National Operations Center of Excellence

NOCoE Best Practices: Arterial Management Control Strategies

Report #10

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Introduction

OVERVIEW

Arterial roadways are a significant portion of the highway network, especially in urban areas. There are many benefits to a Transportation Systems Management and Operations (TSMO) program focused on control strategies for signalized corridors to improve travel time and reliability; multimodal system efficiency; cost-effectiveness; and importantly, road safety. These outcomes benefit transportation agencies and the traveling public.

The AASHTO *Transportation Operations Manual* (TOM) includes Chapter 21: Arterial Management as the primary focus point on this topic. Other related information on arterial management are available in:

- Chapter 13: Performance-Based Practical Design (PBPD)
  - 13.4: Analysis Methods
  - 13.5.2: Integration with TSMO | Arterial Operations
  - 13.7.3: Examples of PBPD TSMO Projects | Innovative Intersections
  - 13.7.5: Examples of PBPD TSMO Projects | Active Traffic Management
- Chapter 14: Performance Measures for Operational Improvements
  - 14.2: Performance Measures
  - 14.3: Reorientation to Improving Performance
- Chapter 18: Overview of Tactical Elements
  - 18.4.3: Tactic Categories | Arterial Management

A number of leading approaches to arterial management have moved into mainstream application:

- **Automated Traffic Signal Performance Measures (ATSPMs):** Data-driven tools leveraging high-resolution signal controllers to log state changes and vehicle detections as they occur to provide proactive, real-time monitoring to revise timing as needed.
- **Crowdsourced Traffic Analytics and Data-Driven Operations:** Uses anonymized mobility data to rapidly identify congestion hot spots and prioritize signal retiming initiatives without costly fieldwork.**:**
- **AI Adaptive Signal Control Technologies (ASCT):** Replaces fixed signal timing with real-time adjustments based on traffic demand, reducing vehicle delay by 10 to 30 percent.
- **Active Corridor Management:** Integrates traveler information, dynamic lane reversals, and incident management to balance demand across regional networks.
- **Arterial Preservation Program:** Comprehensive approach to revise signal timing, make intersection improvements, update technology, limit curb cuts and optimize access points to prevent development-related bottlenecks.

Concepts

AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES

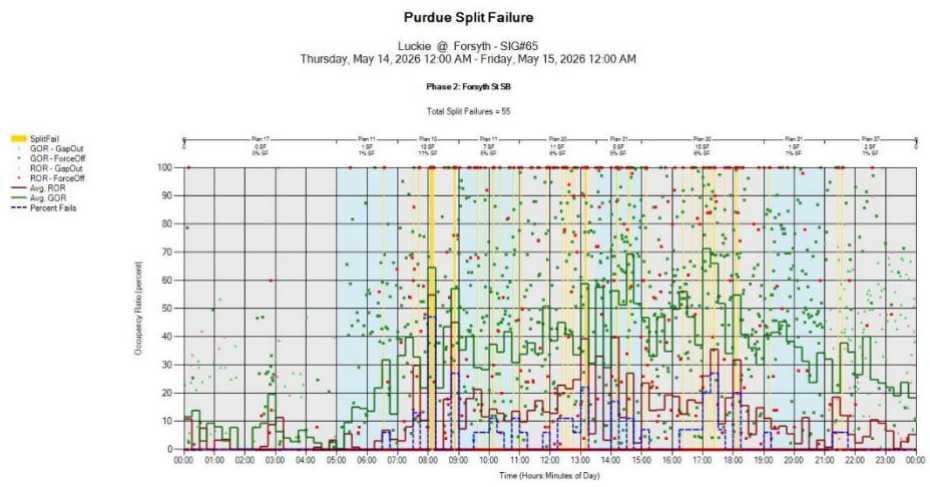
ATSPMs are high-resolution data systems that continuously collect, analyze, and visualize traffic data at signalized intersections. They enable agencies to make proactive, data-driven decisions to optimize signal timing, reduce delays, and improve corridor mobility. Traditional traffic signal management is typically reactive, relying on occasional studies or public complaints. ATSPMs improve upon these approaches by using high-resolution logging to collect data at fraction of a second intervals using existing traffic sensors and traffic signal controllers. This is continuously monitored to gather real-time performance data on vehicle volume, roadway approach speeds, wait times, and pedestrian/cyclist delays. The raw data is analyzed using visualization tools to diagnose issues at intersections along an arterial corridor such as *Purdue Coordination Diagrams and Split Monitor* reports[1].

