TSMO BENEFIT-COST REFERENCE

June 18, 2024

Overview

This memo serves as a quick reference for benefit-cost information on TSMO applications that are critical to MoDOT's TSMO program and future work. It pulls information from national and peer research on TSMO benefits and costs. This memo covers the following categories of TSMO applications:

1. **Work Zone Management and Technologies**
2. **Traffic Incident Management (TIM)**
3. **Traffic Signal Retiming and Coordination**
4. **Data Management**
5. **Artificial Intelligence (AI) and Machine Learning (ML)**
6. **Road Weather Management**
7. **Detection-based Warnings and Automated Decision Support**
8. **Connected Vehicles / Vehicle-to-Everything (V2X) Technologies**

Key Resources

This memo pulls information from the following key resources:

- USDOT ITS JPO: Benefits Database
- ODOT TSMO Countermeasure Study
- FHWA TSMO Benefit-Cost Analysis Compendium

Work Zone Management and Technologies

Work zone management and technologies cover a range of TSMO applications to improve safety and reliability around work zones. Typical B/C ratios for ITS applications in work zones are 2:1 or higher depending on the application[1].

Application	Description	Goals	Typical Benefits	Typical Costs	Typical B/C	B/C Research Availability
Queue Warning System[2]	Devices (e.g., Dynamic Message Signs, flashing lights) that warn drivers of upcoming slow or stopped traffic	Safety: Crash reduction	14% to 45% reduction in crashes	- Minnesota: $15M or $3.75M per mile on 1-95 - West Virginia: $85k for fog warning - Florida: $26M for mobile warning system	1.6/1 – 2.4/1	High
Truck Mounted Radar Speed Sign[3]	Radar speed sign mounted on a truck, such as a slow-moving maintenance truck to alert drivers if their speed exceeds the work zone limit	Safety: Speed reduction in work zones	5% to 23% reduction in traffic speeds, vs. 4% to 8% in work zones without them (2016)			Low
Automated Speed Enforcement (ASE) in work zones	Speed cameras that automatically photograph a vehicle's license plate and sent a speeding ticket if driver is speeding, deployed in work zones and other areas where speeding is a problem.	Safety: Reduction in speeding, crash reduction, heightened attention	- California: 6% reduction in speeding in work zone (2016)[4] - Mobile ASE: 19% reduction in total crashes, 64% decrease in speeding over 10mph (2010)[5]	- Depends on equipment and operating costs, often "turnkey" and negotiated with vendor - Most research estimates for large scale ASE systems	4/1 for the UK's national ASE system (2004)[6]	High for permanent ASE, Medium for work zone / mobile ASE
Automated Truck-Mounted Attenuator (TMA)	Fully automating the driving of TMAs, to remove human drivers from these high crash risk vehicles.	Safety: Removes crash risks for human TMA drivers	- Missouri: TMA system effectively managed gap distance[7] - Florida: $273k in crash savings over traditional TMA (2021)[8]	- Missouri: $301,485 per unit (published 2023)[9] - Florida: $295k per unit (2021)[10]		Medium

[1] USDOT, Roadway Operations & Maintenance: Work Zone Management, 2017, https://www.itskrs.its.dot.gov/sites/default/files/executive-briefings/2017/BCLL_ROADWAY_WORKZONE_2017.pdf
[2] Entire Row: Ohio DOT, *Transportation Systems Management & Operations Study Guidebook*, April 2020, page 36.
[3] Entire Row: ITS JPO Benefits Database, *Truck-mounted radar speed signs were effective in reducing traffic speeds by 5 to 23 percent versus reductions of 4 to 8 percent in work zones without them*, January 2016, https://www.itskrs.its.dot.gov/2017-b01170.
[4] ITS JPO Benefits Database, *Augmented speed enforcement system in work zone significantly reduced the number of vehicles traveling in excess of 65 mph*, January 2013, https://www.itskrs.its.dot.gov/2015-b01056
[5] NHTSA, Speed Safety Camera Enforcement, https://www.nhtsa.gov/book/countermeasures-that-work/speeding-and-speed-management/countermeasures/enforcement/speed-safety-camera-enforcement
[6] Ibid.
[7] ITS JPO Benefits Database, Missouri Study Indicated That the Leader-Follower Truck Mounted Attenuator (TMA) System Effectively Managed Gap Distance, with an Average Gap Distance Difference between Actual and Desired Being -3.21 Feet for Mobile Work Zones in Kansas City, March 2023, https://www.itskrs.its.dot.gov/2023-b01787.
[8] ITS JPO Benefits Database, ATMA in Mobile Work Zones in Gainesville, Florida Reveals an Estimated Crash Savings of $273,080 When Deployed instead of Traditional Truck-Mounted Attenuators, 2021, https://www.itskrs.its.dot.gov/2023-b01764.
[9] ITS JPO Benefits Database, Missouri DOT's V2V-Enabled Truck Mounted Attenuator Leader-Follower System Was Estimated to Cost $301,485 Per Unit, Considering System Integration, Maintenance and Support, and Training Costs, March 2023, https://www.itskrs.its.dot.gov/2024-sc00551
[10] ITS JPO Benefits Database, *The Estimated Technology Procurement and Deployment Cost of an Automated Truck-Mounted Attenuator System for Mobile Work Zone Operations was $295,000*, March 2021, https://www.itskrs.its.dot.gov/2023-sc00537.

