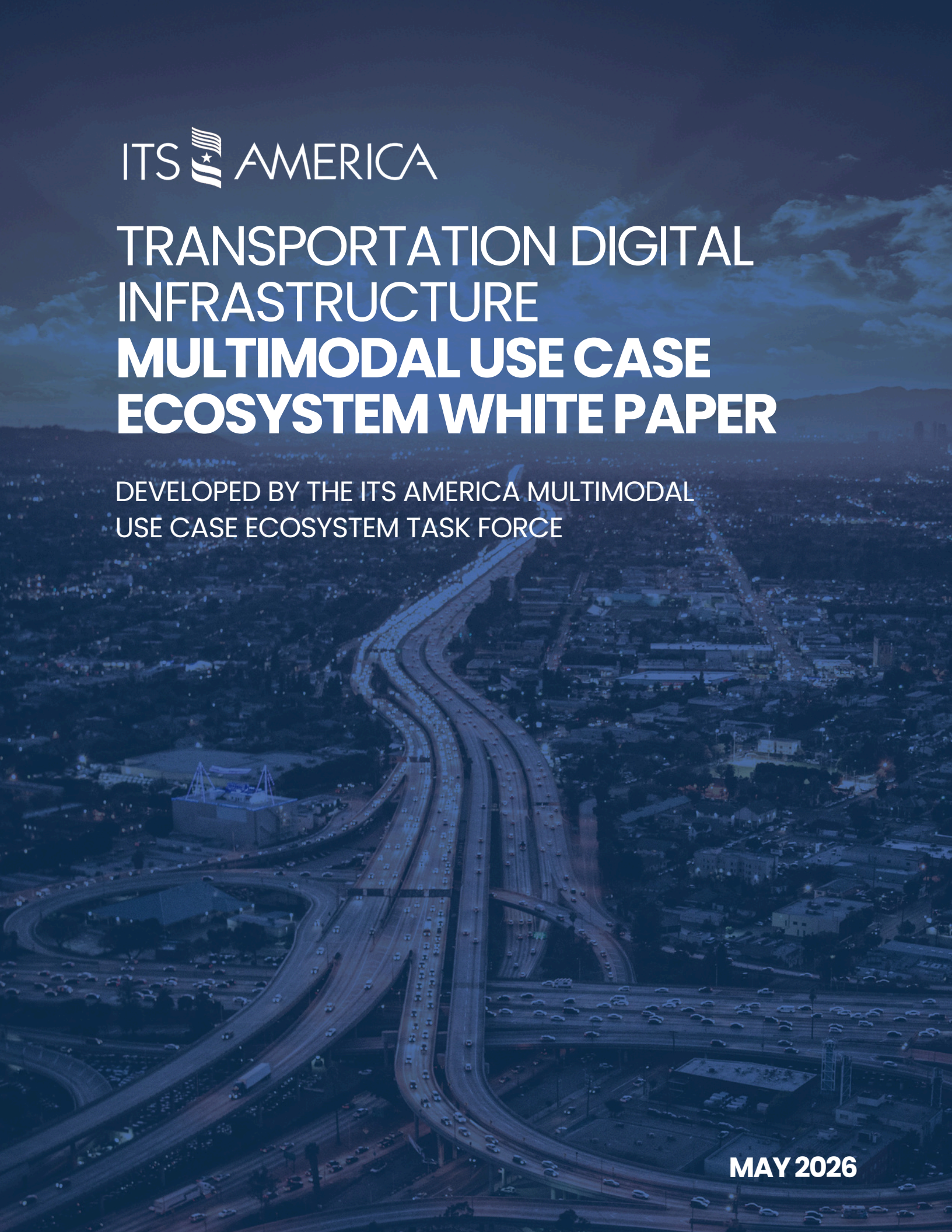

ITS AMERICA

TRANSPORTATION DIGITAL INFRASTRUCTURE **MULTIMODAL USE CASE ECOSYSTEM WHITE PAPER**

DEVELOPED BY THE ITS AMERICA MULTIMODAL USE CASE ECOSYSTEM TASK FORCE

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EXECUTIVE SUMMARY

Transportation Digital infrastructure (TDI) stands as the essential foundation for modernizing America's transportation system, uniting physical and digital assets to create a safer, more efficient, and future-ready multimodal ecosystem that advances national safety, mobility, network and system resiliency, and economic growth. TDI transforms every facet of our national transportation system, from efficiently moving people and goods to enabling first responders to respond to emergencies faster.

