National Park Service
U.S. Department of the Interior

Washington Support Office – Park Facility Management Division
Washington, D.C.

National Park Service
Traveler Information Technologies in the National Park System


Top Left: *AI-Generated Images of a Fictional Roadway at Grand Canyon National Park. Source: U.S. DOT Volpe Center, 2024.*
Top Right: *Installation of Parking Sensors at Indiana Dunes National Park. Source: U.S. DOT Volpe Center, 2024.*
Bottom Left: *Vehicle Incident on Closed Road at Mojave National Preserve in 2022. Source: National Park Service, 2022.*
Bottom Right: *Dynamic Message Sign located in Lyons, Colorado Area to Intercept Visitors Traveling to Rocky Mountain National Park. Source: Federal Highway Administration, 2011.*

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14. ABSTRACT
This report details completed and ongoing traveler information-focused Intelligent Transportation System (ITS) deployments on National Park Service (NPS) lands. It reviews six ITS technologies areas – data feeds, mobility data, vehicle-to-everything (V2X) technology, machine learning and artificial intelligence, geofenced alerts, and physical infrastructure and equipment – which can address common NPS transportation challenges, such as congestion, safety, and operational efficiency. Technology reviews include the status of NPS usage and key takeaways for implementation. The report also provides recommendations to increase the adoption of these technologies and thus improve planning, operational efficiency, and visitor experience across the park service's transportation system.

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Traveler information, parks, intelligent transportation systems, roadway digital infrastructure, data feeds, mobility data, vehicle-to-everything (V2X) technology, machine learning, artificial intelligence, geofenced alerts, physical infrastructure and equipment, transportation management

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- U.S. DOT Office of the Secretary of Transportation (OST)
- U.S. Department of Agriculture (USDA) Forest Service (USFS)
- U.S. DOI Bureau of Land Management
- U.S. Census Bureau
- U.S. Geological Survey (USGS)

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Acronyms and Abbreviations

TERM	DEFINITION
ACS	Access Control System
AI	Artificial Intelligence
API	Application Programming Interface
AVL	Automated Vehicle Location
CAD	Computer-Aided Dispatch
CalTrans	California Department of Transportation
CCTV	Closed-Circuit Television
CDS	Curb Data Specification
CV	Connected Vehicles
C-V2X	Cellular Vehicle to Everything
DOI	Department of Interior
DOT	Department of Transportation
FHWA	Federal Highway Administration
FLMA	Federal Land Management Agency
FTA	Federal Transit Administration
GATIS	General Active Transportation Infrastructure Specification
GPS	Global Positioning System
GTFS	General Transit Feed Specification
IOO	Infrastructure Owner Operator
ITS	Intelligent Transportation System
I2V	Infrastructure to Vehicle
JPO	Joint Program Office (part of U.S. DOT)
LBS	Location Based Service
LCS	Lane Closure System
LPI	License Plate Inventory
LPR	License Plate Readers
LTE	Long-Term Evolution
LTE-V2X	Cellular Vehicle to Everything

TERM	DEFINITION
MDODE	Managing Disruptions to Operations Data Exchange
MDS	Mobility Data Specification
ML	Machine Learning
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NPS	National Park Service
PII	Personally Identifiable Information
PIA	Privacy Impact Assessment
PTA	Privacy Threshold Analysis
RDI	Roadway Digital Infrastructure
RITIS	Regional Integrated Transportation Information System
SMS	Short Message Service (Text Messages)
TCAT	Taskar Center for Accessible Technology
TDI	Transportation Digital Infrastructure
TDx	Transportation Data Exchange
TPIMS	Truck Parking Information Management System
TRB	Transportation Research Board
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VMS	Variable Message Sign
V2I	Vehicle to Infrastructure
V2P	Vehicle to Pedestrian
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
WASO	Washington Support Office (part of NPS)
WYDOT	Wyoming Department of Transportation
WZDx	Work Zone Data Exchange

EXECUTIVE SUMMARY

The National Park Service (NPS) transportation system offers a challenging but exciting testing ground for new technologies and existing technologies which have yet to be deployed at scale. As a core participant in the Federal Lands Transportation Program, NPS engages in cooperative research and technology development, with the U.S. Department of Transportation (23 USC 201(c)(7)), which provides opportunities for parks to be a test bed for transportation innovation.[1] NPS is proactively adapting to industry trends that are increasing transportation system safety, connectivity, and autonomy.

This report details completed and ongoing NPS technology deployments and summarizes relevant innovative technologies. This report also updates previous technology assessments from 2005 and 2011 to evaluate existing and emerging traveler information technologies. The researched technologies included in this report were developed in alignment with the NPS Park Facility Management Division's National Transportation Strategy[2], by applying research and innovation strategies to strengthen program management, as well as its objectives to:

- **Protect resources and strengthen transportation systems:** Research strategies to safeguard natural and cultural resources, reduce risks to transportation assets, and ensure systems remain reliable during severe weather events.
- **Improve the visitor experience:** Explore ways to enhance transportation safety, meet visitors' needs, connect with nearby communities, and prepare for emerging transportation options.
- **Invest in long-term infrastructure:** Develop strategies to improve management of roads, bridges, and other transportation assets to ensure sustainable performance over time.

BACKGROUND AND KEY FINDINGS

Intelligent Transportation Systems (ITS) refers to a broad spectrum of technologies that manage the transportation network, ranging from data and communications infrastructure to automated driving systems. Physical ITS equipment is a relatively mature technology area, including technologies such as variable message signs (VMS) and traffic counters. Emerging ITS technologies are increasingly leveraging widespread public access to a smartphone or navigation system while traveling and often rely on cloud computing and processing (storing and accessing data and programs on remote internet servers). This report reviews six ITS technologies areas, including both physical and cloud-based technologies of various maturities, which can address common NPS transportation challenges, such as congestion, safety, and operational efficiency. These technologies are detailed below including the status of NPS usage and key takeaways for implementation.

Data Feeds: Standardized data on transportation system information, made available for public consumption through navigation applications.

- NPS is currently piloting transit, road closure, and road restriction feeds.
- Authoritative information available in a standard format offers many benefits for visitors.

[1] NPS; Federal Lands Transportation Program. (2025).
[2] NPS; 2025 National Transportation Strategy. (2025).

- Additional data feed standards are being developed for other transportation use cases, such as active transportation and parking/curb data.
- As NPS considers further build-out of data feeds, the NPS Application Programming Interface (API) architecture is a powerful resource to store and make data available to the NPS digital products and third-party developers.

Mobility Data: Vehicle or mobile device-generated location data aggregated to track and analyze movement within the transportation system.

- NPS has completed significant research on mobile device data and vehicle data for planning purposes.
- Commercially available mobility data can generate historical and real-time transportation network condition information. This in turn can be utilized to disseminate more accurate traveler information to visitors across a greater number of parks.
- Mobility data requires a combination of GPS, cellular signals, Wi-Fi, and Bluetooth from visitor vehicles or devices to create data. Data, privacy, security, and connectivity concerns should be considered and evaluated on a park-by-park basis prior to implementation.

Vehicle to Everything (V2X): Vehicle-based technologies that can share real-time data with other vehicles, roadway users, and physical infrastructure.

- V2X is being deployed in a growing number of states and has the potential to more efficiently alert drivers to safety, congestion and other issues of concern along roadway corridors.
- V2X accommodates trusted, secure, and timely data exchanges across a variety of communication options.
- NPS has not yet piloted or implemented V2X technology.

Machine Learning (ML) and Artificial Intelligence (AI): Set of data processes that enable systems to augment routine human tasks or enable new capabilities that humans cannot perform.

- Many ML and AI methods are fully established and do not have any considerable risks, while others emerge with data privacy and security concerns that have yet to be fully understood.
- Data is the foundation of AI—fueling model training, informing decision-making, and determining the accuracy, transparency, and usefulness of AI systems. An AI/ML system is only as good as the input data it receives, making it critical to invest in improved data collection.
- Two new classes of AI have recently been developed. Both can have widespread applications, but can be subject to bias and potential for incorrect outputs (e.g. “hallucinations”):
  - **Generative AI:** A class of AI models that create new content such as text, images, audio, and code. Unlike traditional AI, which classifies or predicts, generative AI produces original outputs that resemble human-created content.
  - **Agentic AI:** A class of AI models that can autonomously pursue goals, make decisions, and take actions in a given environment—often without constant human oversight.
- NPS has piloted AI/ML technology on several occasions, such autonomous vehicle pilots in parks and License Plate Readers (LPRs) to generate transportation data. These technologies have the potential to streamline agency functions while also expanding the amount of traveler information available to visitors across a greater number of parks.

Geofenced Alerts: Targeted messages sent to mobile devices or vehicles within a defined geographic area.

- Messages can be sent via text, mobile phone app notifications, or through connected vehicle technology.
- State Departments of Transportation (DOTs) are deploying geofenced alert systems to provide standard traveler information (such as congestion or planned closure alerts) and better manage emergency situations such as severe weather events. Similar use cases could be developed in park settings.
- Privacy needs are important to consider, in terms of who receives alerts, and whether an opt-in or opt-out approach should be followed.
- NPS has not yet piloted or implemented geofenced alerts.

Physical Infrastructure and Equipment: ITS equipment that is deployed inside park settings. Common examples include traffic detectors, closed-circuit television (CCTV) cameras, automated passenger counters, telematics systems in shuttles, satellite internet connections, access control systems (ACS), cameras/license plate reader (LPR) systems, or VMS. Though some agencies use on-premises storage (i.e., servers located at their facilities), in some cases, these technologies require some type of cloud system to store data or control equipment functions.

- Physical equipment is still widely used and relied upon at NPS park units as a means of generating and/or disseminating traveler information to visitors.
- Properly implemented physical equipment can streamline park operations, improve visitor experience, and enhance transportation safety.
- Physical equipment can make other emerging technologies more effective, by providing input data for AI models, data feeds, and geofenced alerts.
- Deployment, implementation, and maintenance considerations should be addressed prior to purchasing or installing any physical equipment, including concerns associated with data, privacy, security, and reliability, as well as an understanding of available electrical and communication infrastructure.

RECOMMENDATIONS

Table 1 and Table 2 summarize the recommended next steps NPS should take to deploy innovative transportation solutions in the national park context. The recommendations are organized by technology area and potential next steps for NPS. Recommendations are further detailed in the 'Recommendations to Advance Traveler Information Strategies' section of this report. Though this report breaks the technology research areas into six different sections, it is important to acknowledge that the technology areas are overlapping and connected (i.e., data feeds rely on mobility data, and AI/ML can be embedded into data collection and processing methods).

NPS should continue research in all six technology areas because each demonstrates promise to improve park management and operations. Data feeds, mobility data, and AI/ML appear to be advancing most rapidly, which should warrant additional attention for NPS. V2X and geofenced alerts are relatively untested technologies in a public lands setting but provide effective traveler information in other settings.

The successful deployment of each technology area will require expanded knowledge bases with WASO, NPS regions, and parks. Future pilots recommended as part of this report will be aligned with funding priorities, visitor experience enhancement goals, and applicable stakeholder interests. NPS previously invested significant efforts into physical infrastructure, mobility data, and data feeds, so the agency is better prepared to quickly advance efforts in these areas.

Across all technology areas, NPS should develop more detailed technology deployment roadmaps outlining implementation steps, appropriate park types for deployment, and evaluation criteria to determine the added value and impact. NPS should also consider data privacy and security, specifically as it relates to communications and cloud processing, when piloting and deploying any new technologies.

Table 1. Recommendations By Technology Area and Potential Next Steps for NPS

Technology Area	Exploratory Research	Pilot	Permanent Deployment
Data Feeds	●	●	○
Mobility Data	●	●	●
V2X Technologies	○	○	
Machine Learning and Artificial Intelligence	○	○	
Geofenced Alerts	○	○	
Physical Infrastructure and Equipment	●	●	●
Key:	● NPS is prepared to immediately begin recommended next steps	○ NPS will need time to begin recommended next steps	

Source: NPS and U.S. DOT Volpe Center, September 2025

Table 2: Overall Recommendations for the Six Technology Areas

Technology Area	Recommendations
Data Feeds	• Continue to advance agency-wide road and transit data feeds to relay information to visitors. • Support the development of a road restriction data feed using the Transportation Data Exchange (TDx) specification, or a comparable restriction feed, and explore ways to incorporate recreation elements. • Foster robust relationships with navigation applications. • Support creation of more standardized data products, such as traveler information alerts and other park transportation system information, that can be accessible throughout the NPS digital products, including the NPS API, NPS.gov, and NPS mobile application.
Mobility Data	• Continue to follow advancements in mobility data technologies and options. • Conduct mobility data pilots in park settings to evaluate the effectiveness of different historical and real-time mobility data options. • Consider data privacy and security, specifically as it relates to communications and cloud processing, when deploying mobility data pilots.
V2X Technologies	• Conduct further research into V2X technologies. • In conjunction with U.S. DOT's Intelligent Transportation Systems Joint Program Office (ITS JPO), engage with partner agencies currently piloting V2X technologies, particularly in Wyoming, Utah, and Colorado.
ML and AI	• Advance the use of well-established ML/AI tools and techniques (e.g., travel forecasts, LPRs). • Where possible, provide authoritative AI training data to the general public.
Geofenced Alerts	• Pilot geofenced alert systems within park settings. • Pilot the integration of geofencing technology into one or more existing alert systems, where beneficial. • Explore the use of internal (NPS app) and external navigation applications to send geofenced alerts to park visitors. • Consider data privacy and security, specifically as it relates to communications and cloud processing, when deploying geofenced alerts pilots.
Physical Infrastructure and Equipment	• Identify and define transportation challenges and the existing physical infrastructure and equipment needed to address them to ensure the appropriate physical infrastructure and equipment are considered for the park setting. • Understand the necessary baseline infrastructure needed to pilot traveler information technologies and plan for it to be in place prior to installing physical equipment to ensure the appropriate solution is deployed. • Consider data privacy and security, specifically as it relates to cloud processing, when choosing physical equipment and infrastructure to deploy ITS technologies.

Source: NPS and U.S. DOT Volpe Center, September 2025

2. Introduction

This report provides an overview of existing and potential traveler information technologies available for use on National Park Service (NPS) lands. The intended audience for this report includes Washington Office (WASO) staff and other NPS staff interested in implementing traveler information technologies. The project team from the U.S. Department of Transportation Volpe Center (Volpe) compiled the information in this report with input from advisors at NPS parks and regions, along with other stakeholders at the Federal Highway Administration (FHWA), Intelligent Transportations Systems Joint Program Office (ITS JPO), and U.S. Forest Service (USFS).

This report provides a high-level overview of relevant traveler information technologies. This report provides an overview of ITS and roadway digital infrastructure (RDI) frameworks; summarizes past research efforts that inventoried ITS technologies in use on NPS lands; and explores six key research areas and their associated data privacy and security requirements (data feeds, mobility data, machine learning (ML) and artificial intelligence (AI), geofenced alerts, and physical infrastructure and equipment).

The recommendations in this report will inform future deployments of traveler information technology pilots at parks. Future traveler information technology pilots recommended as part of this report will be aligned with funding priorities, visitor experience enhancement goals, and stakeholder interests.

2.1 Project Goals

In 2024, NPS recorded over 331.9 million recreational visits, an increase of 6.36 million recreation visits (or two percent) from 2023, across its 85 million acres of land and 431 units.[3] To meet the needs of these visitors, NPS depends on a safe, reliable, and efficient transportation system. Traveler information technologies can help meet these visitors' needs.

The goal of this effort is to better understand which traveler information technologies are applicable in the NPS context and how these technologies can be deployed at park units, all while meeting federal data privacy and security requirements. Further objectives of the project include:

1. Ensuring that visitors have accurate information at the right time to make informed travel decisions. The "right time" can be early in the trip planning process, in route to and within the park, or as the visitor is departing the park.
2. Identifying, inventorying, and evaluating technologies in different park environments.
3. Expanding knowledge of technologies that improve planning, operational, management, or visitor experience goals, while ensuring deployed technologies meet all necessary federal data privacy and security requirements.
4. Improving processes for data integration into the NPS website and mobile application, as well as third-party navigation applications.
5. Providing guidance to parks and NPS regional staff on collaboration with partners by seeking input from an advisory team consisting of staff from NPS, Volpe, FHWA (Federal Lands and Federal Aid Divisions), ITS JPO, and other relevant transportation agencies.

[3] NPS. Visitor Use Data. (2024).

6. Researching how to apply Vehicle to Everything (V2X), RDI, and transportation digital infrastructure (TDI) strategy concepts on federal lands and evaluating the ongoing road closure and incident pilot effort at NPS.

2.2 Traveler Information Technologies Overview

Traveler information such as data on road closures, traffic conditions, available transit options and route information, etc. provides visitors and the traveling public with inputs to make more informed travel decisions. Reliable, accurate traveler information is crucial for efficient and effective NPS operations and management, as well as for visitors. Traveler information technologies can mitigate some of the most common transportation-related challenges faced by NPS park units, detailed below.

- **Crowding and Congestion:** Park visitors sometimes face challenges obtaining transportation and wayfinding information when traveling to and within parks. This can worsen congestion and sometimes result in visitors entering closed or restricted road facilities due to limited or inaccurate traveler information such as a lack of posted signage. This can negatively impact the experiences of park visitors, create safety and operational challenges for park units, and harm natural and cultural resources. Visitation at some parks exceeds the capacity of available transportation infrastructure assets and services, especially during peak seasons and times, or during special events. Congestion can form particularly at park entrances as rangers collect entrance fees and provide visitors with information. Congestion and crowding diminish the visitor experience, damage resources, and pose numerous operational challenges. Traveler information technologies can help NPS manage these conditions by providing visitors with clear transportation and wayfinding information, determining a better understanding of traveler behavior, assisting with visitor demand predictions, and managing visitor flows more efficiently.
- **Parking Availability:** Many NPS park units are primarily accessible only to visitors arriving in personal vehicles. Parking, therefore, can often be heavily congested during periods of high visitation. This can exacerbate roadway congestion due to circling vehicles and create problems with unauthorized parking along roadways or in sensitive natural areas, which generate safety issues and harm natural resources. Traveler information technologies can provide real-time parking information to assist with reducing traffic congestion, enhancing parking security, and optimizing traffic routes.
- **Public Safety and Emergency Response:** Providing timely emergency response, especially in remote areas, is a major concern for park units. Delayed responses due to poor communications technology and issues locating distressed individuals can result in negative outcomes for park staff and visitors who need emergency assistance. Traveler information technologies can improve public safety by detecting and verifying incidents, allowing authorities and emergency response personnel to better respond and provide timely public safety information. Traveler information can also alert park visitors to potential safety hazards, such as weather-related road conditions.
- **Resource Protection:** Transportation systems impact natural resources through vehicle emissions, noise pollution, wildlife crashes, habitat disruptions, and land fragmentation. Improved traveler information systems help visitors better plan their travel inside parks, and by extension reduce congestion, air pollution from excessive idling, and unnecessary driving within parks. These systems can also direct vehicles and pedestrians towards designated parking areas

or trails, thus preventing potential damage to natural resources caused by going off-trail or driving and parking outside of approved roads or parking lots.

- **Operations (Fee Collection, Speed Management):** Conventional entrance fee collection methods (with payment upon entry) are becoming more challenging to administer in busier park units and can result in congestion and a diminished visitor experience during times of high visitation. Traveler information technologies could improve operations by implementing advanced reservation systems to reduce visitor wait times at entrance stations. Speed management is another operational challenge for park units. Many parks have limited law enforcement resources available, despite this being a critical component of maintaining a safe roadway environment inside of parks. Traveler information technologies can determine the locations and times where speeding is most common to both inform safety improvements, and alert park staff and law enforcement to safety issues in real time.

2.2.1 What are Intelligent Transportation Systems (ITS)?

Traveler information technologies are examples of ITS, but ITS is more than just traveler information technologies. The definition of ITS differs depending on the source or agency. NPS uses ITS as an umbrella term for numerous technologies that are deployed to manage transportation networks. ITS technologies are often connected to physical infrastructure such as traffic detectors, weather sensors, computer databases, and variable message signs (VMS).[4] Examples of ITS technologies not directly related to traveler information include smart traffic signals, automated entry gates, and automated driving systems.