Traffic Incident Management (TIM)

TIM strategies include a range of technologies, processes, and partnerships to respond to crashes and incidents with greater efficiency and safety for both responders and travelers.

Application	Description	Goals	Typical Benefits	Typical Costs	Typical B/C	B/C Research Availability
TIM Systems or Programs	TIM systems or programs integrate a variety of technologies and processes to monitor the transportation system, respond to incidents, and share traveler information[11]. This constitutes a more comprehensive and formalized approach to TIM and other TSMO activities.	Mobility: Reduced incident-related delay, improved traveler information Safety: Reduced secondary crashes and responder incidents Environmental: Reduced emissions	- GA NaviGAtor system: Over $187M in annual savings due to reduced incident delay, emissions, and secondary crashes (2004)[12] - MD Coordinated Highways Action Response Team (CHART): Over $961M in annual savings due to reduced delay, secondary crashes, fuel consumption, and emissions (2012)[13] -Broward County, FL SMART SunGuide TMC: 4% reduction incident clearance times; 18% reduction roadway clearance times (2006)[14]	- GA NaviGAtor system: $42.5M in annual costs (2004)[15] - Note that the MD CHART analysis did not focus on calculating annual costs.	- GA NaviGAtor: 4.4/1 (2004)[16]	Medium (but almost 20 years old (2004))
Towing and Recovery Incentive Programs (TRIP)	Incentive programs for pre-certified, targeted recovery operators to clear incidents within a set time (e.g. a monetary bonus for heavy-duty recovery companies)	Mobility: Reduced incident-related delay	-GA DOT: 80% reduction in roadway clearance time due to TRIP for heavy duty recovery companies (2018)[17]			Low
Aerial drone imagery for TIM	Using drones to collect aerial imagery of incidents to improve information available for decision-making	Mobility: Reduced incident-related delay	-WA State Patrol: 75% reduction in road closure times, saving $350/minute (2022)[18] -NC State Highway Patrol: 50% reduction in clearance times (2017)[19]			Low

[11] FHWA, TSMO Benefit-Cost Analysis Compendium, Case Study 6.6 Georgia Navigator TIM System, 2015, https://ops.fhwa.dot.gov/publications/fhwahop14032/ch6.htm#66
[12] Ibid.
[13] FHWA, TSMO Benefit-Cost Analysis Compendium, Case Study 6.5 Coordinated Highways Action Response Team, Maryland, 2015, https://ops.fhwa.dot.gov/publications/fhwahop14032/ch6.htm#65
[14] ITS JPO Benefits Database, In Broward County, Florida, the 2006 analysis for the SMART SunGuide TMC roadway and incident clearance times showed reductions of 18 percent and 4 percent respectively over 2005, July 31 2009, https://www.itskrs.its.dot.gov/2009-b00603
[15] FHWA, TSMO Benefit-Cost Analysis Compendium, Case Study 6.6 Georgia Navigator TIM System, 2015, https://ops.fhwa.dot.gov/publications/fhwahop14032/ch6.htm#66
[16] Ibid.
[17] ITS JPO Benefits Database, Georgia Department of Transportation's (GDOT) Towing and Recovery Incentive Program (TRIP) Can Reduce Clearance Times by 80 Percent, January 9, 2023, https://www.itskrs.its.dot.gov/2023-b01706
[18] ITS JPO Benefits Database, A Report Shows Unmanned Aircraft Systems Can Reduce Road Closure Times by 75 Percent When Deployed for Traffic Incident Management (TIM) saving $350 per minute, January 9, 2023, https://www.itskrs.its.dot.gov/2023-b01704
[19] ITS JPO Benefits Database, A field test of an aerial drone equipped with 3-D imaging technology enabled investigators to reconstruct a crash scene in 25 minutes versus two hours using a conventional method; results suggest clearance times can be cut by more than 50 percent, May 31, 2018, https://www.itskrs.its.dot.gov/2018-b01258.