Key Benefits:

Safety: Helps reduce rear-end collisions and congestion-induced safety risks.

Reduced Delay: Lowers overall stop-and-go conditions by maximizing green-light synchronization.

Cost Efficiency: Reduces the high cost of manual traffic counts and simulation modeling.



Source: Georgia DOT, *ATSPM web page*, 2025.

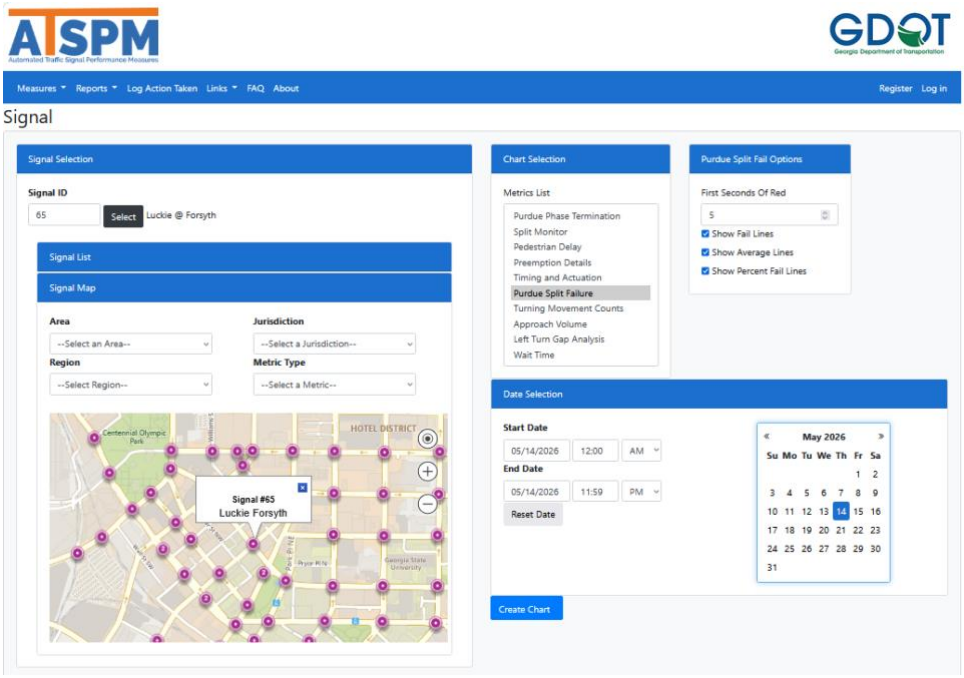
Sample Purdue Traffic Signal Timing Split Failure Chart

ATSPMs reduce traffic congestion by providing tools to proactively retime signals. Instead of waiting 3 to 5 years between retiming efforts, engineers can continuously monitor the network and modify signal timing splits based on actual demand.

[1] Georgia Department of Transportation, *Automated Traffic Signal Performance Measures Component Details*, (Atlanta, GA: Atkins North America), January 23, 2023, pg. 13 and pg. 23.

This approach identifies unused green time so that excess capacity is redirected to congested approaches where bottlenecks may exist. In addition, the equipment monitoring function(s) will alert traffic signal program managers automatically if intersection detection or pedestrian push buttons fail and maintenance is necessary, ensuring signals do not default to inefficient, pre-timed background signal timing.