This document serves as a high-level resource for Intelligent Transportation Systems (ITS) professionals to explore the benefits TDI offers across the entire transportation ecosystem with policymakers, federal, state, and local government decision makers, and other transportation sector leaders. The purpose of the white paper is to demonstrate the wide range of TDI applications through six categories of use cases identified by the task force: movement of people, movement of goods, asset management and construction, emergency preparedness, special events, and cross-industry integration. The use cases identified in this document span multiple modes of transportation and highlight the multijurisdictional approach of TDI. To demonstrate the in-depth application of TDI, this document analyzes a sample of use cases from each of the six categories, identifies the challenges each use case addresses, provides a TDI solution, and explains a real-world application of the TDI solution.

This document is intended to serve as a reference for informed decision-making, strategic planning, and policy formulation across the transportation sector. Through engagement with its content, readers will acquire enhanced insight into practical TDI applications, established strategies, and potential avenues for collaboration and innovation within the dynamic multimodal transportation landscape.

Importantly, the in-depth use cases discussed in this white paper do not cover the full breadth and depth of TDI applications. An extensive list of TDI solutions that were identified by members of this task force can be found in Appendix A.

This document was prepared by the Multimodal Use Case Ecosystem Task Force of ITS America, operating under the organization's Digital Infrastructure Standing Advisory Committee. The Task Force comprised members from public, private, academic, and research sectors across the ITS community.

1 Transportation Digital Infrastructure in a Multimodal Ecosystem

DEFINING TRANSPORTATION DIGITAL INFRASTRUCTURE

Our nation's transportation system has transformed beyond just physical infrastructure to include TDI that addresses numerous challenges, improves operational efficiency, and enhances user experience. However, to ensure that innovators, enablers, and deployers are working towards a consensus-based approach, we must identify a consensus definition. Defining TDI is a crucial step to comprehensively integrating transportation technologies and solutions into the transportation system. ITS America proposes the following definition:

> *Digital infrastructure represents the public and private technology assets that create, exchange, or use data to provide information and insights for transportation systems that advance safety, security, efficiency, and economic growth.*[1]

[1] Intelligent Transportation Society of America. (Under Development). *Digital infrastructure: The path to modernizing the transportation system.*

INTRODUCTION TO MULTIMODAL TDI USE CASES

TDI includes a wide range of technology assets that work together to enable aspects of the nation's transportation system. Agencies have deployed many of these technologies across a broad range of multimodal applications throughout our nation's transportation system by both private and public sector innovators, often partnering together. TDI implementation often requires data interoperability, here defined as different systems being able to communicate and exchange information in standardized, mutually understandable ways.[2]

To create a representative sample of use cases, the task force identified six categories: movement of people, movement of goods, asset management & construction, emergency preparedness, special events, and cross-industry integration. Each category aims to present a wide range of real-world scenarios and applications where stakeholders can effectively use TDI to address various challenges, streamline operations, and enhance user experience.

THE SIX CATEGORIES ARE AS FOLLOWS:

Movement of People:

Multimodal trip making, including rail, roads, transit, shuttles, ferries, air, transportation network companies (TNCs), and micromobility.

Movement of Goods:

Freight operations from dock-to-door across multiple modes, including maritime, rail, air, and roadways, and from long-haul to first- mile/last-mile.

Asset Management and Construction:

Planning, designing, constructing, tracking, operating, maintaining, upgrading, and optimizing transportation assets throughout their lifecycle.

Emergency Preparedness:

Planning, preparation, mitigation, adaptation, and recovery by first responders to natural disasters, unexpected disruptions, major accidents, and other emergency events.

Special Events:

The movement of people around major events, such as the FIFA World Cup, Olympics & Paralympics, concerts, sporting events, and other large gatherings, accounting for street closures, route change, and other circumstantial factors.