The ITS JPO states that ITS "refers to a system of technologies and operational advancements that, when combined and managed, improve the capabilities of the overall transportation system… by integrating advanced information and communications-based technologies into transportation infrastructure and vehicles." ITS JPO identified several research areas that fit under the ITS umbrella, such as automated driving systems, emerging technologies (i.e., connected vehicles, road/infrastructure communication, and advanced safety systems), cybersecurity, AI and ML, and data exchanges. ITS JPO has also compiled a list of emerging ITS research areas, including the acceleration of ITS deployment (evaluation, professional capacity building, architecture and standards, and communications), automation, cybersecurity, data access and exchanges, and enabling technologies.[5]

The ITS JPO publishes ITS Deployment Tracking surveys to survey current ITS practice and trends.[6] Table 3 summarizes the most deployed ITS technologies as identified by the survey. Key takeaways from the most recent survey in 2023 include:

- ITS technologies such as VMS[7] (as a means of disseminating information), closed-circuit television (CCTV) for traffic monitoring and incident detection, and road weather information systems have reached maturity, with large amounts of freeway agencies using them. Arterial agencies also widely utilize video monitoring systems, in addition to inductive loop detectors.

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[4] NPS. Intelligent Transportation Systems. (2024).
[5] Chan-Edmiston, Sarah; et al.; "Intelligent Transportation Systems (ITS) Joint Program Office: Strategic Plan 2020–2025"; p. 7. (May 2020).
[6] U.S. DOT ITS JPO. "Intelligent Transportation Systems Deployment." (2024).
[7] Note: Variable Message Signs (VMS) are also referred to as Changeable Message Signs or Dynamic Message Signs.

- External data is commonly used by both freeway and arterial agencies to assist with traffic management tasks, with the most common data sources being publicly available mapping and traffic information applications, notifications from the public, and third-party data purchased from commercial providers.
- Connected vehicle technology is less widespread than many conventional ITS technologies, with usage currently limited to select freeway and arterial agencies. However, roughly a quarter of these agencies are planning to deploy these technologies in the future.

Table 3: Most Deployed ITS Technologies by U.S. Freeway and Arterial Agencies (2023)

ITS Technology Area	Technology	% of Freeway Agencies Using ITS in 2023	% of Arterial Agencies Using ITS in 2023
Widely Adopted Technologies	VMS for Traveler Information	89%	-
Widely Adopted Technologies	CCTV Detection Systems	85%	78% (State DOT), 60% (Local Agency)
Widely Adopted Technologies	Permanent Weather Monitoring Systems	79%	-
Widely Adopted Technologies	Inductive Loops	-	82% (State DOT), 78% (Local Agency)
Widely Adopted Technologies	Radar/Microwave Detection	69%	77% (State DOT), 28% (Local Agency)
Safety Technologies	Queue Warning System	40%	-
Safety Technologies	Wrong-Way Driving Detection System	33%	13% (State DOT), 1% (Local Agency)
Safety Technologies	Over-Height Warning System	24%	19% (State DOT), 1% (Local Agency)
Safety Technologies	Dynamic Curve Warning System	22%	12% (State DOT), 2% (Local Agency)
Safety Technologies	Speed Feedback Sign	-	40% (State DOT), 32% (Local Agency)
Safety Technologies	Pedestrian Warning System	-	40% (State DOT), 23% (Local Agency)
Work Zone Technologies	Portable VMS	70%	-
Work Zone Technologies	Speed Feedback Trailer	59%	-
Work Zone Technologies	Portable CCTV	51%	-
External Data Sources	Publicly Available Mapping/ Traffic Information Applications	70%	54% (State DOT), 21% (Local Agency)
External Data Sources	Notifications from the Public	62%	54% (State DOT), 29% (Local Agency)
External Data Sources	Purchased Third-party Commercial Data	61%	54% (State DOT), 3% (Local Agency)

Source: ITS JPO (2024)[8]

2.2.2 Roadway Digital Infrastructure (RDI)

In recent years, RDI has emerged as a new term to describe a set of digital transportation technologies that can supplement more conventional ITS approaches. There is currently no nationally recognized

[8] ITS JPO; *Intelligent Transportation Systems Deployment Tracking Survey: 2023 Key Findings*; (2024).

definition for RDI, though FHWA and its partners are working to advance federal discourse on this topic. One definition (promoted in materials from several transportation groups, such as the Transportation Research Board (TRB) and The Eastern Transportation Coalition) defines RDI as:

> *Collective public and private technology assets that create, exchange, or use data or information to improve the transportation system by the provision of existing and new services for travelers, businesses, and agencies. RDI is not just data, but also assets that generate, move, process, and display data and information that support end user usage of the generated information.*[9]

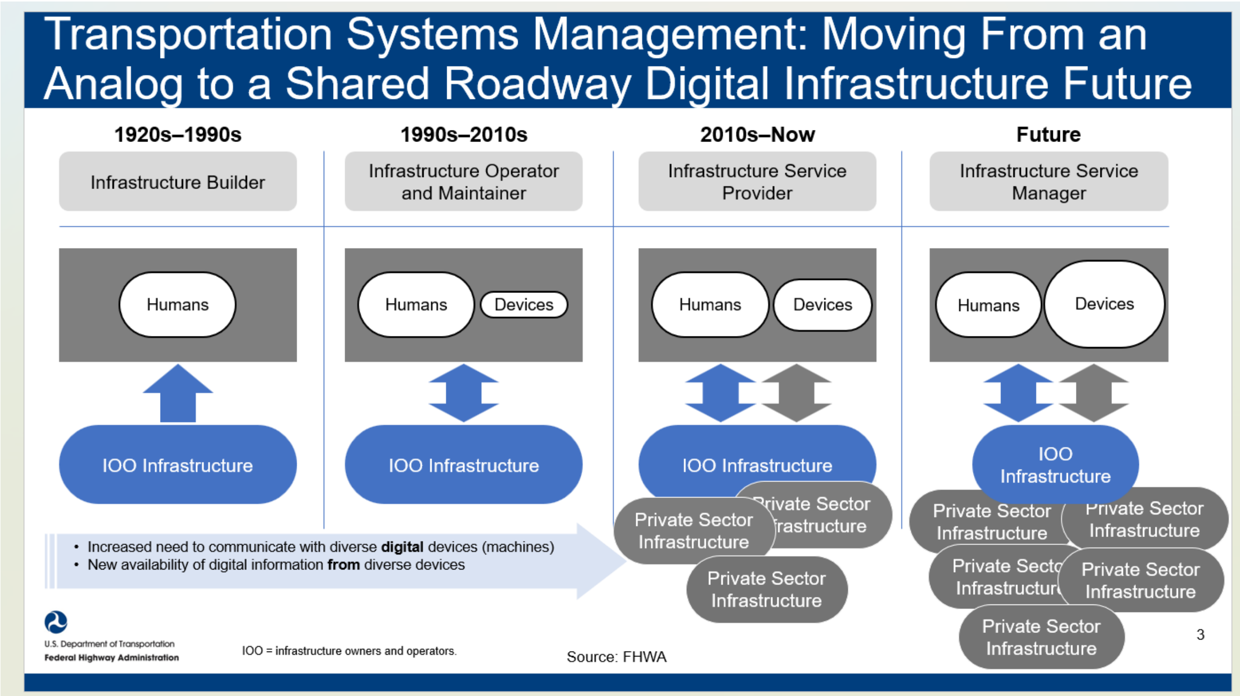
Key differences between ITS and RDI include the infrastructure these systems rely on, the institutional approaches followed, and the policy context under which they operate. Conventional ITS infrastructure operates from centralized networks that are often owned and operated by government agencies, led by conventional procurement and engineering practices, with a primary focus on vehicle mobility and safety on a localized scale. In contrast, RDI systems are thought to rely more on emerging technologies for data collection and storage (such as vehicle-roadway integration and cloud technology), crowd sourcing, public-private business models, innovative procurement and partnerships, cross-disciplinary input, the safe systems context, and national-level synchronization.[10]

RDI is an emerging technology area with very few specific, action-oriented deployments currently operating around the country. Potential near-term, RDI-related deployment opportunities include V2X communications and the Work Zone Data Exchange (WZDx) feed along multi-state corridors.

In the 13 years since the 2011 report, ITS has grown to encompass new technologies and components (Figure 1). The new model of ITS includes more stakeholders beyond government-owned and led technologies. This expansion allows for more types of data and more ways to reach visitors.

[9] The Eastern Transportation Coalition. "Virtual Information Exchange: Considerations for Digital Infrastructure - Project Examples and Planning for the Future". (June 2023).
[10] Transportation Research Board. "TRB Webinar: National Digital Infrastructure Strategy and Roadway Operations Data Exchanges"; Slides 7-9. (December 2023).

Figure 1: Transportation Systems Management Trends



Source: FHWA

3. Background & Methodology

3.1 Past Research Efforts

This report updates two previous reports, both of which were prepared by the Volpe Center for the NPS:

1. The 2005 report titled Intelligent Transportation Systems (ITS) in the NPS: 2005 Baseline Inventory and Preliminary Program Assessment[11]; and,
2. The 2011 update report titled Intelligent Transportation Systems in the National Parks System and Other Federal Public Lands - 2011 Update.[12]

The 2005 Baseline Inventory and Preliminary Program Assessment provided a foundational inventory of ITS applications at 59 NPS units. The report identified 20 ITS technologies, organized into four categories: Travel & Traffic Management, Public Transportation Management, Maintenance & Construction Management, and General/Other. The report inventoried 214 total ongoing or planned ITS projects, of which only ten percent (or 21 projects) were considered complete.

The 2011 report updated the baseline inventory of ITS technologies and expanded it to include work completed at 94 units across all Federal Land Management Agencies (FLMAs). Many of the conclusions from the 2005 report provided context for the findings, best practices, and recommendations in the

[11] U.S. DOT Volpe Center. Intelligent Transportation Systems (ITS) in the NPS: 2005 Baseline Inventory and Preliminary Program Assessment. (2005).
[12] U.S. DOT Volpe Center. Intelligent Transportation Systems in the National Parks System and Other Federal Public Lands - 2011 Update. (2011).

2011 report update. The 2011 inventory identified 19 technologies, several of which were introduced in the baseline inventory. The 2011 report modified or simplified categories and their corresponding ITS technologies to reflect the concentration of ITS application types in use by public lands units since 2005.

Similar to how the 2011 baseline inventory update relied on conclusions from the 2005 report, many of the conclusions from the 2011 report update provided the context for the findings, best practices, and recommendations of this 2025 research report update. However, unlike the 2011 report which broadened the landscape from NPS to all FLMAs, this 2025 report update brings the focus back to traveler information technologies at NPS units. This report is also more narrowly focused on traveler information technologies, rather than ITS, and how these technologies are being, or could be, planned and implemented at NPS units to enhance the visitor experience. The project team also investigated other research efforts related to transportation planning at NPS, FLMAs, and state departments of transportation (DOTs).

3.2 Study Methodology

To complete this report, the project team:

- Conducted technology research on the six key traveler information technology areas;
- Assessed data privacy and security for the technologies researched in this report;
- Hosted three "open house" style virtual meetings with NPS regional transportation staff to verify technology inventory, identify benefits attained and costs incurred from existing ITS deployments, and discuss lessons learned and document future needs related to ITS planning, deployment, and operations; and,
- Hosted three advisory team meetings with an interagency advisory team to solicit input on the overall project direction and collaboration with partners.

4. 2025 ITS Inventory

The project team's baseline inventory largely borrows the conventions established in the 2005 and 2011 Reports. This report does not contain any new categories, but several technologies were added to corresponding categories (Table 4). The 2025 technology column was developed by the project team with input from U.S. DOT ITS experts, NPS and other FLMA staff, and research of various external sources.

Table 4: Comparison of 2005, 2011, and 2025 Technologies Relevant in Public Lands by Category

Category	2005 Technology	2011 Technology	2025 Technology
Travel & Traffic Management	• Variable Message Signs (VMS) • 511 System Integration • Highway Advisory Radio • Trip Planning Tools • Traffic Monitoring System • Parking Management & Availability • Loop Detectors / Traffic Counters • Weather/Road Condition Information • Travel Information Kiosks • Traffic Management Centers/Facilities (Physical & Virtual)	• VMS with 3G Cellular Communication Update Capability • 511 System Integration • Highway Advisory Radio • Trip Planning Tools • Integrated Traffic Monitoring System (with Real-Time Data) • Parking Management & Availability • Vehicle Probe Data (Global Positioning System (GPS))	• VMS with Automatic Update Capability • Real-time data feeds on closures, incidents, & work zones • Highway Advisory Radio (Primarily Low-Connectivity Parks) • Trip Planning Tools (AI-Based and/or Forecasts) • Integrated Traffic Monitoring System with Real-Time Data & Predictive Tools including AI • Parking Management & Availability (with Real-Time Data) • Mobility, Original Equipment Manufacturer & Connected Vehicle (CV) Data • Road Condition Information from Navigation Systems and Cellular Vehicle to Everything (C-V2X) Communications • Other Data Feeds (Parking, Crowding, Multimodal, Ridehailing) • Vehicle Counters/Sensors • Advanced Traffic Management Centers with Enhanced Technologies (Automatic Incident Detection, AI)
Public Transportation Management	• In-Vehicle Electronic Information • Computer-Aided Dispatch (CAD)/Automatic Vehicle Location (AVL) System • Transit Management • Operations and Fleet Management	• In-Vehicle Electronic Information • CAD/AVL System • Automated Passenger Counters • General Transit Feed Specification (GTFS) (Static)	• In-Vehicle Electronic Signage & Announcement Information • Advanced CAD/AVL System (Operations Data, Integration with Real-Time Traveler Information Systems) • Automated Passenger Counters • GTFS (Real Time)
Maintenance & Construction	• Road Construction Information • Work Zone Management	-	• Smart Work Zone Technology (Connected Equipment with Sensors, Geofenced Alerts, Queue Warning Systems)
Incident Management	-	• Road-Weather Information System • Road Surveillance • Work Zone Management • Incident Management System	• Geofenced Alerts • Incident Management System • WZDx/ Transportation Data Exchange (TDx) Data Feeds • Safety Management
Entry Management	• Automated Entry System	• Automated Entry System • Automated Fee/Fare Payment • License Plate Reader (LPR)	• Automated Entry System (with LPR tie-in) • Automated Fee/Fare Payment • LPR with AI Analytics Capabilities • Reservation Systems (Unit Entry; Use of Popular Trails & Points of Interest within Units)
Other / General	• Integrate ITS with State/Local DOTs & Cross-Agency Coordination • ITS Needs Assessment	• Integrate ITS with State/Local DOTs & Cross-Agency Coordination • ITS Needs Assessment	• Full ITS System Integration • ITS Needs & Risk Assessment

Source: U.S. DOT Volpe Center, September 2025

5. Key Traveler Information Technologies Research Areas

This section summarizes research on six key traveler information technologies identified by the project team: data feeds, mobility data, V2X, ML and AI, geofenced alerts, and physical infrastructure and equipment (Table 5). The following sections provide a summary of each key technology, how NPS currently utilizes the technology, other potential applications of the technology, and considerations on how to deploy the technology while minimizing data, privacy, and security concerns. For all researched technologies, it will be crucial to work with the parks to ensure that staff on the ground can maintain and operate the technologies and physical equipment.

Table 5: Key Traveler Information Technologies Research Areas

Technology Area	Description
Data Feeds	Standardized data on transportation system information, made available for public consumption through navigation applications.
Mobility Data	Vehicle or mobile device-generated location data aggregated to produce traveler information.
Vehicle to Everything (V2X)	V2X technologies enable vehicles to "talk" to other vehicles, pedestrians, and roadway infrastructure.
Machine Learning (ML) & Artificial Intelligence (AI)	AI is an engineered or machine-based system that can, for a given set of objectives, generate outputs such as predictions, recommendations, or decisions influencing real or virtual environments. AI systems are designed to operate with varying levels of autonomy. ML is a branch of AI that focuses on the development of systems capable of learning from data to perform a task without being explicitly programmed to perform that task. Learning refers to the process of optimizing model parameters through computational techniques such that the model's behavior is optimized for the training task.
Geofenced Alerts	Targeted messages sent to mobile devices or vehicles within a defined geographic area.
Physical Infrastructure & Equipment	Technologies that are physically installed at parks. Examples include traffic counters, sensors, CCTV systems, telematics systems in shuttles, and VMS. In many cases, these technologies utilize some type of cloud system to store data or control equipment functions.

Source: U.S. DOT Volpe Center, September 2025

5.1 Data Feeds

Data feeds are structured files of information designed to be easily read and processed by computer devices and provide up-to-date and/or continuous information to their users. Relevant transportation data feeds can encode information about traffic conditions, road closures, transit schedules, parking availability, micromobility options, and curb management. Third-party applications often access authoritative data feeds through the provider's Application Programming Interface (API) and ingests the information into their products. Accurate information about transportation conditions allows visitors to efficiently and safely make decisions about navigation to and within parks.

Widely adopted data feed standards, such as the General Transit Feed Specification (GTFS), make it easier for third-party applications to ingest data in a standardized format from many infrastructure owners and operators. Other transportation-related data feeds, such as the Transportation Data Exchange (TDx), have been developed recently and have lower adoption rates by third-party applications. Transportation-related data feeds will continue to become more prevalent and important, as travelers and visitors increasingly seek transportation information from third-party digital sources.

5.1.1 NPS Utilized Technologies

TDx Road Closure and Incident Alert Application

NPS first created a road closure and incident data feed in September 2022.[13] After a severe monsoon, Mojave National Preserve staff observed visitors and travelers driving on closed and unsafe roads. This resulted in several vehicular incidents (Figure 2). Park staff indicated that third-party navigation applications had not been displaying the road closures. This experience served as the impetus for the TDx data feed pilot; NPS needed to communicate road closures via a standardized data structure to third-party navigation applications to prevent driving on closed, and unsafe, roads. The pilot data feed communicated closures on five major roads in Mojave National Preserve.

Based on positive feedback from park staff and third-party navigation applications on the pilot data feed, NPS developed a service-wide feed via the Road Closure and Incident Alerts Application. Parks can now create alerts through the internal NPS application, and then the alerts are automatically pushed to the Road Events endpoint of the NPS API. Multiple third-party navigation applications and work zone equipment companies are actively ingesting the Road Events through the NPS API. As of September 2024, 33 parks have used the tool to create a road closure or incident alert. These 33 park units represent approximately 28 percent of 2023 visitation for all NPS park units that have roads. Third-party applications ingesting the NPS road closure feed include TomTom, Google, Apple, and TriHydro.

[13] The NPS road closure and incident feed follows U.S. DOT's Transportation Data Exchange (TDx) specification, developed in 2021.

Figure 2. Vehicle Incident on Closed Road at Mojave National Preserve in 2022

Source: National Park Service, 2022

Road Restriction Specification

In 2024, after Hurricane Helene damaged a portion of I-40 in North Carolina, navigation applications began routing commercial vehicles through Great Smoky Mountains National Park's Newfound Gap Road. This road is restricted to commercial vehicles and is impassable by large trucks. In response, NPS created the first data feed to provide road restriction information on the Newfound Gap Road. NPS has used this pilot feed to engage with third-party navigation applications about their ability to relay road restriction information to drivers through their applications. Third-party navigation applications do not typically provide road restriction information, so initial efforts focused on building awareness of the feed with navigation applications and identifying opportunities to display this information directly to visitors.