Traffic Signal Retiming and Coordination

Traffic Signal Retiming and Coordination includes initiatives and technologies to update traffic signal timing plans and improve coordination.

Application	Description	Goals	Typical Benefits	Typical Costs	Typical B/C	Research Availability
Traffic Signal Retiming[20]	Updating the timing plans for one signalized intersection or a corridor of intersections based on latest traffic volumes. Recommended every few years or after changes to the transportation systems or land use impacting a given area.	- Mobility: Reduction in travel time and delay -Fuel: Reduction in fuel and vehicle costs for travelers	5% to 25% reduction in travel time; 2% to 15% reduction in vehicle operations costs	On average $3,000 per intersection	55/1 to 62/1	High
Traffic Signal Coordination[21]	Coordinating traffic signal timing along a corridor to allow for a “green wave” of vehicles traveling through a sequence of lights; optimizing the split/offset to allow for progressive traffic flow.	-Mobility: Reduction in travel time and delay -Fuel: Reduction in fuel and vehicle costs for travelers	11.4% to 30% reduction in travel time; 7.8% reduction in fuel costs	On average $7,000 per intersection	Limited B/C data noted in ODOT study	Medium
Adaptive Traffic Signal Control	Coordinating traffic signal timing across a signal network, based on real-time detector data to accommodate current, prevailing traffic patterns.	-Mobility: Reduction in travel time -Fuel: Reduction in fuel and vehicle costs for travelers	NC: ~$112k to $120k in annual cost savings per intersection in the corridor; 6% to 9% reduction in weekday travel time (prior to 2015)[22] -CO study: $112,300 annual cost savings per intersection (prior to 2015)[23]	-NC: $22k to $82.3k install cost per intersection (prior to 2015)[24] -CO study: $22k install cost per intersection (prior to 2015)[25]	-NC: 1.58/1 to 5.64/1[26] -CO study: 5.64/1[27]	Medium

[20] Entire Row: Ohio DOT, *Transportation Systems Management & Operations Study Guidebook*, April 2020, page 40, 24..

[21] Entire Row: Ohio DOT, *Transportation Systems Management & Operations Study Guidebook*, April 2020, page 41, 24.

[22] FHWA, TSMO Benefit-Cost Analysis Compendium, Case Study 5.2 Adaptive Traffic Signal Control in Greely and Woodland Park, Colorado, 2015, https://ops.fhwa.dot.gov/publications/fhwahop14032/ch6.htm#52

[23] FHWA, TSMO Benefit-Cost Analysis Compendium, Case Study 5.3 Adaptive Traffic Signal Control, 2015, https://ops.fhwa.dot.gov/publications/fhwahop14032/ch5.htm#51

[24] FHWA, TSMO Benefit-Cost Analysis Compendium, Case Study 5.2 Adaptive Traffic Signal Control in Greely and Woodland Park, Colorado, 2015, https://ops.fhwa.dot.gov/publications/fhwahop14032/ch5.htm#51

[25] FHWA, TSMO Benefit-Cost Analysis Compendium, Case Study 5.3 Adaptive Traffic Signal Control, 2015, https://ops.fhwa.dot.gov/publications/fhwahop14032/ch5.htm#51

[26] FHWA, TSMO Benefit-Cost Analysis Compendium, Case Study 5.2 Adaptive Traffic Signal Control in Greely and Woodland Park, Colorado, 2015, https://ops.fhwa.dot.gov/publications/fhwahop14032/ch5.htm#51

[27] FHWA, TSMO Benefit-Cost Analysis Compendium, Case Study 5.3 Adaptive Traffic Signal Control, 2015, https://ops.fhwa.dot.gov/publications/fhwahop14032/ch5.htm#51

Data Management (Page 1 of 2)

Data Management covers a variety of strategies for improving, augmenting, and managing how operations data is collected, stored, and shared.

