need to understand and monitor vehicle queues, including the locations of start/head and end/tail of vehicle queues.
Vehicles that are moving at excessive speeds or traveling the wrong way can result in crashes.	***Need #11:*** TMC operators need to receive real-time alerts of extreme vehicle speeds.
	Need #12: TMC operators need to receive real-time alerts of vehicles traveling the wrong direction (i.e., wrong-way vehicles).

Table 9: Coverage and Environment Challenges/Issues and Corresponding TMC Operator User Need(s)

Challenge / Issue	TMC Operator User Need
The coverage area required for automated incident detection varies significantly depending on the application.	***Need #13:*** TMC operators may need complete coverage of a roadway network (e.g., all freeways in a metro area or statewide, traffic lanes and shoulders) for automated incident detection. NOTE: Some applications may require only some road sections to be monitored.

Challenge / Issue	TMC Operator User Need
Incidents occur at all times of the day and night, and during all weather, visibility, and traffic conditions, including weather events (rain, snow, fog) and other events (e.g., fire, smoke).	***Need #14:*** TMC operators need automated incident detection to be functional in all lighting conditions, including daylight, low light, and dark conditions.
	Need #15: TMC operators need automated incident detection to be functional in all weather conditions.
	Need #16: TMC operators need automated incident detection to be functional in low visibility conditions not caused by weather events (e.g., smoke).
	Need #17: TMC operators need automated incident detection to be functional in all traffic conditions from free-flowing to extreme congestion.

Table 10: Alerts, Displays and Configuration Challenges/Issues and Corresponding TMC Operator User Need(s)

Challenge / Issue	TMC Operator User Need
TMC operators manage several tasks simultaneously and will be bothered by false alerts that take their attention away from other tasks.	***Need #18:*** TMC operators need to receive minimal occurrences of false alerts (e.g., alerts that are not valid incidents) from automated incident detection.
TMC operations staff work closely with one another and often with law enforcement and other partners to coordinate incident response activities.	***Need #19:*** TMC operators need to be able to configure how (e.g., user interface displays, email, text message) and to whom notifications from automated incident detection are delivered.
TMC operators receive notifications of incidents from many different sources and make decisions about validity and potential impact to traffic and safety.	***Need #20:*** TMC operators need the option to validate or dismiss incidents, as alerts are received and before responding to them.
There can be a tradeoff in terms of TMC operators' preferences for incident detection and alerts, to be effective in responding to those events that need response without being overwhelmed by lower priority events. For example, tolerance for frequency of false alerts versus faster times to detect and notify.	***Needs #21:*** TMC operators need the ability to configure incident alerts and displays (e.g., identify which alerts to receive, thresholds for providing alerts, detection areas, and other parameters) uniquely for each individual system user**.**
	Need #22: TMC operators need the ability to turn on and off alerts for each incident type (e.g., stopped vehicle, debris, slow traffic/congestion.)
	Need #23: TMC operators need the ability to turn on and off alerts for incident types by roadway geometry and location (e.g., for incidents occurring on the shoulder to define traffic queues that are typical versus atypical).
	Need #24: TMC operators need the ability to configure the duration from incident detection to incident alert (e.g., real-time alert, alerts that are sent after a stopped vehicle on the shoulder has been in the same place for five minutes).

Challenge / Issue	TMC Operator User Need
	Need #25: TMC operators need the ability to configure speed thresholds for detecting congestion or slow traffic conditions.
	Need #26: TMC operators need the ability to configure thresholds for identifying start/head and end/tail of traffic queues.
	Need #27: TMC operators need the ability to configure incident alerts (e.g., on/off, speed thresholds) in real-time and by pre-determined parameters such as day of the week, time of day, speed thresholds, or other pre-determined times or thresholds.
During peak traffic periods or significant events (e.g., significant weather events, emergencies) the volume of incidents is so high that the usual TMC process for evaluating and triaging incidents is modified or abandoned. Operator responses are limited to only the highest priority incidents (e.g., full closures, fatal or serious injury crashes) and lower-priority incidents may not be addressed during the peak of these events.	***Need #28:*** TMC operators need a mechanism to prioritize alerts and allow real time filtering, to allow an alternate simplified workflow for responding to incidents.
TMC operators are tasked with understanding how traffic conditions are changing over time in order to adjust response actions as needed.	***Need #29:*** TMC operators need real-time information about incident timelines, such as timestamps, verified incident information, and start/head and end/tail of traffic queues.
	Need #30: TMC operators need the ability to re-classify incident events to change their priority level over time.
Due to large volumes of incidents during peak periods, TMC operators cannot manually perform all assessment and response tasks simultaneously.	***Need #31:*** TMC operators need decision support features that assist them in managing multiple incidents (e.g., ability to display a clustering of multiple detections as part of one overall incident, prioritize the display of incidents, assign a confidence factor to incidents detected, integrate incident detection with camera control to automatically zoom to incidents.)
Regardless of how well automated incident detection products perform, if the information is not delivered in a timely manner and to those who need it, the effectiveness decreases substantially.	***Need #32***: TMC operators need to understand the expected time elapsed from incident occurrence to when the system detects and reports an incident. NOTE: Time to detection requirements may vary for each agency use case or each type of detection. For example, detection of a stopped vehicle may be required within 5 seconds, while detection congestion may be required within several minutes of the occurrence.

Challenge / Issue	TMC Operator User Need
	Need #33: TMC operators need to understand latency of communication mediums that transfer detection notifications from the field to a central location, including time elapsed from detection to receipt of notification. NOTE: Communication time/latency requirements may vary for each agency use case and is often dependent upon agency communication capabilities, not necessarily AID product dependent.

Table 11: Integration with Agency Systems and Practices Challenges/Issues and Corresponding TMC Operator User Need(s)

Challenge / Issue	TMC Operator User Need
Agencies are often challenged with leveraging existing infrastructure for overall efficiency in terms of initial investment and ongoing maintenance.	***Need #34:*** In some situations, TMC operators need automated incident detection functions to be performed using in place, agency-owned equipment or infrastructure.
Use of multiple user interfaces is inefficient for understanding current conditions and performing traffic operations functions.	***Need #35:*** TMC operators need automated incident detection to be integrated with existing TMC system user interfaces, such as Advanced Traffic Management Systems (ATMS), for viewing alerts and other information generated by incident detection.
Agency investment and ongoing maintenance required to operate TMC support systems can require significant staff time and other resources.	***Need #36:*** TMC operators need automated incident detection software/systems to be easily and quickly installed, calibrated and/or configured, and integrated with existing agency systems.
	Need #37: TMC operators need automated incident detection systems to be pre-calibrated and pre-configured to local conditions (e.g., traffic patterns, usage trends, local environments) prior to agency deployment.
	Need #38: TMC operators need support from the AID product vendor to re-calibrate and reconfigure automated incident detection products after the initial installation and calibration is complete.
	Need #39: TMC operators need automated incident detection systems to self-calibrate in real-time as conditions change. NOTE: For example, systems that use video from pan-tilt-zoom (PTZ) cameras need to automatically adjust analytics as the camera moves to a new position and perform “masking” to disregard stationary objects in the field of view rather than triggering a false alert as an incident.

Challenge / Issue	TMC Operator User Need
	Need #40: TMC operators need to minimize resources (e.g., physical space in the TMC, data storage capacity) required to house and operate automated incident detection systems.
TMC operations can be significantly disrupted if automated incident detection components such as field equipment or software, or communications are not functioning properly.	***Need #41:*** TMC operators need the ability to monitor the operability (i.e., to perform health monitoring) of automated incident detection systems.
All agency-operated systems that use video must adhere to the agency's policies for storing, deleting, or archiving video from traffic cameras.	***Need #42:*** TMC operators need incident detection systems that utilize video to follow agency processes and procedures for storing and deleting video, per agency policies.

5.0 Automated Incident Detection Product Capabilities

To document capabilities of AID products, the companies identified in Section 3.0 Industry Scan that offer or operate AID products in the following categories were contacted and asked to provide a 60-minute webinar product demonstration to the ENTERPRISE members.

- Video Analytics Systems that Use In-Place Traffic Cameras
- Detection-Equipped Traffic Cameras
- Non-Video Based Products
- Agency Tools and Platforms Using External Data

Due to the number of available products and deployments found in the industry scan and the overall scope of this project, companies identified in the following categories were not included in the AID product demonstrations.

- Incident Feeds from Third-Party Traffic Data Providers
- Wrong-Way Vehicle Detection Systems

The following companies that offer commercially available AID products responded to the request and presented product AID capabilities during seven separate webinars during May and June of 2021. Two companies presented video analytics systems that use in-place traffic cameras category, two companies presented capabilities for detection-equipped traffic cameras, and three companies presented in the non-video-based products category.

- Bosch
- Citilog
- FLIR
- Navtech Radar
- OptaSense
- TrafficVision
- Waycare (Acquired by Rekor in January 2022)

In addition to the presentations by companies offering commercially available AID products, the following agencies presented in-house platforms using external data that are used by their agencies to assist in AID.

- Colorado DOT
- Pennsylvania DOT

Prior to the product demonstration webinars, the user needs included in Section 4.0 were shared with each company and agency to provide a basis for demonstrating product capabilities. An introductory meeting was held to discuss the structure of each webinar and provide a standard template that would be used by the research team to document product capabilities. The intent of the product demonstration webinars was to provide ENTERPRISE members with an understanding of different AID product capabilities. Approximately 20-30 attendees participated in each webinar. Attendees included ENTERPRISE Board members and TMC staff from ENTERPRISE agencies. The webinars were recorded and posted on a password-protected webpage that was available through the end of the project for ENTERPRISE members who were unable to attend the live webinars.

This section highlights overall observations from the product demonstration webinars. Individual documentation from each product demonstration webinar is included in the Appendix. It is important to note that during the webinars not all AID capabilities were demonstrated due to time constraints, however presenters were asked to review the webinar documentation and provide any additional information not shared during the webinar demonstration.

5.1 Detection Capabilities, Coverage and Environment

During each of the product demonstration webinars, detection capabilities were noted or shown through recorded video for seven incident types (e.g., stopped vehicle, extremely slow vehicle) that correspond to the TMC operator user needs (See Section 4.0). A summary of the detection capabilities for the nine products and platforms demonstrated is provided in Table 12. Many of the detection capabilities are well developed across the systems. For example, all products or platforms detect congestion or slow traffic. Only two of the systems detect extreme vehicle speed.

Table 12: AID Webinar Demonstration Detection Capabilities

Incident Types Detected	OFF THE SHELF PRODUCTS							AGENCY PLATFORMS	
	Detection Equipped Cameras		Video Analytics Using In-Place Cameras		Non-Video			External Data	
	Demo 1	Demo 2	Demo 3	Demo 4	Demo 5	Demo 6	Demo 7	Demo 8	Demo 9
Stopped Vehicle	✓	✓	✓	✓		✓	✓	✓	✓
Extremely Slow Vehicle	✓	✓	✓	✓		✓	✓		
Congestion/Slow Traffic	✓	✓	✓	✓	✓	✓	✓	✓	✓
Non-vehicle object or entity (debris, pedestrian, animal)	✓	✓	✓	✓		✓	✓	✓	
Queue (location of front and back)	✓	✓	✓		✓	✓	✓	✓	✓
Wrong-Way	✓	✓	✓	✓		✓			
Extreme Vehicle Speed	✓					✓			

Each of the demonstrations indicated that detection is functional in all weather conditions as shown in Table 13. Platforms and products that use external data (which often ingest data from vehicle probes) do not work as well to detect incidents in free-flowing conditions due to lower probe penetration rates. Table 13 indicates the detection conditions by each product or platform noted or demonstrated during the webinars.

Table 13: AID Webinar Demonstration Detection Conditions/Environment

Detection Conditions/ Environment	OFF THE SHELF PRODUCTS							AGENCY PLATFORMS	
	Detection Equipped Cameras		Video Analytics Using In-Place Cameras		Non-Video			External Data	
	Demo 1	Demo 2	Demo 3	Demo 4	Demo 5	Demo 6	Demo 7	Demo 8	Demo 9
All lighting conditions (daylight, low light, dark)	✓		✓	✓	✓	✓	✓	✓	✓
All weather conditions	✓	✓	✓	✓	✓	✓	✓	✓	✓
Low visibility not caused by weather events (e.g., smoke)	✓		✓	✓	✓	✓	✓	✓	✓
All traffic conditions (free-flowing to extreme congestion)	✓	✓	✓	✓		✓			

Following are selected additional observations noted during the webinar demonstrations of detection capabilities, coverage, and environment.

- For camera-based products and systems, coverage and detection will vary with type of camera, type of lens, camera height, and obstructions in the field of view. Each deployment is unique and configurable.
- Vision-based systems will not detect if it is completely dark.
- If fiber is utilized (to provide a series of traffic flow indicators from a combination of noise and vibration) weather and lighting is not an issue as the fiber optic cable is buried.
- PTZ cameras can be used with some products, however AID doesn't work unless the camera is in its home position.
- Thermal cameras work well to detect smoke and fire in tunnels as well as in low light or low visibility conditions to detect pedestrians. Thermal cameras are more expensive initially, but less maintenance is required compared to a high-definition camera.

5.2 Alerts, Displays, and Configuration

False detection alerts can be distracting and over time operators may choose to ignore them. AID companies are aware of this concern by transportation agencies and work with each agency to configure and adjust their products to minimize alerts. This could include increasing or decreasing the time at which an alert is provided to an operator following a detection, configuring the speed at which congestion is detected, or turning on/off alerts by roadway geometry or incident type.

The detection of an incident is instant; however, communication latency for an alert to reach the operator is dependent on the infrastructure. Notification of detection alerts are typically provided to operators visually on a dashboard provided by the AID company or integrated into a system at the TMC. Alerts for some products may also be sent for example via email.

Table 14 provides a summary of operator support and configuration provided by each AID product or agency platform demonstrated as part of this project. There are varying levels of operator support provided by each product or platform. There are also some gaps in configuration such as re-classifying incidents, real-time information about incident timelines, and prioritizing events; however, these types of capabilities are often performed by an agency's ATMS.

Table 14: AID Webinar Demonstration Operator Support and Configuration

Operator Support and Configuration	OFF THE SHELF PRODUCTS							AGENCY PLATFORMS	
	Detection Equipped Cameras		Video Analytics Using In-Place Cameras		Non-Video			External Data	
	Demo 1	Demo 2	Demo 3	Demo 4	Demo 5	Demo 6	Demo 7	Demo 8	Demo 9
Validate or dismiss incidents as they are received	✓		✓	✓		✓	✓		✓
Configure alerts and displays uniquely for each individual user	✓			✓		✓			✓
Turn on and off alerts for each incident type	✓	✓	✓	✓		✓	✓	✓	✓
Turn on and off alerts by roadway geometry and location	✓		✓	✓		✓	✓		✓
Configure the duration from incident detection to incident alert	✓		✓	✓		✓	✓		✓
Configure speed thresholds for detecting congestion or slow traffic	✓	✓	✓	✓	✓	✓	✓		
Configure thresholds for locating head and tail of traffic queues	✓	✓				✓	✓		✓
Configure alerts in real-time and by pre-determined parameters	✓		✓	✓		✓			✓
Prioritize alerts and allow real time filtering	✓		✓			✓	✓		
Real-time information about incident timelines	✓		✓	✓		✓	✓		✓

Operator Support and Configuration	OFF THE SHELF PRODUCTS							AGENCY PLATFORMS	
	Detection Equipped Cameras		Video Analytics Using In-Place Cameras		Non-Video			External Data	
	Demo 1	Demo 2	Demo 3	Demo 4	Demo 5	Demo 6	Demo 7	Demo 8	Demo 9
Re-classify incident events to change their priority level over time	✓		✓			✓			✓

5.3 Integration with Agency Systems and Practices

AID products offer a variety of options for obtaining data from AID systems, such as edge-based (at the camera location), server based, or in the cloud. AID products are typically designed to integrate with an agency's ATMS. In some cases, an integration partner is needed to assist.

Every year technology and software products continue to improve which enhances AID detection capabilities. Video analytics systems utilize an agency's in-place traffic cameras, enabling multiple uses for existing camera infrastructure. If fiber optics is used for AID detection, the necessary equipment is located away from the roadside.

Once a system is deployed, onsite training and remote training are provided by some companies as options for support. In addition, health monitoring is often provided to monitor operability of components and field equipment. Maintenance agreements are commonly offered by AID companies to provide routine upgrades and ongoing support.

6.0 Agency Experiences

Following the product demonstrations described in Section 5.0, a peer exchange webinar was conducted on September 15, 2021. The purpose of the webinar was to highlight agency experiences with AID products. The webinar included presentations grouped into three categories:

- Agency Experiences with AID Products
- AID Pilots and Testing by ENTERPRISE Agencies
- AID Planned System

6.1 Agency Experiences with AID Products

This section provides highlights from presentations during the peer exchange webinar noting experiences with AID products.

Agency: Virginia DOT
AID Product: Citilog

- Citilog was used by the Virginia DOT to monitor and provide a quick visual verification of no blockages prior to opening and closing shoulders at two locations (I-66 system consisted of 45 cameras, I-494 system consisted of 9 cameras) from 2015 to 2018.
- Citilog established the initial detection zone and provided periodic calibration through a maintenance contract.
- Instances of false or inaccurate detections were limited due to the periodic adjustments of detection zones to account for camera shifts.
- The back-office system consisted of 17 servers of which half were for backup. Initially edge analytics was specified, however there was a cost savings with utilizing central servers.
- The system was decommissioned in 2018 due to a road widening project to build Highway Occupancy Toll lanes along I-66. The I-495 system was dismantled when switching to static time of day shoulder operation due to Traffic Operations Center (TOC) software replacement that doesn't include dynamic shoulder module.
- A Citilog system is currently in use in Virginia since 2012 on I-495, I-395 and I-95 Express Lanes which are operated by Transurban through a concession.