General Transit Feed Specification (GTFS)

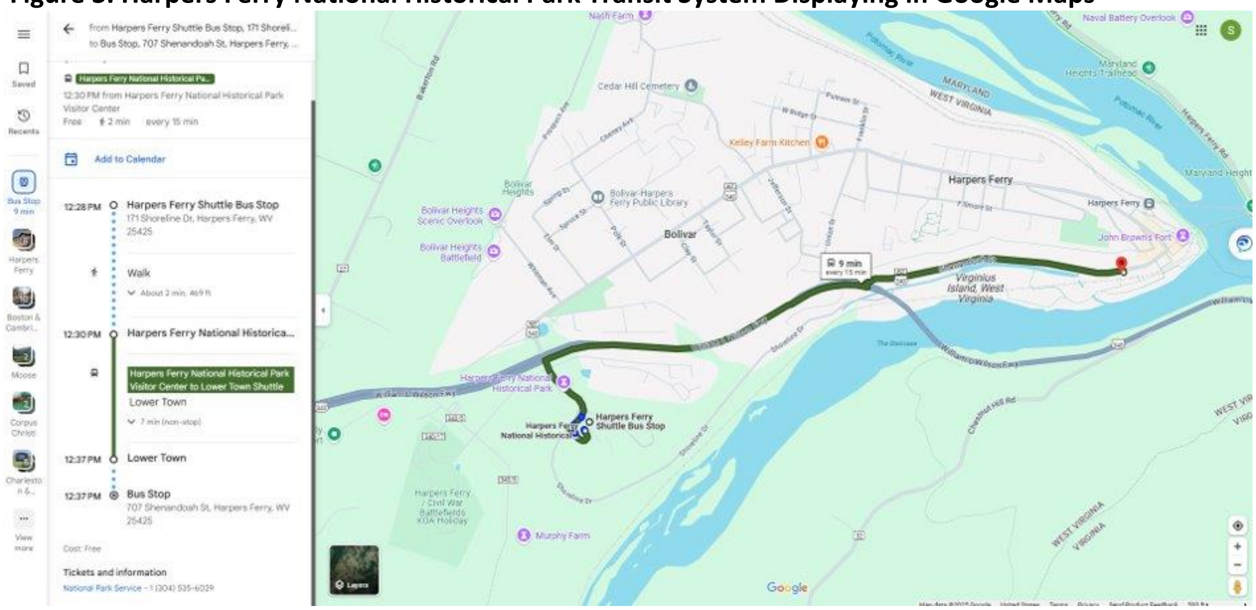
The General Transit Feed Specification (GTFS) is an open data feed standard maintained by the non-profit Mobility Data.[14] Static GTFS data feeds encode information about transit schedules and routes, and real-time GTFS data feeds provide trip updates, vehicle positions, and service alerts to inform passengers of service disruptions and updated arrival times. GTFS is the widely accepted method for transmitting transit information to third-party applications, and the Federal Transit Administration (FTA) requires transit agencies that receive FTA funding to submit static GTFS feeds for inclusion in the National Transit Database.[15]

[14] Mobility Data. General Transit Feed Specification Home Page. (2025).
[15] U.S. DOT FTA. The National Transit Database (NTD): Changes to Reporting Requirements for 2025-2026. (2025).

As of October 2025, NPS developed or compiled 23 static and three real-time GTFS feeds for NPS park unit transit systems, accounting for 85 percent (23 million) of total boardings (27 million) at NPS park units in 2023. The GTFS feeds are published on the NPS Developer Resources webpage[16], and the feeds are ingested by Google Maps, Apple Maps, Transit, Bing, and Rome2Rio (Figure 3). NPS is also exploring using the GTFS feeds to display standardized transit information on park websites and on transit message boards at stops.

Creating GTFS feeds enhances the efficiency of NPS transit information presentation and dissemination, by better providing transit information for trip planning and navigation via third-party applications and NPS digital products. By providing accurate and up-to-date transit information, GTFS can also help visitors choose to take transit to, and within, parks, which eases roadway and parking congestion.

Figure 3. Harpers Ferry National Historical Park Transit System Displaying in Google Maps



Source: Google Maps, 2025

Parking Availability Data

Parking availability data refers to real-time information about the availability of parking spaces, providing details on the number of vacant parking spots, their location, and sometimes the type of parking (on-street parking, parking lot, garage parking, etc.). This data is collected through various sensors, cameras, or mobile applications and can be used by drivers to find and navigate to available parking spaces efficiently, reducing congestion and emissions while saving time.[17]

Parking lots do not currently have a widely accepted data feed standard. In a park context, some park unit's parking pages on the NPS website, such as Arches National Park's parking page[18], have hourly forecasts for each day that project busy times for each parking lot. Indiana Dunes National Park has

[16] NPS. NPS Developer Resources webpage. (n.d.).
[17] Datarade. Parking Availability Data: Best Datasets & Databases. (2024).
[18] NPS. Arches National Park's parking page. (n.d.).

piloted capturing parking lot availability in real-time. Indiana Dunes' parking lot data has been collected and made available for visitors seasonally since Summer 2022. Though it is not designated as an official data feed standard, other parks may be able to follow Indiana Dunes' example to format their parking availability data and similarly make it available for visitors.

5.1.2 Researched Technologies

The project team evaluated the following data feed specifications that encode standardized information about a variety of transportation assets and system/network components. NPS may benefit from implementing some of the following data feeds to better communicate the existence and condition of the NPS transportation network to visitors.

WZDx Specification

The Work Zone Data Exchange (WZDx) encodes standardized, up-to-date information about dynamic work zone conditions on roads to facilitate ingestion by data consumers. WZDx contains work zone and device sub-feeds.[19] The work zone sub-feed provides high-level information about work zone road events that involve a change from standard operations, and the device sub-feed provides information about the location and status of field devices deployed in work zones. Third parties, such as original equipment manufacturers and navigation applications, can ingest the data feed to help automated driving systems and humans safely navigate work zones.

FHWA began developing the WZDx specification in 2018, and the Work Zone Data Working Group oversaw development of future versions of the specification. Many state and local transportation agencies have set up data feeds based on the specification and are available in the Work Zone Data Exchange Feed Registry.[20]

NPS initially developed the road closure data feed pilot at Mojave National Park and Preserve, mentioned above, using the WZDx data specification. NPS then moved to using the TDx specification for the Road Closure and Incident Alerts application, which is described in the following section.

TDx Specification

Building off the WZDx specification, FHWA began developing the Transportation Data Exchange (TDx) specification in 2021 as an extension of the WZDx specification.[21] TDx communicates work zone and detour information captured in the WZDx specification, as well other roadway information. ITS JPO and FHWA maintain the TDx specification, and local, state, tribal, and federal transportation agencies are the primary producers. Third parties, such as navigation applications and Connected and Automated Vehicles, ingest the data feed to communicate the roadway information to the traveling public.

The TDx specification includes road incident and road restriction sub-feeds to standardize sharing information about transportation events and infrastructure. The project team is currently developing a pilot road restriction feed under the TDx specification in response to hurricane impacts at Great Smoky Mountains National Park, noted above.

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[19] U.S. DOT ITS JPO. Work Zone Data Exchange (WZDx). (2023).
[20] U.S. DOT ITS JPO. Work Zone Data Exchange Feed Registry. (2025).
[21] U.S. DOT ITS JPO. Transportation Data Exchange (TDx). (2023).

There are opportunities to continue developing the TDx feed through the Federal Geographic Data Committee and related efforts to bring together stakeholders and develop data feeds. NPS could consider collaboration within this format to include road-related fields specific to FLMA roads, such as fees or reservations required to enter the park.

Managing Disruptions to Operations Data Exchange (MDODE)

Building on the development of the TDx and WZDx specifications, FHWA is supporting integration of information on all roadway disruptions (including work zones, incidents, road weather events, and planned special events) through the Managing Disruptions to Operations Data Exchange (MDODE) specification program. The MDODE program includes three key elements:

1. Continued development and evolution of collaborative specifications (such as TDx and WZDx),
2. Development of a shared platform for technical collaboration owned and maintained by agency and private sector interests, and
3. Growing institutional capability for capturing, sharing, and using disruptions data.

The MDODE Concept of Operations, developed as a product of significant collaboration with stakeholders across federal and state government, industry, institutions of research, and third-party data providers, addresses the needs for data discoverability (maintaining visibility of data sets with relevance to operational use cases), data quality and trustworthiness, and promoting opportunities for private sector innovation both in the evolution of available data and in creation of value-added tools for working with disruptions data.[22]

The FHWA Managing Disruptions to Operations team leads the MDODE effort in close collaboration with other federal programs including the National RDI Strategy Project. NPS has been involved in early discussions on MDODE and has been integral to demonstrating the adaptation of the WZDx feed for weather-related closures. NPS has many unique disruptions due to the nature of park environments. As an "internal" Infrastructure Owner Operator (IOO), NPS's unique perspective will continue to inform FHWA's development of the MDODE strategy that is adaptable to encompasses the many unique roadway disruptions that rarely occur in urban centers but are commonplace in park areas.

Lane Closure System

Six states (Colorado, California, Indiana, Maryland, Ohio, and Wisconsin) have developed lane closure policies and management systems to assist in the scheduling of work zones. Lane closure policies specify when and how lanes can be closed (or cannot be closed) for a given stretch of roadway. These policies and management systems restrict lane closure hours in line with peak travel times and coordinate lane closures to manage the combined impacts. Lane closure management systems allow state DOTs to easily and effectively coordinate, track, and communicate lane closures both within the agency and to the media, emergency responders, and the traveling public.[23]

Since 2010, the California DOT (Caltrans) has used the Lane Closure System (LCS) to provide standardized road and lane closures information.[24] LCS details the approved closures planned for the

[22] U.S. DOT ITS JPO. The Operational Data Environment (ODE) Fact Sheet. (n.d.).
[23] U.S. DOT FHWA Office of Operations. Lane Closure Policies and Management Systems. (Fall 2010).
[24] California Department of Transportation. Lane Closure System. (2024).

next seven days, plus current lane, ramp, and road closures due to maintenance, construction, special events, etc. This system provides similar information to the WZDx and TDx standards but provides that information in a different format. The NPS has not implemented LCS because the information is already captured in WZDx and TDx data feeds. It is not clear whether Caltrans is considering a switch to WZDx or TDx specifications.

Mobility Data Specification (MDS)

The Los Angeles DOT originally created the Mobility Data Specification (MDS) in 2018. MDS is now owned and maintained by the Open Mobility Foundation.[25] Cities and municipalities use MDS to encode information about the status, location, and destination of shared mobility options such as dockless e-scooters, bikeshares, and ridehailing. MDS is then ingested by third-party applications to display correct shared mobility options and locations. It provides a standardized framework for collecting, managing, and sharing data between shared mobility providers and city governments. For example, the San Francisco Municipal Transportation Agency collected real-time operational data from shared mobility providers via MDS, including scooter and bike locations, mobility trip data, and fleet condition and distribution information to ensure compliance with city regulations and optimize service availability.

Curb Data Specification (CDS)

Similar to MDS, the Los Angeles DOT created the Curb Data Specification (CDS) in 2019. CDS is also now owned and maintained by the Open Mobility Foundation.[26,27] Like MDS, cities use CDS to encode information about activity and regulations at curbs. The CDS data feed is then ingested by third-party applications to display available curb space and associated regulations. CDS helps agencies effectively manage curb space, improve traffic flow, optimize parking and loading zones, and coordinate with rideshare companies. Chicago DOT uses CDS to share parking regulations with commercial fleet operators, such as commercial loading zones for delivery services.[28]

Open Sidewalks

The OpenSidewalks Schema is a proposed open pedestrian transportation network data standard from the University of Washington’s Taskar Center for Accessible Technology (TCAT).[29] The OpenSidewalks Schema would be used for describing and sharing pedestrian network data. Data in the schema represents a network of pedestrian paths, including sidewalks and crosswalks. The data would then be ingested by third-party applications to provide travelers with information on pedestrian route safety and

[25] Open Mobility Foundation. About MDS. (2023).
[26] Open Mobility Foundation. About CDS. (2023).
[27] The Open Mobility Foundation (OMF) stewards an open-source tool called “Mobility Data Specification” (MDS) that was initially developed by cities to help manage dockless micro-mobility programs (including shared dockless e-scooters). MDS is a set of Application Programming Interfaces (APIs) that create standardized two-way communications for cities and private companies to share information about their operations, and that allow cities to collect data and publish regulations that can inform efficient traffic management and public policy decisions to enhance safety, equity and quality of life. The OMF continues to develop MDS while working on new projects in curb management and emerging modes. (Source: Open Mobility Foundation).
[28] Populus. "City of Chicago Selects Populus as Digital Solution to Manage New Permanent Shared Scooter Program". (June 2022).
[29] Taskar Center for Accessible Technology, University of Washington. Open Sidewalks. (2024).

accessibility. This would allow users to choose routes that meet their accessibility needs and allow transportation agencies to plan and prioritize sidewalk implementation and improvement. TCAT has created an inventory of sidewalks covering 55 percent of Washington state residents and expects to expand this coverage to 90 percent of the state's population by 2026.[30] NPS has not investigated OpenSidewalks, but if funded, NPS could engage with TCAT on the applicability of implementing the schema in park units in Washington and potentially other states.

General Active Transportation Infrastructure Specification (GATIS)

The Bureau of Transportation Statistics began leading the development of the GATIS specification in 2024.[31] This data feed aims to create a routable dataset of bike, pedestrian, and physical accessibility infrastructure that can be used for individual travelers, along with other transportation-focused stakeholders. This standard is in the early stages of development.

Indoor Mapping Data Format

The Indoor Mapping Data Format is a recent format adopted by Apple to provide more detailed information on large public or private spaces.[32] This format is available for airports, malls, hospitals, and arenas, among other highly visited indoor spaces. Apple Maps also requests indoor positioning for Apple users to allow Apple Maps to leverage the users position within the large public space. This allows for detailed information nearest to the user, and detailed routing instructions.

Under the ITS JPO's ITS4US Program, Georgia DOT is using a software application that allows users to upload and update indoor maps in GeoJSON, Drawing Exchange Format, Scalable Vector Graphics, PDF, and PNG formats. Georgia DOT's team has also installed beacons throughout the indoor facility that use Bluetooth low energy detected by mobile phones to provide additional position accuracy. When editing the indoor facility map, users can add up to ten properties for a destination which allows for compatibility with Apple's Indoor Mapping Data Format properties.

Truck Parking Information Management System Data Exchange Specification (TPIMS)[33]

Truck drivers, fleet managers, and owner-operators experience challenges with truck parking. Long-haul truck drivers often struggle to find safe parking, which can reduce national freight productivity. More importantly, searching while fatigued and parking in unauthorized spots puts truck drivers and other motorists at risk.

To mitigate this, in 2016, eight members of the Mid America Association of State Transportation Officials developed the Truck Parking Information Management System (TPIMS). TPIMS provides drivers, fleet managers, and owner-operators with up-to-the-minute parking availability along major freight corridors throughout eight states: Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Ohio, and Wisconsin.

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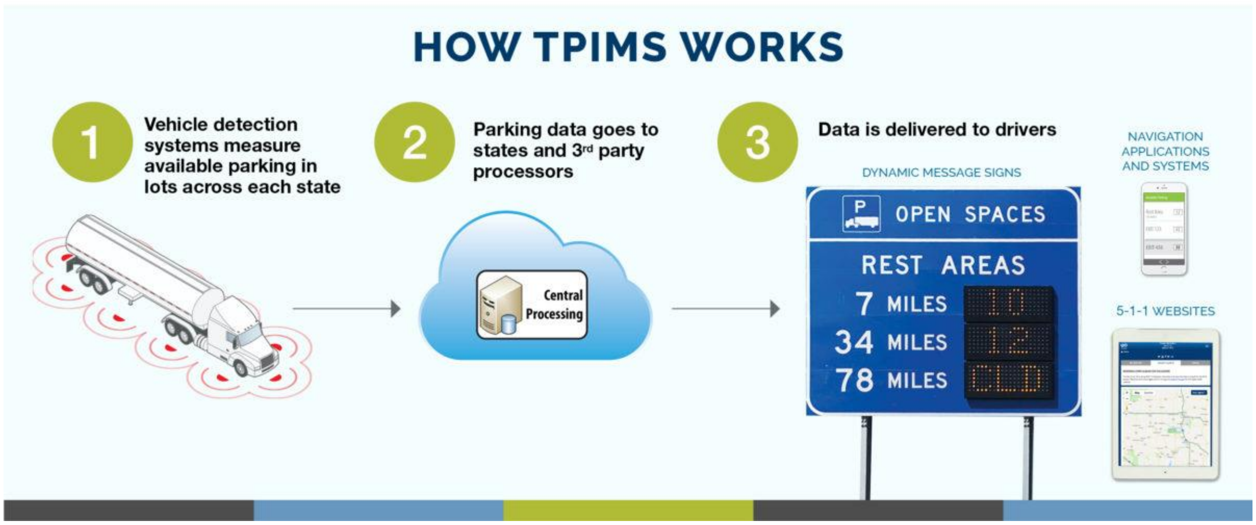
[30] Taskar Center for Accessible Technology, University of Washington. OS-CONNECT WA State Project for Sidewalks Inventory and Accessibility Mapping. (2024).
[31] U.S. DOT Bureau of Transportation Statistics. GATIS specification. (2025).
[32] Apple. Indoor Mapping Data Format Overview. (2021).
[33] Trucks Park Here. Parking Information. (2024).

TPIMS provides truck parking availability information on highway signs, traveler information websites, and some third-party applications.

The truck parking data is available for use by website and application developers and is provided by each state in two data feeds. The first data feed includes parking availability data updated at least every five minutes for public and participating private truck parking locations. The second data feed includes metadata for the truck parking areas. The TPIMS Data Exchange Specification Document provides a detailed description of the JSON format the two data feeds use.[34] Figure 4 illustrates the TPIMS process.

Figure 4. TPIMS Process



Source: Trucks Park Here, 2019

Other Data Feeds

Digital transportation infrastructure continues to be an increasingly important way to communicate traveler information. As transportation data feed standardization becomes more common, there are other transportation asset types that could benefit from data feed representation. Some areas of potential interest for NPS are fueling type information, ridehailing pick up drop off information, and congestion information.

5.1.3 Deployment Considerations

The NPS API is equipped to provide large amounts of information to third parties. NPS deploys three transportation data feeds: the TDx Road Closure and Incident Feed, GTFS, and the Road Restriction Specification Feed. Currently, only the TDx Road Closure and Incident Feed is available in the NPS API, via the Road Events endpoint. As NPS considers further build-out of data feeds, the NPS API architecture is a powerful resource to store and make data available to the NPS digital products and third-party developers.

Data feeds have the following data, privacy, and security concerns:

[34]Trucks Park Here. TPIMS Data Exchange Specification Document Version 1.1. (2019).

- **Inaccurate Feed Information.** If the data feed displays inaccurate information, the visitor experience could be negatively impacted, such as road closures not displaying online and visitors getting routed along a closed road. Additionally, inaccuracies in the data feeds could lead to liability issues. For example, if height clearance under a bridge is listed as higher than the actual clearance on a road restrictions feed, NPS could possibly be held liable if a truck crashed into the bridge due to inaccurate clearance information online.
- **Collecting and Storing Information in the Data Feeds.** There are minimal concerns surrounding personally identifiable information (PII) in the feeds, as these data feeds are typically digital representations of standard NPS traveler information, such as bus schedules or road closures. However, malicious actors are using increasingly sophisticated techniques to deduce personal information from location or asset data. Agencies that use data feeds should treat data as sensitive personal data and carefully consider and manage risk throughout the lifecycle of any specification implementation.

5.2 Mobility Data

Mobility data refers to data generated by vehicles and mobile devices. Mobility data can be a valuable means to understand visitor travel patterns to inform park planning and operations. Mobility data can be aggregated to generate traffic conditions data, near real-time directions, and travel advisories. Unlike more traditional forms of traffic measurement, such as traffic sensor systems, mobility data can generally be sourced without physical roadside infrastructure. This significantly reduces the cost of collecting data and allows for collection to take place on most roads, over wide areas.[35] Transportation agencies can utilize multiple sources of location data to monitor traffic conditions, explained further in Table 6. It should be noted however that most types of mobility data require an alternate data source for validation purposes.

Table 6. Description of Major Mobility Data Types

Type	Description	Location Precision
Cellular Devices	Mobile device location, estimated based on cellular signals, calculated using proximity to nearby cellular communications infrastructure. Cell phone location data is determined based on triangulation, a method that uses radio communication between a cellular device and multiple nearby cell towers to estimate the device's (and by extension the vehicle's) current location and direction.[36]	300 – 1,000+ Meters
Location Based Services (LBS)	Mobile device location estimate based on one or more available location signal types, including GPS, cellular data, Wi-Fi, and Bluetooth. LBS data generates location information based on a combination of different data sources to establish what is likely the most thorough estimate of a vehicle's location.[37]	5 – 50 Meters[38]
Connected Vehicles (CVs)	High-resolution vehicle trajectory and telemetry data (e.g. seatbelt usage, harsh braking, windshield wiper activation) tracked using onboard sensors. Data identifies location similar to LBS and, in some cases, may be using other short-range communication. The data is more reflective of consumer vehicles.	3 Meters[39]
Probe Vehicles	A vehicle transmitting location data that functions as a "probe" into traffic flow conditions.[40] Vehicles transmit real-time speed and location data through an in-vehicle GPS tracker or a GPS tracker from a device inside the vehicle, such as a mobile phone. The fleets are more reliable for freight vehicles on highways.	3 – 50 Meters
Dashcam Footage	Emerging vehicle-based data from dashcams can analyze real-time dashcam footage to generate a better understanding of on-the-ground road conditions, which can provide information on items such as road surface conditions, traffic flow, and parking availability.[41]	Video feed can be tied to road network

Source: U.S. DOT Volpe Center, September 2025

[35] Nebraska Department of Transportation. Evaluation of Opportunities and Challenges of Using INRIX Data for Real-Time Performance Monitoring and Historical Trend Assessment. (December 2017).
[36] HERE. HERE Probe Data - Developer Guide. (September 2024).
[37] Travel Forecasting Resource. Location-Based Services Data. (2024).
[38] Schewel, Laura. Location-Based Services (LBS) Data Beats Cellular on Spatial Precision Accuracy. (May 2017).
[39] Dimitrijevic, Branislav; et al. Assessing Connected Vehicle Data Coverage on New Jersey Roadways. (2022).
[40] HERE. Probe Data - Developer Guide. (September 2023).
[41] Vizzon. How On-Vehicle Images Can Be Used to Fill in Gaps from Roadside Cameras and Provide Greater Insights to DOT's. (2024).