Application	Description	Goals	Typical Benefits	Typical Costs	Typical B/C	Research Availability
Electronic Crash Reporting Systems	Electronic data capture solutions for crash information, citation data, and related personal contacts. This makes it simpler to link crash data with roadway inventory and traffic volume data.[28]	- Efficiency: Eliminated paper reporting and associated manual data entry, supporting simultaneous access by multiple agencies	SC DOT: Electronic crash system reduced police investigation time by 63% and decreased average report processing time by 85% (2016)[29] Iowa DOT: Officer-generated crash reports received electronically increased to 68% from 47% as a result of making data reporting and analysis tools available to local law enforcing agencies (2005)[30]	Iowa DOT: $275,000 for computer hardware and peripherals (2005)[31]	-	Medium
Open-Source Data and Crowdsourced Data	Three common sources of crowdsourced data are social media platforms, third-party crowdsource providers, and specially developed mobile apps. These data, which includes information related to speed, travel time, incident type, travel behavior, public sentiment, vehicular operation, can be passively or actively transmitted and may be quantitative or qualitative in nature.	-Efficiency: Better traveler information, could reduce the need for installing and maintaining additional roadway sensors -Safety and Reliability: faster and more accurate responses to incidents	Colorado DOT: Operators have reported a 5- to 10-minute reduction in response times[32]	-	-	Medium

[28] ITS JPO Benefits Database, "South Carolina DOT's Electronic Crash System Reduced Police Investigation Time by 63 Percent and Decreased Average Report Processing Time by 85 Percent," April 30, 2021, https://www.itskrs.its.dot.gov/2021-b01556
[29] Ibid.
[30] ITS JPO Benefits Database, "Officer-generated crash reports received electronically into the statewide crash database increased to 68 percent from 47 percent as a result of making data reporting and analysis tools available to local law enforcing agencies," January 2, 2005, https://www.itskrs.its.dot.gov/2013-b00882
[31] Ibid.
[32] FHWA, Crowdsourcing for Advancing Operations Fact Sheet, 2020, https://www.fhwa.dot.gov/innovation/everydaycounts/edc_6/docs/crowdsourcing_factsheet_edc6.pdf

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Application	Description	Goals	Typical Benefits	Typical Costs	Typical B/C	Research Availability
Automated Traffic Signal Performance Measures (ATSPM)	A suite of performance measures, data collection and data analysis tools to support objectives and performance-based approaches to traffic signal operations, maintenance, management and design.[33]	-Safety: Identification of locations with potential safety issues, discovery, repair, and resolution of failed detectors, broken communication, inefficient green distribution, poor coordination, pedestrian operational issues -Efficiency: Avoidance of manual data collection and unneeded retiming/maintenance activities, reduced public complaint response time	-Georgia DOT: $9.5 M in total savings due to manual data collection avoided and complaint response time reduction -Utah DOT: $107.9 M in total savings due to manual data collection avoided, complaint response time reduction, quicker response to failed detection, signalized intersection capacity and progression benefits -Cranberry Township, PA: $1.7 M total savings due to manual data collection avoided, scheduled maintenance avoided, complaint response time reduction -Maricopa County, AZ DOT: $1.5 M total savings due to manual data collection avoided, scheduled maintenance avoided, complaint response time reduction -Lake County, Illinois DOT: $4 M total savings due to manual data collection avoided, complaint response time reduction (All benefits in this cell published 2020 and from the same source[34])	-	-	High

[33] FHWA, Automated Traffic Signal Performance Measures webpage, 2024, https://ops.fhwa.dot.gov/arterial_mgmt/performance_measures.htm#:~:text=Automated%20Traffic%20Signal%20Performance%20Measures%20%28ATSPMs%29%2C%20included%20in,and%20efficiency%20of%20signalized%20intersections%20for%20all%20users.

[34] ITS JPO Benefits Database, “An Automated Traffic Signal Performance Measures (ATSPM) Maintenance Program Implemented by Utah DOT Was Projected to Save $108 Million In Reduced Agency Labor Costs And Improved Operations Over 10 Years”, March 29, 2021, https://www.itskrs.its.dot.gov/2021-b01544

Artificial Intelligence (AI) and Machine Learning (ML)

Early AI and ML applications for TSMO have shown promise to increase efficiency and accuracy in areas such as incident detection and traffic signal coordination.