Agencies: Kansas DOT and Missouri DOT (Kansas City Scout)
AID Product: TrafficVision

- In 2013, Kansas City Scout in Kansas City (includes Kansas DOT and Missouri DOT) procured 48 camera licenses from TrafficVision. Kansas City Scout wanted a product that was configurable with PTZ cameras. In addition, an API integration with their ATMS was desired. The product could not be vendor specific and needed to be able to use any standard video stream.
- In 2015 Kansas City Scout extended the TrafficVision licenses by 80, in addition to the original 48 licenses. Currently, 128 of 320 cameras are equipped with TrafficVision.

- Kansas City Scout's use of TrafficVision is focused on incident detection and debris detection. There are false positives with the TrafficVision product, however Kansas City Scout has been pleased with the overall number of false positives. Figure 4 shows the alert provided to an operator of a stranded vehicle.

Figure 4: Kansas City Scout Alert of a Stranded Vehicle (Photo courtesy of Kansas City Scout)

- Kansas City Scout has an "easy button" within their ATMS that will auto fill information based on alerts, with approvals for example to post messages on DMS or send emails of alerts. Of the alerts feeding the dashboard with the easy button, 80% are from data provided by TrafficVision and 20% are from data provided by Kansas City Scout. See Figure 5.

Figure 5: Kansas City Scout Alert TrafficVision API Integration with ATMS Software Easy Button (Courtesy of Kansas City Scout)

- Initially servers were used to operate TrafficVision, but Kanas City Scout has transitioned to a virtual server bank where TrafficVision can provide updates and support the virtual servers.
- Annual software updates cost 10-20% of the original licensing cost. Video analytics gets better each year, so it is a benefit to purchase the updates annually.
- Operators see a benefit with AID, however it is another data point to monitor during daily TMC operations. Filtering the alerts from TrafficVision has helped operators focus on identifying the most important alerts.

Agency: Georgia DOT
AID Product: TrafficVision

- Georgia DOT deployed TrafficVision on 3 routes (5-mile HOT lane, 20 mile stretch on I-75, and another 17-mile stretch).
- Georgia DOT saw a 4-to-8-minute reduction in detection times using TrafficVision AID compared to detection times prior to implementing. In addition, the greatest impact has been seen for detecting incidents in rural areas.
- One (1) or two (2) TMC staff initially monitored and adjusted settings from TrafficVision during testing. Other TMC staff were not told of the testing. This was a successful approach as many of the false positives that are typical complaints from TMC staff were reduced during the testing phase as adjustments were made. Operators were then able to see a benefit with the alerts provided.
- Georgia DOT is looking at integrating TrafficVision with their ATMS as a new ATMS product is procured.

Agency: Georgia DOT
AID Product: OptaSense

- Georgia DOT's Governor challenged the DOT to identify high-risk, high-reward projects. One project selected for funding under this direction was a project to deploy the OptaSense solution on fiber optic cable along 25 miles on Interstate 20 for traffic data collection (not used for AID). At this location Georgia DOT also had fiber under many exit and entrance ramps which with the OptaSense product can provide volumes on ramps.
- As part of this effort, Georgia DOT purchased the equipment from OptaSense.
- The project was initially conducted to identify an approach to replace legacy detection. Overall, there have been positive outcomes with OptaSense, however a complete switch will not be made, as fiber is needed and the precise location of the in-place fiber for the product to produce accurate results for traffic data collection.
- Once the project was kicked off with the product installation complete, there were not many changes. It was self-sufficient and no additional staffing requirements were needed.

6.2 AID Pilots and Testing by ENTERRISE Agencies

The Ontario Ministry of Transportation, MnDOT, and Iowa DOT who are members of ENTERPRISE described AID pilots and testing within their agency during the peer exchange webinar.

Agency: Ontario Ministry of Transportation (MTO)
AID Products: Bosch and TrafficVision

- MTO is conducting an intelligent video analytics project to use existing infrastructure, investigate edge computing, reduce bandwidth and storage, provide automatic alarm notification, and prepare for future mobility and CAV.

- Use cases for the project are focused on detecting congestion, low visibility, pedestrians, slow moving traffic, stopped vehicles, and wrong-way vehicle movements.
- The Central Region TMC was selected for the pilot site focused on a short section of Hwy 403 with 5 Bosch cameras utilized and 10 in-place cameras utilized for TrafficVision. The analytics completed by TrafficVision for in-place cameras are cloud based.
- Prior to starting the pilot project, configurations, calibration, measurements, and camera training were needed for the Bosch cameras. Field visits were required to determine the height of static objects (signs and gantries) and horizontal and vertical distances which was time consuming. See Figure 6.

Figure 6: Lane marking measurements for Bosch AID (Photo courtesy of MTO)

- Video streams from in-place cameras were provided directly to TrafficVision. TrafficVision was easy to configure and self-calibrate. Field visits were not required. Traffic Vision was integrated with Genetec SDK used by MTO. See Figures 7 and 8.

Figure 7: Screenshot of TrafficVision Dashboard (Photo courtesy of MTO)

Figure 8: Screenshot of Genetec SDK Dashboard (Photo courtesy of MTO)

- MTO plans to conduct an evaluation for both products (Bosch and TrafficVision).

Agency: Minnesota DOT (MnDOT)
AID Product: TrafficVision

- MnDOT started an initial pilot of TrafficVision in March of 2020, but then stopped the test due to COVID. Another test was then started in Spring 2021. With the initial test there was not an option for a cloud-based system, but since March 2020 that has changed. With the cloud-based system no hardware is needed. However, a local server based option is available if desired.
- For the pilot that began in Spring 2021, data streams from 16 cameras from MnDOT's 511 system were provided to TrafficVision.
- It has been beneficial for MnDOT to use existing data feeds and have the option to change cameras since the TrafficVision licensing is by each individual video feed. In addition, TrafficVision was easy to set up and calibrate. There is also the option to ignore areas outside of travel lanes and ignore message signs to reduce false positives.
- Incident detection works well if the camera is calibrated and returns to its home position. There is an option to have multiple home positions. If the camera is not in its home position it will still provide incident detection but there are more false positives.
- Construction zones are challenging with automated incident detection due to increased false positive alarms. However, there is the option to turn off the alarms in the software if desired.
- MnDOT RTMC supervisors have been monitoring the tool, but it has not been used in practice by RTMC operators. MnDOT may expand the TrafficVision product to 20 cameras in Fall 2021 and conduct additional testing.
- MnDOT would need to integrate AID into their ATMS in order for it to be successful.

Agency: Iowa DOT
AID Product: TrafficVision

- In May 2021 Iowa DOT started a pilot utilizing TrafficVision. Thirty-one (31) cameras were connected to the TrafficVision software in a metro area to detect congestion in known hotspots.

- It has been user friendly, with operators able to understand the system with little knowledge of the product.
- There were a lot of false positives initially, but with adjustments made to parameters this has decreased.
- It is not integrated in Iowa DOT's ATMS.
- Some operators like the additional alerts and others indicated there are still too many false positives. Typically, the false positives occur at night with low visibility.
- Iowa DOT would like to continue the deployment in rural areas.
- There is a concern about the effort that would be required to conduct regular calibration if the system were to be implemented on all 400 of Iowa DOT's traffic cameras.

6.3 AID Planned System

The Maryland DOT State Highway Administration (SHA) described their experience with planning for an AID product as part of a design-build project to be completed in Spring 2024.

Agency: Maryland DOT State Highway Administration (SHA)
AID Product: Navtech Radar

- Maryland DOT SHA described an AID system they are planning to deploy as part of a 20-mile construction project along the Baltimore Beltway.
- AID was included in this project due to safety concerns with known congestion in this area.
- The design-build team selected for the project included Navtech Radar with their proposal submittal. The submittal noted that Navtech Radar's product recommends 5-year preventative maintenance, produces low false alarms, and alarms are provided as requested by Maryland DOT SHA through an XML feed.
- Ninety (90) Navtech Radar sensors are planned across the corridor. Since the system is not yet deployed, Maryland DOT SHA has relied on information provided in the submittal which included examples of Navtech Radar deployments in Europe.

7.0 Key Project Highlights

Selected key project highlights as identified through an industry scan, common TMC operator user needs, AID product demonstrations, and presentations of agency AID experiences are provided below.

TMC Operator Common User Needs for Automated Incident Detection:

- Each AID system deployment is unique, however TMC Operators need a system to provide detection capabilities for their desired deployment (e.g., stopped traffic, congestion, debris on roadway, front and back of queue) and coverage for different needs (e.g., traffic lanes, shoulders).
- Detection that is reliable in various lighting, weather, and visibility conditions is important to TMC operators. TMC operators also need AID systems to be configurable and provide alerts when an incident is detected.
- To avoid multiple platforms for TMC operators to monitor, it is important that AID systems also have the capability to integrate with existing agency systems and practices.

Automated Incident Detection Systems and Capabilities:

The AID products and tools focused on for this project were grouped into four categories. Product demonstration webinars were provided by several companies and transportation agencies. Additionally, nine agencies shared experiences with AID products in a peer exchange webinar format. See Table 15.

Table 15: Number of Webinar Demonstrations and Presentations on AID Products and Experiences

AID Category	Number of Webinar Demonstrations of Product Capabilities	Number of Agency Peer Exchange Presentations
Video Analytics Systems that Use In-Place Traffic Cameras	3	6
Detection-Equipped Traffic Cameras	2	1
Non-Video Based Products	3	2
Agency Tools and Platforms Using External Data	2	-

Detection Capabilities:

- Detection capabilities overall are well developed across AID systems but also vary.
- All products and agency platforms reviewed can detect congestion or slow traffic. Most products are capable of detecting stopped vehicles and queues. However, only two of the AID systems demonstrated in this project are able to detect extreme vehicle speed.

Coverage and Environment:

- Each of the demonstrations indicated that incident detection is functional in all weather conditions. Platforms and products that use external data (often including data from vehicle probes) do not work as well to detect incidents in free-flowing conditions due to lower probe penetration rates.

- Coverage and detection accuracy for camera-based systems will vary based on the type of camera, type of lens, camera height, and obstructions in the field of view. Each deployment is unique and configurable. Vision-based systems will not detect if is completely dark.
- If fiber is utilized (to provide a series of traffic flow indicators from a combination of noise and vibration) weather and lighting is not an issue as the fiber optic cable is buried.

Alerts, Displays and Configuration:

- False detection alerts can be distracting and over time operators may choose to ignore them. AID companies are aware of this concern by transportation agencies and work with each agency to configure and adjust their products to minimize false alerts. This could include increasing or decreasing the time at which an alert is provided following a detection, configuring the speed at which congestion is detection, or turning on/off alerts by roadway geometry or incident type. Overall, agencies that have deployed AID products have been pleased with the number of false positives due to the configuration capabilities provided by the AID products.
- There are varying levels of operator support provided by each product or platform. There are also some gaps in support capabilities such as re-classifying incidents, real-time information about incident timelines, and prioritizing events; however, these types of capabilities are often performed by in an agency's ATMS.
- Agencies have found that some products are easy to configure and set up without field work while some require upfront field measurements and camera training prior to deploying.
- Incident detection, as noted by one agency, works well if a PTZ camera is calibrated and returns to its home position. If the camera is not in its home position, it will still provide incident detection but there are more false positives.

Integration with Agency Systems and Practices:

- AID products offer a variety of options for obtaining data from AID systems, such as edge-based (at the camera location), server based, or in the cloud. AID products are typically designed to integrate with an agency's ATMS. In some cases, an integration partner is needed.
- TMC operators have varying opinions about use of AID systems. Some operators see a benefit with the additional information source, while others find it challenging to monitor another data point along with other in-place systems. Integrating AID systems with agencies' ATMS will assist in reducing the number of data points to monitor.
- Georgia DOT saw a 4- to 8-minute reduction in detection times using an AID system compared to detection times prior to implementing. In addition, Georgia DOT had only a few staff test the AID product without other staff knowing and configured the system prior to deploying with other operators. This was beneficial as the number of false alarms were reduced during the initial calibration and adjustment period, prior to expanded implementation with additional staff.

The AID systems reviewed for this project vary in detection capabilities, detection coverage, and detection environments. In addition, all products or agency platforms are configurable, provide alerts to TMC operators and can be integrated with an agency's ATMS. The product capabilities documented and the TMC operator common user needs for AID can be used and modified by ENTERPRISE members to identify their agency's specific needs for deploying AID systems.

Appendix: Product Demonstration Webinar Summaries

Product Demonstration Webinar Summaries: Automated Incident Detection Companies

- Bosch
- Citilog
- FLIR
- Navtech Radar
- OptaSense
- TrafficVision
- Waycare (Acquired by Rekor in January 2022)

Product Demonstration Webinar Summaries: Automated Incident Detection Agency Platforms

- Colorado DOT Traffic Operations Dashboard
- Pennsylvania DOT Traffic Alerts Dashboard

Vendor	Bosch	
Website	https://www.boschsecurity.com	
Contacts	Charles Whitfield (Charles.whitfield@us.bosch.com), Joel White (joel.white@us.bosch.com), and Mike Trinklein (mike.trinklein@us.bosch.com)	
Webinar Demonstration	May 4, 2021	
Product Overview		
Brief overview of how the product detects traffic incidents: Researcher notes from demonstration: • Bosch cameras for traffic applications include pan/tilt/zoom, dome, and thermal. The cameras include a sensor which is constantly streamed out in real time. The data is pulled into a cloud based solution and provided back within in the camera. The cameras provide the ability for real-time event and post processing data. Bosch notes: • Nothing additional.		

Detection Capabilities, Coverage and Environment			
Traffic Incidents Detected Detects presence of these incidents *(Needs #1-12)*	**Incident Type**		Researcher notes from demonstration:
	Stopped Vehicle	☒	• Noted as a capability. Ohio DOT US 33 Smart Mobility Corridor uses Bosch cameras for a number of uses including stopped vehicles.
	Extremely Slow Vehicle	☒	• Noted as a capability. Ohio DOT US 33 Smart Mobility Corridor uses Bosch cameras for a number of uses including slow moving vehicles.
	Congestion/ Slow Traffic	☒	• Ohio DOT US 33 Smart Mobility Corridor uses Bosch cameras for a number of uses including congestion. Volume and congestion data is sent from the camera to the cloud.
	Non-vehicle object or entity (e.g., debris, pedestrian, animal)	☒	• Ohio DOT US 33 Smart Mobility Corridor uses Bosch cameras for a number of uses including pedestrian detection. • In Marysville Ohio pedestrians are detected at multiple intersections which it then broadcast coordinates via DSRC (to on board units and a monitoring center). The data is also aggregated.
	Queue (Location of front and back of traffic queue)	☒	• Ohio DOT US 33 Smart Mobility Corridor uses Bosch cameras for a number of uses including queue detection. Queue detection at a ramp was shown and the message provided to an onboard unit (DSRC message provided through partnership with MC Corbin) alerting a driver of congestion ahead.
	Wrong-Way Vehicle	☒	• Wrong-way detection video shown at an Iowa intersection. There are two zones of detection (embedded dual detection) at this intersection. If a vehicle is going the wrong-way on an exit ramp it will detect it twice. An email with a camera image of the wrong-way vehicle is then sent to the TMC. • Another example video was shown where two cameras are used to detect vehicles in Michigan where once a vehicle

<table>
<tr>
<td rowspan="3"></td>
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<td colspan="2">enters at one of the ramps it is committed to cross the border into Canada. Once the wrong-way maneuver is detected by a fixed camera it communicates to a PTZ camera and triggers the camera to move to view the wrong-way vehicle.
• Ohio DOT US 33 Smart Mobility Corridor uses Bosch cameras for a number of uses including wrong-way drivers. Data and video is reviewed to verify it wasn't a false positive.
• There are many different actions once a wrong-way event is triggered. Bosch partners with others to provide, for example, real time alerts to DMS.</td>
</tr>
<tr>
<td>Extreme Vehicle Speed</td>
<td>☐</td>
<td colspan="2">• Not discussed during the demonstration.</td>
</tr>
<tr>
<td colspan="4">Comments on traffic incidents detected by the product.
Researcher notes from demonstration:
• Nothing additional.
Bosch notes:
• All the above capabilities are supported by in-camera "edge" analytics. For non-vehicle detection, pedestrian is supported but debris and animal detection are inaccurate because by its nature, debris can be anything and similarly animals will vary. Training analytics using the Machine Learning customer detector functionality of the camera analytics engine is possible but would require labor hours to train and likely prove inaccurate.</td>
</tr>
<tr>
<td>Coverage Limits for Detection
(Needs #5,6,8,13)</td>
<td colspan="4">Describe the product's coverage area (e.g., all lanes of traffic, roadway shoulders, field of view, detection coverage distance).
Researcher notes from demonstration:
• Not discussed during the demonstration.
Bosch notes:
• Coverage and detection distances will vary dependent on the camera/lens and specific camera technology deployed. Typically, our team would review use cases and the intended deployment locations(s) to then use simulation tools to make best recommendations on the suggested technology to deploy.</td>
</tr>
<tr>
<td rowspan="5">Detection Conditions/ Environment
(Needs #14-17)</td>
<td colspan="3">Detection is functional in:</td>
<td>Researcher notes from demonstration:</td>
</tr>
<tr>
<td colspan="2">• All lighting conditions (daylight, low light, dark)</td>
<td>☐</td>
<td>• In low light detection capability tends to be reduced, Bosch is working on models to fix this.</td>
</tr>
<tr>
<td colspan="2">• All weather conditions</td>
<td>☒</td>
<td>• Weather (rain, wind, snow, ice, light, dark) conditions do not affect the video.
• Some cameras have a wiper and defrost, depending on the environment.</td>
</tr>
<tr>
<td colspan="2">• Low visibility not caused by weather events (e.g., smoke)</td>
<td>☐</td>
<td>• Not discussed during the demonstration.</td>
</tr>
<tr>
<td colspan="2">• All traffic conditions (free-flowing to extreme congestion)</td>
<td>☒</td>
<td>• Noted capability.</td>
</tr>
</table>