Over the past several years there has been a large body of knowledge created on this topic and open-source software available through FHWA and leading agencies such as Utah DOT and Georgia DOT. Pennsylvania DOT, Maricopa County (AZ), Clark County (WA), Seminole County (FL), and Portland (OR) Bureau of Transportation have been leading implementors. *The Performance-Based Management of Traffic Signals*, National Cooperative Research Highway Research (NCRHP) Research Report 954 and *Automated Traffic Signal Performance Measures: Management, Operations and Maintenance* NCHRP Synthesis Report 659 provide the full background to the strategy.



Source: Georgia DOT, *ATSPM web page*, 2025.

Georgia DOT ATSPM Web Page

More recently the City of Moorhead, MN and the City of Manchester, NH each received FY2024 US DOT SMART Grants to create integrated advanced traffic management systems, integrate ATSPMs, improve traffic redistribution and routing with additional detection. In addition, one project is advancing transit signal priority and the other integrating connected vehicle technology. The goals are to enhance transportation safety, improve travel time reliability, reduce delays, and improve systemwide resiliency while improving emissions, safety, and communications.

CROWDSOURCED TRAFFIC ANALYTICS AND DATA-DRIVEN OPERATIONS

Background

Crowdsourcing merges the words "outsourcing" and “crowd” together as practice of acquiring, in the road transportation context, data or content by soliciting and receiving contributions from a large, dispersed group of people, typically through some sort of electronic data exchange. This allows organizations to tap into collective information to create knowledge and solve complex problems efficiently. Crowdsourcing data enables transportation agencies to cost effectively apply proactive strategies to improve their situational awareness, enabling thoughtful decision processes that lead to safer and more reliable travel. Multiple streams of data can be integrated and used in real time to improve transportation system operations while protecting privacy and security of individual user data.

Transportation agencies are increasingly turning to crowdsourced information to improve the quality and quantity of operations data to support traffic analytics, transforming how they monitor and manage roadway networks. Wherever motorists travel this information is continuously created and effectively fills critical gaps in data availability, capturing a diverse mix of information such as speed, travel time, incident type, travel behavior, public sentiment, vehicular operation, and other metrics. Three common sources of crowdsourced data for transportation are purpose built mobile apps, third-party data providers, and social media platforms. These data can be passively or actively transmitted depending on the timeliness needed by the end use. Travel patterns can be observed across complex networks, arterial streets, throughout rural corridors, and across jurisdictional boundaries in real time.

Key Benefits:

Operations Improvements: Higher quality traveler information as well as the opportunity to implement proactive operations strategies that are effective in reducing traffic congestion.

Advancing Safety and Reliability. Improves accuracy in identification leading to more timely responses to traffic incidents and other congestion-causing events, resulting reduction in the potential for secondary crashes.

Cost Savings. Agencies are enabled to use their existing intelligent transportation systems infrastructure more effectively and additional roadway detection may not need to be installed and maintained.