Application	Description	Goals	Typical Benefits	Typical Costs	Typical B/C	Research Availability
AI for incident detection	AI-based platforms and real-time data analyses have the ability to detect roadway crashes at a higher rate, and facilitate faster validation which leads to reduced emergency response[35]	-Safety: Enhanced incident response and prediction, improved video detection to avoid conflicts	NV: Uncovered 20% more crashes than previously reported and reduced crash response times by nine to ten minutes on average (2020)[36] Southern NV: average reduction in incident response times of 12 minutes (2019)[37]	-	-	Low
AI for traffic signal timing and coordination	AI can be used to service all modes of transportation by predicting vehicle and pedestrian arrivals, queues, and delays	-Safety: Enhanced incident response and prediction, improved video detection to avoid conflicts -Efficiency: Identify strategies that optimize systems and allocate scare resources -Mobility: Potential to reduce congestion with big-data insights	FDOT: Resulted in an overall travel time reduction of 9.36% for eight corridors NV: Contributed to a 17% reduction in primary crashes (2020)[38] Alcalá de Henares, Spain: Reduced serious pedestrian-vehicle conflicts by 20% (2016)[39]	-	-	Medium

[35] ITS JPO Benefits Database, Artificial Intelligence based Roadway Safety and Work Zone Detection Technology in Nevada Uncovered 20 Percent More Crashes Than Previously Reported and Reduced Crash Response Times by Nine to Ten Minutes on Average, April 21, 2022, https://www.itskrs.its.dot.gov/2022-b01642
[36] Ibid.
[37] ITS JPO Benefits Database, Southern Nevada has seen an average reduction in incident response times of 12 minutes since using a proprietary, cloud-based artificial intelligence (AI) system, March 20, 2020, https://www.itskrs.its.dot.gov/2020-b01447
[38] ITS JPO Benefits Database, Artificial Intelligence based Roadway Safety and Work Zone Detection Technology in Nevada Uncovered 20 Percent More Crashes Than Previously Reported and Reduced Crash Response Times by Nine to Ten Minutes on Average, April 21, 2022, https://www.itskrs.its.dot.gov/2022-b01642
[39] ITS JPO Benefits Database, A prototype intelligent pedestrian traffic signal system tested at an intersection in Alcalá de Henares, Spain reduced serious pedestrian-vehicle conflicts by 20 percent, January 26, 2018, https://www.itskrs.its.dot.gov/2018-b01231

Road Weather Management (Page 1 of 2)

Road Weather Management strategies improve mobility, reliability, and safety during weather events through strategies such as targeted traveler information, warnings, and operational interventions including Variable Speed Limits (VSL)

Application	Description	Goals	Typical Benefits	Typical Costs	Typical B/C	Research Availability
Road Weather Warnings/Alerts and Dynamic Message Signs (DMS)	Displays real-time information to warn motorists of roadway incidents, construction or congestion ahead that could pose a hazard or cause delay	Safety: reduction in average speed	Minnesota: Up to a 1.5-mph reduction in average speed and 2.0-mph reduction in 85th-percentile speed (2021)[40] Michigan: 5.66 mph reduction in speed (2022)[41]	-	West Virginia: 1.57/1 for fog warning (2012)[42] Michigan: 1.012/1 considering travel time savings benefits and DMS installation and maintenance costs (2022)[43]	Medium
Variable Speed Limits (VSL)	Works by dynamically changing posted speed limits to reflect current road conditions. VSL systems use sensors to detect freeway congestion or weather conditions and algorithms to determine how, when, and where to implement temporary changes in speed limits.	-Safety: reduction in crashes and increased driver compliance -Efficiency: faster clearance times	Ohio: Crashes during snow events declined 42% after winter season, incident clearance times have been reduced by 31 minutes on average (2020)[44] Utah: Decreased crashes by approximately 50% and increased driver compliance by 9% (2021)[45] Florida: Can reduce rear-end crash risk under fog conditions by 48.7% (2018)[46]	-	-	Medium