One key differentiation between the different types of mobility data is that mobile devices can provide data on multiple modes, but data vendors must predict the travel mode each mobile device is using. Alternatively, vehicle-based mobility data can clearly tell the mode but will not provide information on portions of the trip not utilizing the vehicle. This could result in incomplete data for parks where visitors typically take multimodal trips to reach destinations within the park.

GPS location-based systems are generally considered more accurate than cellular data-based systems, since they can obtain location data under a variety of conditions, including remote areas with poor cell coverage. They also generally offer the best location resolution out of all mobility data technologies.[42] However, conventional GPS-based probe systems may not always provide as wide of a coverage range as most cellular data-based systems, since they only receive data from vehicles equipped with GPS receivers (typically commercial vehicles) or vehicles using GPS-enabled mobile devices.[43]

Mobility data is generally output as points, with various attributes attached to them (e.g., coordinates of last known location, direction, and sometimes speed). One key challenge for agencies working with mobility data is the large size of datasets – even in smaller metropolitan areas, these can contain millions of waypoints. It is therefore common for agencies to rely on third-party packages and platforms that aggregate raw data into a more usable format. It should also be noted that the accuracy of mobility data is dependent on the number of vehicles or mobile devices capable of providing measurements along a corridor. Studies into the accuracy have found that it is generally most effective at estimating traffic conditions along higher volume roads, especially during the daytime hours when more vehicles or devices are on the roads providing reference data. This same research has found that probe data on nighttime traffic conditions, and traffic conditions during times of variable congestion, can be less accurate.[44]

5.2.1 NPS Utilized Technologies

Location-Based Data

Third party navigation applications such as Google Maps, Waze, and Apple Maps currently utilize location data to provide near real-time traveler information to motorists. This information on traffic conditions is already available for drivers in several national parks, although its accuracy often depends on factors such as the availability of cell service and overall traffic volumes. A minimum number of vehicles or devices is generally required to produce accurate mobility data. This data is also not validated by or produced in coordination with NPS or parks but rather is generated automatically by navigation interfaces.

Several national parks also utilize mobile devices or connected vehicle location data to inform transportation planning, management, and operations activities.[45] In 2023, NPS used mobile device data to understand visitor travel patterns as they reached the park and while in the park. These findings

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[42] Schewel, Laura. Location-Based Services (LBS) Data Beats Cellular on Spatial Precision Accuracy. (May 2017).
[43] U.S. DOT FHWA. Work Zone Performance Measurement Using Probe Data. (September 2013).
[44] Vermont Agency of Transportation. The Eastern Transportation Coalition Probe Data Validation: HERE, INRIX and TomTom. (March 2021).
[45] Tsai, Wei-Lun; H. Merrill, Nathaniel; C. Neale, Anne; Grupper, Madeline. Using cellular device location data to estimate visitation to public lands: Comparing device location data to U.S. National Park Service's visitor use statistics. (2023).

informed a larger planning effort.[46] NPS social science staff have also utilized location-based services to understand visitor spending patterns inside and within proximity to parks. NPS is exploring this data to inform travel forecasting tools and other visitor-facing products.

5.2.2 Researched Technologies

Mobility data continues to evolve as travelers become more connected. Data vendors are also becoming more sophisticated in the ways they process, analyze, and visualize these data. As such, the project team researched promising new data vendors and methods of disseminating these data to travelers.

Historical and Real-Time Mobility Data

Mobility data is commercially available from several major traffic data providers, such as INRIX, HERE, and TomTom. Most government transportation agencies can access historical mobility data from INRIX via the National Performance Management Research Data Set Analytics Suite operated by the Regional Integrated Transportation Information System (RITIS) CATT Lab at the University of Maryland. INRIX data is made available on RITIS through an agreement with FHWA. The National Performance Management Research Data Set provides mobility data for all National Highway System roads, although lower volume or rural roads may not have full coverage due to lower accuracy.

Most mobility data providers also sell access to real-time probe vehicle information, which can be used to generate traveler alerts and directions. For example, Georgia DOT used historical mobility data measurements from RITIS analytics to build travel forecasts for major holiday weekends. Georgia DOT analyzed INRIX mobility data measurements taken from RITIS in prior years across the state's road network to identify when specific areas of the state's highway network experienced the worst congestion problems. Georgia DOT then published this information online to help members of the public better plan their trips.[47]

Some transportation agencies are also using mobility data to provide real-time traveler information. Utah DOT recently built a public-facing dashboard based on real-time traffic mobility data from the Iteris Clearguide platform.[48] This dashboard is focused on roads in the Cottonwood Canyon Area, which can experience substantial congestion in the winter months due to popular attractions such as ski resorts and hiking areas (Figure 5).[49] Data on estimated segment travel times is provided by a system that integrates connected vehicle GPS mobility data with other traveler information sources such as road incident and work zone reports. The resulting dashboard is intended to help visitors better plan their trips during the times of year with the greatest potential for congestion.

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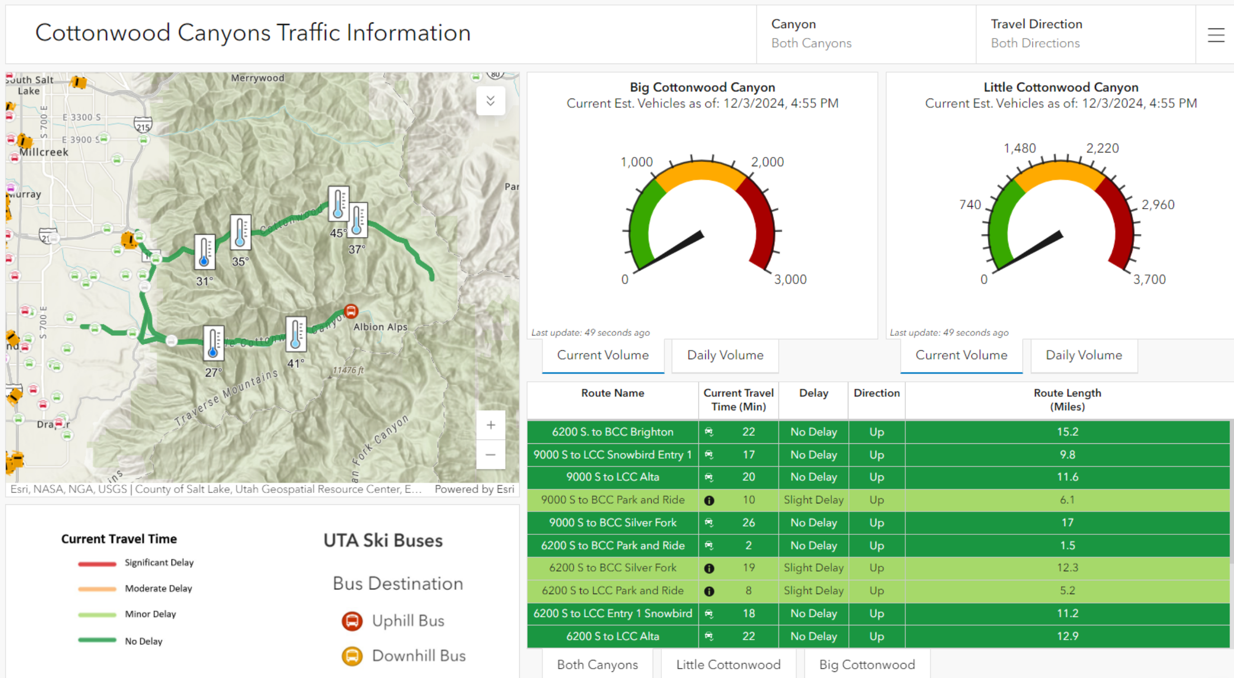
[46] RSG and NPS. Mount Rainier National Park Regional Transportation Analysis Project. (2023).
[47] Pack, Michael; Ivanov, Nikola; MLP LLC. Use of Vehicle Probe and Cellular GPS Data by State Departments of Transportation. (2021).
[48] Business Wire. Iteris Awarded $1.3 Million Data-as-a-Service Contract from Utah Department of Transportation. (2023).
[49] Utah DOT Cottonwood Canyons. Cottonwood Canyons Road Information. (2023).

Figure 5: Screenshot of the Utah DOT Cottonwood Canyon Area Traffic Information Dashboard



Source: Utah DOT, December 2024

5.2.3 Deployment Considerations

Mobility data and associated technologies have the following data, privacy, and security concerns:

- **Collection of PII.** The location of a person's phone or vehicle is generally considered to be a form of PII. The best practice for LBS-based data systems is to remove, aggregate, or anonymize any forms of PII collected. If NPS plans to utilize similar technology interfaces, a Privacy Threshold Analysis (PTA) / Privacy Impact Assessment (PIA) process will still likely be required to ensure the selected platform meets applicable security standards.
- **Data Acquisition.** Mobility data is not directly collected by NPS, so any data must be acquired from a data vendor. Depending on the pricing for the mobility data, the acquisition process may require more time and effort. Data vendors may also charge recurring costs for continued access to their platforms. State DOTs also often purchase mobility data and make it available for transportation agencies within the state, including NPS units. For each arrangement, NPS must consider the terms for data access, storage, and any limitations on circulating the data with internal or external stakeholders.
- **Limited Telecommunications in Park Settings.** Mobility data requires a combination of GPS, cellular signals, Wi-Fi, and Bluetooth from visitor vehicles or devices to create data. Although mobility data based on connected vehicles have an increasingly high sample rate, the impact of poor connectivity can be especially impactful on low volume roads, which are typical in park settings. This may be a consideration to evaluate on a park-by-park basis for areas of the park that have poor connectivity or low volume on the roads.

5.3 Vehicle to Everything (V2X)

V2X technology enables vehicles, road users, roadside infrastructure and operations to communicate information instantaneously. These technologies have the potential to reduce the severity and number of vehicle crashes, decrease congestion and travel times and to move people to their destination more reliably and efficiently.

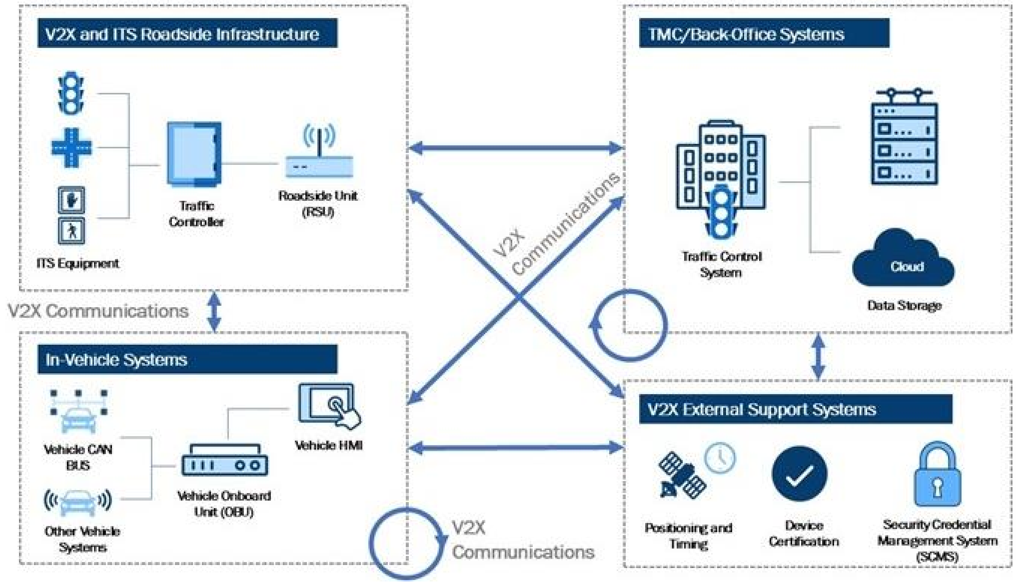
An increasing number of modern passenger and commercial vehicles have, or will soon have, installed technology that can share data with other vehicles (referred to as Vehicle to Vehicle (V2V) communication), bicyclists and pedestrians (Vehicle to Pedestrian (V2P) communication), and physical infrastructure roadside units through Vehicle to Infrastructure (V2I) communication. Infrastructure-to-Vehicle (I2V) communications are another option for a connected vehicle program—these send traveler information from roadside units to nearby vehicles.

V2X technologies feature both direct and network-based wireless communications. Communication in a CV system is generally carried out via Cellular V2X (LTE-V2X) communications.[50] LTE-V2X relies on 4G Long-Term Evolution (LTE) and/or 5G cellular communications to transmit connected vehicle messages.[51]

In general, the V2X ecosystem includes various components including V2X roadside infrastructure (i.e., roadside units), In-Vehicle Systems (onboard units along with human machine interface), V2X External Support Systems (positioning and timing, security credential management system, etc.), and a V2X Communications layer that enables communication between and among vehicles, vulnerable road users, and roadside infrastructure (Figure 6).[52]

[50] U.S. GAO. CONNECTED VEHICLES: Additional DOT Information Could Help Stakeholders Manage Spectrum Availability Challenges and New Rules. (2022).
[51] U.S. DOT ITS JPO. Vehicle-to-Everything (V2X) Deployer Resource. (December 2024).
[52] U.S. DOT ITS JPO. Vehicle-to-Everything (V2X) Technology 2024 Executive Briefing. (December 2024).

Figure 6: The V2X Block Diagram - Fundamental Elements of a V2X Ecosystem



Source: U.S. DOT, December 2024

5.3.1 NPS Utilized Technologies

V2X technologies are not currently utilized in a park setting. However, some vehicles traveling along NPS roads may already have V2X capabilities, and the frequency of these vehicles within national parks is only expected to increase as more original equipment manufacturers incorporate this technology into their products.

5.3.2 Researched Technologies

Wyoming DOT (WYDOT) V2X Pilot

In 2016, the Wyoming Department of Transportation (WYDOT) initiated a multi-phase V2X pilot with FHWA support. The primary focus of this pilot is a stretch of I-80 that passes through southern Wyoming. This segment of highway is prone to severe winter storms, which can result in safety challenges such as poor visibility, high winds, and slick road surface conditions.[53] The intention of the V2X pilot is to provide drivers with advanced warning regarding these hazardous conditions, to reduce common incidents such as truck blow overs and vehicle pile-ups.[54] WYDOT's V2X alert system can warn drivers about weather conditions, traffic congestion, speed restrictions (including variable speed limits), work zones, and vehicle restrictions, thus improving driver situational awareness.[55] The initial phase of the pilot saw the installation of 75 roadside units at safety hotspot locations along I-80, and 400 onboard units on select large vehicles (mostly road maintenance vehicles and trucks owned by private freight companies), which are frequent users of the focus sections of I-80.

[53] Gopalakrishna, Deepak; et al. Connected vehicle pilot deployment program phase 1, security management operational concept: ICF/Wyoming. (2016).
[54] U.S. DOT ITS JPO. Connected Vehicle Pilot Program: Wyoming (WYDOT). (2018).
[55] Trihydro Corporation. Piloting Connected Vehicle Technology. (2023).

WYDOT's latest efforts have focused on pushing out V2X-generated alerts to smartphones (via third-party navigation applications). WYDOT is eventually planning to send more alerts directly to V2X-enabled vehicles, though currently, only select car models sold within the last ten years contain the hardware needed to display these alerts.

Figure 7: A Member of the WYDOT Installation Crew Installs the Onboard Units

Source: WYDOT

Connecting the West Program

In 2024, WYDOT, Utah DOT, and Colorado DOT began an expanded V2X pilot, known as "Connecting the West", which will allow the three agencies to increase V2X connectivity and expand the number of vehicles that can receive alerts.[56,57] The pilot program will focus on using technologies to inform Traveler Information Messages, signal preemption and prioritization, snow plow preemption, transit signal prioritization, and LiDAR detection of vehicle, pedestrian, and cyclist movements for safety analysis.

5.3.3 Deployment Considerations

V2X technologies have the following data, privacy, and security concerns:

- **Vulnerability of V2X Communications.** CVs are an emerging technology area, so there will be several privacy and security risks that will need to be considered prior to the implementation of any such system on NPS lands. CV equipment in private vehicles is generally beyond the scope of what NPS can control, but it will be important to ensure that any roadside or in-vehicle units installed as part of a CV system on NPS lands meet appropriate security requirements identified by federal and state partners. U.S. DOT is establishing common security procedures for V2X communication, and additional guidance will likely be released in the coming years as this technology develops further.
- **Components of a CV System.** U.S. DOT identified the security credential management system as one of the most important components of a secure CV system. This system uses temporary, one-time digital certificates to verify the accuracy of each V2X communication sent between vehicles and other connected devices.[58] The certificates are intended to confirm that a

[56] Rossi, Andrew. Wyoming Has Been Quietly Testing Technology That Connects Vehicles to Roads. (2024).
[57] Utah DOT. UDOT to "Connect the West" with Major Federal Grant. (June 2024).
[58] U.S. DOT ITS JPO. Vehicle-to-Everything (V2X) Deployer Resource. (2024).

communication being received is accurate and authentic, while the temporary/one-time nature of certificates is meant to minimize the likelihood of certificates containing information that can easily identify or be associated with specific vehicles and/or individuals. Another component of a secure V2X system is “misbehavior detection,” where a V2X system can automatically flag incoming messages that do not make sense (based on sensor data and messages from other senders) and reject a potentially false message.

- **Interoperability.** V2X communications need to be interoperable to be successful. Interoperable connectivity refers to the ability of a diverse range of mobile, in-vehicle, and roadside devices to communicate ubiquitously, efficiently, and securely in a privacy-protected manner using multiple wireless communications technologies, wireless messages, open data formats, and standards. U.S. DOT has also recently published a national plan for accelerating the deployment of V2X technology, with a focus on standards for interoperability and the potential safety benefits of this technology.[59]

[59] U.S. DOT ITS JPO. National V2X Deployment Plan Supplement. (2024).

5.4 Machine Learning (ML) and Artificial Intelligence (AI)

ML and AI are broad terms to describe statistical methods that analyze data and identify patterns. These methods enable systems to augment routine human tasks or enable new capabilities. According to the National Institute of Standards and Technologies, AI and ML are defined as: [60]

- **AI**: An engineered or machine-based system that can, for a given set of objectives, generate outputs such as predictions, recommendations, or decisions influencing real or virtual environments. AI systems are designed to operate with varying levels of autonomy.
- **ML**: A branch of AI that focuses on the development of systems capable of learning from data to perform a task without being explicitly programmed to perform that task. Learning refers to the process of optimizing model parameters through computational techniques such that the model's behavior is optimized for the training task.

Table 7 summarizes the breadth of algorithms within this field, and how they can range from simple moving averages to sophisticated models, aiming to mimic human behavior.