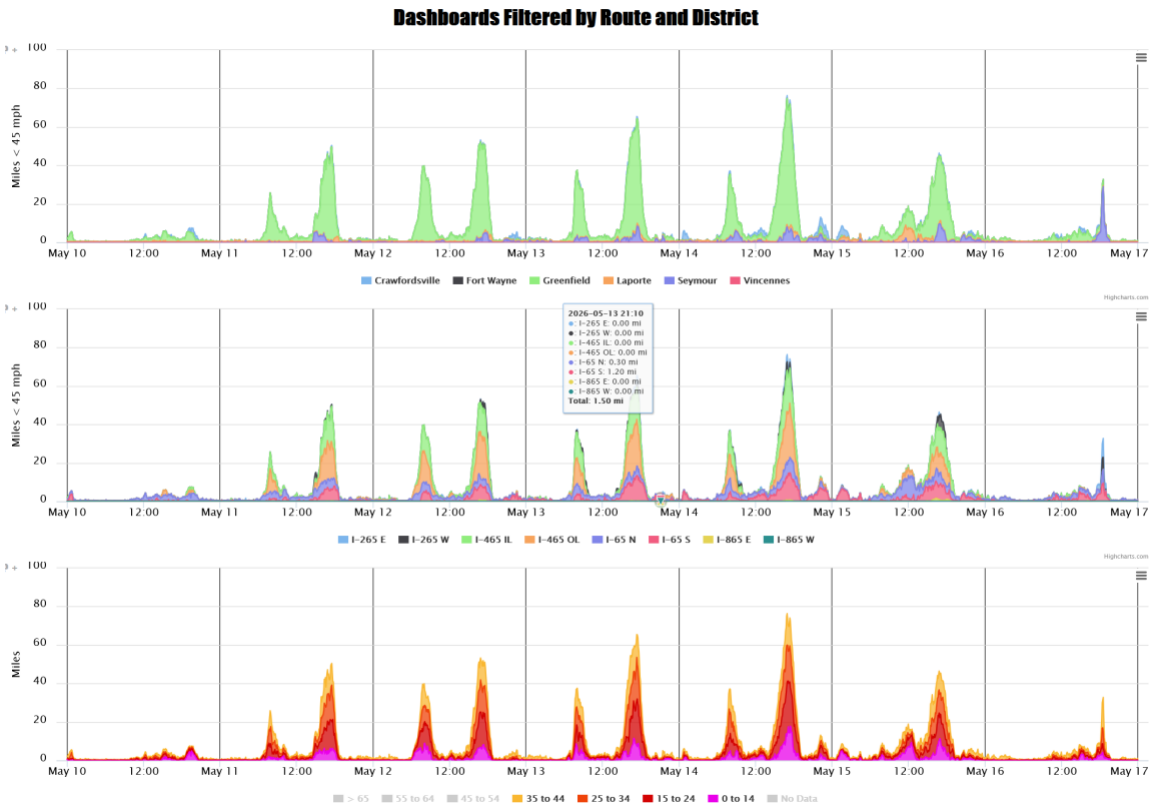
Crowdsourced data can often be accessed directly by traffic management centers (TMCs) with limited time lags. Complementing crowdsourced data with advanced integration tools, and now artificial intelligence, enables TMC operators to shift from a reactive posture after congestion forms across the roadway network from bottlenecks. By focusing more quickly on key information, TMC operators can identify and proactively manage emerging events immediately, resulting in safer, more reliable travel. As a result, situational awareness at TMCs can be significantly improved without compromising personally identifiable information of road users. Camera and roadway sensor infrastructure can have high capital and maintenance costs.

Crowdsourced data offers a cost-effective alternative that operates independently of local hardware malfunctions or system outages. Some data sources are free with little to no cost to process, while other data can be purchased at a more efficient cost point than investment traffic monitoring equipment.

State of the Practice

Most transportation agencies using crowdsourcing of data have focused their efforts on obtaining data from a specific source and applying it to a single application area, such as traffic incident management, traffic signal timing, safety analysis, or traveler information. This can be expanded into a system that gathers multiple streams of real-time data, integrates it, and uses it in multiple application areas for improved operations, as in the following examples:

- In Illinois, the **Lake County Department of Transportation** uses real-time dashboards and supporting tools to integrate ATSPM and crowdsourced data together in the agency's PASSAGE TMC to efficiently adapt traffic signal timing to manage disruptions to the roadway network by providing motorists real time traffic congestion information due to crashes and construction events through web information social media, smartphone apps, radio and variable message signs. PASSAGE connects back to the TMC 610 traffic signals, 400 PTZ traffic monitoring cameras, and 600+ video detection cameras.
- The **Kentucky Transportation Cabinet** integrates data from multiple sources, including social media, weather data, third-party data providers, and a mobile app to improve transportation operations and maintenance. System-generated alerts from the *Big Data System* inform TMC operators of incidents and events sooner, so they can better plan the agency's response.
- The **Colorado Department of Transportation** uses a map-based Traffic Operations Dashboard that pulls in real-time crowdsourced data from multiple sources, allowing a more proactive response to even minor incidents. Operators have reported a 5- to 10-minute reduction in response times, which can go a long way toward preventing or reducing incident-related congestion and avoiding secondary crashes.
- The **Maine Department of Transportation** developed an app for its work crews to communicate weather and road conditions. Previously, crews radioed operators in the DOT's TMC to share information about icy roads, etc. The app improves the temporal and location accuracy of road and weather data and allows operators to focus on incident identification and response during events.
- The **Indiana Department of Transportation** uses third-party probe data to actively manage traffic on major highways and corridors of interest. The agency worked with Purdue University to create *Traffic Ticker* and other dashboard tools that improve real-time operational decision-making and support training and after-action reviews.



Source: Purdue University, *Traffic Ticker*, 2026.

Indiana Department of Transportation Interstate System Dashboard

- **Louisville Metro** has been using for some time an approach to rapidly assess signal timing changes by applying Microsoft's Power BI® to its Waze data creating a robust solution. The data analytics tool set enables more timely and less cost assessment compared with traditional manual assessment methods such as floating car studies.
- **City of Austin, TX** had difficulty gathering useful traffic data due to limited camera coverage to prioritize corridors for signal retiming. The City now purchases crowdsourced open data from INRIX and implemented a new data-driven strategy rather than the previous approach that rotated through corridors to retime on multiyear basis. This approach improved resource allocation and more efficient regional traffic flow.
- The **District of Columbia DOT** performs minute-by-minute monitoring of arterial performance by incorporating crowdsourced data from Waze into a dashboard that enables agency staff to make effective decisions on where to proactively retime signals.
- Five municipal counties that manage roads in and around **Lake Tahoe** identified congestion and associated traffic patterns by using anonymized cell phone data from AirSage as infrastructure planning inputs and creation of traffic management strategies.

FHWA's Every Counts program (EDC-6) has an extensive list of *Sample Crowdsourcing for Operations Applications* to a variety of applications including arterial management.

AI ADAPTIVE SIGNAL CONTROL TECHNOLOGIES

Description

As part of a continuum of arterial traffic signal technologies, Adaptive Signal Control Technologies (ASCT) are the next step beyond advanced traffic responsive traffic signals. ASCT replaces fixed and/or actuation-based signal timing patterns with dynamic adjustments based on real-time traffic demand data from sensors (e.g., loops, radar, or video detection) along with mathematical optimization formulas to adjust the length of green and red phases in real-time. This automation acts like software but does not rely on advanced predictive reasoning or machine learning models. This traditional implementation of ATSC is a base on which can be added an overlay of artificial intelligence (AI) and machine learning (ML) models (such as deep reinforcement learning) to analyze live video and sensor data. Instead of just responding to cars currently stopped at the intersection, these systems anticipate approaching traffic volumes and coordinate signals across an entire corridor. By using this real-time data fusion and predictive analytics approach to automatically adjust timing windows based on traffic flows travel delay can be reduced by as much as 10 to 30 percent.

Applications

The AI/ML extension of ASCT has been in the testing phase as pilot applications stage prior full network implementation in various agencies:

- **Maricopa County, Arizona:** Implemented an AI optimization model for dynamic traffic-demand adjustments at a signalized intersection in the Anthem Test Bed. A camera connected via Wi-Fi to an on-site computer with an AI optimization engine to monitor traffic at the intersection. The AI tool was connected to a central virtual management center directly wired to the intersection's traffic signal controller to enable real-time signal adjustments based on traffic conditions. The benefits were quantified through various performance metrics then extrapolated to county wide basis including intersection delay time (per vehicle reduction of 46 percent) and operating costs (estimated as 75 percent reduction).
- **California Department of Transportation (Caltrans) and the Transportation Agency for Monterey County** launched a five-year pilot the beginning of May 2026 on a nine intersection corridor of State Route 68 in Monterey County using AI Adaptive Traffic Signal Control as a follow up to the environmental document phase. The system uses intersection cameras to synchronize green lights and reduce congestion. Video cameras monitor traffic volume in real time and communicate with downstream signals to coordinate green signal indications for passing platoons of cars. The system's performance metrics will inform intersection control evaluation between planned roundabouts or continuing use of the optimized AI ASCT implementation with the goal of infrastructure cost savings.