<table>
<tr><td></td><td colspan="3">Provide any additional details about the detection environment.
Researcher notes from demonstration:
• Nothing additional.
Bosch notes:
• With any video technology, if visibility is diminished there is a potential for the accuracy of detections to be reduced. All is dependent on how extreme the conditions are in the last 3 bullets above. Other areas that should be considered in this category are false-positives where camera shake, blowing foliage and other items in the field of view can trigger false alters. Bosch has fine-tuned the detection engine and underlying technology to reduce false-positives and increase overall detection accuracy under all conditions.</td></tr>
<tr><th colspan="4">Alerts/Displays and Configuration</th></tr>
<tr><td>False Alerts
(Need #18)</td><td colspan="3">Demonstrate and discuss the product’s ability to minimize false alerts.
Researcher notes from demonstration:
• When a camera deployment is set up it is monitored to look for false positives which then can be filtered out or adjusted as needed. There is no one size fits all, each deployment is different.
Bosch notes:
• Bosch has fine-tuned the detection engine and underlying technology to reduce false positives and increase overall detection accuracy under all conditions. Using embedded deep leaning neural network classifiers, the overall accuracy of detections is in the mid 90% range. Depending on specific use case detection, accuracy will be in the high 90% ranges.</td></tr>
<tr><td>Notifications
(Need #19)</td><td colspan="3">How are alerts provided to TMC operators or other users when an incident is detected? How can notifications be customized (e.g., email, text) for each recipient?
Researcher notes from demonstration:
• Viewing the live video will show the alerts, which then can be communicated a variety of ways depending on an agency’s needs.
• Through Bosch partnerships, alerts may be provided for example to DMS or an on-board unit.
• Alerts can be provided in a variety of different ways, the dashboard for the Ohio DOT US 33 Smart Mobility Corridor of alerts and data analysis was shown.
Bosch notes:
• This again is dependent on use cases and need. The cameras support multiple alert communication methods and in most cases we have partner integrations such that direct alerting can happen in the end user’s environment or technologies including DSRC, active messaging to DMS, beacons and other active signage are used.</td></tr>
<tr><td rowspan="3">Operator Support and Configuration
(Needs #20-31)</td><td colspan="2">This product allows users to:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>• Validate or dismiss incidents as they are received.</td><td>☐</td><td>Not discussed during the demonstration.</td></tr>
<tr><td>• Configure incident alerts and displays uniquely for each individual user.</td><td>☐</td><td>Not discussed during the demonstration.</td></tr>
</table>

	• Turn on and off alerts for each incident type.	☒	
	• Turn on and off alerts by roadway geometry (e.g., turn off shoulder alerts) and location (e.g., designate typical versus atypical traffic queues).	☐	Not discussed during the demonstration.
	• Configure the duration from incident detection to incident alert.	☐	Not discussed during the demonstration.
	• Configure speed thresholds for detecting congestion or slow traffic.	☒	
	• Configure thresholds for locating start/head and end/tail of traffic queues.	☒	
	• Configure incident alerts in real-time and by pre-determined parameters.	☐	Not discussed during the demonstration.
	• Prioritize alerts and allow real time filtering.	☐	Not discussed during the demonstration.
	• Real-time information about incident timelines.	☐	Not discussed during the demonstration.
	• Re-classify incident events to change their priority level over time	☐	Not discussed during the demonstration.
	Other decision support features (please explain): Researcher notes from demonstration: • Nothing additional. Bosch notes: • Much of what is described above can stem from a camera analytics detection. Camera is an active and intelligent sensor that can initiate real-time mitigation and remote alerts. A number of the items listed above would be achieved by integrations or in collaboration with partner devices. For example: WrongWay Driver detection; the camera can detect the WWD and then track to validate whether driver self corrects or continues into the main roadway but the camera does not directly control mitigation protocols like active alert signage, DSRC messages and other mitigation protocols.		
Time to Detection *(Need #32)*	*What is the amount of time elapsed from incident occurrence to detection?* Researcher notes from demonstration: • Not discussed during the demonstration. Bosch notes: • The time is milliseconds.		
Latency of Detection to Alert *(Need #33)*	*Comment on the latency of communicating alerts to TMC operators or other users, if applicable.* Researcher notes from demonstration: • Not discussed during the demonstration. Bosch notes:		

	• Since the detection is in the camera itself, detection is instant. Communication latency is wholly dependent on the infrastructure in place to transmit the alerts.
Integration with Agency Systems and Practices	
Use of Agency Equipment *(Need #34)*	*Does the system utilize existing DOT-owned equipment to perform detections? If yes, how? If no, what equipment is used and where is it housed?* Researcher notes from demonstration: • Not discussed during the demonstration. Bosch notes: • Today detection is done in the camera itself so it would have to be a Bosch camera. Very soon we will be adding an in-cabinet Graphic Processing Unite (GPU) based processing solution that will not only boost capabilities in Bosch cameras but also support other video streams by applying the Bosch deep learning detection technology in the traffic cabinet.
Installation and Integration *(Needs #35,36, 40,42)*	*What is the installation/integration process?* Researcher notes from demonstration: • Not discussed during the demonstration. Bosch notes: • Bosch cameras install similar to other cameras deployed in traffic applications. *How can the product be integrated with agency systems such as Advanced Traffic Management Software (ATMS)?* Researcher notes from demonstration: • There is an integration partner program at Bosch that assists agencies to integrate Bosch cameras with an ATMS. It is easiest if an ATMS provider is requested to integrate with a Bosch camera. Bosch notes: • Integration is dependent on the ATMS platform but understand that Bosch is an open detector solution, so we provide the API and support for integrations. Bosch cameras support the ONVIF camera protocols so in many cases a more and more ATMS systems more to supporting ONVIF the cameras are easily supported. *What physical space is required at agency facilities for equipment and data storage?* Researcher notes from demonstration: • Not discussed during the demonstration. Bosch notes: • This needs more detail to answer completely. If we are discussing data aggregation and reporting we have a flexible cloud-based solution where data can be stored as long as necessary and viewed in provided dashboards or pilled via APIs into any end user solution. *If applicable, how is storage and periodic purging of video handled?* Researcher notes from demonstration: • Not discussed during the demonstration. Bosch notes:

	• Storage of video would be on premise using a Bosch or other recording solution and storage. This is completely dependent on number of cameras, resolution, frame-rates, retention time, etc.
Calibration *(Need #37-39)*	*Describe how the system is pre-calibrated by the vendor prior to agency deployment, any ongoing calibration needs, and self-calibration capabilities.* Researcher notes from demonstration: • Not discussed during the demonstration. Bosch notes: • Once deployed and calibrated any additional calibration can for the most part be handled remotely unless the camera needs to be repositioned.
Health Monitoring *(Need #41)*	*Describe how the product monitors the operability of its components and field equipment.* Researcher notes from demonstration: • Not discussed during the demonstration. Bosch notes: • Bosch cameras support SNMP. The Bosch Remote Portal cloud-based system is recommended as a no-fee solution for camera management, health monitoring and active altering on camera health conditions.
Use by Transportation Agencies / Case Studies	
List the transportation agencies (and contacts if available) that currently use your AID product. Provide web links to case studies or other documentation featuring agency use of the product. Researcher notes from demonstration: • Ohio DOT • Iowa DOT • Michigan DOT Bosch notes: • https://www.boschsecurity.com/us/en/news/trends-and-technologies/data-solutions-in-its/ • https://www.boschsecurity.com/us/en/industries/intelligent-transportation-systems-its/ • https://www.boschsecurity.com/us/en/news/customer-stories/drive-ohio/ • https://media.boschsecurity.com/fs/media/pb/images/industries_2/transportation/its_brochure.pdf	
Other Product Highlights	
Describe any additional product highlights if not previously noted. Researcher notes from demonstration: • Bosch showed live video (e.g., from a Bosch latest generation camera embedded Nero networks directly in the camera) at an intersection in Columbus during the demonstration. Intelligence has been in Bosch cameras for the past 15 to 20 years, however the cameras are moving to embed neural networks for the on board processing capabilities. These cameras use the same type of processor as what is used in a cell phone. • Initially cameras were deployed for monitoring, today automated incident detection is a need and important to users. • Bosch is working on capabilities to provide alerts from cameras to DMS as well as V2X solutions.	

- Image processing developed by Bosch for automotive safety solutions is utilized for the AI in Bosch cameras.
- Bosch is starting to take camera views at an intersection and lay it into an overhead Birdseye view to track all movements, approaches, detection zones etc. An example in Vail, Colorado was shown alerting operators of pedestrians.
- For agencies with existing older model cameras, Bosch is developing edge processing that can sit in a roadside cabinet and boost a current, older Bosch device.
- Privacy currently is not an issue (can't see a face or a read a license plate) and data is anonymous (metadata stream).

Bosch notes:

- Nothing additional.

<table>
<tr><td>Vendor</td><td colspan="3">Citilog</td></tr>
<tr><td>Website</td><td colspan="3">https://www.citilog.com/</td></tr>
<tr><td>Contacts</td><td colspan="3">Eric Toffin (eric.toffin@citilog.com), Jean-Marie Guyon (jmguyon@citilog.com), Amine Hauoi (amine@sensysnetworks.com)</td></tr>
<tr><td>Webinar Demonstration</td><td colspan="3">May 6, 2021</td></tr>
<tr><td colspan="4">Product Overview</td></tr>
<tr><td colspan="4">Brief overview of how the product detects traffic incidents (3-4 sentences):
Researcher notes from demonstration:
Artificial intelligence has been utilized since 1997 by Citilog.
In 2006, Citilog started using machine learning algorithms (improving over time the more they are used).
In 2017, Citilog started using deep learning. A GPU is used to compute images and computer power for deep learning. Citilog smart products are trained with real use cases and datasets.
Video analytics is used to detect, then deep learning validates to provide an alert.
Citilog notes:
Nothing additional.</td></tr>
<tr><td colspan="4">Detection Capabilities, Coverage and Environment</td></tr>
<tr><td rowspan="8">Traffic Incidents Detected
Detects presence of these incidents (Needs #1-12)</td><td colspan="2">Incident Type</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>Stopped Vehicle</td><td>☒</td><td>Noted capability of detecting a stopped vehicle in a tunnel and outdoor. Showed a video of a vehicle blocking a lane.</td></tr>
<tr><td>Extremely Slow Vehicle</td><td>☒</td><td>Showed a video of a slow vehicle that was detected.</td></tr>
<tr><td>Congestion/ Slow Traffic</td><td>☒</td><td>Noted capability of congestion in a tunnel and outdoor.</td></tr>
<tr><td>Non-vehicle object or entity (e.g., debris, pedestrian, animal)</td><td>☒</td><td>Noted capability of detecting congestion in a tunnel and outdoor. Showed a video in a tunnel where a vehicle was stopped and pedestrians were around the vehicle. Alerts for pedestrian and vehicle were provided. Showed a video of a pedestrian detected on the shoulder of a bridge.
Debris detection on a shoulder can be done, however it can be difficult with calibration due to size, shape, color, distance, and lighting conditions.</td></tr>
<tr><td>Queue (Location of front and back of traffic queue)</td><td>☒</td><td>The end of the queue is typically managed on the ATMS. However, it can be achieved using Citilog smart filters.</td></tr>
<tr><td>Wrong-Way Vehicle</td><td>☒</td><td>Noted capability of detecting wrong-way driving in a tunnel and outdoor. Showed a video of a wrong-way vehicle detected entering a highway.</td></tr>
<tr><td>Extreme Vehicle Speed</td><td>☐</td><td>Receiving extreme vehicle speed alerts is not standard, but possible.</td></tr>
</table>

<table>
<tr><td></td><td colspan="3">Comments on traffic incidents detected by the product.
Researcher notes from demonstration:
• Incident detection can also be utilized for reversible HOV/HOT lanes to ensure there are no vehicles present before the lane is reversed.
Citilog notes:
• If animals are present in the field of view, depending on their behavior, they may trigger alarms such as stopped vehicle, debris or slow vehicle</td></tr>
<tr><td>Coverage Limits for Detection (Needs #5,6,8,13)</td><td colspan="3">Describe the product's coverage area (e.g., all lanes of traffic, roadway shoulders, field of view, detection coverage distance).
Researcher notes from demonstration:
• A team of engineers is available to help design the system for the best coverage and ensure there is overlap between cameras to avoid missing incidents.
• Height of the cameras in a tunnel are typically 20 feet or less and the distance covered therefore is less than a camera outdoors where they are typically mounted higher.
Citilog notes:
• Nothing additional.</td></tr>
<tr><td rowspan="6">Detection Conditions/ Environment (Needs #14-17)</td><td colspan="2">Detection is functional in:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>• All lighting conditions (daylight, low light, dark)</td><td>☒</td><td>• Showed video of camera video at night. Cameras have light sensitivity.
• Showed video with a dark environment that provided an alert of a pedestrian.
• Low light conditions are dependent on camera sensitivity.</td></tr>
<tr><td>• All weather conditions</td><td>☒</td><td>• Provided a video of an incident in a snow weather event.
• However, fog and heavy snowfall may impair visibility to a point where vehicles cannot be seen by either a human or by analytics.</td></tr>
<tr><td>• Low visibility not caused by weather events (e.g., smoke)</td><td>☒</td><td>• Noted capability of detecting smoke in a tunnel. Not able to detect smoke outdoors.</td></tr>
<tr><td>• All traffic conditions (free-flowing to extreme congestion)</td><td>☒</td><td>• Noted capability.</td></tr>
<tr><td colspan="3">Provide any additional details about the detection environment.
Researcher notes from demonstration:
• Nothing additional.
Citilog notes:
• Nothing additional.</td></tr>
<tr><td colspan="4">Alerts/Displays and Configuration</td></tr>
</table>

<table>
<tr><td rowspan="1">False Alerts
(Need #18)</td><td colspan="3">Demonstrate and discuss the product's ability to minimize false alerts.
Researcher notes from demonstration:
• Conditions are more prone to false alarms in outdoor/highway compared to tunnels. This is due to cameras in tunnels being mounted lower (closer view) in tunnels compared to cameras mounted higher (further view) outdoors.
• For video analytics on highways and bridges users can expect:
o detection time: 15 sec,
o detection rate: 80-90%, and
o false alarms: 1 to 4 false alarms/day/camera.
If applying deep learning to the same sight, users can expect the same detection time and detection rate. However, the false alarms are reduced by 90% which is 0,1 to 0,4 false alarms/day/camera.
Citilog notes:
• Nothing additional.</td></tr>
<tr><td>Notifications
(Need #19)</td><td colspan="3">How are alerts provided to TMC operators or other users when an incident is detected? How can notifications be customized (e.g., email, text) for each recipient?
Researcher notes from demonstration:
• Alerts can be provided through the Citilog dashboard or integrated with the ATMS. Alerts pop up on the screen or dashboard when a detection occurs.
• Citilog does not have notifications that can be customized for each operator.
• Incident detection can also be utilized for smart shoulder monitoring. A video of detection was shown of an accident on the shoulder. VMS and lane monitoring signs were then activated by TMC operators once alerted of the shoulder incident.
Citilog notes:
• Nothing additional.</td></tr>
<tr><td rowspan="8">Operator Support and Configuration
(Needs #20-31)</td><td colspan="2">This product allows users to:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>• Validate or dismiss incidents as they are received.</td><td>☒</td><td></td></tr>
<tr><td>• Configure incident alerts and displays uniquely for each individual user.</td><td>☐</td><td>Citilog does not have notifications that can be customized for each operator.</td></tr>
<tr><td>• Turn on and off alerts for each incident type.</td><td>☒</td><td></td></tr>
<tr><td>• Turn on and off alerts by roadway geometry (e.g., turn off shoulder alerts) and location (e.g., designate typical versus atypical traffic queues).</td><td>☒</td><td></td></tr>
<tr><td>• Configure the duration from incident detection to incident alert.</td><td>☒</td><td>Not discussed during the demonstration. Ability confirmed by Citilog</td></tr>
<tr><td>• Configure speed thresholds for detecting congestion or slow traffic.</td><td>☒</td><td>Not discussed during the demonstration. Ability confirmed by Citilog</td></tr>
<tr><td>• Configure thresholds for locating start/head and end/tail of traffic queues.</td><td>☐</td><td>The end of queue is typically managed in the ATMS.</td></tr>
</table>