Table 7. ML and AI Algorithm Types

Type	Learning Approach
Time Series Forecasting	Sub-field of models that focuses on forecasting future trends in data. These can be relatively simple approaches that focus on moving averages. NPS is utilizing this with its travel forecasting tool.
Supervised	Uses “truth data” to produce a classification or regression model.
Unsupervised	Does not use truth data; clustering, one of the most popular unsupervised classes of algorithms, finds relationships in the data to group observations into clusters without knowing the content or meaning of the observations.
Semi-Supervised	Uses human-labeled “truth data” for a small subset of the model generation process but then extends the results using an unsupervised approach.
Self-Supervised	Uses a two-step training process in which the algorithm assigns labels or categories to unstructured or un-labeled data first and then performs classification or regression tasks using the model-generated labels; some self-supervised learning algorithms involve manual tuning of the model during the classification or regression task to improve model performance.
Reinforcement	Uses a reward function and a trial-and-error process that, over many iterations, teaches the model the actions it can take to maximize the reward.
Generative AI	Similar to self-supervised model but enhanced ability to generate new content, such as text or images. [61]
Imitation Learning[62]	Aims to mimic expert human behavior. The goal is to replicate expert’s behavior in similar situations using a dataset of demonstrated actions.
Agentic AI	Aims to autonomously pursue goals, make decisions, and take actions in a given environment—often without constant human oversight.

Source: U.S. DOT, September 2025

[60] National Institute of Standards and Technology. The Language of Trustworthy AI: An In-Depth Glossary of Terms. (2024).
[61] McKinsey & Company. What is Generative AI?. (April 2024).
[62] Deep AI. What is Imitation Learning? (n.d.).

There are numerous AI use cases in transportation, which include advanced driver assistance systems and automated driving systems, emergency management, remote sensing, and asset management, among many others. Some of these technologies, such as automated driving systems, have already been piloted in the NPS context and are not included in this report. Traveler information-focused AI applies most frequently to third-party applications, tools, or interfaces that are managed by private sector partners.[63] However, some public agencies have been able to incorporate AI technologies into existing traveler information systems, such as 511 or traffic management center TMC interfaces. For example, in 2017, Transport for London integrated an AI-based chatbot, called "TravelBot", into Facebook Messenger.[64] Transport for London has recently started expanding this chatbot.[65]

The field of AI has recently moved forward with the expansion of Generative AI systems, such as OpenAI's ChatGPT and Google's Gemini, that create completely new content, typically based on plain-English prompts from users. Unlike older AI systems, generative applications have a lower barrier to entry for users but are still able to provide higher quality responses or outputs. This increases risks regarding one of the most prominent AI-related concerns: hallucinations. Hallucination occurs when an AI model generates a slightly or completely inaccurate result. In many cases, these hallucinations sound reasonable and convincing, which creates risks for users. One study found that even the best models generate hallucination-free text about 35 percent of the time.[66]

In addition, generative AI systems have major energy requirements. One ChatGPT request consumes ten times as much energy as a Google Search. A recent estimate produced by the Lawrence Berkeley National Laboratory found that by 2028, US-based AI systems may consume as much electricity as 22 percent of American households.[67] These energy requirements can make generative AI more costly than traditional approaches.

5.4.1 NPS Utilized Technologies

Park Typologies

NPS is working on streamlining trip planning information on NPS digital products (NPS.gov and the NPS app). To meet this goal, NPS developed park typologies based on different park characteristics so that similar parks can easily identify best practices for sharing trip planning information, specific to the site's unique transportation infrastructure.

The team used a hierarchical clustering method to create the park typologies. This method defines each data point (in this case a park unit) as its own cluster before the algorithm generates clusters with those data points that they are most like. The resulting clusters could be visualized using a dendrogram, which

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[63] Vasudevan, Meenakshy; Townsend, Haley; Nhi Dang, Thao; O' Hara, Amy; Burnier, Carolina and Ozbay, Kaan. Identifying Real-World Transportation Applications Using Artificial Intelligence (AI): Summary of Potential Application of AI in Transportation. (July 2020).
[64] Transport for London. TfL Launches New Social Media 'TravelBot'. (June 2017).
[65] Targett, Edward; TfL Eyes Chatbots to Drive Down Contact Centre Demand: Beware "Deviations" and "Harsh" Voices. (March 2024).
[66] Tech Crunch. Study Suggests that Even the Best AI Models Hallucinate a Bunch. (August 2024).
[67] O'Donnell, James and Crownheart, Casey. We Did the Math on AI's Energy Footprint. Here's the Story You Haven't Heard. (May 2025).

allowed for interpretation on what made clusters of parks unique. Parks became evidently grouped based on their shared location, visitation levels, and binary attributes (such as parking or roads).

NPS found the best results with nine clusters, or park typologies. NPS then further grouped parks with common features that affect transportation into three subclusters: Plan Ahead Parks, Transit Parks, and Hidden Gems. These results are shown in Table 8.

Table 8. Park Typology Results

Subgroup	Defining Feature	Typology	# of Parks	Examples
Plan Ahead Parks	Visitation Extremes	Rural high visitation	63	OLYM, YELL, HAVO
Plan Ahead Parks	Visitation Extremes	Urban high visitation	34	BOST, GATE, JEFF
Plan Ahead Parks	Visitation Extremes	High seasonal variation	43	APIS, GAAR, GRSA
Hidden Gems	Lower Relative Visitation	Urban low visitation	67	ANTI, LIHO, EDIS
Hidden Gems	Lower Relative Visitation	Rural low visitation	73	APCO, CHCU, KAWW
Hidden Gems	Lower Relative Visitation	Low visitation sites	19	EFMO, HSTR, PUHE
Transit Parks	Transit Available	Urban sites	40	SAMA, FEHA, LINC
Transit Parks	Transit Available	NPS transit parks	49	ACAD, ZION, NAMA

Source: National Park Service, 2024

5.4.2 Researched Technologies

AI-based technologies are increasingly falling into two categories: those using generative AI and those using more traditional AI methods. NPS has transportation applications that may benefit from both technology types. The project team evaluated promising technologies in both areas.

AI Trip Planners

AI Trip planners are travel planning websites which utilize generative AI systems to provide suggested destinations, directions, and other traveler information based on a prompt entered by a user. One example, Layla AI, offers pre-established trip plans, such as a "7 Days of Adventure in Zion and Bryce Itinerary," a set of directions for a seven-day tour through Zion and Bryce Canyon NPS.[68] This itinerary includes recommendations for activities within parks, such as trails, and allows users to select hotels and flights. Since this is produced from available online information, it is unknown if the information shared is the park's preference and includes safety concerns or whether the information shared may be incorrect, as can be seen in other AI-based tools. More established travel platforms, such as TripAdvisor, are also now beginning to incorporate AI-powered features into their applications to personalize the recommendations they provide.[69]

AI-Generated Images

Another area of generative AI that may relate to traveler information technologies on NPS lands is AI-generated images. A growing number of third-party platforms allow users to easily generate AI images by entering simple text prompts. These are a major concern when it comes to hallucination or misinformation, due partly to their growing prevalence on social media platforms. Misleading AI-generated images of National Parks have been circulated on platforms such as Facebook, which

[68] Layla.AI. Bryce Canyon and Zion National Park Itinerary. (December 2024).
[69] TripAdvisor. Free Trip Planner & AI Itinerary Builder. (2025).

exaggerate some of the main features or attractions of these parks (see images in Figure 8). It is also possible to easily generate misleading traveler focused images using common generative AI platforms, such as Adobe Firefly. For example, the images below show semi-realistic views of a road that does not exist (left), and a road passing through a tree (right), which does exist, although the size of the opening is significantly exaggerated compared to real life (Figure 8).

Figure 8: AI-Generated Images of a Fictional Roadway at Grand Canyon National Park (Left) and a Road Traveling Through a Tree Trunk at Redwoods National Park (Right) [70]

Source: U.S. DOT Volpe Center, November 2024

AI-Generated Podcasts

In 2024, Google released NotebookLM, based on their generative AI model, Gemini.[71] This product uses prompts but can also ingest data, such as links, videos, and text, to create full-length podcast discussions between two hosts. These discussions can present information in a more engaging way for people and can do so with little direction. One source found slight risks from model hallucination and content moderation of the podcasting tool.[72]

Chatbots and Intelligent Assistants

Chatbots and intelligent assistants, such as Apple's Siri and Amazon's Alexa, have been an early application of generative AI to break through to the general public. These technologies are increasingly being piloted for transportation uses. The San Francisco Metropolitan Transportation Council Bay Area 511 system utilizes an AI-enhanced chatbot to collect and respond to 511 traveler information requests. The system relies on more recent advances in Natural Language Processing, with an interactive voice

[70] Both images created using text prompts from Adobe Firefly.
[71] Google. NotebookLM. (2024).
[72] MIT Technology Review. People are Using Google Study Software to make AI Podcasts—and They're Weird and Amazing. (October 2024).

response module based on Alexa.[73] Similarly, WYDOT and Trihydro built an Alexa-enabled Traveler Information Skill, which can provide users with information on road conditions, closures, and work zones for the first 200 miles of a trip.[74]

Transportation Management

AI-based systems can also be deployed as part of a transportation management system. Delaware DOT is working to deploy machine learning algorithms that automate certain transportation management center elements, based on data collected from roads, signals, and connected vehicles. This system will then be able to automatically detect incidents and disruptions along roadways and adjust signaling and other systems to compensate.[75] The system is also capable of traffic monitoring via "machine vision," which can use traffic cameras to generate traffic counts, as well as volume, density, and vehicle identification/re-identification (including classification).[76]

Video Analytics

Computer vision, the process of analyzing the contents of an image or video, has become an increasingly standard AI application. In the field of transportation, this has become widely used for LPRs, multimodal analysis at busy streets, and asset management of pavement conditions. A key factor remains related to the quality of the video feed for analysis, but AI models are becoming highly capable of identifying vehicles, people, bikes, scooters, and license plates with many types of video feeds. The NPS Multimodal Strategy & Innovation Branch received funding from FHWA's Federal Lands Highway Innovation & Research Council to pilot deployment of LPRs in three to five parks while meeting federal data security and privacy requirements. The study aims to understand how vehicles flow to and through parks, as this information is critical for maintaining high-quality visitor travel experiences.

5.4.3 Deployment Considerations

Some machine learning methods are fully established and do not have any considerable risks, but others are emerging with data privacy and security concerns that have yet to be fully understood, due in part to the rapidly developing nature of this technology. There is a general consensus that some security concerns related to generative AI may not be fully solvable at the moment,[77] though several specific security/privacy issues that can be mitigated are becoming clearer.

ML and AI have the following data, privacy, and security concerns:

- **"Hallucinations" and False Information.** One key concern pertaining to generative AI systems is model "hallucination." This can take the form of an AI system making an incorrect prediction or generating false information by accident.[78] Mitigating for this requires a well-planned out

[73] U.S. DOT. Identifying Real-World Transportation Applications Using Artificial Intelligence (AI): Summary of Potential Application of AI in Transportation. (July 2020).
[74] Trihydro and WYDOT. Alexa Traveler Information Skill, Powered by the Situation Data Exchange. (2023).
[75] Vasudevan, Meenakshy; et al. Identifying Real-World Transportation Applications Using Artificial Intelligence (AI): Summary of Potential Application of AI in Transportation. (2020).
[76] Delaware DOT. Artificial Intelligence-enhanced Integrated Transportation Management System (AI-ITMS) Final Report. (2024).
[77] Harvard Business Review. AI's Trust Problem. (2024).
[78] IBM. What Are AI Hallucinations? (September 2023).

approach to AI model management, including maintaining effective "training data" for models to utilize.[79] Ineffective or incomplete training data can increase the likelihood of hallucination. False input data can result in an AI model spreading misinformation, even if the model itself was designed correctly. That said, it is not clear that correct input data will fully safeguard against misinformation.

- **Jailbreaking and Hacking of Generative AI Systems.** Another security concern issue is jailbreaking/hacking of generative AI systems. Many AI Large Language Models have safeguards or restrictions pre-installed to prevent them from outputting harmful or misleading results.[80] However, it can be possible for hackers to infiltrate generative AI systems and install malware that "jailbreaks" those systems, thus bypassing protections and producing false and/or harmful results, so it is important to evaluate AI models and their data on an ongoing basis for security purposes.[81] This topic could potentially be of concern in a PIA covering a hypothetical AI traveler information system on NPS lands, especially considering that most AI chat interfaces utilize third-party software.
- **Accidental Release/Exposure of Secure or Personal Information.** Another important concern associated with generative AI models is accidental release/exposure of secure or personal information. It is important to vet the data fed into a generative AI model to ensure that the results it produces do not contain information that should not be made publicly available, even if a prompt fed into a model were to request this information.[82] This may require adding extra security protocols to protect sensitive information which must be included in training data.
- **Collection and Storage of PII.** Computer vision models will require some interaction with images that will contain PII. These considerations will likely be similar to using probe vehicle data, but it will be important to consider data storage procedures for video data. Computer vision models will require analyzing images, but these do not need to be stored after the initial analysis. Instead, the output is likely the more important information (e.g. vehicle count) and could be stored without any PII.

[79] MIT University. When AI Gets It Wrong: Addressing AI Hallucinations and Bias. (n.d.).
[80] Georgetown University, Center for Emerging Technology. What Does AI Red-Teaming Actually Mean?. (October 2024).
[81] IBM. The CEO's Guide to Generative AI: Cybersecurity. (2023).
[82] CNBC. The No. 1 Risk Companies See in Gen AI Usage isn't Hallucinations. (May 2024).

5.5 GEOFENCED ALERTS

Geofenced alerts are targeted messages sent to mobile devices entering a defined geographic area. These types of alerts are most commonly sent as a short message service (SMS), also known as text messages, or push notifications from an application on a mobile device. A growing number of transportation agencies are using geofenced alerts to send targeted real-time information on road closures or other travel alerts to individuals in the vicinity of a particular location or incident. There is some variability in terms of how these alert systems function, particularly when it comes to whether they can reach all individuals in an affected area or only those who have previously signed up for alerts.

There are several core components to a geofenced alert system. A geofence is a virtually defined geographic area created using a web application, which generally relies on GPS technology to target mobile devices. Geofencing software detects when a mobile device enters or exits a geofenced area and automatically sends relevant information and data to that device based on its location.[83] There are several approaches to operating a geofenced alert system.

1. Many systems, including those deployed by state DOTs, rely on an individual to opt in before they can receive notifications. This method has less associated privacy/legal concerns, since everyone receiving such messages will have consented to receiving them. However, it also therefore limits the reach of geofenced traveler information messages to those who have previously signed up.
2. Some state DOTs have developed alert systems capable of sending automatic traveler information notifications to all mobile devices in a geofenced area, regardless of whether individuals have signed up to receive them. These broader reaching, automatic systems are generally restricted to use under emergency circumstances, however, and are not typically used to disseminate regular traveler information.
3. A final area of consideration for geofencing technology is V2X, which can send location-based alerts directly to vehicles.

5.5.1 NPS Utilized Technologies

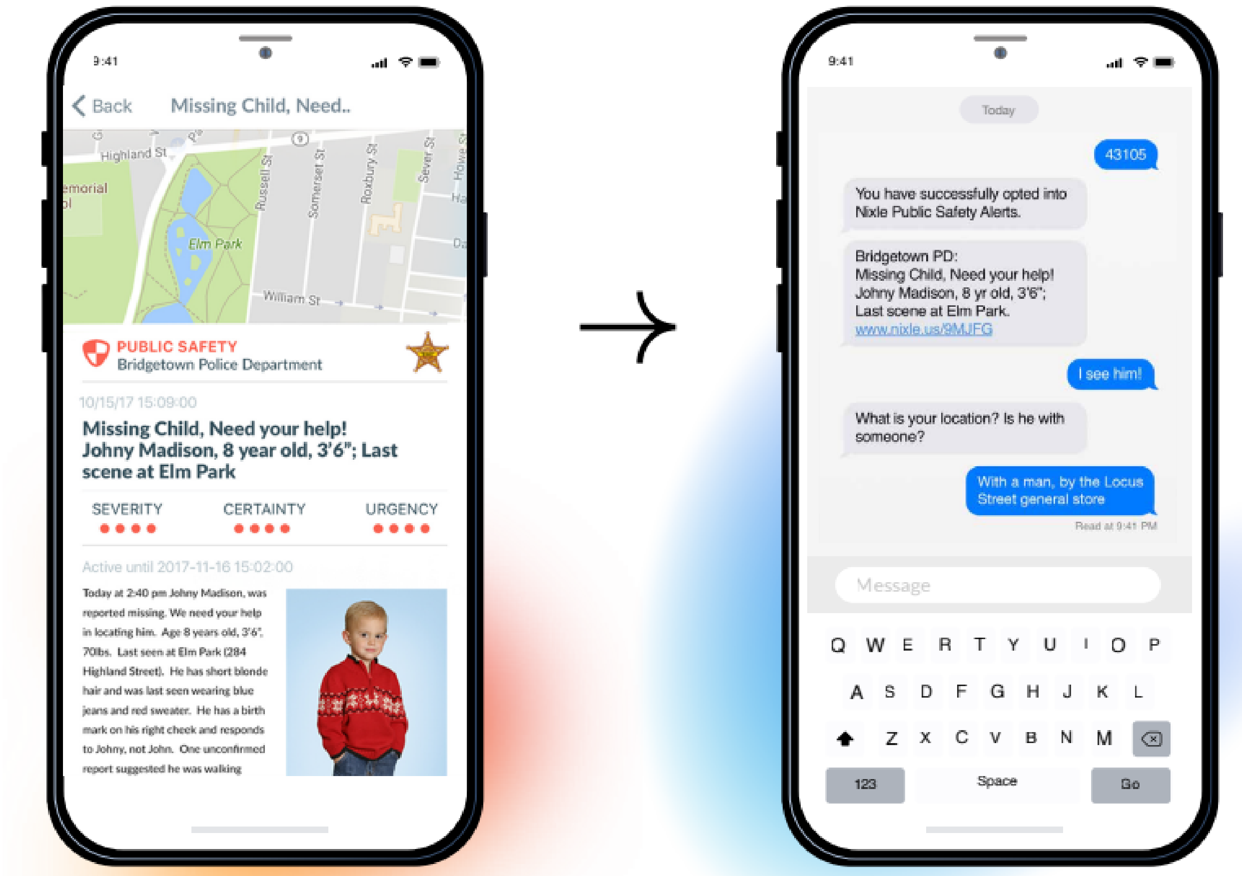
Text and Email Alert Application (Everbridge's Nixle)

Some NPS park units have piloted alert systems with geofence capabilities, such as Everbridge Nixle, an information service that connects people to relevant information depending on their physical location (Figure 9).[84,85] Everbridge Nixle provides U.S.-based organizations with "an open communication forum that connects public safety officials, municipalities, schools, and businesses to the communities they serve before, during, and after critical events through real-time two-way communication by allowing administrators to send targeted voice, SMS, email or social media messages."[86] This platform requires users to opt-in prior to receiving messages.[87] For example, Yosemite National Park uses Everbridge Nixle to provide alerts about parking lot availability. However, the Yosemite National Park alerts do not

[83] U.S. DOT FHWA. Using Geofencing to Actively Monitor, Collect, and Share Information. (2024).
[84] Everbridge. Everbridge Nixle. (2023).
[85] Everbridge. Resident FAQs. (2024).
[86] Everbridge Nixle. Everbridge Nixle for U.S. Government Agencies & Businesses. (2024).
[87] Everbridge Nixle. Nixle: Message Types. (2023).

include a geofenced component and are sent to all phone numbers that have opted in (regardless of their location). U.S. Park Police also use Everbridge Nixle to disseminate emergency and special event information in the NPS National Capital Region parks, and members of the public can sign up via the Everbridge platform.[88]

Figure 9: Example of Everbridge Communications and Text Message Alerts



Source: Everbridge Nixle, 2023[89]

5.5.2 Researched Technologies

Transportation-focused geofenced alert systems fall into several categories. Some are focused on pushing general traveler information to users of applications, while others are capable of sending emergency-focused traveler alerts to all individuals in an affected area. Geofenced alert technology can also be included in other ITS areas, including work zone protection and V2X communications. The project team evaluated promising technologies in each of these areas.

Mobile and Web-Based Application Alerts

[88] NPS. Nixle Registration. (2015).

[89] Everbridge. *Everbridge Nixle Data Sheet*. (2023).

State and local transportation agencies have been deploying geofenced alert systems to provide location-based information to travelers. Most of these systems require a user to opt in to receive alerts, which are sent via text messages or app notifications. One example is QuickMap, an existing traveler information application managed by Caltrans. To receive geofenced alerts via the app, an individual must sign up and enable their location services. Caltrans staff develop geofences and custom alert messages internally, which are sent out to drivers via a partnership with a location services provider. The system also ties in with the agency's LCS to send automatic geofenced alerts in the vicinity of a planned road or lane closure starting 30 minutes before the closure through when it ends.