- **The Utah Department of Transportation** (UDOT) assessed available detection systems and initially deployed AI 3D lidar sensor system to over a dozen intersections and connected to the agency's ASCT traffic management system. The system detects and tracks vehicles, while gathering real-time data to dynamically adjust traffic signal timing to improve multimodal safety and movement for vehicles, cyclists, and pedestrians. More recently UDOT expanded its integration to over 100 intersections.

Source: Utah DOT, *UDOT among first in nation to implement LiDAR safety software, August 20, 2024*.

Sample Utah DOT LiDAR Sensor Image

These lidar sensors employ a deep learning AI perception model that has been trained on four million labeled objects collected from locations with diverse traffic patterns, intersection designs, and environmental conditions. The sensors are integrated with NVIDIA high-performance accelerated computing technology that provides low-latency object detection, classification, and tracking to improve detection accuracy while protecting personally identifiable information. This vendor's lidar sensors are Build America/Buy America compliant lidar as a detection system for traffic actuation.

This provides real-time insights into traffic flow, road user behavior, and potential safety risks. Future applications include support for V2X communications and other use-cases such as near-miss detection and wrong-way driving. The agency measures traffic signal performance using its public-facing analytics provided by ATSPMs for over 1,300 traffic signals across the state. UDOT continues to evaluate the integration of multiple technology vendors, moving toward a centralized, AI-driven traffic management system.

- **City of Galveston, Texas** was recently awarded a $2M US DOT Strengthening Mobility and Revolutionizing Transportation (SMART) grant along with $16M from the Houston-Galveston Area Council for Phase 1 of their Galveston Rapid Evacuation and Transportation System (GREATS) to design the system architecture, purchase equipment, and implement the program. The project will deploy AI-ASCT and intelligent, sensor-based transportation infrastructure to improve emergency evacuation operations and optimize traffic flow surges across the City of Galveston during severe weather and visitor events.

  The AI integration will analyze seasonal trends in vehicle and pedestrian data to monitor and control traffic signal timing. It must also employ state-of-the-art hardware to allow for emergency vehicle preemption and allow for remote monitoring and control of all signalized intersections within the city. The system will first be rolled out in a pilot area

of Seawall Boulevard from 14th Street to 57th Street. After the pilot implementation, the city plans to expand the system across their transportation network. The system is being planned to incorporate future data inputs and control systems to expand its capabilities for drivers and motorists.

ACTIVE CORRIDOR MANAGEMENT

Description

Active Corridor Management integrates traveler information, lane reversals, incident management with dynamic traffic signal timing to balance demand across regional arterial-focused roadway networks. Although this is not a new approach within the overarching topic of integrated corridor management, the advances in technology applications more recently has become more opportune to implement meaningfully.

Applications

Baltimore City Department of Transportation was recently awarded a $2M US DOT SMART grant to implement smart traffic signal systems to mitigate severe congestion from traffic diversion associated with the collapse of the I-695 Frances Scott Bridge over the Patapsco River in the city. The grant will address mobility, safety, and logistics issues for 50 intersections on heavy traffic corridors like Hanover Street, Eastern Avenue, and Pulaski Highway. Complementing the federal grant is a broader citywide effort to retime traffic signals, which helps resolve localized gridlock near bridge detours. Enhancements feature shorter peak-hour light cycles on major thoroughfares and optimized walk times for pedestrians.