<table>
<tr><td></td><td>Configure incident alerts in real-time and by pre-determined parameters.</td><td>☒</td><td>Some parameters can be adjusted in real-time (e.g., turn of certain cameras, lanes, invert traffic lanes)</td></tr>
<tr><td></td><td>Prioritize alerts and allow real time filtering.</td><td>☒</td><td>Not discussed during the demonstration. Ability confirmed by Citilog</td></tr>
<tr><td></td><td>Real-time information about incident timelines.</td><td>☒</td><td></td></tr>
<tr><td></td><td>Re-classify incident events to change their priority level over time</td><td>☒</td><td>Not discussed during the demonstration. Ability confirmed by Citilog</td></tr>
<tr><td></td><td colspan="3">Other decision support features (please explain):
Researcher notes from demonstration:
Can add comments/notes, sort, export incidents, and replay incidents. Can use post-event data to understand where incidents are occurring, how often, etc.
During planned events such as roadway construction, lanes can be turned on or off in the Citilog system. Other filters can also be turned on our off depending on the construction area.
For maintenance operations, filters are typically not used. A TMC operator will discount related alarms to avoid the risk of missing an incident. However, it is possible to turn off some alarm types, or alarm on specific lanes during maintenance operations.
Citilog notes:
Nothing additional.</td></tr>
<tr><td>Time to Detection
(Need #32)</td><td colspan="3">What is the amount of time elapsed from incident occurrence to detection?
Researcher notes from demonstration:
Not discussed during the demonstration.
Citilog notes:
This is an adjustable parameter on the system.</td></tr>
<tr><td>Latency of Detection to Alert
(Need #33)</td><td colspan="3">Comment on the latency of communicating alerts to TMC operators or other users, if applicable.
Researcher notes from demonstration:
Not discussed during the demonstration.
Citilog notes:
From alarm confirmation to sending that alarm to the ATMS/operators, latency will depend on network and protocol used. However typically less than 1 second.</td></tr>
<tr><td colspan="4">Integration with Agency Systems and Practices</td></tr>
<tr><td>Use of Agency Equipment
(Need #34)</td><td colspan="3">Does the system utilize existing DOT-owned equipment to perform detections? If yes, how? If no, what equipment is used and where is it housed?
Researcher notes from demonstration:
Uses in-place agency-owned cameras.
There is the option for server-based analytics (off-the-shelf) or camera edge-based analytics. Performance is the same.
Citilog notes:
Nothing additional.</td></tr>
</table>

Installation and Integration *(Needs #35,36, 40,42)*	*What is the installation/integration process?* Researcher notes from demonstration: • Not discussed during the demonstration. Citilog notes: • Citilog provides training enabling integrators / end-customers to perform configuration and maintenance of the system. Citilog also offers those services. • Once the system (hardware) is installed, a first configuration is performed. The system is then left to function for a number of days and then fine-tuned. *How can the product be integrated with agency systems such as Advanced Traffic Management Software (ATMS)?* Researcher notes from demonstration: • Showed the Citilog interface dashboard to monitor system performance. It is system designed to integrate third party solutions. It is also designed to integrate with ATMS. Citilog notes: • Citilog offers a variety of communication protocols towards 3rd party systems. *What physical space is required at agency facilities for equipment and data storage?* Researcher notes from demonstration: • Analytics servers are required if server-based analytics are used. No physical space is required for camera-based analytics. • A central server (and optionally a redundant central server) is required in any case. Citilog notes: • Nothing additional. *If applicable, how is storage and periodic purging of video handled?* Researcher notes from demonstration: • Incident information is stored in a database and can be replayed or accessed in real-time. Citilog notes: • Nothing additional.
Calibration *(Need #37-39)*	*Describe how the system is pre-calibrated by the vendor prior to agency deployment, any ongoing calibration needs, and self-calibration capabilities.* Researcher notes from demonstration: • Citilog can train users to be self-sufficient or offer a maintenance/service contract. • Use of PTZ cameras is not an issue as long as a home position is used for analytics. When using a PTZ camera, automated incident detection is not occurring until it is placed back into its home position. Citilog notes: • Nothing additional.

Health Monitoring *(Need #41)*	*Describe how the product monitors the operability of its components and field equipment.* Researcher notes from demonstration: • Not discussed during the demonstration. Citilog notes: • Servers and cameras are monitored by the central software CT-Center. Alerts are created when equipment fail/do not respond. These alerts can be sent to the ATMS.

Use by Transportation Agencies / Case Studies

List the transportation agencies (and contacts if available) that currently use your AID product. Provide web links to case studies or other documentation featuring agency use of the product.

Researcher notes from demonstration:

- Citilog has deployments in all regions of the world. Following are some resources in the US:
    - NYSBA, NY – Bridges
    - Manhattan tunnels (PANYNJ, MTABT) – Tunnels
    - Boston, MA – Tunnels
    - I66, VA – Smart Shoulder
    - HOT I95/I495, MD, VA – Managed lanes
    - Baltimore, MD – Tunnels and bridges
    - Port of Miami tunnel, FL – Tunnel
    - Presidio Tunnel, CA - Tunnel

Citilog notes:

- Nothing additional.

Other Product Highlights

Describe any additional product highlights if not previously noted.

Researcher notes from demonstration:

- There are 3 areas of video analytics provided by Citilog.
    - Incident management (focus of today's presentation)
    - Traffic statistics (can be stand alone or with incident management)
    - Traffic efficiency (for intersection control)
- Thermal camera deployments have a shorter field of view (lesser pixel definition). Deep-learning cannot be efficiently applied to thermal cameras.

Citilog notes:

- Nothing additional.

<table>
<tr><th>Vendor</th><th colspan="3">FLIR</th></tr>
<tr><td>Website</td><td colspan="3">https://www.flir.com/</td></tr>
<tr><td>Contacts</td><td colspan="3">Matt Bretoi (matt.bretoi@flir.com) and Jacob DuBose (Jacob.dubose@flir.com)</td></tr>
<tr><td>Webinar Demonstration</td><td colspan="3">April 29, 2021</td></tr>
<tr><td colspan="4">Product Overview</td></tr>
<tr><td colspan="4">Brief overview of how the product detects traffic incidents (3-4 sentences):
Researcher notes from demonstration:
• FLIR AID solutions are off the shelf products that utilize smart sensors and analytics. Everything is happening “at the edge” with dedicated processing.
FLIR notes:
• FLIR has VIP modules (video image processing modules) that allows existing cameras/equipment to be used with FLIR AID analytics.</td></tr>
<tr><td colspan="4">Detection Capabilities, Coverage and Environment</td></tr>
<tr><td rowspan="6">Traffic Incidents Detected
Detects presence of these incidents (Needs #1-12)</td><td colspan="2">Incident Type</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>Stopped Vehicle</td><td>☒</td><td>• Recorded video shown of alerts when a vehicle is stopped in the right lane and a vehicle stopped along a bridge.
• The duration is configurable on an alert notifying an operator (e.g., typically between 5 and 10 seconds for a stopped vehicle, less than 5 seconds for a stopped vehicle in a tunnel).</td></tr>
<tr><td>Extremely Slow Vehicle</td><td>☒</td><td>• Recorded video shown of an alert when a vehicle was under a pre-designated speed.
• Alerts are configurable and can be provided for different speed thresholds.
FLIR notes:
• Underspeed = below a threshold
• Speed drop = percentage slower than average speed at the moment
• Overspeed = is supported with setting a maximum threshold.</td></tr>
<tr><td>Congestion/ Slow Traffic</td><td>☒</td><td>• It was noted that there are 5 categories for level of service (LOS) that are based on speed and 20% occupancy. This was not demonstrated.
• LOS can be looked at by lane and by cross section.</td></tr>
<tr><td>Non-vehicle object or entity (e.g., debris, pedestrian, animal)</td><td>☒</td><td>• Recorded video shown of alerts provided for a fallen object and a pedestrian. It was noted that FLIR products can detect animals but wasn’t demonstrated.
• Thermal cameras provide a 24-hour detection solution for example to identify a pedestrian, even in night/dark conditions.</td></tr>
<tr><td>Queue (Location of front and back</td><td>☒</td><td>• It was noted that alerts can be provided for queue length, but it was not demonstrated.
FLIR notes:
• Queue = level of service, not queue length</td></tr>
</table>

	of traffic queue)		• Set beginning and end to arrive at length, but FLIR does not count vehicles in the queue at this time
	Wrong-Way Vehicle	☒	• Recorded video shown of a wrong way alert in Arizona for mainline detection and a combined mainline and exit ramp detection. • If a wrong-way driver is detected there are many ways to alert drivers depending on the location and system chosen (e.g., warn drivers on DMS of wrong-way driver, turn ramp meters to constant red to prevent vehicles from entering, alert the wrong way driver through signage if they are entering the wrong direction). • The University of South Florida prepared a report that tested and evaluated the accuracy of wrong-way driving (100%), stopped vehicles (94.3%), and pedestrian detection (100%) of FLIR AID: *Testing and Evaluation of Thermal Camera-based and Video-analytic Systems on Wrong-Way Driving, Stopped Vehicles, and Pedestrians* (October 2019)
	Extreme Vehicle Speed	☒	• Alerts can be provided for speed that is under or over a pre-designated value, or a sudden drop in speed. Speed is configurable (e.g., alert for a vehicle going from 70 mph to 35 mph). Recorded video was not shown detecting extreme vehicle speed. FLIR notes: • Speeding is not a supported function. FLIR does not indicate speed for law enforcement purposes.
	Comments on traffic incidents detected by the product. Researcher notes from demonstration: • Additional detection capabilities provided by FLIR: ○ Traffic flow data: Speed per lane, zone occupancy per lane ○ Individual vehicle data: time stamp, lane number, individual speed, classification (up to 5 categories), gap time, length, confidence level ○ Integrated vehicle traffic data: volume, occupancy per lane, average speed, headway, gap time, density, average vehicle length ○ Ramp metering FLIR notes: • Individual vehicle data: Requires specific camera aiming that cannot be combined with AID it is either AID or individual data. Not always or automatically the case, however best practices often dictate this to be the case in design.		
Coverage Limits for Detection *(Needs #5,6,8,13)*	*Describe the product's coverage area (e.g., all lanes of traffic, roadway shoulders, field of view, detection coverage distance).* Researcher notes from demonstration: • Multiple lanes and shoulders demonstrated for wrong-way detection. • One vendor uses a 50-foot detection coverage for wrong-way detection. Another vendor uses longer distances that FLIR accommodates.		

<table>
<tr><td></td><td colspan="3">Mounting height of cameras is typically between 17 feet and 22 feet for wrong way detection, but often greater heights are involved depending on the distance requirements.
FLIR notes:
Max detection range for stopped vehicle = 20x cam height (limited to 1000ft)
Max detection range for debris = 10x camera height (limited to 175ft)
Max detection range for pedestrians = 15x camera height (limited to 275ft)</td></tr>
<tr><td rowspan="6">Detection Conditions/ Environment
(Needs #14-17)</td><td colspan="2">Detection is functional in:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>All lighting conditions (daylight, low light, dark)</td><td>☒</td><td>Demonstrated stopped vehicle and pedestrian thermal camera detection during low light with recorded video.</td></tr>
<tr><td>All weather conditions</td><td>☒</td><td>Dense fog may create an issue.</td></tr>
<tr><td>Low visibility not caused by weather events (e.g., smoke)</td><td>☒</td><td>Smoke and fire detection demonstrated in a tunnel through recorded video. Thermal cameras are used for fire, optical cameras are used for smoke detection.</td></tr>
<tr><td>All traffic conditions (free-flowing to extreme congestion)</td><td>☒</td><td></td></tr>
<tr><td colspan="3">Provide any additional details about the detection environment.
Researcher notes from demonstration:
Salt, spray, and dirt are not an issue with the cameras.
Cold weather depends on the sensor platform.
FLIR notes:
FLIR features/functionality hold regardless of traffic conditions.</td></tr>
<tr><td colspan="4">Alerts/Displays and Configuration</td></tr>
<tr><td>False Alerts
(Need #18)</td><td colspan="3">Demonstrate and discuss the product’s ability to minimize false alerts.
Researcher notes from demonstration:
FLIR understands that DOT TMC operators will not pay attention if AID systems provide too many false alarms.
Thermal images provide less false alerts compared to other detection methods.
FLIR notes:
Nothing additional.</td></tr>
<tr><td>Notifications
(Need #19)</td><td colspan="3">How are alerts provided to TMC operators or other users when an incident is detected? How can notifications be customized (e.g., email, text) for each recipient?
Researcher notes from demonstration:
During the demonstration when a detection was captured on the recorded video an alert popped up on the screen of the user interface.
FLIR notes:
Via our JSON API events can be pushed to third party systems.
Optional we have OPC UA server plug in or can discuss alternative integration methods.</td></tr>
</table>

<table>
<tr><td rowspan="12">Operator Support and Configuration
(Needs #20-31)</td><td colspan="2">This product allows users to:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>• Validate or dismiss incidents as they are received.</td><td>☒</td><td></td></tr>
<tr><td>• Configure incident alerts and displays uniquely for each individual user.</td><td>☒</td><td></td></tr>
<tr><td>• Turn on and off alerts for each incident type.</td><td>☒</td><td></td></tr>
<tr><td>• Turn on and off alerts by roadway geometry (e.g., turn off shoulder alerts) and location (e.g., designate typical versus atypical traffic queues).</td><td>☒</td><td></td></tr>
<tr><td>• Configure the duration from incident detection to incident alert.</td><td>☒</td><td>The duration is configurable for an alert notifying an operator (e.g., typically between 5 and 10 seconds for a stopped vehicle, less than 5 seconds for a stopped vehicle in a tunnel).</td></tr>
<tr><td>• Configure speed thresholds for detecting congestion or slow traffic.</td><td>☒</td><td>Alerts can be provided for speed that is under, speed that is over, or a sudden drop in speed. Speed is configurable (e.g., alert for a vehicle going from 70 mph to 35 mph).</td></tr>
<tr><td>• Configure thresholds for locating start/head and end/tail of traffic queues.</td><td>☒</td><td></td></tr>
<tr><td>• Configure incident alerts in real-time and by pre-determined parameters.</td><td>☒</td><td></td></tr>
<tr><td>• Prioritize alerts and allow real time filtering.</td><td>☒</td><td></td></tr>
<tr><td>• Real-time information about incident timelines.</td><td>☒</td><td></td></tr>
<tr><td>• Re-classify incident events to change their priority level over time</td><td>☒</td><td></td></tr>
<tr><td></td><td colspan="3">Other decision support features (please explain):
Researcher notes from demonstration:
• Nothing additional.
FLIR notes:
• Event notification is configurable
• True/false is optional available</td></tr>
<tr><td>Time to Detection
(Need #32)</td><td colspan="3">What is the amount of time elapsed from incident occurrence to detection?
Researcher notes from demonstration:
• The time from incident occurrence to detection is configurable.
FLIR notes:
• The following reflect a typical installation. There is a programmable range.</td></tr>
</table>

	○ Stopped vehicle <10 sec ○ Debris < 15 sec ○ Pedestrian < 5 sec ○ Queue < 10 sec ○ Wrong way < 5 sec
Latency of Detection to Alert *(Need #33)*	*Comment on the latency of communicating alerts to TMC operators or other users, if applicable.* Researcher notes from demonstration: • Nothing additional. FLIR notes: • On a good reliable communication network latency should be non-existing.
Integration with Agency Systems and Practices	
Use of Agency Equipment *(Need #34)*	*Does the system utilize existing DOT-owned equipment to perform detections? If yes, how? If no, what equipment is used and where is it housed?* Researcher notes from demonstration: • FLIR can work with legacy equipment through a VIP-HD card, however the performance will not be as high. • FLIR FLUX Servers are used as a middleware (does not run the analytics) to store data and events, images and image sequences. FLUX can interface with existing servers. • After 250 smart sensors (cameras) then requires a different server from the basic architecture configuration.
Installation and Integration *(Needs #35,36, 40,42)*	*What is the installation/integration process?* Researcher notes from demonstration: • Currently FLIR AID installations are on highways, tunnels, and bridges to provide TMC operators with actionable information and provide decisions support. • FLIR support includes onsite training or remote training and design tools to determine the best location and mounting options for the best coverage. FLIR notes: • Need to get full details of the existing equipment and the camera locations as those are key for a good performing system. *How can the product be integrated with agency systems such as Advanced Traffic Management Software (ATMS)?* Researcher notes from demonstration: • Not discussed during the demonstration. FLIR notes: • FLIR provides free and public rest API's for integration into ATMS and have done so for various systems such as FL Sunguide for example. *What physical space is required at agency facilities for equipment and data storage?* Researcher notes from demonstration: • Extra servers are not used on the back end or in cabinets, everything is happening "at the edge" with dedicated processing.