[40] Dynamic Message Signs Displaying Weather Alerts Based on Roadside Pavement Sensors Were Associated with Up to a 1.5-mph Reduction in Average Speed and 2.0-mph Reduction in 85th-Percentile Speed. | ITS Deployment Evaluation (dot.gov)
[41] Evaluation of Existing Digital Message Signs in Michigan Revealed a 5.66 mph Reduction in Speed after Seeing the Weather-Related Message on Traffic Speeds. | ITS Deployment Evaluation (dot.gov)
[42] West Virginia's Fog Detection and Warning System Was Estimated to Result in a Benefit-Cost Ratio of 1.57, Based on Crash Data. | ITS Deployment Evaluation (dot.gov)
[43] Evaluation of Existing Digital Message Signs in Michigan Revealed a 5.66 mph Reduction in Speed after Seeing the Weather-Related Message on Traffic Speeds. | ITS Deployment Evaluation (dot.gov)
[44] Crashes during Snow Events Declined 42 Percent after Winter Season Variable Speed Limit Corridor Implementation in Ohio. | ITS Deployment Evaluation (dot.gov)
[45] Changing Variable Speed Limit Signs from White to Amber Legend Decreased Crashes by Approximately 50 Percent and Increased Driver Compliance by Nine Percent in Utah. | ITS Deployment Evaluation (dot.gov)
[46] Simulation Study Estimates a Combination of Connected Vehicle Control and Variable Speed Limit Strategies Can Reduce Rear-End Crash Risk under Fog Conditions by 48.7 Percent. | ITS Deployment Evaluation (dot.gov)

Road Weather Management (Page 2 of 2)

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Application	Description	Goals	Typical Benefits	Typical Costs	Typical B/C	Research Availability
Road Weather Information Systems (RWIS)	Measure real-time atmospheric parameters, pavement conditions, water level conditions, visibility, and sometimes other variables. Comprises Environmental Sensor Stations (ESS) as they also cover non-meteorological variables in the field, a communication system for data transfer, and central systems to collect field data from numerous ESS.	Safety: reduction in crashes	Montana DOT: Improved forecasting accuracy by 32% (2022)[47] Montana: Estimated to save up to $2.2 M in crash occurrence and delay costs (2017)[48]	-	Montana: 20.5/1 – 36/1 using the current RWIS sites (2017)[49]	Medium

[47] A Statewide Adverse Weather Forecasting Model in Montana Using Road Weather Information System Measurements Improved Forecasting Accuracy by 32 Percent. | ITS Deployment Evaluation (dot.gov)
[48] Analysis of Road Weather Information System Enhancements and Expansion in Montana Estimated to Save up to $2.2 Million in Crash Occurrence and Delay Costs. | ITS Deployment Evaluation (dot.gov)
[49] Ibid.

Detection-based Warnings and Automated Decision Support

Detection-based Warnings and Automated Decision Support are two categories of TSMO applications that leverage sensors and automation to increase impact and accuracy, as well as decrease the load on human operators.

Application	Description	Goals	Typical Benefits	Typical Costs	Typical B/C	Research Availability
Detection-based Driver Warning (Intersection Warning)	Technologies that improve motorist awareness of an inclement condition when that condition is present. It includes curve warning systems that measure a vehicle's speed in advance of a curve and, if exceeding the curve's advisory speed, will notify the vehicle by flashing beacons. These strategies tend to be applied in isolated parts of the network that has a particular crash history type.	Safety: reduction in crashes	77% reduction in crashes	$24,500 per site[50] Minnesota DOT: $14,000 for a dynamic curve speed warning sign with solar power and radar detection Iowa State University: Dynamic speed signs cost from $2,000 to $11,000 per display. (2014 dollars) FHWA: Dynamic Speed Feedback Signs on Curves costs less than $10,000 per sign including installation, support, and maintenance (2015 dollars)[51]	2.79/1 - 5.57/1 (curve warning)[52]	High
Automated Decision Support for Traffic Incident Management (TIM)	Technologies that provide automated decision support for TIM, these include: Automated Incident Detection, Computer Aided Dispatch (CAD) for TIM, and Automated Vehicle Location	Efficiency: faster clearance times	Arizona: Incident clearance times were reduced by 32%[53]	Texas DOT: Vehicle Detection and Cameras cost $9000/device and $500 annual; Automated Incident Detection System cost $1,000/Camera and $100 annual[54]	-	Low

[50] ODOT, Transportation Systems Management & Operations Study Guidebook | Ohio Department of Transportation (ohio.gov)
[51] Ibid.
[52] Ibid.
[53] ITS JPO, Next General Traffic Incident Management, Executive Briefing, 2022, https://www.itskrs.its.dot.gov/sites/default/files/2023-03/executive-briefing/2022%20Executive%20Briefing_Next%20Generation%20Traffic%20Incident%20Management_final%20508_03_13_23.pdf
[54] Ibid.