Signals are being updated with new controllers, communication networks, and CCTV cameras. These systems utilize AI-driven video and radar sensors to detect traffic in real-time, adjusting light cycles automatically to current congestion. Adaptive technology will help manage the influx of diverted commercial vehicles, optimizing truck movement logistics and reducing transit-time reliability issues for buses. Researchers at the University of Maryland and the City are leveraging data from these systems to address major bottlenecks, especially during heavy PM peak periods on alternate routes like MD-295 and the Harbor Tunnel Thruway.

The **New Jersey Department of Transportation (NJDOT)** established the Arterial Management Center (AMC) to address the increasing complexity and persistent congestion on the State's arterial transportation networks.

Source: New Jersey DOT, 2025

NJDOT Arterial Management Center

The AMC creates a unified infrastructure by integrating RITIS and 511NJ with the SCATS adaptive traffic signal control system to proactively apply predictive, real-time mobility strategies. AI and machine learning algorithms that forecast congestion hotspots and infrastructure degradation augment the AMC operation. In addition, Vissim and Synchro simulation software tools rigorously test, optimize, and validate signal timing scenarios.

Part of the NJDOT's AMC success founded on a communication strategy that incorporates both internal daily briefings and weekly performance reviews keep traffic engineers and operators aligned and external collaboration with regional centers utilizing the 511NJ platform and DMS boards. This collaborative communication strategy ensures coordination across organizations to reduce travel delays, provide real-time travel information, and fewer reactive maintenance requests. The return on investment of NJDOT's scalable approach to blend advanced computation, machine learning, and human-centric governance is supported by the day-to-day outcomes.

ARTERIAL PRESERVATION PROGRAM

The **Virginia Department of Transportation** has taken a comprehensive, combined technology and physical infrastructure approach to arterial management by revising signal timing, making intersection improvements, updating technology, limiting curb cuts, and optimizing access points to prevent development-related bottlenecks. VDOT's *Arterial Preservation Program* uses holistic corridor planning approach as an alternative to widening major highways. The agency uses innovative applications of arterial management strategies to modernize major corridors using data-driven tech and transit prioritization to enhance safety and reduce congestion. This included the use of anonymized mobile device and probe vehicle metrics for minute-by-minute monitoring, avoiding the need for costly manual vehicle surveys.

The arterial roadways in the network are major highways that function similarly to the interstate system, accommodating long-distance mobility of people and goods. Each corridor is guided by an arterial management plan providing localities and VDOT a guide to future development and supporting transportation infrastructure. The program is voluntary and developed in partnership with localities to plan for infrastructure that supports future land use and development.

In support of the program VDOT has initiated a review of current agency policies and procedures to align with the goals of the *Arterial Preservation Program* to improve upon current policies and encouraging the use of innovative strategies to preserve safety and capacity. The review process will evaluate access management regulations, the design exception process, innovative Intersection and Interchange design policies and guidance, intersection control evaluation, and the agency's project development role related to extension projects in urban areas.

Resources

***AASHTO Transportation Operations Manual* (TOM)**

- Chapter 21: Arterial Management
- Chapter 13: Performance-Based Practical Design (PBPD)
  - 13.4: Analysis Methods
  - 13.5.2: Integration with TSMO | Arterial Operations
  - 13.7.3: Examples of PBPD TSMO Projects | Innovative Intersections
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  - 18.4.3: Tactic Categories | Arterial Management

Federal Highway Administration

EDC-6: Crowdsourcing for Advancing Operations (March 2025).

EDC-6: Crowdsourcing for Advancing Operations Fact Sheet.

Crowdsourcing for Advancing Transportation Operations | Arterial Management Crowdsourcing Examples web page.

Sample Crowdsourcing for Operations Applications.

Adaptive Signal Control Technologies.

Arterial Management Program focus area web pages:

- Traffic Signal Program Management
- Regional Traffic Signal Operations Programs
- Traffic Signal Timing and Operations Strategies
- Automated Traffic Signal Performance Measures

Regional Transportation Systems Management and Operations Case Studies, FHWA-HOP-24-017, September 2024.