	FLIR notes: • Only the servers (1 per 250 channels), by default we use 19" rack mount 1U model. • In case of legacy cameras (existing video equipment/installed) to be added, we require detector rack = 19" rack mount 3U per 8 channels. *If applicable, how is storage and periodic purging of video handled?* Researcher notes from demonstration: • Not discussed during the demonstration. FLIR notes: • We allocate x GB of storage FIFO principle and/or storage max duration.
Calibration *(Need #37-39)*	*Describe how the system is pre-calibrated by the vendor prior to agency deployment, any ongoing calibration needs, and self-calibration capabilities.* Researcher notes from demonstration: • Not discussed during the demonstration. FLIR notes: • Calibration is done during commissioning as part of the start-up.
Health Monitoring *(Need #41)*	*Describe how the product monitors the operability of its components and field equipment.* Researcher notes from demonstration: • FLIR technical and health monitoring includes: ○ No video present ○ Reboot of sensor ○ Configuration speed ○ Camera movement ○ Communication error ○ Image quality monitoring ○ Device temperature monitoring FLIR notes: • Nothing additional.
Use by Transportation Agencies / Case Studies	
List the transportation agencies (and contacts if available) that currently use your AID product. Provide web links to case studies or other documentation featuring agency use of the product. Researcher notes from demonstration: • 32 states/provinces use FLIR for AID including Arizona and Florida. FLIR notes: • AID also being used in VA.	
Other Product Highlights	
Describe any additional product highlights if not previously noted. Researcher notes from demonstration: • There are 3 different cameras with different capabilities used for AID. All FLIR AID systems are fixed mount and do not perform AID functionality with Pan/Tilt/Zoom. ○ High-definition (visual) camera ○ Thermal camera	

        - Lower cost, lower false detections, low missed detections, low maintenance (solid state and can go a long time without cleaning).
        - Do not use windshield wipers. There are heaters onboard (the lens itself allows heat to pass back and forth).
        - Can detect electric vehicles.
    - Hybrid – visual camera and thermal camera together
- The overall cost for various camera types is similar. For example, a thermal camera may be more expensive upfront although the maintenance is less and fewer are needed compared to a high-definition camera.

FLIR notes:

- Nothing additional.

<table>
<tr><th>Vendor</th><th colspan="3">Navtech Radar</th></tr>
<tr><td>Website</td><td colspan="3">https://navtechradar.com/</td></tr>
<tr><td>Contacts</td><td colspan="3">Dan Flynn (dan@sri-radar.com), Seb Baucutt (sebastian.baucutt@navtechradar.com), Shayan Afshar (shayan.afshar@navtechradar.com), Kieron Parker (kieron.parker@navtechradar.com)</td></tr>
<tr><td>Webinar Demonstration</td><td colspan="3">May 18, 2021</td></tr>
<tr><th colspan="4">Product Overview</th></tr>
<tr><td colspan="4">Brief overview of how the product detects traffic incidents (3-4 sentences):
Researcher notes from demonstration:
• Navtech provides a 360 degree rotating, Frequency-Modulated Continuous Wave (FMCW) “spinning” radar technology that can detect moving objects and stopped objects.
• At the end of last year, Navtech deployed a new frequency (35 GHz) of radar for use in the U.S. that can be deployed anywhere.
Navtech Radar notes:
• The radar range resolution is 17cm, allowing detection of objects as small as 50cm x 50cm x 50cm, stopped or moving.
• The ClearWay application uses classification and area specific rules to distinguish an incident from normal activity, and then respond to it.</td></tr>
<tr><th colspan="4">Detection Capabilities, Coverage and Environment</th></tr>
<tr><td rowspan="9">Traffic Incidents Detected
Detects presence of these incidents (Needs #1-12)</td><td colspan="2">Incident Type</td><td>Researcher notes from demonstration</td></tr>
<tr><td>Stopped Vehicle</td><td>☒</td><td>• Provided a video showing the capability of detecting a stopped vehicle.</td></tr>
<tr><td>Extremely Slow Vehicle</td><td>☒</td><td>• Provided a video showing the capability of detecting a slow vehicle.</td></tr>
<tr><td>Congestion/ Slow Traffic</td><td>☒</td><td>• Noted capability, not demonstrated.</td></tr>
<tr><td>Non-vehicle object or entity (e.g., debris, pedestrian, animal)</td><td>☒</td><td>• Noted capability, not demonstrated.</td></tr>
<tr><td>Queue (Location of front and back of traffic queue)</td><td>☒</td><td>• Noted capability, not demonstrated.</td></tr>
<tr><td>Wrong-Way Vehicle</td><td>☒</td><td>• Noted capability, not demonstrated.</td></tr>
<tr><td>Extreme Vehicle Speed</td><td>☒</td><td>• Noted capability, not demonstrated.</td></tr>
<tr><td colspan="3">Comments on traffic incidents detected by the product.
Researcher notes from demonstration:</td></tr>
</table>

<table>
<tr><td></td><td colspan="3">Other detection capabilities include: vehicle counts and classification, situational awareness, and hard shoulder monitoring.
Navtech Radar notes:
The videos demonstrated show the ability of the system to generate alerts based on classification, location, speed, and direction.
Other videos are available showing how these abilities are applied to the use cases not demonstrated.</td></tr>
<tr><td>Coverage Limits for Detection
(Needs #5,6,8,13)</td><td colspan="3">Describe the product’s coverage area (e.g., all lanes of traffic, roadway shoulders, field of view, detection coverage distance).
Researcher notes from demonstration:
Coverage area is configurable.
For continuous coverage, approximately 300-500 meter spacing is needed. Coverage for pedestrian detection would be at the lower end of this range. There are no issues with radar units confilcting with each other when spaced in series because of the FMCW processing.
Navtech Radar notes:
The field of view is 360° which allows it to cover all lanes of multiple roadways.
Roadways with turns are still covered to the extent that the radar has line of sight view.</td></tr>
<tr><td rowspan="6">Detection Conditions/ Environment
(Needs #14-17)</td><td colspan="2">Detection is functional in:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>All lighting conditions (daylight, low light, dark)</td><td>☒</td><td>Noted capability, not demonstrated.</td></tr>
<tr><td>All weather conditions</td><td>☒</td><td>Noted capability, not demonstrated.</td></tr>
<tr><td>Low visibility not caused by weather events (e.g., smoke)</td><td>☒</td><td>Noted capability, not demonstrated.</td></tr>
<tr><td>All traffic conditions (free-flowing to extreme congestion)</td><td>☒</td><td>Noted capability, not demonstrated.</td></tr>
<tr><td colspan="3">Provide any additional details about the detection environment.
Researcher notes from demonstration:
Nothing additional.
Navtech Radar notes:
Radar is preferred over optical, thermal, and lidar in these conditions because RF energy is not affected by weather or lighting conditions.</td></tr>
<tr><th colspan="4">Alerts/Displays and Configuration</th></tr>
<tr><td>False Alerts
(Need #18)</td><td colspan="3">Demonstrate and discuss the product’s ability to minimize false alerts.
Researcher notes from demonstration:
Not discussed during demonstration.
Navtech Radar notes:
System tuning to minimize false alerts is part of the service provided by the Navtech team.</td></tr>
</table>

<table>
<tr><td></td><td colspan="3">

The tuning includes optimizing the processing of the raw radar data and configuring the user defined rules to reliably alert only when desired.
If new sources of false alerts materialize, the tuning can be updated to filter them out.

</td></tr>
<tr><td>Notifications
(Need #19)</td><td colspan="3">How are alerts provided to TMC operators or other users when an incident is detected? How can notifications be customized (e.g., email, text) for each recipient?
Researcher notes from demonstration:

Alarm is displayed on user display platform.
Notifications beyond user display not discussed.

Navtech Radar notes:

The ClearWay application supports configurable email and text messaging as the response to incidents.
The rules that trigger the responses can be active on schedules for multiple shifts.
ClearWay also allows alarm integration with other systems as required.

</td></tr>
<tr><td rowspan="12">Operator Support and Configuration
(Needs #20-31)</td><td colspan="2">This product allows users to:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>• Validate or dismiss incidents as they are received.</td><td>☒</td><td>-</td></tr>
<tr><td>• Configure incident alerts and displays uniquely for each individual user.</td><td>☒</td><td>Noted capability.</td></tr>
<tr><td>• Turn on and off alerts for each incident type.</td><td>☒</td><td>Noted capability.</td></tr>
<tr><td>• Turn on and off alerts by roadway geometry (e.g., turn off shoulder alerts) and location (e.g., designate typical versus atypical traffic queues).</td><td>☒</td><td>Noted capability.</td></tr>
<tr><td>• Configure the duration from incident detection to incident alert.</td><td>☒</td><td>Noted capability.</td></tr>
<tr><td>• Configure speed thresholds for detecting congestion or slow traffic.</td><td>☒</td><td>Noted capability.</td></tr>
<tr><td>• Configure thresholds for locating start/head and end/tail of traffic queues.</td><td>☒</td><td>Queue settings are on section by section basis; users can see head and end of queue as well as query the database to provide a timeline.</td></tr>
<tr><td>• Configure incident alerts in real-time and by pre-determined parameters.</td><td>☒</td><td>-</td></tr>
<tr><td>• Prioritize alerts and allow real time filtering.</td><td>☒</td><td>-</td></tr>
<tr><td>• Real-time information about incident timelines.</td><td>☒</td><td>-</td></tr>
<tr><td>• Re-classify incident events to change their priority level over time</td><td>☒</td><td>-</td></tr>
</table>

	Other decision support features (please explain): Researcher notes from demonstration: • Alerts are configurable. • Navtech's ClearWay Software consumes raw data, processes the data, and then applies a tracking algorithm to track and classify vehicles. Rules are configured by users and if a rule is broken, an alarm is generated. The user interface was shown demonstrating an alarm when a rule was broken. • Users can also configure: lane information, vehicle size (truck or small vehicle) Navtech Radar notes: • The Alarms or Alerts that were demonstrated correspond to Incidents, and in this way the Incidents are validated or dismissed. • Multiple alert Profiles can be set up depending on conditions to rapidly reconfigure alarm settings if required. • These Profiles can be selected in in a pull-down menu by the operators, allowing them to configure and prioritize alerts in real-time. • Situational awareness gives clear information on incident in real time, and alarm summary pages provide real-time information about incident timelines. • Outside of using profiles to select different incident priority sets, changing event priority levels over time is currently a manual configuration.
Time to Detection *(Need #32)*	*What is the amount of time elapsed from incident occurrence to detection?* Researcher notes from demonstration: • This is configurable, detects within 10 seconds. Navtech Radar notes: • This timing is also configurable by area and type of incident, so that higher priority incidents can detect and report faster if desired.
Latency of Detection to Alert *(Need #33)*	*Comment on the latency of communicating alerts to TMC operators or other users, if applicable.* Researcher notes from demonstration: • Not discussed during the demonstration. Navtech Radar notes: • Alerts are triggered in near real-time after the conditions of the incident rule are true. • Alerts at the TMC operator screen are near instantaneous, and alerts reported by text or email will have the latencies of those mechanisms.
Integration with Agency Systems and Practices	
Use of Agency Equipment *(Need #34)*	*Does the system utilize existing DOT-owned equipment to perform detections? If yes, how? If no, what equipment is used and where is it housed?* Researcher notes from demonstration: • The system typically uses existing infrastructure. If a communications network is not available, a small box is installed for storing communications. Navtech Radar notes:

	• The existing infrastructure typically used includes a mounting location, power, and network. • Additional sensors can optionally be used as relay inputs, and DOT equipment can be controlled as a response to rules using relay outputs. • In the server room, the system typically uses DOT power, UPS, network, and rack space.
Installation and Integration *(Needs #35,36, 40,42)*	*What is the installation/integration process?* Researcher notes from demonstration: • A project delivery team is availble for support. • User training is typically a few hours in duration. System administrator training is a full day or more. Navtech Radar notes: • A local electrical contractor is typically used for physical and electrical installation. • The Navtech team supports the installation and then performs commissioning and integration. *How can the product be integrated with agency systems such as Advanced Traffic Management Software (ATMS)?* Researcher notes from demonstration: • Can be integrated through an API. Navtech Radar notes: • ClearWay uses the concept of Plugins to accommodate both incoming data from other sensors and systems and outgoing data and responses to incidents. • The Plugins have an existing template using proven design patterns, reducing implementation time and risk. *What physical space is required at agency facilities for equipment and data storage?* Researcher notes from demonstration: • Not discussed during the demonstration. Navtech Radar notes: • Rack space for the ClearWay server varies by the number of sensors but is typically 4U for a server and a rack mounted UPS if required. • In the Operations Center, the ClearWay application can be run on existing workstations, but agencies typically prefer one or two dedicated workstations. *If applicable, how is storage and periodic purging of video handled?* Researcher notes from demonstration: • N/A Navtech Radar notes: • N/A
Calibration *(Need #37-39)*	*Describe how the system is pre-calibrated by the vendor prior to agency deployment, any ongoing calibration needs, and self-calibration capabilities.* Researcher notes from demonstration:

	• Support is provided onsite or remotely to set up and calibrate the system to the required specifications. Navtech Radar notes: • The background image can be by Google Maps provided by Navtech, or a background image can be provided by agency if preferred.
Health Monitoring *(Need #41)*	*Describe how the product monitors the operability of its components and field equipment.* Researcher notes from demonstration: • Navtech Radar offers health monitoring for its systems. Navtech Radar notes: • The ClearWay system has substantial equipment health monitoring and reporting capabilities. • System logs, warnings, and alarms are recorded in the database for troubleshooting and trend analysis. • If provided VPN access, Navtech performs regular system checks to confirm equipment health and reduce the chance of failures.
Use by Transportation Agencies / Case Studies	
List the transportation agencies (and contacts if available) that currently use your AID product. Provide web links to case studies or other documentation featuring agency use of the product. Researcher notes from demonstration: • City of Cocoa Beach, Florida DOT (included detection of vehicles and pedestrians at a traffic signal) • Texas DOT • United Kingdom • Baltimore, MA Navtech Radar notes: • ClearWay is being widely deployed in Europe and Asia, and references are available on a case by case basis. Following are links to case studies on the Navtech website: • M25 Motorway - Navtech Radar • E4 Motorway - Navtech Radar • Bømlafjord Tunnel - Navtech Radar • Mastrafjord - Navtech Radar	
Other Product Highlights	
Describe any additional product highlights if not previously noted. Researcher notes from demonstration: • Navtech Radar's automated incident detection system is low maintenance, as there is not a need to clean lenses, and road closures are not needed to perform maintainance since the radar is placed on the roadside. • Future innovations include ITS, Situational Awareness 2, CAV, Close Following, Beyond the Horizon, accident prediction and prevention, intersection monitoring, occupancy monitoring and reporting. Navtech Radar notes: • ClearWay has robust camera following if desired in critical areas. This allows a single camera to zoom in on incidents for assessment.	

- If equipped with a camera, ClearWay has a ”Look Here” feature that allows the operator to zoom the camera to a point by clicking on the map.
- ClearWay has numerous convenience features for managing displays and data that allow operators to gain the most value from the system in the shortest time.
- ClearWay has a comprehensive data set available for integration with ATMS and other systems for operations, trending, and analysis.

<table>
<tr><td>Vendor</td><td colspan="3">OptaSense</td></tr>
<tr><td>Website</td><td colspan="3">https://www.optasense.com/</td></tr>
<tr><td>Contacts</td><td colspan="3">Paul Cooper (paul.cooper@optasense.com)</td></tr>
<tr><td>Webinar Demonstration</td><td colspan="3">May 11, 2021</td></tr>
<tr><td colspan="4">Product Overview</td></tr>
<tr><td colspan="4">Brief overview of how the product detects traffic incidents (3-4 sentences):
Researcher notes from demonstration:
• The OptaSense Traffic Monitoring Solution (TMS) converts existing roadside optical fiber cable (single unused/dark strand) into a traffic sensor.
• The sensing range of the product is up to 50 miles (25 miles in each direction from installation point).
• OptaSense equipment is connected to dark fiber on the roadside.
• The fiber-optic sensing technology creates an array of intelligent sensors and detects passing traffic along the entire monitored road. Each virtual sensor uses a combination of noise and vibration to deliver a series of traffic flow indicators.
• The OptaSense product detects “consequences of vehicle incidents e.g., arising queue and congestion” and compliments other AID solutions.
OptaSense notes:
• Nothing additional</td></tr>
<tr><td colspan="4">Detection Capabilities, Coverage and Environment</td></tr>
<tr><td rowspan="7">Traffic Incidents Detected
Detects presence of these incidents (Needs #1-12)</td><td colspan="2">Incident Type</td><td>Researcher notes from demonstration</td></tr>
<tr><td>Stopped Vehicle</td><td>☐</td><td>-</td></tr>
<tr><td>Extremely Slow Vehicle</td><td>☐</td><td>-</td></tr>
<tr><td>Congestion/ Slow Traffic</td><td>☒</td><td>• Noted that OptaSense can pinpoint where traffic begins to slow and congestion and comes to halt to an accuracy of 165 feet/50 meters.
• In Europe, the OptaSense data is being used to control DMS for communicating VSL during congestion.</td></tr>
<tr><td>Non-vehicle object or entity (e.g., debris, pedestrian, animal)</td><td>☐</td><td>-</td></tr>
<tr><td>Queue (Location of front and back of traffic queue)</td><td>☒</td><td>• Noted that OptaSense can detect the head of queue and dynamically track the tail of the queue to an accuracy of 165 feet/50 meters.</td></tr>
<tr><td>Wrong-Way Vehicle</td><td>☐</td><td>-</td></tr>
</table>