Colorado DOT is another state agency that has deployed geofenced alerts, doing so via their COtrip Planner mobile app.[90] The app provides real-time travel information across the state and now utilizes the "TellMe" feature from Castle Rock ITS, which can identify a traveler's projected location (based on current location or direction of travel and speed) and send tailored geofenced alerts to them. Traffic alert messages are generated in house by Colorado DOT traffic operators using the agency's transportation management system and then sent out to app users via "TellMe."

Arizona DOT also incorporated geofenced alerts into their traveler information systems. When a major highway is closed, agency staff provide relevant push notifications to users of its Arizona DOT Alerts app, including incident nature and alternate route suggestions.[91] Similar to Caltrans' QuickMap and Colorado DOT's COtrip Planner, this system requires users to enable their location services prior to being able to receive alerts.

Third-party navigation applications also employ geofencing features. One example is Apple Maps, which has enabled geofenced push notifications at select locations, or under select circumstances (such as when public safety risks are present). Apple's "Indoor Maps" feature, which is available at airports and malls that have partnered with Apple Maps, can provide a welcome message when a user enters a geofenced area, in addition to detailed information about nearby amenities.[92] In order to receive these alerts, an individual must enable location services in the settings of their mobile device.

511 Systems and Highway Emergency Linked Platform Alerts

Several state DOTs have deployed geofenced alert systems to improve communications with motorists during emergency road closures. One example is the New Jersey DOT's 511NJConnect System, which is set up to proactively send traveler information to motorists who are stuck in long-term road closures along select highways.[93] The system is based on the Highway Emergency Linked Platform interface developed by Information Logistics (a third-party technology vendor), using INRIX-supplied data on traffic slowdowns.[94] When activated, the system will send automatic wireless emergency alerts to all mobile devices in the proximity of a reported incident, based on a geofence that is set up around the impacted road segments. This process functions similarly to the process of sending out other types of universal wireless emergency alerts, such as Amber Alerts. Drivers can "opt in" for further

[90] Colorado DOT. COtrip Planner. (n.d.).
[91] Arizona DOT. Geofences are Key to Making the ADOT Alerts App Work for You. (2017).
[92] Haskell, Josh. LAX Adds Apple Maps Feature to Navigate Terminals. (2017).
[93] New Jersey DOT. 511NJConnect System. (n.d.).
[94] Information Logistics. Highway Emergency Linked Platform (HELP). (n.d.).

communications after receiving an initial message, which allows their location data to be transmitted to the New Jersey DOT, allowing the agency to gain a better understanding of traffic conditions and the locations of stuck vehicles.

The Pennsylvania DOT also utilizes a similar system as part of their 511PAConnect system, in which the Pennsylvania Emergency Management Agency has the capability to send automatic notifications to all mobile devices in the vicinity of a major road disruption.[95]

Transportation Data Feed System-Based Alerts

Geofenced alerts can also be employed as part of transportation data feed systems and CVs. The Florida DOT developed a smart work zone notification system which is intended to provide real-time geofenced locations of workers and their equipment in a WZDx compatible format, which can then be pushed to travelers via third-party navigation applications such as Google and Waze.[96]

The Virginia DOT has also tested a geofence-based system that can alert drivers of nearby work zones. Data on the locations of workers and equipment is updated automatically (via connected location sensors attached to construction equipment and work vests) and transmitted to all CVs approaching a work zone.[97]

V2X-Based Geofenced Alerts

V2X technology can also generate geofenced alerts. These messages are communicated using V2X technology (using either direct or network V2X communications) and are targeted towards vehicles in proximity to hazards. Specific types of V2X messages, such as Traveler Information Messages, are sent out to a geofenced area around a potential disruption or hazard. One such example is HAAS Alert, a system installed by some car manufacturers which sends automated alerts to drivers that warn of nearby first responders. This is intended to improve driver awareness and reduce the likelihood of crashes, though it should be noted that this system is not interoperable with respect to current V2X standards.[98] Similar types of alerts are envisioned to provide work zone protection, advanced notification of disabled vehicles (via Highway Emergency Linked Platform Alerts), and other types of human factors crash mitigation.

While geofenced alerts offer potential travel information and safety improvements, they also generate some safety-related concerns that need to be considered. Text messages, navigation applications and systems, and in-vehicle infotainment features can all distract drivers and increase their likelihood of being in a crash.[99] It is therefore important to consider the means through which drivers receive a geofenced alert and attempt to mitigate human factor-related safety concerns.

5.5.3 Deployment Considerations

Geofencing can be deployed at almost any location that has cellular service and is within the path of the tracking satellites. Software is utilized to draw the boundary over a digital map embedded in a mobile

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[95] Pennsylvania DOT (PennDOT). 511PAConnect system. (n.d.).
[96] U.S. DOT FHWA. Using Geofencing to Actively Monitor, Collect, and Share Information. (2024).
[97] Stone, Tom. VIDEO: Virginia DOT deploys V2X geofence for work zones. (2022).
[98] HAAS Alert. V2X Explainer: The Basics on Vehicle-to-Everything Technology. (2023).
[99] U.S. Centers for Disease Control and Prevention. Distracted Driving. (2024).

application or desktop dashboard. The boundary size is flexible, enabling users to set up a geofence for a few parking spaces or a larger regional area.[100] Physical infrastructure associated with geofenced alerts includes a GPS tracking platform, reliable GPS satellites, cellular towers, and Wi-Fi connections, and either a mobile application or a web-based platform.

Geofenced alerts have the following data, privacy, and security concerns:

- **Collection and Storage of PII.** Most researched geofenced alert systems require some form of user identification, such as telephone numbers or geographical indicators, so privacy concerns could be an issue.[101] Therefore, a PTA and PIA could be required for future NPS deployments. Furthermore, most geofence-based alert systems are developed or operated by third-party entities, so any technology platform selected for use on NPS lands would also need to be analyzed under a PIA. However, geofenced V2X alerts such as traveler information messages are considered secure and do not collect PII.
- **Fake or Scam Alerts.** Another risk to consider when deploying a text-based geofenced alert system is the potential for false, or scam, messages.

[100] Chasteen, TJ. What are Geofenced Alerts? Everything You Need to Know. (December 2023).
[101] McCallister, Erika; Grance, Tim; Scarfone, Karen. Guide to Protecting the Confidentiality of Personally Identifiable Information (PII). (2010).

5.6 PHYSICAL INFRASTRUCTURE AND EQUIPMENT

Each traveler information technology has different physical infrastructure needs. Physical infrastructure and equipment components of traveler information technologies can be as simple as standalone equipment (e.g., vehicle counters, dynamic or variable message signs) or more complex system applications (e.g., parking access control or monitoring systems, traffic management systems such as ramp signaling, dynamic lane management, variable speed limits, incident detection, vehicle activated signals, and adaptive traffic signal control).

When considering infrastructure or equipment deployment, it is important to clearly define the challenge and identify existing physical infrastructure or systems at the site. Each NPS unit has different needs and capabilities, often requiring unique or location-specific equipment solutions, some of which are up to date with the industry's best practices and others that are more outdated or antiquated. For example, an urban park environment may have better cellular connectivity and power sources, which may allow NPS to test newer traveler information technologies in this environment. However, a more rural park environment may not have the necessary cellular bandwidth or power infrastructure in place, which would instead require NPS to deploy more antiquated, older technologies and equipment.

FHWA and ITS JPO maintain tools that estimate the costs and benefits of traveler information technology deployments. FHWA's Tool for Operations Benefit Cost Analysis is a planning-level decision support tool intended to support transportation practitioners in the application of benefit cost analyses for a wide range of Transportation System Management and Operations strategies.[102] ITS JPO's ITS Benefits and Costs database also provides decision support data for effective ITS decision-making.[103] While neither of these tools are specific to NPS or other FLMAs, the tools may provide insight into successful deployments.

ITS technologies integrate advanced communications technologies into vehicles and existing infrastructure to improve transportation operations, efficiency, and reliability, thereby expanding traditional infrastructure improvement approaches. As such, ITS technologies are targeted at infrastructure, vehicles, travelers, and the integrated applications among them to enable the development of an ITS.[104] For most ITS applications to be successful, there needs to be physical infrastructure in place such as the infrastructure associated with transportation, communications, and energy systems.

Transportation systems refer to the equipment and logistics involved in moving people and goods across modes of transport including cars, trains, buses, boats, aircrafts, and even space travel.[105] Transportation infrastructure is the foundational structures and systems designed to facilitate the movement of people and goods. The infrastructure components of transportation systems are connected and spread across a region, whereas the physical components of the system exist in a connected network spanning that region to allow for the movements of people, vehicles, and goods

[102] U.S. DOT FHWA. Tool for Operations Benefit Cost Analysis. (n.d.).
[103] U.S. DOT ITS JPO. ITS Benefits and Costs database. (n.d.).
[104] U.S. DOT FHWA. Intelligent Transportation Systems Technologies. (November 2021).
[105] Kohl, April. What Is the Meaning of Transportation System?. (June 2023).

across the region. Transportation is indistinguishably linked to other infrastructure systems such as communications and energy systems.[106]

Communication systems are the networks that connect one technology to another, such as radio or television broadcasting, radio telegraphy, mobile communications, and computer communications. Communication systems are classified based on the physical infrastructure and signal specification.[107] Infrastructure-based classifications include line (wired/bounded) systems, which have a physical link connecting the transmitter to the receiver, and radio (wireless/unbounded) systems, which have no physical links and signals are transmitted through space or air. Without adequate communications systems, ITS deployments will be highly dependent on park staff and are not able to provide real-time updates. For traveler information, communication systems are also a way to reach visitors.

Energy infrastructure comprises the physical and virtual structures and systems that enable power generation, transmission, distribution, and grid communications including, but not limited to, power plants, transmission lines, voltage regulators, and grid controls.[108] Without adequate energy infrastructure, ITS deployments must use alternative energy sources, such as solar panels, or batteries. Depending on the site and energy intensity of the ITS technology, ITS deployments can still be successful with limited energy infrastructure.

5.6.1 NPS Utilized Technologies

NPS has deployed ITS technologies for over 20 years. The project team reviewed available documentation for past and current ITS pilots and projects within specific park units (Table 9).

Table 9. Examples of Past and Current ITS Pilots and Projects in Park Units

Park Unit	Description
Acadia National Park[109]	One of the first recorded NPS ITS deployments took place at Acadia National Park between 1999 and 2002. Acadia piloted automated vehicle location (AVL) systems, departure signs for transit vehicles, parking lot monitors, and traffic and transit volume recorders. The pilot's 2003 evaluation report found that the introduction of these technologies coincided with a substantial increase in transit ridership at the park, resulting in measurable safety and efficiency improvements. The park also experienced operational improvements, such as reductions in unauthorized parking, and improved visitor satisfaction.
Gateway National Recreation Area – Sandy Hook Unit[110]	A 2009 report provided a framework for deploying several ITS technologies at the Gateway National Recreation Area - Sandy Hook Unit for traffic and visitor management. These included an entry management system based on Radio-Frequency Identification technology (connected to automatic entry gates), inductive loop detectors to gather real-time information on vehicle counts and parking lot usage, a CCTV system for monitoring, and a graphic user interface that would link all these systems together so that park management could access data in real time. Specific implementation details for these technologies were to be decided upon at a later date.

[106] Taylor, Michael A.P. Climate Change Adaptation for Transportation Systems; Chapters 1 and 3. (2021).
[107] IEEE Technology Navigator. What is a Communication System. (2024).
[108] U.S. Department of Energy. How EERE Is Addressing Inequitable Energy Infrastructure. (March 2023).
[109] U.S. DOT ITS JPO. Evaluation of Acadia National Park ITS Field Operational Test: Final Report. (2003).
[110] U.S. DOT Volpe Center. Gateway National Recreational Area - Sandy Hook Unit: automated fee entrance plaza and intelligent transportation system technical requirements. (2009).

Park Unit	Description
Cape Cod National Seashore [111]	A 2011 report on Cape Cod National Seashore summarized a potential intelligent parking management system. Recommended technologies included magnetometers for calculating parking lot usage (which could then be published as a data feed), a traveler information system using highway advisory radio and VMS, and a back-end server for processing all the information. The park later opted to test a camera-based counter system at entrances, while the VMS were never installed due to local opposition.
Rocky Mountain National Park[112]	Another 2011 report focused on the deployment of highway advisory radio and VMS technologies at Rocky Mountain National Park. This report evaluated the impact these systems would have on transit ridership, congestion, and the traveler experience within the park. By 2019, the park had five portable VMS in use, while a nearby town had also installed a permanent VMS to relay park-specific information. These signs display information on parking conditions and road restrictions inside the park. The signs have generally been successful, though cellular connectivity issues have limited deployment in portions of the park (as automatic update capabilities require cell service to function). The park also installed three webcams at entrance stations, which are intended to visualize lineups and weather conditions on the park website.
Glacier National Park	Glacier National Park deploys VMS at an entrance station to help accommodate increasing visitation levels. The park also used VMS during a major road rehabilitation project from 2007 to 2019 to help manage peak season traffic. In addition, Glacier National Park implemented a recreation access display online dashboard which communicates information on parking availability, vehicle restrictions, and road closures to the public.
Arches National Park	Arches National Park deployed an online dashboard featuring two real-time webcam feeds (one from the park entrance station and one from an approaching segment of US-191). The park also displays parking status information via a parking lot dashboard, including lot closures, number of spaces available, and usage levels. [113]
Colorado National Monument	Colorado National Monument deployed a dynamic warning system on Rim Rock Drive in 2018, which alerts cars to the presence of bicyclists around curves with obstructed views. Modern loop detectors installed in the pavement can differentiate bicyclists from cars and can automatically trigger a flashing light warning system when a bicyclist is detected ahead of the sign.[114] The system is still installed in the park today. A full evaluation of the system has not been completed yet, though the park's intention is to reduce the number of close calls between bicyclists and drivers.

Source: U.S. DOT Volpe Center, November 2024

Compared to the other five technology research areas identified in this report, NPS is currently deploying all relevant types of physical equipment and infrastructure technologies discussed in this report, including counters and sensors, digital signage, shuttle telematics, and automated access systems across the country. The section below describes the physical equipment for the deployed technologies.

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[111] U.S. DOT Volpe Center. Cape Cod National Seashore Intelligent Transportation Systems Implementation Plan Final Report. (2011).
[112] Western Transportation Institute. Rocky Mountain National Park intelligent transportation system evaluation plan. (2011).
[113] Kissel, Carrie. Using ITS to Improve Traffic Conditions and Visitor Experiences in the National Parks. (September 2020).
[114] Kissel, Carrie. Dynamic Warning Systems Enhance Safety for Cyclists and Vehicles on Scenic Roadways. (September 2020).

Counters and Sensors

Parks deploy traffic counters to count vehicles, bikes, and pedestrians on roads or trails. There are a variety of counter equipment types, each with strengths and weaknesses depending on mode, installation and maintenance procedures, and type of data collected. Table 10 describes the major types of counters.

Table 10. Description of Counter Types

Type	Mode	Description
Pneumatic Tubes	Vehicles or Bikes	Tubes are secured onto a roadway or paved trail. When vehicles, bikes, or other vehicles go over the tube, a burst of air pressure records an entry. A second tube can be placed consecutively to record speed, direction, and vehicle classification.
Inductive Loops	Vehicles or Bikes	Inductive loops are placed into the roadway with a recorder alongside the road. When vehicles, bikes, or other vehicles go over the inductive loops, the recorder tracks the presence of a vehicle. These loops can be tuned to record different types of vehicles.
Magnetometer	All	Magnetometers work well on more remote roads because they can easily be deployed for months at a time and do not rely on external communications or electrical sources. Magnetometers need to be tuned to accurately record data.
Radar	All	Radar counters are often used when speed enforcement is a priority, but many agencies also use radar technology detectors like Wavetronix for traffic data collection. Radar traffic counters can track speed and counts, typically only for vehicles.
Infrared Focused Beam or Breakbeam	Typically Bikes and Pedestrians	Typically, infrared beams are used on trails. These generate a count when the beam is broken. Infrared beams cannot differentiate between pedestrians or bicyclists. However, some counters use two beams to record direction.
Wireless In-Ground Pucks or Mounted Sensors	Vehicles	A wireless in-ground puck or mounted sensor is often an instrument in the shape of a disk or puck that can be installed underground or mounted on pavement. These sensors work only for individual parking spaces. As this is resource intensive, these sensors are generally best used in situations where magnetometer sensors cannot be utilized, such as on-street parking with individual parking spaces.
License Plate Readers	Vehicle	LPRs are becoming more widely used for transportation data collection. LPRs use video analytics to capture the license plate for vehicles and can record these data in real-time.
CCTV Cameras	Vehicle	CCTV refers to a system that uses video cameras to transmit signals to a specific set of monitors or recorders. Unlike traditional broadcast television, which sends signals openly, CCTV operates on a closed-loop system, meaning the video is accessible only to designated users, making CCTV an ideal solution for surveillance and security purposes.
Custom Video Analytics	All	Intelligent video technologies utilize surveillance systems, such as cameras, to detect parking space vacancies to approximate lot occupancy (Figure 10). These systems often require cameras as well as software to assess the incoming streamed video data. This software must either be designed internally or procured from a third-party provider.

Source: U.S. DOT Volpe Center, November 2024

Figure 10. Intelligent Video Software Example Tracking Parking Utilization

Source: IntuVision, 2022[115]

Digital Signage

Digital signage serves as a versatile communication platform that can be strategically placed across various visitor touchpoints, from airports and transportation hubs to visitor centers and popular attractions. It allows agencies to update and convey useful and timely information to travelers, visitors, and commuters. Digital signage, used in combination with other traveler information technologies, such as counters and sensors, can allow management staff to make real-time decisions regarding park operations and promptly inform the public.

NPS currently uses digital signage to help manage its transportation systems (e.g., rerouting traffic to available parking areas during times of congestion), to communicate with visitors (e.g., inform visitors of road closures or delays), and to advance the NPS mission (e.g., help travelers make informed decisions while increasing the efficiency and safety of traffic operations). Table 11 describes the major types of display signs NPS has deployed.

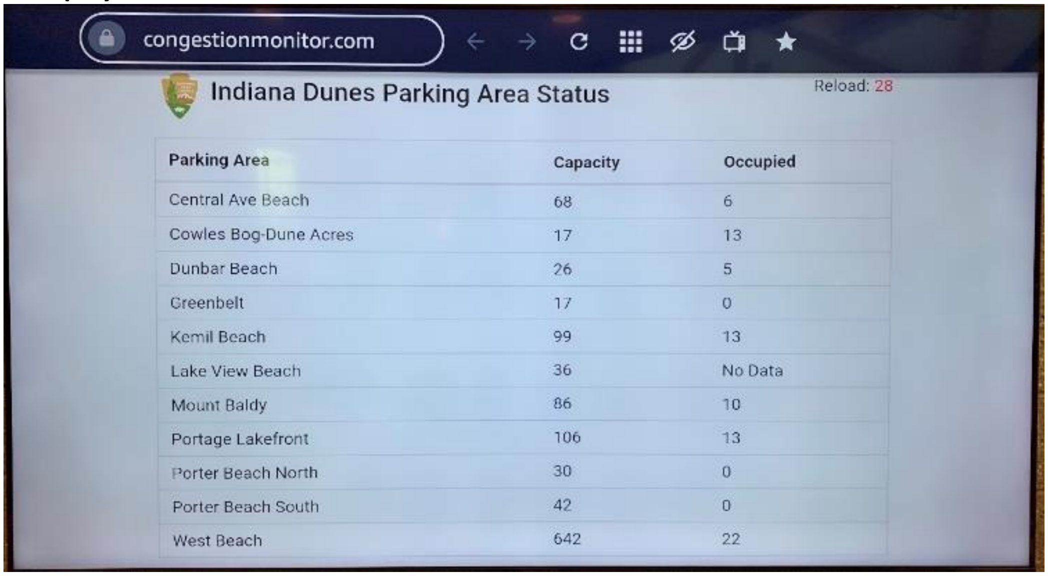
[115] IntuVision. *Video analytics – on the server or at the edge for live or recorded video*. (n.d.)