Automated Traffic Signal Performance Measures, FHWA-HOP-20-002, March 2020.

U.S. DOT ITS-JPO

ITS Deployment Evaluation *database search on "ASCT" results*.

Artificial Intelligence (AI) and Machine Learning (ML) for Transportation - Adaptive Traffic Signal Control (ATSC), December 2021.

AI-Driven Adaptive Signal Control Pilot in Maricopa County, Arizona, Reduced Vehicle Delay by 322 Hours per Week at the Project Intersection, May 2021.

U.S. DOT Smart Grants

Summary List of FY2022, Phase 1 SMART Grants (10 smart traffic signals projects).

Summary List of FY2023, Phase1 SMART Grants (3 smart traffic signals projects).

Summary List of FY2024, Phase 1 SMART Grants (8 smart traffic signals projects).

Summary List of FY2024, Phase 2 SMART Grants.

National Operations Center of Excellence (NOCoE)

Enhancing Traffic Operations through Real-Time, Data-Driven Strategies at NJDOT's Arterial Management Center (AMC), August 2025.

Traffic Signal Systems, Arterial Management, and TSMO Peer Exchange Report.

eTraffic - Traffic Signals and Control Strategies Inventory, January 2025.

Applying Emerging Technologies for Smarter Traffic Signal Optimization Processes, August 2024.

National Cooperative Highway Research Program

Traffic Signal Timing Manual, 3rd Edition (research in progress, Fall 20026 release). See AASHTO July May 2026 webinar on status.

Active Traffic Management Strategies: A Planning And Evaluation Guide, Research Report 1120 (2024)

The Performance-Based Management of Traffic Signals, National Cooperative Research Highway Research (NCRHP) Research Report 954, 2020.

Automated Traffic Signal Performance Measures: Management, Operations and Maintenance NCHRP Synthesis Report 659, 2026.

American Society of Civil Engineers

Arterial TSM&O Strategy Selections and Implementations to Improve Safety and Mobility, paper by Pei-Sung Lin, Yayeor Keita et al, for the International Conference on Transportation and Development (2025).

Agency Programs

Austin, Texas

Open Data Portal.

GIS map of Traffic Signal Evaluation Locations.

California

Scenic Route 68 Corridor Improvements Project, Caltrans, 2026.

Scenic State Route 68 – Salinas to Monterey, Transportation Agency for Monterey County, 2026.

Colorado DOT

Traffic Operations Dashboard

District of Columbia

Traffic Signal Open Data resource

Annual Average Daily Traffic Volume resource.

Georgia

Automated Traffic Signal Performance Measures Component Details, Georgia Department of Transportation by Atkins North America), January 23, 2023

ATSPM web page.

Indiana

Traffic Ticker crowdsourced traffic data.

Kentucky

Crowdsourcing for Operations Case Study, Kentucky Transportation Cabinet.

DataMart, select Traffic menu item, Kentucky Transportation Cabinet.

Lake Tahoe

Smart Grant for Traffic Data Collection, Tahoe Transportation District.

Case Study for Transportation, AirSage.

Lake County, Illinois

PASSAGE TMC ITS Architecture, Lake County Division of Transportation.

PASSAGE TMC website, Lake County Division of Transportation.

Louisville, Kentucky

How we do free traffic studies with Waze data (and how you can too), Louisville Metro Government.

New Jersey

Enhancing Traffic Operations through Real-Time, Data-Driven Strategies at NJDOT's Arterial Management Center (AMC), New Jersey DOT, August 11, 2025.

Pennsylvania

Automated Traffic Signal Performance Measures (ATSPMs), Pennsylvania DOT.

Utah

UDOT among first in nation to implement LiDAR safety software, Utah DOT, August 20, 2024.

ATSPM web page.

Virginia

Virginia DOT *Arterial Preservation Program*.