<table>
<tr><td rowspan="2"></td><td>Extreme Vehicle Speed</td><td>☐</td><td colspan="2">-</td></tr>
<tr><td colspan="4">Comments on traffic incidents detected by the product.
Researcher notes from demonstration:
Other detection capabilities:
Average speed
Journey times / travel times
Traffic counts (available at crossings where the traffic is running perpendicular to the fiber)
Flow rates (available at crossings where the traffic is running perpendicular to the fiber)
OptaSense notes:
Nothing additional</td></tr>
<tr><td>Coverage Limits for Detection
(Needs #5,6,8,13)</td><td colspan="4">Describe the product’s coverage area (e.g., all lanes of traffic, roadway shoulders, field of view, detection coverage distance).
Researcher notes from demonstration:
The product does not detect individual vehicles. The product is well-suited for deployment on major routes with multi-lane highways. Monitors both directions of traffic with connection to one fiber optic cable.
Average speed is available at 165 ft intervals, updated every second.
OptaSense Notes:
The product does “detect” individual vehicle but aggregates information from multiple vehicles to provide speed, queue, congestion information. Future applications based on single vehicle detection are being investigated.</td></tr>
<tr><td rowspan="6">Detection Conditions/ Environment
(Needs #14-17)</td><td colspan="3">Detection is functional in:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td colspan="2">• All lighting conditions (daylight, low light, dark)</td><td>☒</td><td></td></tr>
<tr><td colspan="2">• All weather conditions</td><td>☒</td><td></td></tr>
<tr><td colspan="2">• Low visibility not caused by weather events (e.g., smoke)</td><td>☒</td><td></td></tr>
<tr><td colspan="2">• All traffic conditions (free-flowing to extreme congestion)</td><td>☐</td><td>-</td></tr>
<tr><td colspan="4">Provide any additional details about the detection environment.
Researcher notes from demonstration:
The fiber optic cable is buried; therefore it works in all weather and lighting conditions.
Equipment operates in extreme heat and cold/harsh weather conditions.
OptaSense Notes:
Equipment is installed away from roadside in existing equipment rooms or similar where there is environmental control, power, access to fiber etc.</td></tr>
<tr><td colspan="5">Alerts/Displays and Configuration</td></tr>
<tr><td>False Alerts
(Need #18)</td><td colspan="4">Demonstrate and discuss the product’s ability to minimize false alerts.
Researcher notes from demonstration:</td></tr>
</table>

	• The accuracy was validated for a highway deployment in England: 0 false alarm rate, 100% detection, 3.1 seconds time to detection, availability 100%. OptaSense notes: • Accuracy against common point sensors such a loops, microwave etc. also validated.		
Notifications *(Need #19)*	*How are alerts provided to TMC operators or other users when an incident is detected? How can notifications be customized (e.g., email, text) for each recipient?* Researcher notes from demonstration: • Sends alerts or messages to TMC operators, indicating where congestion and queues are occurring. OptaSense notes: • Nothing additional.		
Operator Support and Configuration *(Needs #20-31)*	*This product allows users to:*		Researcher notes from demonstration:
	• Validate or dismiss incidents as they are received.	☐	Not discussed during demonstration.
	• Configure incident alerts and displays uniquely for each individual user.	☐	Not discussed during demonstration.
	• Turn on and off alerts for each incident type.	☐	Not discussed during demonstration.
	• Turn on and off alerts by roadway geometry (e.g., turn off shoulder alerts) and location (e.g., designate typical versus atypical traffic queues).	☐	Not discussed during demonstration.
	• Configure the duration from incident detection to incident alert.	☐	Not discussed during demonstration.
	• Configure speed thresholds for detecting congestion or slow traffic.	☒	Notification criteria is set in conjunction with the customer (e.g. levels of congestion).
	• Configure thresholds for locating start/head and end/tail of traffic queues.	☐	Not discussed during demonstration.
	• Configure incident alerts in real-time and by pre-determined parameters.	☐	Not discussed during demonstration.
	• Prioritize alerts and allow real time filtering.	☐	Not discussed during demonstration.
	• Real-time information about incident timelines.	☐	Not discussed during demonstration.
	• Re-classify incident events to change their priority level over time	☐	Not discussed during demonstration.
	Other decision support features (please explain): Researcher notes from demonstration: • Nothing additional.		

	OptaSense notes: • Nothing additional.
Time to Detection *(Need #32)*	*What is the amount of time elapsed from incident occurrence to detection?* Researcher notes from demonstration: • It is near instantaneous. OptaSense notes: • Nothing additional.
Latency of Detection to Alert *(Need #33)*	*Comment on the latency of communicating alerts to TMC operators or other users, if applicable.* Researcher notes from demonstration: • Detection is near instantaneous. OptaSense notes: • Nothing additional.
Integration with Agency Systems and Practices	
Use of Agency Equipment *(Need #34)*	*Does the system utilize existing DOT-owned equipment to perform detections? If yes, how? If no, what equipment is used and where is it housed?* Researcher notes from demonstration: • In-place dark fiber is used along the roadside. OptaSense notes: • Nothing additional.
Installation and Integration *(Needs #35,36, 40,42)*	*What is the installation/integration process?* Researcher notes from demonstration: • It is a simple and rapid installation; no road closures are needed. OptaSense notes: • Nothing additional. *How can the product be integrated with agency systems such as Advanced Traffic Management Software (ATMS)?* Researcher notes from demonstration: • The OptaSense graphical interface is available, but the data may also be integrated with the user's interface of choice (e.g., ATMS). This is achieved through an API protocol. OptaSense notes: • Nothing additional. *What physical space is required at agency facilities for equipment and data storage?* Researcher notes from demonstration: • Equipment is located in a building away from the roadside, where available racking space (19-inch rack with 10 to 12 spacing) exists. Each installation can cover up to 50 miles (25 miles in either direction). OptaSense notes: • Equipment is installed every 50 miles. This converts the fiber into an array of "virtual" speed sensors every 165 feet/50 meters. *If applicable, how is storage and periodic purging of video handled?*

	Researcher notes from demonstration: • N/A OptaSense notes: • Nothing additional.
Calibration *(Need #37-39)*	*Describe how the system is pre-calibrated by the vendor prior to agency deployment, any ongoing calibration needs, and self-calibration capabilities.* Researcher notes from demonstration: • Once the system is installed it does not need periodic calibration. OptaSense notes: • Nothing additional.
Health Monitoring *(Need #41)*	*Describe how the product monitors the operability of its components and field equipment.* Researcher notes from demonstration: • Not discussed during the demonstration. OptaSense notes: • Equipment status is remotely monitored to ensure high availability.

Use by Transportation Agencies / Case Studies

List the transportation agencies (and contacts if available) that currently use your AID product. Provide web links to case studies or other documentation featuring agency use of the product.

Researcher notes from demonstration:

- North Dakota DOT
  - NDDOT Case study on OptaSense website: https://optasense.com/case-study-optasense-traffic-monitoring-solution-deployed-on-us-highway/
- Georgia DOT
  - High Resolution Traffic Monitoring at the Speed of Light (Roads and Bridges, July 2020) https://www.roadsbridges.com/high-resolution-traffic-monitoring-speed-light
  - GADOT Case Study on OptaSense website: https://www.optasense.com/case-study-optasense-traffic-monitoring-solution-deployed-on-interstate-20-atlanta/
- Utah DOT
- Nevada DOT
- Florida DOT
- New Zealand Transport Agency (NZTA)
- Rijkswaterstaat (Amsterdam, The Netherlands)
- Traffikverket (Stockholm, Sweden)

OptaSense notes:

- Nothing additional.

Other Product Highlights

Describe any additional product highlights if not previously noted.

Researcher notes from demonstration:

- Fiber optic sensing in an emerging technology beginning only 4 or 5 years ago. However, a lot of work has been done to validate the data using comparisons to data generated by in-place sensors such as inductive loops or radar.

• Operational costs are very low compared to point detection solutions. OptaSense notes: • Operational life cycle costs are an order of magnitude lower than point sensors and comparable to the full cost of probe data sources.

<table>
<tr><th>Vendor</th><th colspan="3">TrafficVision</th></tr>
<tr><td>Website</td><td colspan="3">http://www.trafficvision.com/</td></tr>
<tr><td>Contacts</td><td colspan="3">Ray Keys (raykeys@trafficvision.com), Clem Lau (clem@omnibond.com), Josh Kissel (josh@trafficvision.com)</td></tr>
<tr><td>Webinar Demonstration</td><td colspan="3">June 8, 2021</td></tr>
<tr><td colspan="4">Product Overview</td></tr>
<tr><td colspan="4">Brief overview of how the product detects traffic incidents (3-4 sentences):
Researcher notes from demonstration:
• Uses patented video detection technology, leveraging existing cameras to provide agency immediate notification of incidents.
• Uses fixed or PTZ cameras, connecting to existing or new cameras. Processes video streams (in the cloud or on-premise) from agency cameras to provide real-time detection and data collection.
TrafficVision notes:
• Patented video incident detection technology is server agnostic and can process live video streams both on premise or in the cloud.
• AutoLearn mode provides basic AID capabilities “out of the box” without need for calibration of camera views. AutoLearn mode is an automatic method of obtaining some traffic incident and congestion data and requires no camera calibration.</td></tr>
<tr><td colspan="4">Detection Capabilities, Coverage and Environment</td></tr>
<tr><td rowspan="6">Traffic Incidents Detected
Detects presence of these incidents (Needs #1-12)</td><td colspan="2">Incident Type</td><td>Researcher notes from demonstration</td></tr>
<tr><td>Stopped Vehicle</td><td>☒</td><td>Demonstrated.</td></tr>
<tr><td>Extremely Slow Vehicle</td><td>☒</td><td>Demonstrated.</td></tr>
<tr><td>Congestion/ Slow Traffic</td><td>☒</td><td>Demonstrated.</td></tr>
<tr><td>Non-vehicle object or entity (e.g., debris, pedestrian, animal)</td><td>☒</td><td>Demonstrated.</td></tr>
<tr><td>Queue (Location of front and back</td><td>☐</td><td>Do not have start/end of queue detection.</td></tr>
</table>

<table>
<tr><td rowspan="4"></td><td>of traffic queue)</td><td></td><td colspan="2"></td></tr>
<tr><td>Wrong-Way Vehicle</td><td>☒</td><td colspan="2">Demonstrated.</td></tr>
<tr><td>Extreme Vehicle Speed</td><td>☐</td><td colspan="2">Tracked in data collected, but no alert.</td></tr>
<tr><td colspan="4">Comments on traffic incidents detected by the product.
Researcher notes from demonstration:
• Other detections/data collected include speed, flow rate, and occupancy.
TrafficVision notes:
• In addition to the data collected as noted above, Per Vehicle Data – classification (4 classes + unidentified supported) and other data can be collected and exported as a CSV file.</td></tr>
<tr><td>Coverage Limits for Detection
(Needs #5,6,8,13)</td><td colspan="4">Describe the product’s coverage area (e.g., all lanes of traffic, roadway shoulders, field of view, detection coverage distance).
Researcher notes from demonstration:
• TrafficVision adapts its software to the camera view and then works with the TMC operators to get the most out of the cameras.
TrafficVision notes:
• If the DOT chooses to have cameras along a certain stretch of highway then TrafficVision can provide continuous 24/7/365 AID coverage for that length of highway using those camera feeds.
• TrafficVision’s coverage area can include both directions of travel from one camera providing it has sufficient view.</td></tr>
<tr><td rowspan="5">Detection Conditions/ Environment
(Needs #14-17)</td><td colspan="3">Detection is functional in:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td colspan="2">• All lighting conditions (daylight, low light, dark)</td><td>☒</td><td>• Showed a detection in a tunnel with a dirty camera lens.
• Showed daylight, low light, and night detections.
• If it is completely dark, there is nothing to see and unable to detect since it is a vision-based system.</td></tr>
<tr><td colspan="2">• All weather conditions</td><td>☒</td><td>• Demonstrated detections in rain, also with rain drops on camera.
• Demonstrated detection in snowy condition, snow falling, ice on lens, white/snowy view.</td></tr>
<tr><td colspan="2">• Low visibility not caused by weather events (e.g., smoke)</td><td>☒</td><td>• Showed detection in foggy conditions.
• Showed detection with smoke in a tunnel.</td></tr>
<tr><td colspan="2">• All traffic conditions (free-flowing to extreme congestion)</td><td>☒</td><td>• Showed detections of free-flowing and congested situations.</td></tr>
</table>

<table>
<tr><td></td><td colspan="3">Provide any additional details about the detection environment.
Researcher notes from demonstration:
• Nothing additional.
TrafficVision notes:
• TrafficVision will work together with the DOT to optimize the camera views and preset positions to maximize AID functionality.
• Please note for Need #14: Although the presence of some ambient light is preferred, TrafficVision can operate in dark conditions but has limited functionality. Under Dark conditions, base incident detection functions such as stopped vehicle and data such as counting and speeds, are still attainable as TrafficVision technology can track a vehicle’s head and tail lights. More precise features such as vehicle classification are heavily dependent on a camera’s ideal view and the presence of sufficient ambient light. If a higher level of data is required in low light conditions, agencies can mitigate by use of additional technologies such as IR Illuminators, thermal cameras, etc. TrafficVision allows an agency to use their existing cameras, each of which is usable for TrafficVision to varying degrees dependent on camera views and physical conditions.</td></tr>
<tr><td colspan="4">Alerts/Displays and Configuration</td></tr>
<tr><td>False Alerts
(Need #18)</td><td colspan="3">Demonstrate and discuss the product’s ability to minimize false alerts.
Researcher notes from demonstration:
• Not discussed during demonstration.
TrafficVision notes:
• Working with the operators to optimize the camera views – maximize travel lanes views minimize direct glare helps to minimize false alerts. Settings allow a user to reduce false alerts on a per camera basis.</td></tr>
<tr><td>Notifications
(Need #19)</td><td colspan="3">How are alerts provided to TMC operators or other users when an incident is detected?
How can notifications be customized (e.g., email, text) for each recipient?
Researcher notes from demonstration:
• On-screen alert appears on the camera display in the user interface (yellow box).
TrafficVision notes:
• TrafficVision has the ability to send email alert notifications. With the appropriate email service these email alerts can be sent as text messages as well.
• In addition to visual alerts within the TrafficVision user interface, users can also choose to be notified by an audible alert.
• TrafficVision can easily integrate with any ATMS and send alerts via its API.</td></tr>
<tr><td rowspan="3">Operator Support and Configuration
(Needs #20-31)</td><td colspan="2">This product allows users to:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>• Validate or dismiss incidents as they are received.</td><td>☒</td><td>• Showed incident type, incident cleared by, and reason cleared.</td></tr>
<tr><td>• Configure incident alerts and displays uniquely for each individual user.</td><td>☒</td><td>• TrafficVision provides the ability to choose multiple features (e.g., pedestrians, stopped vehicle) and configurations using a check box, unique to each individual camera.</td></tr>
</table>

	• Turn on and off alerts for each incident type.	☒	• Demonstrated.
	• Turn on and off alerts by roadway geometry (e.g., turn off shoulder alerts) and location (e.g., designate typical versus atypical traffic queues).	☒	• Showed that lanes can be configured (e.g., shoulders don't need to be configured to provide detections) • Showed that you can configure each camera to be more or less sensitive to detections, speed thresholds for alerting congestion, time of day, day of week rules, etc.
	• Configure the duration from incident detection to incident alert.	☒	• Demonstrated setting the preferred time to send an alert if a stopped vehicle has been sitting for a pre-set amount of time.
	• Configure speed thresholds for detecting congestion or slow traffic.	☒	• Demonstrated and noted that a scale of 0-100 (slower to higher speed sensitivity) can be selected. • Also, users can set speed and duration based thresholds to alert for such things as traffic slowdowns, increase in congestion, etc.
	• Configure thresholds for locating start/head and end/tail of traffic queues.	☐	• N/A. Does not detect start and end of queues.
	• Configure incident alerts in real-time and by pre-determined parameters.	☒	• Ability to set rules for time of day and day of week, (pre-determined parameters). • Ability to save settings for individual and groups of cameras.
	• Prioritize alerts and allow real time filtering.	☐	-
	• Real-time information about incident timelines.	☒	• Shows historical timelines of incidents.
	• Re-classify incident events to change their priority level over time	☐	-
	Other decision support features (please explain): Researcher notes from demonstration: • TrafficVision software can be configured for switching direction of traffic (e.g., contraflow). • Historical data: ○ Demonstrated dashboards (by camera) to view a log of historical activity for: volume comparisons, stopped incidents comparisons, slow speed comparisons, congestion incidents comparisons. ○ Demonstrated generating monthly reports to show where most incidents have occurred.		