Table 11. Current Digital Signage Deployments at NPS

Type	Description
Variable Message Signs (VMS)	VMS broadcast information to visitors at key locations. Information shared via VMS includes traffic congestion warnings, parking availability, incidents, roadwork zones, speed limits, and road closures. These signs can help influence visitors' decision making when traveling to, from, or through an NPS unit. If visitors notice that their intended destination is at or near capacity, other vacancies listed on the VMS can encourage them to visit another area of the park. This can help reduce congestion at popular areas by reducing circling and idling while waiting for parking spaces to open or reducing the queueing of vehicles at entrance kiosks and stations and can help distribute visitor traffic. Some VMS models can also include vehicle counters, which can allow for more data-driven messaging. There are two types of VMS, portable signs and permanent signs. A portable VMS can easily be moved around to different high-impact locations and does not require an electrical installation (battery or solar powered). However, a portable sign does have to be available and requires configuration each time it's moved. Portable VMS units, often movable via trailer, can be either battery or solar powered. Programming VMS can often be done remotely with a cellular connection, though some VMS may need to be updated on site. A permanently installed VMS requires less space than a portable sign. However, it would need to be uninstalled and reinstalled if the roadway is reconfigured, requires a power source, and permanent signage may also require compliance with park signage standards, but could be designed to complement the surrounding environment. Programming VMS can often be done remotely with a cellular connection, though some VMS may need to be updated on site. Fixed variable message signs are typically more expensive.
Mounted Monitors or Television Screens	In addition to outdoor VMS, parks can also broadcast relevant information indoors, particularly at communal areas such as visitor centers. Mounted monitors or television screens can serve as a generally inexpensive option to broadcast relevant information. Connecting a monitor to the internet via a smart TV or an external device can provide access to general webpages with updated traffic and parking information, like the monitor installed at Indiana Dunes National Park's Visitor Center as part of its Smart Parking ITS System (Figure 11).
Transit Boards	Transit boards display key transit, commuter, and traffic data on Light Emitting Diode (LED) displays. These signs often display transit information, promotional materials, weather updates, and any relevant information that would add value to travelers such as real-time transit status, next arrival and departure signs, traffic maps with drive times, and car, bike, and scooter share availability, etc.

Source: U.S. DOT Volpe Center, November 2024

Figure 11. Display Monitor at the Indiana Dunes National Park Visitor Center



congestionmonitor.com

Indiana Dunes Parking Area Status

Reload: 28

Parking Area	Capacity	Occupied
Central Ave Beach	68	6
Cowles Bog-Dune Acres	17	13
Dunbar Beach	26	5
Greenbelt	17	0
Kemil Beach	99	13
Lake View Beach	36	No Data
Mount Baldy	86	10
Portage Lakefront	106	13
Porter Beach North	30	0
Porter Beach South	42	0
West Beach	642	22

Source: U.S. DOT Volpe Center, 2022

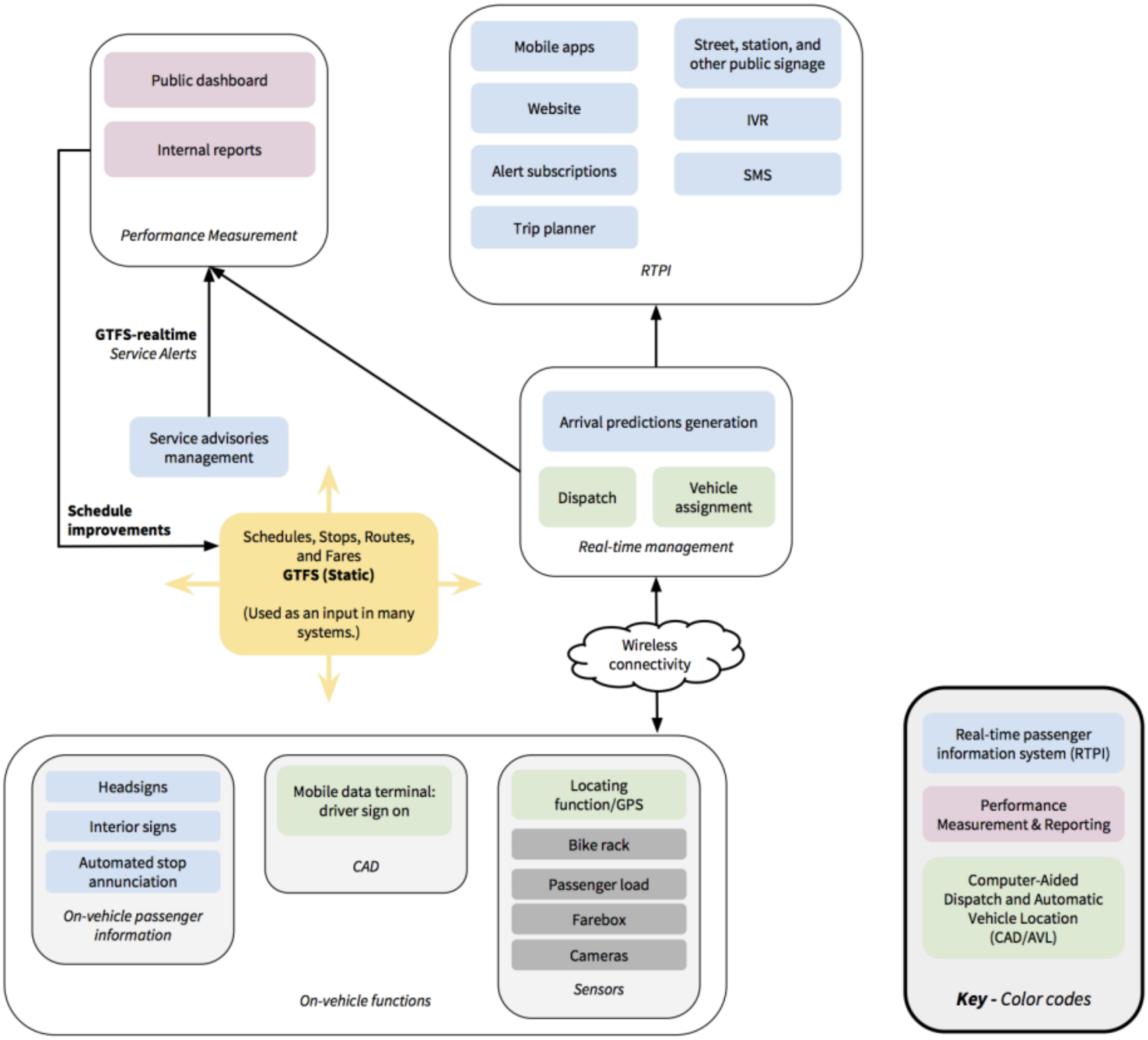
Shuttle Telematics

Shuttle telematics includes a suite of technologies. The major traveler information-related technologies include Automatic Vehicle Location (AVL), Computer Aided Dispatch (CAD), and Automatic Passenger Counters. AVLs transmit real-time data about a transit vehicle's location to servers and internal applications, which can be a key component of a GTFS real-time system.[116] CAD systems provide an interface for "dispatchers and managers to monitor and manage transit vehicle fleets and communicate with drivers."[117] Automatic Passenger Counter technology automatically counts passengers as they alight the bus, generating useful passenger information for future planning and operations. Figure 12 provides an overview of the components of a real-time transit information system, including CAD/AVL.

[116] Oregon DOT. Real-Time Transit Information. (n.d.).

[117] Portland Area Comprehensive Transportation System (PACTS). PACTS Transit Committee. (2021).

Figure 12. Real-Time System Transit Information System



Source: Oregon DOT

Satellite Internet Connections

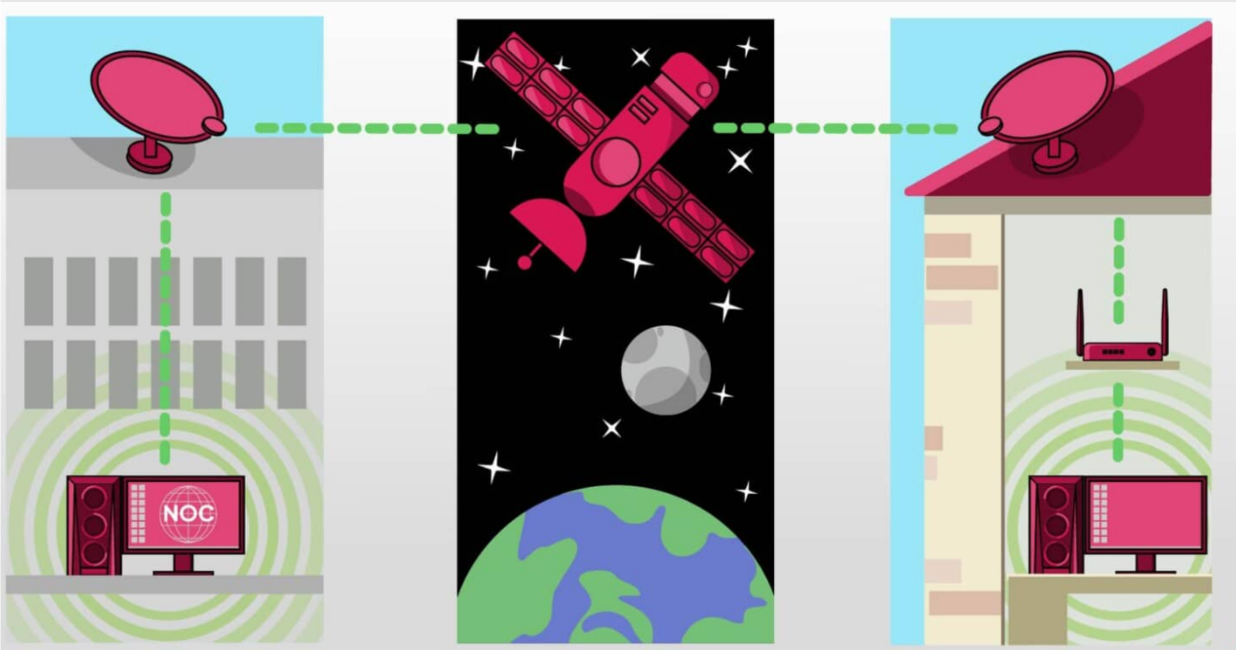
Satellite internet is a type of internet connection that uses satellite technology to transmit and receive data.[118] Satellite internet technology can provide internet access to remote or rural areas where traditional wired connections are not feasible, which is particularly useful for NPS units that have limited or no wired internet connectivity. Satellite internet is available across all 50 states. Satellite connections are useful for reliability and convenience, access in remote and rural areas, and high speeds. However, there are also some downsides in that it is vulnerable to bad weather, has relatively high prices, and typically does not support a virtual private network. When combined, encryption, network security measures, physical security, and cybersecurity awareness initiatives can be a comprehensive approach

[118] Broadband Search. [What is Satellite Internet?](#) (2025).

to safeguarding user data in the realm of satellite internet services. That said, network vulnerabilities may exist within satellite technology, exposing it to cyber threats, and the security of satellite connections may vary depending on specific circumstances and applicable privacy laws, which dictate how personal data is handled.[119]

Satellite internet infrastructure includes a network of satellites that orbit near earth offering lower latency and faster speeds, ground stations which manage the communication between satellites and the broader internet infrastructure, and user terminals, also known as home satellite dishes and modems, which facilitate the connection from the location to the satellite network (Figure 13). Satellite internet can also provide Wi-Fi, but it requires additional equipment such as a Wi-Fi router to create a Wi-Fi network.[120]

Figure 13. Architecture of Satellite Internet



Source: Broadband Now, August 2024

SpaceX is the most well-known satellite internet provider available with its Starlink Project. Unlike traditional geostationary systems, Starlink's Low Earth Orbit satellites minimize latency, enhancing the performance of real-time applications. Starlink has also begun expanding its service into cellular satellite networks. HughesNet and Viasat are among other popular satellite internet providers. Table 12 offers a comparison of the services offered by each provider.

[119] Chang, Elton. Data Privacy and Security in Satellite Internet Services. (December 2024).
[120] Broadband Now. What is Satellite Internet? Pros, Cons, and Terminology. (August 2024).

Table 12: Comparison of Popular Satellite Internet Providers

Provider	Download Speeds	Upload Speeds	Monthly Cost (from Summer 2024)	Contract Length Requirements	Data Caps
Starlink	50 to 220 Mbps	10 to 25 Mbps	$120 to $5k / month	None	Unlimited
HughesNet	50 to 100 Mbps	5 Mbps	$49.99 to $94.99 / month	2 Years	100 to 200 GB
Viasat	Up to 150 Mbps	3 Mbps	$69.99 to $149.99 / month	None	None

Source: Broadband Now, August 2024

Access Control Systems (ACS)

Access Control Systems (ACS), also referred to as automated access systems, are security technologies designed to monitor and regulate access to restricted locations. Gated ACS typically includes a gate that can be opened and closed electronically, a control panel for authorized personnel, and a method for verifying the identity of the driver and vehicle or pedestrian.[121] Gated ACS can help to manage visitors effectively with systems that track presence and issue temporary access codes or badges. Gated access control systems are in use at NPS entrance stations and visitor centers.

Parking Access and Revenue Control Systems are real-time computerized parking systems designed to manage and regulate the entry and exit of vehicles in parking facilities.[122] The gate is the most widely used method for access control devices to regulate the flow of traffic in a parking lot. These types of systems can be managed by employees or automated machines.[123] ITS technologies for parking systems have a wide range of capabilities, whereas these types of systems can collect parking data using a variety of technologies, have predictive capabilities, provide real-time parking information on signage, mobile applications / websites, or other systems, to name a few.

These systems can generate traveler information data, such as parking entries and exits. This information can be used as a proxy for visitor behavior, informing congestion projections and management strategies.

Operators can implement ACS by using either proprietary or non-proprietary hardware. In addition, organizations can use on-premises access control or cloud-based access control.[124] These ACS options are detailed below.

- **On-Premises Access Control.** Organizations can use on-premises ACS as a means of security. These systems require routine maintenance for the servers housed on site, which is performed by internal IT and security teams. Consequently, these teams must dedicate time, capital, and personnel to maintain these on-premises servers.
- **Cloud-Based Access Control.** Cloud-based access control systems use servers that store data off-site and are maintained by a third-party vendor, such as Amazon Web Services and Google. The

[121] Bajaj, Saurabh. Gated Entry Systems – Tips to Reduce Costs, Improve Safety and Convenience. (February 2023).
[122] Gorrie Regan. PARCS (Parking Access Revenue Control Systems). (2024).
[123] Gautam, Shubhankar. A Guide to Parking Access Control Systems. (July 2020).
[124] Maxsenti, Mike. A Complete Guide to Access Control Security Systems. (April 2024).

advantages of a cloud-based ACS include remote access capabilities, the centralization of physical security system across an enterprise, and API integration capabilities.

Some of this physical equipment is already in use at NPS, mainly gated ACS at the entrance stations and visitor centers. Table 13 describes the physical equipment related to ACS. Table 14 describes the connectivity requirements for ACS.

Table 13. ACS Physical Equipment

Type	Description
Tags	Tags prove the identity of permitted users and allow access. They can include key fobs, proximity cards, smartphone credentials, radio-frequency identification chips, and biometrics. Each of these technologies is encrypted with an identification number and sends signals to the access control panel.
Tag Readers	Installed at the entry and exit points of a restricted area, tag readers contain antennas, which receive the signal and encrypted number when a user presents the tag to the reader. Then, the reader sends the number to the access control panel.
Access Control Panel	The core of the ACS, storing the authorized information configured by the administrator. This component receives the encrypted tag ID number from the reader. The number is decoded and compared to the numbers already registered in the system. If the number matches, the user can gain access.
Electronic Locking System	Automatically unlocks or remains locked to deny access depending on whether the ID number read and decoded by the access control panel matches the registered numbers in the building security system.
Physical Entry Points or Entry/Exit Stations	Designated locations where individuals or vehicles can enter an area or property. In NPS's case, this is often an entrance station, visitor center, fee kiosk, or an automatic gate. Entry points are typically equipped with a gate or barrier to ensure that not just anyone can access the property. Entry/exit stations can also be equipped with ticketing dispensing, access, and credit card functionalities.
Pay Stations	Pay stations can accept entry tickets, exit tickets, validated tickets, and validation coupons. They also calculate parking fees, accept and process credit cards, print and issue a receipt on request, and issue a paid exit ticket. There are two main types of pay stations - Pay on Foot or Pay in Lane.
Swinging Arm Gate Openers	Gates that mechanically push/pull the gate to be closed and opened.
Sliding Gate Openers	Gates that push the gate to one side down a track using a motor and gears.
Fee Computers	Perform automatic fee calculations. Multiple fee computers and validators may be utilized in conjunction with several types of ticket dispensers for a complete on-line system.
License Plate Reader (LPR)/License Plate Inventory (LPI)	LPR uses the combination of a camera and database to allow the camera to capture a license plate image, convert the image to alpha numeric text and compare that text to a database of registered plates. LPI uses the combination of a handheld device and a database to allow a person to manually capture a license plate and log it into a database for future reference.

Source: U.S. DOT Volpe Center, November 2024

Table 14. ACS Connectivity Requirements

Connectivity Requirement	Description
Wiring*	Wiring is required to connect the gated ACS to the gate operator arm and other components. The wiring should be installed according to the manufacturer's specifications and local codes and regulations.
Power Source*	Power is required to operate the gated ACS and its components. This can be provided through a standard electrical outlet, a dedicated circuit, or through solar power sources.
Internet Connectivity	Internet connectivity is required for cloud-based ACS and to enable remote access and management. A reliable and secure internet connection is crucial for the proper functioning of these systems.
Telephone Line Connectivity	Telephone line connectivity may be required for certain types of gate ACS, such as intercom systems.
Connecting to Existing Gate Operator Arm	The gate ACS should be connected to the existing gate operator arm to control the opening and closing of the gate.

*Some of these items included in this table are not limited to ACS [i.e., most, if not all, ITS infrastructure requires power and communications/backhaul (wired or wireless)]. *Source: U.S. DOT Volpe Center, November 2024*

5.6.2 Deployment Considerations

Traveler information-related physical infrastructure and equipment have the following deployment considerations, including data, privacy, security, and reliability concerns.

- **Data Collection and Storage.** Much of the traveler information-related physical infrastructure that is already installed at NPS units do not include PII or other sensitive information, but rather largely contains numerical data such as counts (i.e., vehicle and trail counters, parking sensors, etc.). However, many vendors and some physical equipment, such as cameras, offer options to collect additional information such as license plate data or facial recognition images, which are considered PII.[125] In addition, the data collected by physical equipment is often stored in the cloud, which requires a FedRAMP certification, and cybersecurity may also need to be considered for any field equipment that will have remote access. [126,127] If NPS plans to utilize these types of physical infrastructure or equipment, a PTA/PIA review will likely be required to ensure the equipment selected meets applicable data privacy and security standards.
- **Infrastructure and Equipment Reliability.** These technologies are often dependent on reliable broadband bandwidth, which may be unreliable or spotty in some areas, especially more rural areas. Additionally, system failures are a possible outcome of software errors. For example, a camera might not deliver reliable data at night or in extreme weather conditions, or a sensor might not be adjusted properly, resulting in inaccurate vehicle counts. To manage these risks, routine maintenance and testing will be required.

[125] Many state DOTs have policies on keeping video images. As such, it is also important to understand the local and state policies, not just the federal policies and regulations, when deploying physical equipment.
[126] FedRAMP certification, or the Federal Risk and Authorization Management Program, is a government-wide program that standardizes the security assessment and authorization process for cloud services used by U.S. federal agencies to ensure that cloud service providers meet strict security requirements to mitigate risks of data breaches and cyber threats.
[127] Cybersecurity incidents such as simple hacking of field equipment (e.g., VMS vandalism) to more sophisticated cyber events have been reported in recent years. More information related to cybersecurity and the safety of our nation's transportation systems can be found at https://www.transportation.gov/priorities/cybersecurity.