Connected Vehicle (CV) / Vehicle-to-Everything (V2X) Technologies

CV and V2X technologies leverage wireless communications between infrastructure and technologies to relay traveler information, safety warnings, and more.

Application	Description	Goals	Typical Benefits	Typical Costs	Typical B/C	Research Availability
CV/V2X Applications for Road Weather Manageme-nt	Leveraging CV/V2X communications to enhance and improve the performance of Road Weather Management strategies	-Safety: Reduce crashes via weather alerts and speed reductions -Mobility: Reduce congestion, increase reliability	Salt Lake City, UT: V2X equipped corridors and connected snowplows resulted in 3.87% reduction in crash rates, travel speeds closer to the speed limit, and successful snowplow signal preemption (2022)[55] WY CV Pilot: Over 50% of drivers given a winter weather alert reduced their speed; 60% for High Wind Alerts (2022)[56]	-	-	Medium
Speed Limit Warnings	CV/V2X communications to directly warn drivers about speed limits or variable speed limits	-Safety: Reduce crashes	- Columbus, OH: School zone speed limit warnings increased compliance from 18% to 56% (2021)[57] - NYC CV Pilot: Speed limit warnings increased compliance by 16% (2022)[58]	- US: $20k-$52k per Km to deploy roadside unit network (2020)[59] - Columbus, OH Smart City Challenge: $11.4 M for 1-year demo (2021)[60]	-	Medium
Other Warnings	Using CV/V2X communications to directly warn drivers of safety risks or congestion	-Safety: Reduce crashes -Mobility: Reduce congestion, increase reliability	Tampa, FL CV Pilots: Wrong-way driving alerts successfully avoided 14 potential wrong-way crashes[61]; Forward Collision Warnings decreased forward collision conflicts by 9%; entire program decreased travel time by 30%(2021)[62]		-	Medium

[55] ITS JPO Benefits Database, "Field Study Shows Routes of Connected Snowplows Had a Larger Reduction in Roadway Crash Rates (up to 3.87) than their Non-Equipped Counterparts (1.82)", May 26, 2023, https://www.itskrs.its.dot.gov/2023-b01752

[56] ITS JPO Benefits Database, "The Wyoming CV Pilot Found that Over 50 Percent of Drivers Given a Work Zone or Winter Weather Alert Reduced their Speed," April 3, 2023, https://www.itskrs.its.dot.gov/2023-b01735

[57] ITS JPO Benefits Database, "Connected Vehicle Technology Implementation in Columbus Increased Compliance of Posted School Zone Speed Limits From 18 Percent to 56 Percent", August 30, 2022, https://www.itskrs.its.dot.gov/2022-b01674

[58] ITS JPO Benefits Database, "Connected Vehicle Speed Limit Warnings Increased Speed Compliance by 16 Percent During a Pilot Test in New York City", November 28, 2022, https://www.itskrs.its.dot.gov/2022-b01691

[59] ITS JPO Costs Database, "The Cost To Implement a Roadside Unit (RSU) Network With One Kilometer (Km) RSU Spacing Can Range From $20,000 to $52,000 per Km", March 30, 2023, https://www.itskrs.its.dot.gov/2023-sc00530

[60] ITS JPO Benefits Database, "The Total Deployment and Operations Cost of a Connected Vehicle Technology Implementation in Columbus, Ohio over a One-Year Demonstration Period Was Estimated to Be $11,374,200," September 15, 2022, www.itskrs.its.dot.gov/2022-sc00515

[61] ITS JPO Benefits Database, "Connected Vehicle Pilot in Tampa Successfully Alerted Drivers in 14 Potential Wrong-Way Ramp Entries and Nine Potential Trolley Crashes over 18 Months," March 31, 2021, https://www.itskrs.its.dot.gov/2021-b01550

[62] ITS JPO Benefits Database, "Tampa Connected Vehicle Pilot Showed a Nine Percent Decrease in Rate of Forward Collision Conflicts and a Nearly 30 Percent Reduction in Travel Times," July 21, 2021, https://www.itskrs.its.dot.gov/2021-b01583