	○ Showed how to query the top 10 cameras for various alert types (e.g., pedestrians). TrafficVision notes: • Another use case for configuring direction of travel is for managed lanes. A user can create multiple rules to assign the direction of travel based on time of day and day of week. • TrafficVision noted that "prioritization of alerts" is a functionality that is typically addressed at the ATMS level. • Can also filter by camera and/or detection type per date in the UI. • Detection regions can also be turned off for detections using a user defined polygon mask. • Detection alerts for slow traffic can be customized by the DOT through thresholds for yellow slow traffic alerts and red slow traffic alerts.
Time to Detection *(Need #32)*	*What is the amount of time elapsed from incident occurrence to detection?* Researcher notes from demonstration: • In Georgia where there is 100% coverage over 15 miles in a rural area, TrafficVision picked up an incident 6 to 8 minutes before it was reported to the TMC via external sources. TrafficVision notes: • TrafficVision enables each TMC to customize the alert response elapsed time from incident occurrence to detection. Settings can be applied on a per camera basis for stopped vehicle detection so that an alert will be issued after a vehicle/object is stopped in the detection zone for X seconds.
Latency of Detection to Alert *(Need #33)*	*Comment on the latency of communicating alerts to TMC operators or other users, if applicable.* Researcher notes from demonstration: • This is configurable. TrafficVision notes: • TrafficVision allows for a user programmable amount of time between when an incident is detected by the system to when an alert is actually raised. The actual latency between the incident occurring and detection by TrafficVision is nominal.
Integration with Agency Systems and Practices	
Use of Agency Equipment *(Need #34)*	*Does the system utilize existing DOT-owned equipment to perform detections? If yes, how? If no, what equipment is used and where is it housed?* Researcher notes from demonstration: • There is no hardware installation if processing of video streams occurs in the cloud. Uses video streams from in-place agency cameras, either fixed cameras or PTZ cameras. TrafficVision notes: • To elaborate on the researcher's comments, TrafficVision technology gives an agency the flexibility to incorporate their existing DOT-owned equipment and add new equipment. The processing can reside in-house, on the edge or cloud. The TrafficVision system is capable of using both existing and new cameras of any

	combination of manufacturer. The TrafficVision system was designed to adapt to an agency's existing or new ecosystem so that they can take advantage of today's technology and scale as needed - essentially future proofing their investment.
Installation and Integration *(Needs #35,36, 40,42)*	*What is the installation/integration process?* Researcher notes from demonstration: • Connected to the agency's video feed(s) for installation/integration. TrafficVision notes: • The agency camera feeds only need to meet the requirement that they are: ○ Resolution: 240p minimum ○ Framerate: 15 fps minimum ○ Media Encoding: MPEG-4 (e.g., H.264) ○ Bitrate: 256 kbps minimum ○ Protocol: RTSP, RTMP, HTTP-hls • For processing in the cloud the video feeds need to be accessible in the cloud. *How can the product be integrated with agency systems such as Advanced Traffic Management Software (ATMS)?* Researcher notes from demonstration: • Can be integrated into video wall, ATMS, satellite stations and other agency equipment. TrafficVision notes: • Integration noted above is achieved with the use of the TrafficVision API. Similarly, the TrafficVision API can be used to interface to VMS or other systems as required. *What physical space is required at agency facilities for equipment and data storage?* Researcher notes from demonstration: • Processing of video streams can occur on-premise or in the cloud. TrafficVision notes: • Nothing additional. *If applicable, how is storage and periodic purging of video handled?* Researcher notes from demonstration: • Not discussed during the demonstration. TrafficVision notes: • Stored incident video can be purged at a time interval defined by the DOT
Calibration *(Need #37-39)*	*Describe how the system is pre-calibrated by the vendor prior to agency deployment, any ongoing calibration needs, and self-calibration capabilities.* Researcher notes from demonstration: • PTZ cameras have an auto-calibration feature at the start. One or more "pre-sets" can be added to further calibrate. TrafficVision notes: • TrafficVision provides for two modes for analytics for all camera streams:

<table>
<tr><td></td><td>

AutoLearn mode: AutoLearn mode is an automatic method of obtaining some traffic incident and congestion data and requires no camera calibration.
Preset Mode: requires manual camera calibration, or defining the areas in a camera’s video picture for traffic detection. These detection areas, which are plotted to scale, are depicted by outlines superimposed over the camera video. Camera view calibration is a 4 step process with on screen instructions shown if desired.

</td></tr>
<tr><td>Health Monitoring
(Need #41)</td><td>
Describe how the product monitors the operability of its components and field equipment.
Researcher notes from demonstration:
Not discussed during the demonstration.
TrafficVision notes:
TrafficVision technology monitors the usefulness of a cameras stream for analytics and displays if a stream is active or inactive. Items such as frame rate and view quality are monitored as well and displayed in the TrafficVision User Interface.
</td></tr>
<tr><th colspan="2">Use by Transportation Agencies / Case Studies</th></tr>
<tr><td colspan="2">
List the transportation agencies (and contacts if available) that currently use your AID product. Provide web links to case studies or other documentation featuring agency use of the product.
Researcher notes from demonstration:
Georgia DOT
TrafficVision notes:

KC Scout http://www.trafficvision.com/kc-scout-case-study
MTO https://boyd-wilson-myli.squarespace.com/trafficvision-helps-panam-games
PENNDOT
Pennsylvania Turnpike
New Mexico DOT

</td></tr>
<tr><th colspan="2">Other Product Highlights</th></tr>
<tr><td colspan="2">
Describe any additional product highlights if not previously noted.
Researcher notes from demonstration:

Additional data collection features provided include per lane counts and per direction speed displayed on a map.
All the data is downloadable for each camera (csv file). The data will show that a camera was moved. What incidents have been cleared and by who.

TrafficVision notes:

TrafficVision enables DOT users to customize the system to external influences for each individual camera through a “drift tolerance” parameter. Using the drift tolerance, TrafficVision can

Drift Tolerance and Drift Correction

Drift tolerance allows you to set a threshold at which the system no longer analyzes the system in presets mode. If the current camera drift is greater than the tolerance level, the system will no longer operate in presets mode. When current camera drift is within the tolerance threshold, you can enable drift correction to enable the system to adjust your preset to match slight drifts of the camera.
Drift Correction allows the software to try and correct the calibrated lane lines to continue getting more robust data. This is useful for cameras that may drift slightly off the calibrated preset view due to wind and other conditions.

</td></tr>
</table>

- TrafficVision's "Auto recalibration" after camera movement enables the system to adjust calibration for the adjusted camera view if the new view is within the drift tolerance level of a preset assigned for that camera view.

Vendor	Waycare (Acquired by Rekor in January 2022)		
Website	https://waycaretech.com/		
Contacts	Paul-Matthew Zamsky (paul.zamsky@waycaretech.com)		
Webinar Demonstration	June 2, 2021		
Product Overview			
Brief overview of how the product detects traffic incidents (3-4 sentences): Researcher notes from demonstration: • Waycare is a cloud-based platform that provides artificial intelligence (AI) solutions for proactive traffic management to provide automated incident identification, crash prediction and forecasting, irregular congestion detection, and collaborative tools for faster response. • Modules are created for different users such as traffic management, service patrol, first responders, roadway maintenance, and transit agencies. • Waycare integrates with a variety of systems through APIs including infrastructure data, Computer Aided Dispatch (CAD), Automatic Vehicle Location (AVL), third-party data, telematics, crowdsource data, and existing ATMS providers. • Waycare works with agencies to provide real-time data into vehicles. Connected Vehicle (CV) data is gathered from sensors on vehicles in real time and integrated with Waycare. Data gathered may include fuel levels, braking, air on or off, etc. used to drive insights for the operations. • Aggregated data is typically generated by probes that provide traffic speed, volume, etc. along with including individual car data (e.g., location, speed, driver behavior) to enrich the overall dataset. • Machine learning algorithms process the ingested data, to teach the Waycare system over time, using both historical data and real time data. • Information is displayed in layers that can be turned on or off (e.g., incidents, cameras, DMS). • OpenStreetMap (https://www.openstreetmap.us/) is used as the base map.			
Detection Capabilities, Coverage and Environment			
Traffic Incidents Detected Detects presence of these incidents *(Needs #1-12)*	**Incident Type**		Researcher notes from demonstration
	Stopped Vehicle	☒	-
	Extremely Slow Vehicle	☒	• Slow vehicle is detected as an anomaly.
	Congestion/ Slow Traffic	☒	• Demonstrated on a live system.
	Non-vehicle object or entity (e.g., debris, pedestrian, animal)	☒	• Showed an interactive rendering on a slide.

<table>
<tr><td rowspan="4"></td><td>Queue (Location of front and back of traffic queue)</td><td>☒</td><td>Demonstrated on a live system.</td></tr>
<tr><td>Wrong-Way Vehicle</td><td>☐</td><td>-</td></tr>
<tr><td>Extreme Vehicle Speed</td><td>☐</td><td>-</td></tr>
<tr><td colspan="3">Comments on traffic incidents detected by the product.
Researcher notes from demonstration:
Other capabilities include:
Abandoned vehicle
Vehicle on fire
Police activity
EMS
Incidents were detected 15 minutes earlier using the CV data from the vehicle compared to a traditional CAD system and detected 34% faster than a 911 call, documented from a case study in the Bay Area.
In southern Nevada in 2020 using Waze data, an 18% reduction in primary crashes was seen, and 91% of vehicles reduced their speed. This resulted in 16 times return on investment (ROI).</td></tr>
<tr><td>Coverage Limits for Detection
(Needs #5,6,8,13)</td><td colspan="3">Describe the product’s coverage area (e.g., all lanes of traffic, roadway shoulders, field of view, detection coverage distance).
Researcher notes from demonstration:
To have required vehicle penetration for full roadway coverage in Waycare, data from 1 in 10 vehicles is ideal. At this level there is full roadway coverage and no extra data is needed. 1 in 20 vehicles is adequate and 1 in 50 vehicles is scarce.
Most deployments to date have been in metro areas. However, any major interstate or state highway would likely have enough traffic flow (vehicle penetration) to enable a basic understanding of the traffic conditions in the Waycare system. For crashes, more dense data is needed.</td></tr>
<tr><td rowspan="5">Detection Conditions/ Environment
(Needs #14-17)</td><td colspan="2">Detection is functional in:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>All lighting conditions (daylight, low light, dark)</td><td>☒</td><td>Waycare integrates with a variety of systems through APIs and lighting conditions are not an issue.</td></tr>
<tr><td>All weather conditions</td><td>☒</td><td>Waycare integrates with a variety of systems through APIs and weather conditions are not an issue.</td></tr>
<tr><td>Low visibility not caused by weather events (e.g., smoke)</td><td>☒</td><td>Waycare integrates with a variety of systems through APIs and visibility is not an issue.</td></tr>
<tr><td>All traffic conditions (free-flowing to extreme congestion)</td><td>☐</td><td>Most deployments to date have been in metro areas. However, any major interstate or state highway would likely</td></tr>
</table>

			have enough traffic flow (vehicle penetration) to enable a basic understanding of the traffic conditions in the Waycare system. For crashes, more dense data is needed.
	Provide any additional details about the detection environment. Researcher notes from demonstration: • Nothing additional.		
Alerts/Displays and Configuration			
False Alerts *(Need #18)*	*Demonstrate and discuss the product's ability to minimize false alerts.* Researcher notes from demonstration: • Not discussed during demonstration.		
Notifications *(Need #19)*	*How are alerts provided to TMC operators or other users when an incident is detected? How can notifications be customized (e.g., email, text) for each recipient?* Researcher notes from demonstration: • Notifications are provided within the Waycare user interface.		
Operator Support and Configuration *(Needs #20-31)*	*This product allows users to:*		Researcher notes from demonstration:
	• Validate or dismiss incidents as they are received.	☒	Demonstrated
	• Configure incident alerts and displays uniquely for each individual user.	☐	-
	• Turn on and off alerts for each incident type.	☒	Demonstrated
	• Turn on and off alerts by roadway geometry (e.g., turn off shoulder alerts) and location (e.g., designate typical versus atypical traffic queues).	☒	Able to configure for typical vs. atypical traffic congestion.
	• Configure the duration from incident detection to incident alert.	☒	Demonstrated.
	• Configure speed thresholds for detecting congestion or slow traffic.	☒	Demonstrated.
	• Configure thresholds for locating start/head and end/tail of traffic queues.	☒	Create a baseline initially, but since it's machine learning, constantly adapting. (Takes 1-3 months to be fully deployed in an agency, looks at about 3 years of past data. Look at percentage of accuracy, then adjust)
	• Configure incident alerts in real-time and by pre-determined parameters.	☐	Create a baseline initially, but since it's machine learning, constantly adapting

	• Prioritize alerts and allow real time filtering.	☒	
	• Real-time information about incident timelines.	☒	
	• Re-classify incident events to change their priority level over time	☐	-
	Other decision support features (please explain): Researcher notes from demonstration: • Can merge incidents from Waycare to agency CAD feeds.		
Time to Detection *(Need #32)*	*What is the amount of time elapsed from incident occurrence to detection?* Researcher notes from demonstration: • Not discussed during demonstration. However, Waycare integrates with a variety of systems therefore the time to detection is dependent upon each detection data source that integrates into Waycare.		
Latency of Detection to Alert *(Need #33)*	*Comment on the latency of communicating alerts to TMC operators or other users, if applicable.* Researcher notes from demonstration: • Not discussed during the demonstration. The Waycare user interface provides alerts to users.		
Integration with Agency Systems and Practices			
Use of Agency Equipment *(Need #34)*	*Does the system utilize existing DOT-owned equipment to perform detections? If yes, how? If no, what equipment is used and where is it housed?* Researcher notes from demonstration: • There is no hardware installation.		
Installation and Integration *(Needs #35,36, 40,42)*	*What is the installation/integration process?* Researcher notes from demonstration: • Not discussed during the demonstration. *How can the product be integrated with agency systems such as Advanced Traffic Management Software (ATMS)?* Researcher notes from demonstration: • Waycare is working with ATMS vendors to integrate Waycare's system into their ATMS. If it is not integrated, once the incident is confirmed on the Waycare user interface, the incident is ingested into the ATMS and works in parallel. For example, the user views the Waycare platform for incident verification, then turns it over to ATMS for response. When there's a response plan available, then that data is pushed to the ATMS. *What physical space is required at agency facilities for equipment and data storage?* Researcher notes from demonstration: • N/A *If applicable, how is storage and periodic purging of video handled?*		

<table>
<tr><td></td><td>Researcher notes from demonstration:
N/A</td></tr>
<tr><td>Calibration
(Need #37-39)</td><td>Describe how the system is pre-calibrated by the vendor prior to agency deployment, any ongoing calibration needs, and self-calibration capabilities.
Researcher notes from demonstration:
Not discussed during the demonstration.</td></tr>
<tr><td>Health Monitoring
(Need #41)</td><td>Describe how the product monitors the operability of its components and field equipment.
Researcher notes from demonstration:
Not discussed during the demonstration.</td></tr>
<tr><th colspan="2">Use by Transportation Agencies / Case Studies</th></tr>
<tr><td colspan="2">List the transportation agencies (and contacts if available) that currently use your AID product. Provide web links to case studies or other documentation featuring agency use of the product.
Researcher notes from demonstration:
None noted.</td></tr>
<tr><th colspan="2">Other Product Highlights</th></tr>
<tr><td colspan="2">Describe any additional product highlights if not previously noted.
Researcher notes from demonstration:
Crash prediction features – Waycare uses its datasets to create a regional response plan (e.g., how long is the incident expected to last) or a transit revision action plan (e.g., using adaptive traffic signal data and transit data.)</td></tr>
</table>

Agency and Platform	Colorado DOT (CDOT) Traffic Operations Dashboard
Contacts	Jamie Yount (Jamie.yount@state.co.us)
Webinar Demonstration	May 26, 2021

Product Overview

Brief overview of how the product detects traffic incidents (3-4 sentences):

Researcher notes from demonstration:

- CDOT developed a Traffic Operations Dashboard to detect incidents in a timelier manner. The dashboard that has been developed is a proof of concept demonstrating alerts from different types of data that is pulled into the dashboard.
- There are 3 sources of crowdsourced data used by CDOT, and 2 sources are used by the Traffic Operations Dashboard:
    - INRIX Data – Used for travel time predictions on Variable Message Signs (VMS) and to set Variable Speed Limits (VSL). In the future it is an anticipated the VSL will be weather based or a combination of weather and crowd sourced data.
    - HERE Live Traffic Data – Used in Traffic Operations Dashboard.
    - Waze Traffic Alerts – Used in Traffic Operations Dashboard.
- The dashboard was built in partnership between a CDOT GIS team and ESRI. The dashboard was developed staying within the templates and framework of ESRI for ease of maintenance. Custom development can be more difficult to maintain.
- Options to view by toggling on or off the data include:
    - HERE Live Traffic
    - Radar from National Weather Service (NWS)
    - Waze Traffic Alerts
    - AVL from maintenance vehicles
    - CDOT weather stations
    - Red flag warnings from NWS
    - Winter storm warning, watches, and high winds
    - OS/OW permitting
    - CoTrip Road Conditions (CDOT 511)
    - CoTrip point alerts
    - VMS signs

CDOT notes:

- Nothing additional.

Detection Capabilities, Coverage and Environment

	Incident Type		Researcher notes from demonstration
Traffic Incidents Detected Detects presence of these incidents *(Needs #1-12)*	Stopped Vehicle	☒	Demonstrated alert from vehicle stopped on shoulder.
	Extremely Slow Vehicle	☐	Not discussed during the demonstration.
	Congestion/ Slow Traffic	☒	Not demonstrated. However, Waze alerts include “Jams” that can show congestion or queues. Otherwise operator input is needed to identify congestion or queues. CDOT does not have another automated source of data to identify congestion or queues.

	Non-vehicle object or entity (e.g., debris, pedestrian, animal)	☒	Demonstrated alert from hazard on road (pothole).
	Queue (Location of front and back of traffic queue)	☒	Not demonstrated. However, Waze alerts include “Jams” that can show congestion or queues. Otherwise operator input is needed to identify congestion or queues. CDOT does not have another automated source of data to identify congestion or queues.
	Wrong-Way Vehicle	☐	Not discussed during the demonstration.
	Extreme Vehicle Speed	☐	Not discussed during the demonstration.
	Comments on traffic incidents detected by the product. Researcher notes from demonstration: • Nothing additional. CDOT notes: • Nothing additional.		
Coverage Limits for Detection *(Needs #5,6,8,13)*	*Describe the product’s coverage area (e.g., all lanes of traffic, roadway shoulders, field of view, detection coverage distance).* Researcher notes from demonstration: • The dashboard provides a view of the entire state and the scale of information displayed changes when zooming in and out. CDOT notes: • Nothing additional.		
Detection Conditions/ Environment *(Needs #14-17)*	*Detection is functional in:*		Researcher notes from demonstration:
	• All lighting conditions (daylight, low light, dark)	☒	Not discussed during the demonstration. However, Waze Traffic Alerts work in all lighting conditions.
	• All weather conditions	☒	Not discussed during the demonstration. However, Waze Traffic Alerts work in all weather conditions.
	• Low visibility not caused by weather events (e.g., smoke)	☒	Not discussed during the demonstration. However, Waze Traffic Alerts work in all visibility conditions.
	• All traffic conditions (free-flowing to extreme congestion)	☐	Not discussed during the demonstration.
	Provide any additional details about the detection environment. Researcher notes from demonstration: • Nothing additional. CDOT notes: • Nothing additional.		