- **Unauthorized Access and Equipment Damage.** One key concern pertaining to physical infrastructure is the ability to safeguard the equipment from unauthorized access and damage. Methods for safeguarding include locks, gates, security personnel, and surveillance equipment. For example, at Indiana Dunes National Park, vehicle counting sensors are installed in lockboxes attached to poles or in locked park bathhouses and facilities to keep unauthorized personnel from handling or removing this equipment. However, even with this approach, the physical equipment has been stolen, tampered with, or damaged by unauthorized personnel. This could potentially be of concern to NPS if the physical equipment is particularly valuable or contains sensitive information or PII. Mitigating these risks requires a well-thought-out approach to security measures such as changing the locks or updating passwords.[128]
- **Impacts on Natural, Cultural, and Historic Resources.** Installing physical infrastructure and equipment could potentially impact natural, cultural, and/or historic resources. However, technologies that reduce congestion and other harmful vehicle impacts such as emissions could also help preserve natural resources long-term.
- **Environmental Compliance.** NPS requires anything built outside of the road prism to go through a compliance process to consider the impacts on the natural environment, cultural resources, and historic resources. Various National, State, Tribal, and local laws, policies, and regulations (i.e., the National Environmental Policy Act of 1969 (NEPA), the National Historic Preservation Act of 1966 (NHPA), etc.), as well as those specific to NPS and/or other federal agencies (i.e., the Organic Act of 1916, the 1970 National Park System General Authorities Act[129], Secretary of the Interior's Standards, etc.) are in place to protect natural, cultural, and historic landscapes. The installation of physical infrastructure or equipment could trigger compliance processes.
- **Physical Infrastructure and Equipment May Require Review and Compliance.** As per NPS staff, anything built outside of the road prism will have to go through a compliance process. NPS review and compliance refers to the process through which the direct and indirect effects of a grant project are considered for impacts on the natural environment, cultural resources, and historic resources. This process applies federal laws, regulations, and standards related to historic preservation and environmental protection to federally sponsored projects that affect historic resources. Review and compliance are relevant for any grantees that have received a grant from one of the competitive grant programs and Congressionally Directed Spending. All review and compliance reviews must be complete **prior** to the commencement of project work. In general, Section 106 of the NHPA and NEPA reviews take around 60 days total to complete once a complete submission is received by NPS, as does a Section 110 review for designated National Historic Landmarks, which requires both NPS headquarters and regional office staff review. NPS processes NEPA reviews at the same time as the Section 106/110 reviews.

[128] Virginia DOT recently deployed Medeco XT Intelligent Keys and Electronic Traffic Cabinet Locks as a simple drop-in replacement for current locks, allowing Virginia DOT to quickly update and harden security for more than 6,000 traffic cabinets statewide with technology to add security and control access to only authorized personnel. (Source: *Strengthening Physical and Cyber Security: VDOT's Statewide Deployment of Medeco XT*.)

[129] The Organic Act, which created the National Park Service in 1916, directs the Service to conserve park resources "unimpaired" for the enjoyment of future generations. The 1970 National Park System General Authorities Act, as amended in 1978, prohibits the Service from allowing any activities that would cause derogation of the values and purposes for which the park units have been established. (Source: https://www.nps.gov/subjects/policy/mp-9-facilities.htm).

6. Recommendations to Advance Traveler Information Technologies

This section presents recommendations to increase traveler information technologies adoption to improve planning, operational efficiency, and the visitor experience. NPS can develop more detailed technology deployment roadmaps across all technology areas, which will determine implementation steps, suitable types of parks for deployment, and evaluation criteria. The recommendations can be categorized into three approaches for advancing the technologies.

- **Exploratory Research:** Recommendations in this category are in the least advanced stage of readiness for any deployments. The goal of exploratory research is to generate hypotheses and identify patterns that can guide more structured and detailed research in the future.
- **Pilots:** Recommendations in this category are in a more advanced stage of readiness for deployments than the exploratory recommendations, but they are not quite ready to be considered permanently. These projects are temporary and should measure benefits and challenges through data collection and evaluation.
- **Permanent Deployments:** Recommendations in this category are in the most advanced stage of readiness for deployment. These projects involve permanent design and construction.

Table 15 summarizes the overarching recommendations for each technology area, which are further detailed in the respective technology area recommendation sections below. The recommendations are ordered by approach type (exploratory research, pilots, and permanent deployments). These recommendations are provided for NPS to consider. Within each technology area, some recommendations may be more actionable for NPS to pursue based on available funding, agency priorities, and stakeholder interests.

Table 15. Recommendations for Advancing Technologies by Approach

No.	Recommendation	Approach	Technology Area
1	Expand and maintain partnerships with external stakeholders from popular navigation applications.	Permanent Deployment or Widespread Adoption	Data Feeds
2	Continue to advance agency-wide road and transit data feeds to relay information to visitors.	Permanent Deployment or Widespread Adoption	Data Feeds
3	Consider data privacy and security when choosing physical equipment and infrastructure to deploy traveler information technologies.	Permanent Deployment or Widespread Adoption	All
4	Create more standardized data elements that can be accessible through the NPS digital products, including the API and NPS app.	Pilot	Data Feeds
5	Conduct mobility data pilots in different park settings to evaluate the effectiveness of different historical and real-time mobility data options.	Pilot	Mobility Data

No.	Recommendation	Approach	Technology Area
6	Continue to deploy established AI and ML techniques for traveler information related work.	Pilot	ML/AI
7	Where possible, make authoritative data easily accessible to decrease misinformation.	Pilot	ML/AI
8	Pilot the integration of geofencing technology into one or more existing NPS alert systems, where beneficial.	Pilot	Geofenced Alerts
9	Pilot geofenced alert systems within park settings.	Pilot	Geofenced Alerts
10	Support the development of a road restriction data feed using the TDx specification and explore ways to incorporate recreation elements.	Exploratory Research and Pilot	Data Feeds
11	Continue to follow advancements in mobility data technologies and options.	Exploratory Research and Pilot	Mobility Data
12	Conduct further research into V2X technologies. Engage partner agencies piloting V2X technologies, particularly in Wyoming, Utah, and Colorado.	Exploratory Research	V2X
13	Explore the use of external navigation applications to send geofenced alerts to park visitors.	Exploratory Research	Geofenced Alerts
14	Understand the necessary infrastructure required to support ITS technologies and plan to install it prior to installing physical equipment for generating traveler information.	Exploratory Research	Physical Infrastructure and Equipment

Source: U.S. DOT Volpe Center, September 2025

For all recommendations, NPS should ensure staff is available and willing to engage with the technologies, as well as maintain the physical infrastructure and equipment on the ground as necessary. The most successful and effective traveler information technology projects must have commitment from park staff and leadership to ensure alignment with organizational goals and increase commitment to the project.

6.1 Traveler Information Technology Data Feeds Recommendations

NPS should consider the following recommendations for data feeds.

For each data feed type, first improve the asset inventory and then move towards real-time data feeds and eventually forecasted conditions. Table 16 outlines incremental improvements to provide traveler information on inventory first, then real-time status of assets, and finally on forecasted future condition of assets.

Table 16. Data Feed Maturity Status for Major Transportation Assets

Asset	Inventory	Real-Time Status	Forecasts / Future Conditions
Roads	Roads are fully inventoried online, including location, name, and some restrictions. However, this is not available for all parks in the road closure tool.	**Road Events (NPS API)**: Currently, parks can identify whether the road is open or closed.	Upcoming planned road closures and projected congestion that is available online to the public would assist with trip planning and improve overall visitor experience.

Asset	Inventory	Real-Time Status	Forecasts / Future Conditions
	Other Areas: Restrictions, Wildlife Migration.	**Other Areas:** Restrictions, Congestion, Wildlife Migration.	
Transit	**National Transit Inventory:** Includes system name, vehicle type, passenger boardings, vehicle ownership, agreement type, transit service purpose. **GTFS:** Currently inventorying information relevant to riders, such as stops, fares, and routes.	Real-time transit information for some parks is available online to the public on third-party mapping applications through the GTFS real-time. It includes whether it is currently operating and the wait time for stops.	Planned transit system closures and anticipated delays would be useful to visitors as they plan their trip. Projected transit congestion may be useful in some cases but might be harder to predict and may not significantly impact trip planning.
Parking Lots	**NPS Road Inventory Program:** Includes location, name, and size. **Other Areas**: Spaces, Visitor Amenities, and Available Power and Cell service.	Real-time parking lot conditions and/or congestion leading up to parking lots at the park would be beneficial to visitors on their trip to the park. Indiana Dunes National Park has piloted parking availability.	**Content Management System (VMS):** Projected parking congestion is available on NPS.gov. It is being used by some parks.
Paved Trails (Front Country or Transportation Trails)	**Partially Inventoried**: Includes name, location, accessibility, length and completion time, level of difficulty, trail material type, amenities, points of interest, and transportation connections, such as other trails and transit stops. Geospatial database to be submitted to the Federal Lands Transportation Facility Inventory in 2026. **Future Areas**: Greater accessibility information (e.g. slope).	Real-time trail conditions that are available to the public online on third-party mapping applications would be valuable to visitors for short-term trip planning. This could include whether the trail is open or closed, current level of crowding, snow/ice, and wildlife warnings.	Planned trail closures could be valuable for visitors to assist with trip planning. Projected level(s) of congestion could be useful to visitors but may not significantly impact trip planning or overall visitor experience.

Source: U.S. DOT Volpe Center, November 2024

Continue to advance service wide road and transit data feeds to relay information to visitors. NPS has deployed WZDx feeds for their roads and GTFS feeds for their major transit systems. Both feeds are becoming more widely adopted and trusted by navigation applications, and NPS should sustain these efforts to maintain accurate data and share authoritative information with the public.

Support the development of a road restriction data feed using the TDx specification and explore ways to incorporate recreation elements. NPS should develop a data feed with road restriction information for all NPS roads, including commercial vehicle restrictions and restrictions on vehicle height, weight, and length. As U.S. DOT agencies develop the WZDx and TDx feeds to better integrate other disruptions, NPS should recommend updates to integrate public lands elements, such as timed entry restrictions.

Foster and maintain relationships with third-party navigation applications to provide accurate information to visitors. NPS should continue to build relationships with private navigation applications such as Google Maps, Apple Maps, Waze, and Transit to ensure that accurate NPS information is being shared in their products.

Create more standardized data elements that can be accessible through the NPS digital products, including the NPS API and NPS app to improve traveler information for visitors. NPS should continue to build data feeds and integrate the feeds with the NPS API so the information is pulled and integrated into the NPS app. NPS should also integrate the existing Road Events API endpoint into the NPS app. The findings and outcomes of the Enhancing Trip Planning project should also be leveraged to assist with this recommendation and ensure that the traveler information is structured most effectively on the NPS digital products.

6.2 Mobility Data Recommendations

NPS should consider the following mobility data recommendations.

Continue to keep up to date on emerging mobility data sources, and where possible, conduct pilots in varied park settings to identify and reduce congestion issues in parks. Data sources (i.e., CVs, mobile phones etc.) and geographic coverage change as these technologies evolve, so this research should be revisited every few years to understand the current best data for NPS use cases. As new types of data become available, new methods of analyzing, visualizing, and disseminating that data become possible. Examples from state DOTs, such as Utah DOT's Cottonwood Canyon Road conditions dashboard, demonstrate promising opportunities to create more detailed and real-time traveler information in NPS settings, particularly in parks with quality connectivity.

6.3 Vehicle To Everything (V2X) Recommendations

NPS should consider the following V2X recommendations to identify high-value pilot opportunities.

Conduct further research on V2X technologies and engage state DOT agencies piloting V2X technologies to understand the use of this technology in an NPS setting. NPS should conduct further research on V2X technologies applicable in public lands settings, evaluate ongoing V2X deployments, and consider participation in V2X pilots as this technology spreads further. If there is a desire for NPS to pilot these technologies now, an NPS unit could partner with a state DOT or another transportation agency that is operating a V2X pilot, to expand the reach of this technology into a nearby national park unit and assess its effectiveness at pushing traveler information to visitors.

The WYDOT V2X pilot monitors road conditions during severe weather and provides real-time alerts. There could be an opportunity for NPS to coordinate with WYDOT to potentially include Grand Teton National Park, Yellowstone National Park, or Bighorn Canyon National Recreation Area into this pilot.

U.S. DOT also launched its V2X Accelerator Program for V2X Technologies to accelerate interoperable V2X deployments in Utah, Colorado, Wyoming, Arizona (Phoenix Area), and Texas (Houston). Similarly, there could be an opportunity for NPS to coordinate with FHWA and the States to potentially include other NPS units in Utah, Colorado, Wyoming, Arizona, or Texas into this pilot. V2X communications would be especially impactful at parks that wish to share safety-focused traveler information directly to drivers.

6.4 AI and ML Recommendations

NPS should consider the following AI and ML recommendations.

Continue pilots that use established data science techniques, particularly ML algorithms, to improve the visitor experience. Both the travel forecasting and LPR pilots use established data science techniques. LPRs have some risks of data privacy and security with video-based data collection, but there are established methods to securely store data to protect visitor privacy. Planning and traveler information applications generally have lower risk levels because there tends to be an analyst reviewing the data before it reaches the public. This "human in the loop" check ensures that any misinformation or bias is corrected before it directly creates any negative impact on parks.

Where possible, provide authoritative information to the general public to reduce the likelihood of AI "hallucinations". Generative AI is already being used widely by visitors. These models are based on what is available online. Wherever possible, NPS should make their authoritative information easily available and consumable through NPS.gov and the NPS API. This would reduce the likelihood of model hallucination, thus ensuring that visitors relying on AI generated information are less likely to receive misinformation.

6.5 Geofenced Alerts Recommendations

NPS should consider the following geofenced alerts recommendations.

Pilot geofenced alert systems to evaluate their effectiveness at disseminating traveler information. NPS should pilot geofenced alert systems within one or more park settings to evaluate their effectiveness at disseminating different types of traveler information. Items to consider when developing a pilot or series of pilots include:

- **Park setting.** A rural or more remote park setting may have different use cases compared to an urban or more developed park. Another key factor to consider is the availability of cell service, which is required to operate such a system.
- **Nature of the alerts.** NPS could pilot emergency-only alerts that are disseminated in a similar way to wireless emergency alerts, and/or provide general traveler information-focused alerts that are only sent to those individuals who have signed up to receive them. Other alerts could focus on parking lot usage and availability, road condition during extreme weather events, and road restrictions.
- **Means through which the alerts are sent out.** Older geofencing systems have typically relied on SMS messages to send notifications, while some newer systems rely on push notifications sent via applications. NPS would need to identify a partner, whether it be more conventional text-based geofencing services, or a partnership with a third-party app such as Apple Maps, to provide this

information to travelers over their system(s). Alternatively, it could also be possible to explore the addition of geofence alert capabilities to the NPS app.

Pilot integration of geofencing technology into existing alert systems where beneficial to relay traveler information to visitors. Several NPS units already utilize SMS message alerts to relay traveler information to visitors. Geofencing technology could be applied to an existing text alert system that is in use at a NPS unit. For example, Yosemite National Park's existing Everbridge system sends automated messages to all individuals who have opted in, regardless of whether their cellular device is physically inside park boundaries. NPS could consider modifying it to provide traveler information-focused geofenced alerts (such as parking and congestion updates) to individuals based on their locations. Park staff also expressed interest in building a new emergency-focused alert system that would supersede the county managed alerts park visitors currently receive.

Explore geofenced alerts via third-party navigation applications and state DOT partners to provide alerts to visitors entering parks. NPS could consider a pilot/partnership with a third-party navigation application to provide app-based alerts to visitors entering parks, which would notify them about the availability of detailed map information. Third party mapping applications, such as Apple Maps, provide highly detailed digital maps of some indoor spaces such as malls and airports. Though parks are typically more expansive than these enclosed destinations, non-urban parks do have defined areas that could report detailed geospatial information on amenities and transportation options to mapping applications. This would likely be more challenging in urban parks given that their boundaries are sometimes discontinuous. NPS could also consider the feasibility of partnering with an external public agency which already operates a geofenced alert system. Some state departments of transportation offer geofenced alert functionality as part of existing traveler information applications. NPS should explore a potential geofencing pilot between a larger or higher visitation park unit and one of these state-managed applications.

6.6 Physical Infrastructure and Equipment Recommendations

NPS should consider the following recommendations for physical infrastructure and equipment.

Identify and define transportation challenges and the existing physical infrastructure and equipment needed to address them to ensure the appropriate physical infrastructure and equipment are considered for the park setting. NPS may want to identify parks with traveler information challenges which could be best addressed using physical infrastructure deployments. This may include options such as:

- Real-time traffic or parking detection, especially in instances where other options such as probe/location data, are not capable of providing accurate counts. The work at Indiana Dunes National Park could inform deployments at other parks with frequent congestion issues.
- Safety-oriented equipment, such as oversize vehicle detection systems. This could be piloted in conjunction with the road restrictions data feed at select locations of concern.
- Camera system deployments to help aid park staff with visitor reservations, as well as provide real-time data on road congestion, etc. The work at Yosemite National Park could inform deployments at other parks with high visitation.

Understand the necessary baseline infrastructure needed to pilot traveler information technologies and plan for it to be in place prior to installing physical equipment to ensure the appropriate solution is deployed. For many traveler information technologies to be successful, there must be physical infrastructure components. Ensuring that the utilities, power, and cellular connectivity infrastructure is in place prior to installing physical equipment will allow NPS to more seamlessly deploy different types of physical infrastructure projects. If the necessary infrastructure is not in place, NPS should plan to make infrastructure improvements as part of the pre-planning phase prior to any pilot or deployment. NPS could also consider creating a database with each unit's existing and planned communications and energy infrastructure. NPS could then use this database to help parks to identify feasible technologies for future pilots.

Consider data privacy and security concerns when choosing physical equipment and infrastructure to deploy ITS technologies to comply with all applicable data privacy and security standards. As discussed, critical infrastructure is often interconnected with information technology, making it highly vulnerable to privacy and security concerns. NPS should work through the data privacy and security process for any physical infrastructure necessary for deployment. This may include:

- Developing a well-thought-out approach to security measures such as access control and securing valuable equipment to avoid damage, access to, or theft of any physical equipment.
- Use cameras and sensors that do not automatically collect and/or store additional information such as license plate data or facial recognition images, which are generally considered to be a form of PII. If NPS does choose to use physical equipment that does collect and store this type of data and information, then a PTA/PIA review will likely be required to ensure the infrastructure or equipment selected, as well as where the data is stored (i.e., vendor-provided clouds or websites), all meet applicable data privacy and security standards and are FedRAMP certified as required.

7. Conclusion

A growing number of NPS units are piloting and deploying traveler information technologies to address common transportation-related challenges such as congestion, visitor safety, resource protection, and operations management. Physical equipment (i.e., traffic counters, VMS, sensors) is a relatively mature technology area at this point, while newer traveler information technologies are increasingly built on novel data sources (i.e., CVs, mobile data, etc.) and widespread access to a smartphone or digital navigation system. Many transportation agencies are shifting their traveler information technology deployment efforts towards newer technology areas, and it is recommended that NPS do the same.

NPS should consider the technologies' applicability within the unique NPS unit context. A summary of those technologies is as follows:

- **Data feeds** provide transportation information to third-party navigation applications, which can be shared with the public in a standardized format. Some data feeds, such as the GTFS and TDx, have already been piloted and are ready for widespread deployment. Emerging data feeds, such as the road restrictions and curb data feeds, should be piloted and evaluated for impact.

- **Mobility data** provides a promising opportunity for improved data to support park planning and traveler information dissemination. This data is commercially available, so NPS can pursue pilots in the near term to evaluate the effectiveness and applicability of mobility data options.
- **V2X** technologies allow vehicles to "talk" with other vehicles, roadway users, and infrastructure. NPS has not piloted V2X, but these technologies are relatively mature with state DOTs. NPS should continue researching the topic and pursue partnerships with agencies scaling V2X.
- **ML and AI** can augment existing technologies by providing new functions that humans cannot perform. NPS should investigate specific applications of AI within its operational context, such as AI travel assistant functions.
- **Geofenced alerts**, sent via text or app notifications, would allow NPS to communicate traveler information to park visitors based on their specific location. This option is readily available for parks to pilot.
- **Physical infrastructure** is a more established technology area, but there are emerging applications, such as LPRs. NPS should pilot or install newer physical technologies, in addition to more conventional ones, where possible, to address park-specific transportation challenges.

For all future technology deployments, NPS should ensure staff are available and willing to engage with the technologies, as well as maintain the physical infrastructure and equipment on the ground as necessary. The most successful, effective traveler information technology projects must have commitment from park staff and leadership to ensure alignment with organizational goals and increase assurance to the project.

This report offers high-level research for NPS to advance traveler information technologies. That said, these technologies are continuously advancing year-to-year. NPS should continue research in all six technology areas, especially for data feeds, ML/AI, and mobility data, as these are rapidly evolving and may offer additional deployment opportunities in the near future. The next phase of this effort will involve continued research (as appropriate) and pilot planning for some or all the technology areas, in coordination with subject matter experts at U.S. DOT.