<table>
<tr><th colspan="4">Alerts/Displays and Configuration</th></tr>
<tr><td>False Alerts
(Need #18)</td><td colspan="3">Demonstrate and discuss the product’s ability to minimize false alerts.
Researcher notes from demonstration:
• Not discussed during the demonstration.
CDOT notes:
• Nothing additional.</td></tr>
<tr><td>Notifications
(Need #19)</td><td colspan="3">How are alerts provided to TMC operators or other users when an incident is detected? How can notifications be customized (e.g., email, text) for each recipient?
Researcher notes from demonstration:
• Alerts are provided in a list format on the dashboard. The user selects the event to view additional details.
CDOT notes:
• Nothing additional.</td></tr>
<tr><td rowspan="11">Operator Support and Configuration
(Needs #20-31)</td><td colspan="2">This product allows users to:</td><td>Researcher notes from demonstration:</td></tr>
<tr><td>• Validate or dismiss incidents as they are received.</td><td>☐</td><td>Not discussed during the demonstration.</td></tr>
<tr><td>• Configure incident alerts and displays uniquely for each individual user.</td><td>☐</td><td>Not discussed during the demonstration.</td></tr>
<tr><td>• Turn on and off alerts for each incident type.</td><td>☒</td><td>Users are able to toggle on and off information (e.g., Waze Traffic Alerts, AVL) to display on the dashboard.</td></tr>
<tr><td>• Turn on and off alerts by roadway geometry (e.g., turn off shoulder alerts) and location (e.g., designate typical versus atypical traffic queues).</td><td>☐</td><td>Not discussed during the demonstration.</td></tr>
<tr><td>• Configure the duration from incident detection to incident alert.</td><td>☐</td><td>N/A – based on each data source</td></tr>
<tr><td>• Configure speed thresholds for detecting congestion or slow traffic.</td><td>☐</td><td>N/A – based on each data source</td></tr>
<tr><td>• Configure thresholds for locating start/head and end/tail of traffic queues.</td><td>☐</td><td>N/A – based on each data source</td></tr>
<tr><td>• Configure incident alerts in real-time and by pre-determined parameters.</td><td>☐</td><td>N/A– based on each data source</td></tr>
<tr><td>• Prioritize alerts and allow real time filtering.</td><td>☐</td><td>Not discussed during the demonstration.</td></tr>
<tr><td>• Real-time information about incident timelines.</td><td>☐</td><td>Not discussed during the demonstration.</td></tr>
</table>

<table>
<tr><td></td><td>Re-classify incident events to change their priority level over time</td><td>☐</td><td>Not discussed during the demonstration.</td></tr>
<tr><td></td><td colspan="3">Other decision support features (please explain):
Researcher notes from demonstration:
Nothing additional.
CDOT notes:
Nothing additional.</td></tr>
<tr><td>Time to Detection
(Need #32)</td><td colspan="3">What is the amount of time elapsed from incident occurrence to detection?
Researcher notes from demonstration:
Unknown. Data is provided by third-party data sources (e.g., Waze, HERE Technologies).
However, CDOT anecdotally has seen a decrease of 5 to 10 minutes reduction in total incident detection and response time through the use of the dashboard. The dashboard has also improved situation awareness for operations and maintenance staff. In addition, more accurate and timely traveler information is provided.
CDOT notes:
Nothing additional.</td></tr>
<tr><td>Latency of Detection to Alert
(Need #33)</td><td colspan="3">Comment on the latency of communicating alerts to TMC operators or other users, if applicable.
Researcher notes from demonstration:
CDOT's dashboard displays alerts via an API from third-party data sources (e.g., Waze, HERE Technologies). When an incident is reported through the API it will then trigger an alert in the CDOT Traffic Operations Dashboard.
CDOT notes:
Nothing additional.</td></tr>
<tr><td colspan="4">Integration with Agency Systems and Practices</td></tr>
<tr><td>Use of Agency Equipment
(Need #34)</td><td colspan="3">Does the system utilize existing DOT-owned equipment to perform detections? If yes, how? If no, what equipment is used and where is it housed?
Researcher notes from demonstration:
N/A. Incident detection is provided from third-party data sources (e.g., Waze, HERE Technologies).
CDOT notes:
Nothing additional.</td></tr>
<tr><td>Installation and Integration
(Needs #35,36, 40,42)</td><td colspan="3">What is the installation/integration process?
Researcher notes from demonstration:
N/A. The dashboard was developed in partnership with ESRI.
CDOT notes:
Nothing additional.
How can the product be integrated with agency systems such as Advanced Traffic Management Software (ATMS)?</td></tr>
</table>

	Researcher notes from demonstration: • Currently TMC operators log incidents detected (e.g., from the dashboard) in the ATMS. CDOT plans to deploy a new ATMS in the Fall 2021 and the dashboard information as well as other sources of information may be integrated into the ATMS at that time. CDOT notes: • Nothing additional. *What physical space is required at agency facilities for equipment and data storage?* Researcher notes from demonstration: • N/A CDOT notes: • Nothing additional. *If applicable, how is storage and periodic purging of video handled?* Researcher notes from demonstration: • Data from the dashboard is stored and archived. CDOT notes: • Nothing additional.
Calibration *(Need #37-39)*	*Describe how the system is pre-calibrated by the vendor prior to agency deployment, any ongoing calibration needs, and self-calibration capabilities.* Researcher notes from demonstration: • N/A CDOT notes: • Nothing additional.
Health Monitoring *(Need #41)*	*Describe how the product monitors the operability of its components and field equipment.* Researcher notes from demonstration: • N/A CDOT notes: • Nothing additional.
Use by Transportation Agencies / Case Studies	
List the transportation agencies (and contacts if available) that currently use your AID product. Provide web links to case studies or other documentation featuring agency use of the product. Researcher notes from demonstration: • N/A CDOT notes: • Nothing additional.	
Other Product Highlights	
Describe any additional product highlights if not previously noted. Researcher notes from demonstration: • Moving forward CDOT would like to: ○ Increase the use of the dashboard within CDOT (e.g., maintenance field staff).	

- Improve the public facing interface with the feeds.
- Develop and implement predictive capabilities (e.g., sporting events, road closures)
- Include mobile RWIS and road friction data. There are 60 mobile RWIS on supervisor vehicles, buses, and snowplows. The vehicle operator/driver is provided information from the sensor through Bluetooth which has been very beneficial to the driver
- Improve performance measures for snow and ice program.
- Develop snowplow dynamic routing – keep resources moving.
- Develop and implement additional data sources and dashboards (e.g., operational readiness, avalanche operations).

CDOT notes:

- Nothing additional.

<table>
<tr><td>Agency and Platform</td><td colspan="3">Pennsylvania DOT (PennDOT) Traffic Alerts Dashboard</td></tr>
<tr><td>Contact</td><td colspan="3">Ryan McNary (rymcnary@pa.gov)</td></tr>
<tr><td>Webinar Demonstration</td><td colspan="3">June 9, 2021</td></tr>
<tr><td colspan="4">Product Overview</td></tr>
<tr><td colspan="4">Brief overview of how the product detects traffic incidents (3-4 sentences):
Researcher notes from demonstration:
• PennDOT developed a traffic alerts dashboard to alert operators of incidents more quickly. There are 13 different Computer Aided Dispatch (CAD) providers used within the state by County 911 centers and those feeds are not shared with the DOT. With the Traffic Alerts dashboard, the goal was to fill that gap in the TMC with crowdsourced incident data. Other goals were to maintain situational awareness, speed up the incident verification process, and enable faster coordination between the TMC and other PennDOT entities (e.g., maintenance team).
• The sources of information for the dashboard include:
○ INRIX incident data
○ Road Condition Reporting System (RCRS)
○ Camera locations
○ Video you can stream
○ Google traffic Application Programming Interface (API) (always live)
○ Waze alert information (typically confidence score of 5 or above, but operator can choose)
PennDOT notes:
• Nothing additional.</td></tr>
<tr><td colspan="4">Detection Capabilities, Coverage and Environment</td></tr>
<tr><td rowspan="7">Traffic Incidents Detected
Detects presence of these incidents (Needs #1-12)</td><td colspan="2">Incident Type</td><td>Researcher notes from demonstration</td></tr>
<tr><td>Stopped Vehicle</td><td>☒</td><td></td></tr>
<tr><td>Extremely Slow Vehicle</td><td>☐</td><td>-</td></tr>
<tr><td>Congestion/ Slow Traffic</td><td>☒</td><td>INRIX can only provide congestion related data.</td></tr>
<tr><td>Non-vehicle object or entity (e.g., debris, pedestrian, animal)</td><td>☐</td><td>-</td></tr>
<tr><td>Queue (Location of front and back of traffic queue)</td><td>☒</td><td>Typically from Waze incident information and then an operator can view a nearby camera to see the head and tail of congestion.</td></tr>
<tr><td>Wrong-Way Vehicle</td><td>☐</td><td>-</td></tr>
</table>

<table>
<tr><td></td><td>Extreme Vehicle Speed</td><td>☐</td><td colspan="3">-</td></tr>
<tr><td></td><td colspan="5">Comments on traffic incidents detected by the product.
Researcher notes from demonstration:
• Other alert types include minor accident, major accident, and lane closed.
PennDOT notes:
• Nothing additional.</td></tr>
<tr><td>Coverage Limits for Detection
(Needs #5,6,8,13)</td><td colspan="5">Describe the product’s coverage area (e.g., all lanes of traffic, roadway shoulders, field of view, detection coverage distance).
Researcher notes from demonstration:
• Data is not available on Turnpikes, only on state routes.
PennDOT notes:
• The dashboard is geofenced around the “Core Roadway” network. Approximately, 4,000 miles of roadway that has been deemed operationally vital (major interstates and arterials).</td></tr>
<tr><td rowspan="6">Detection Conditions/ Environment
(Needs #14-17)</td><td colspan="3">Detection is functional in:</td><td colspan="2">Researcher notes from demonstration:</td></tr>
<tr><td colspan="2">• All lighting conditions (daylight, low light, dark)</td><td>☒</td><td colspan="2" rowspan="3">INRIX data is probe data and not affected by lighting, weather, or visibility conditions. Waze data is from individuals reporting incidents and not affected by conditions or the environment.</td></tr>
<tr><td colspan="2">• All weather conditions</td><td>☒</td></tr>
<tr><td colspan="2">• Low visibility not caused by weather events (e.g., smoke)</td><td>☒</td></tr>
<tr><td colspan="2">• All traffic conditions (free-flowing to extreme congestion)</td><td>☐</td><td colspan="2">-</td></tr>
<tr><td colspan="5">Provide any additional details about the detection environment.
Researcher notes from demonstration:
• Nothing additional.
PennDOT notes:
• Nothing additional.</td></tr>
<tr><td colspan="6">Alerts/Displays and Configuration</td></tr>
<tr><td>False Alerts
(Need #18)</td><td colspan="5">Demonstrate and discuss the product’s ability to minimize false alerts.
Researcher notes from demonstration:
• Users have the ability to configure the confidence and severity levels of the data sources.
PennDOT notes:
• There is machine learning built behind the dashboard, so if an operator selects a certain incident as a “false alert” it will eventually learn to omit or correctly place the incident for future iterations. Also, the system has correlation logic to accommodate multiple incident alerts from a variety of sources. This helps with verifying an incident because all sources are linked together within those logic constraints.</td></tr>
<tr><td>Notifications</td><td colspan="5">How are alerts provided to TMC operators or other users when an incident is detected? How can notifications be customized (e.g., email, text) for each recipient?</td></tr>
</table>

(Need #19)	Researcher notes from demonstration: • Alerts are provided within the dashboard interface. PennDOT notes: • In a real time feed, with the most recent update on top, and a delta that shows how long the incident duration is active since the first received alert (constantly refreshing). All columns of the dashboard feed are sortable.		
Operator Support and Configuration *(Needs #20-31)*	*This product allows users to:*		Researcher notes from demonstration:
	• Validate or dismiss incidents as they are received.	☒	
	• Configure incident alerts and displays uniquely for each individual user.	☒	• As the dashboard was developed, PennDOT ensured it could be configured with user-defined preferences.
	• Turn on and off alerts for each incident type.	☒	
	• Turn on and off alerts by roadway geometry (e.g., turn off shoulder alerts) and location (e.g., designate typical versus atypical traffic queues).	☒	• Users can turn on and off alerts from certain roadways or specific routes. Users can select their district or statewide.
	• Configure the duration from incident detection to incident alert.	☒	• Users can see the incident duration in two locations, directly on the feed alert and in the “real-time” incident timeline
	• Configure speed thresholds for detecting congestion or slow traffic.	☐	-
	• Configure thresholds for locating start/head and end/tail of traffic queues.	☒	Users can see the heads and tails of congestion with every incident iteration on the Google Map, and they can look back in time with the slider capability in the incident timeline feature to determine where congestion was throughout its duration.
	• Configure incident alerts in real-time and by pre-determined parameters.	☒	This is done on the back end through programmed logic
	• Prioritize alerts and allow real time filtering.	☐	-
	• Real-time information about incident timelines.	☒	There is the ability to create a real time incident timeline. Users can go to an incident timeline and play a video of timestamps to see for example the queue tail – becoming better or worse.
	• Re-classify incident events to change their priority level over time	☒	Priority levels will change as the source data arrives.

	Other decision support features (please explain): Researcher notes from demonstration: • Nothing additional. PennDOT notes: • When an operator enters a verified incident into their PennDOT RCRS (incident management), it joins with the crowdsourced incident data so they can see it's verified.
Time to Detection *(Need #32)*	*What is the amount of time elapsed from incident occurrence to detection?* Researcher notes from demonstration: • In 2018, PennDOT found that incidents were detected by INRIX within 7 minutes, by Waze within 9 minutes, and by PennDOT's RCRS within 13 minutes. INRIX typically picks up an incident first because INRIX is providing speed data. PennDOT notes: • Those are statewide values, and minutes vary less or more throughout the state.
Latency of Detection to Alert *(Need #33)*	*Comment on the latency of communicating alerts to TMC operators or other users, if applicable.* Researcher notes from demonstration: • TMC operators that use the dashboard are alerted as soon as an incident type is detected. PennDOT notes: • Nothing additional.
Integration with Agency Systems and Practices	
Use of Agency Equipment *(Need #34)*	*Does the system utilize existing DOT-owned equipment to perform detections? If yes, how? If no, what equipment is used and where is it housed?* Researcher notes from demonstration: • The dashboard uses the existing PennDOT RCRS. PennDOT notes: • RCRS is only used for verifying incidents.
Installation and Integration *(Needs #35,36, 40,42)*	*What is the installation/integration process?* Researcher notes from demonstration: • Not discussed during the demonstration. PennDOT notes: • Design and development time for the user interface and to understand the data properly coming from INRIX and Waze. Significant effort was spent designing the logic and business rules for incident correlation/reducing duplicate alerts. System resides on PennDOT servers and is web-based, so nothing needs installed on an end user's computer. *How can the product be integrated with agency systems such as Advanced Traffic Management Software (ATMS)?* Researcher notes from demonstration: • Not linked to PennDOT's ATMS yet, however it is being considered. PennDOT notes: • Nothing additional.

	What physical space is required at agency facilities for equipment and data storage? Researcher notes from demonstration: • N/A PennDOT notes: • See above. *If applicable, how is storage and periodic purging of video handled?* Researcher notes from demonstration: • Not discussed during the demonstration. PennDOT notes: • We do not store video on the traffic alerts website, but we do store incidents for certain lookback periods. Those are predefined with some residing in the production database and after a week they can be retrieved from the system archive database. PennDOT's TSMO Performance Program keeps all incidents from Waze and INRIX indefinitely if further analysis is needed.
Calibration *(Need #37-39)*	*Describe how the system is pre-calibrated by the vendor prior to agency deployment, any ongoing calibration needs, and self-calibration capabilities.* Researcher notes from demonstration: • For each data source, users can configure the confidence and incident type severity as applicable. PennDOT notes: • Nothing additional.
Health Monitoring *(Need #41)*	*Describe how the product monitors the operability of its components and field equipment.* Researcher notes from demonstration: • Not discussed during the demonstration. PennDOT notes: • No field equipment is used.
Use by Transportation Agencies / Case Studies	
List the transportation agencies (and contacts if available) that currently use your AID product. Provide web links to case studies or other documentation featuring agency use of the product. Researcher notes from demonstration: • Used by PennDOT only. The dashboard was developed in house for use by PennDOT. PennDOT notes: • Used by 7 traffic management centers for 24/7 operations. There are plans potentially switching the system over to allow off-network access to grant capabilities to other public partners (i.e. City TMCs). Additional cost to add this capability since it was designed differently upon inception.	
Other Product Highlights	
Describe any additional product highlights if not previously noted. Researcher notes from demonstration: • The system can generate various reports for use in after action reviews. However, this does not have an export function yet. PennDOT notes: • Nothing additional.	

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