Cross-Industry Integration:

The collaboration and integration of different sectors, such as the telecommunications, energy, and technology sectors into and across the transportation sector.

This paper highlights a sample of TDI use cases throughout our nation's transportation system to help users and decision-makers understand how TDI applications can address challenges, provide significant benefits, and inspire new ideas, while driving adoption and innovation within the industry.

[2] National Library of Medicine. (2026, February). *Data interoperability.* Network of the National Library of Medicine. nnlm.gov/guides/data-glossary/data-interoperability

HOW USE CASES ARE STRUCTURED

To help readers navigate and understand each TDI use case, the following consistent structure is employed across every category. This approach enables clear comparison and highlights recurring themes and challenges throughout the various applications:

Description:

A brief overview of the use case, outlining its main purpose, context, and relevance within the transportation system.

Key Stakeholders:

Identification of primary groups impacted by or involved in the use case, such as travelers, agencies, operators, and community partners.

Deployment Examples:

Real-world instances or pilot programs illustrating how the use case has been put into practice.

Benefits:

Key advantages and positive outcomes resulting from deployment or adoption of the use case, including improvements in efficiency, safety, accessibility, or cost-effectiveness.

Common Implementation Challenges:

Typical obstacles or barriers encountered during implementation, including technical, organizational, and operational issues. Many of these challenges are shared across multiple categories and use cases.

This standardized format not only prepares the reader for a deeper exploration of each use case, but also underscores that certain challenges, such as data integration, interoperability, and stakeholder coordination, are prevalent across different categories and scenarios. Recognizing these commonalities can help inform strategies for successful deployment and innovation.

NOTE ON USE CASE CATEGORIES

The categories and use cases presented above do not constitute an exhaustive list. Instead, they are intended to serve as representative examples, illustrating a broad range of real-world scenarios where TDI can be effectively applied. Stakeholders should consider these categories and specific examples as starting points for understanding the diverse applications of TDI across different transportation challenges and operational needs.

2 Movement of People

The movement of people within our nation's transportation system is rapidly evolving as new technologies reshape how travelers plan, navigate, and complete their journeys. TDI serves as the backbone supporting this transformation, enabling safe, efficient, and accessible multimodal travel. By integrating data from various transportation modes and providing essential information, TDI empowers both users and operators with the processes, standards, specifications, and tools needed to make traveling easier, reduce congestion, improve safety, and enhance overall user experience. This section presents examples of how TDI can enhance safety, efficiency, and convenience.

USE CASES INCLUDED IN THIS SECTION:

- **Complete Trip Apps:** These platforms centralize trip planning, reservation, and payment for multimodal travel, integrating information on public transit, ridesharing, cycling, rolling, and walk-ing. These multimodal apps help users plan their complete trip and switch between modes within a journey.
- **Transit Information:** This information provides users and operators with up-to-date data across multiple services and modes (e.g., bus and commuter rail), enabling safer, more efficient, and more convenient multimodal travel.
- **Incentivization to Reduce Vehicle Miles Traveled (VMT):** These tools incentivize travelers to choose multimodal transportation options, through engaging rewards and challenges, aiming to decrease single-occupancy vehicle use.
- **Universal Payment System:** Universal payment systems enable travelers to pay for trips spanning different transportation modes or providers through a single integrated platform, streamlining multimodal trip planning and payment.

COMPLETE TRIP PLATFORMS

Complete trip platforms provide a centralized method for users to seamlessly plan, reserve, and pay for multimodal travel. Distinct from conventional navigation platforms or applications, they integrate real-time information for public transit, ridesharing, and non-motorized modes like cycling and walking. These solutions help address the "first-mile/last-mile" challenge, which refers to the difficulty travelers often face in getting from their starting location to the nearest transit option (the first mile), and from the final transit stop to their ultimate destination (the last mile).[3,4]

Complete trip platforms rely heavily on TDI, which provide access to real-time, interoperable transportation data across modes and providers, to deliver accurate and appropriate information to users.

BENEFITS

Complete trip platforms bridge gaps, offering door-to-door directions and integrating multiple modes of travel to make multimodal journeys more practical and accessible to a wide range of users. This can help address the first-mile/last-mile segments that can be barriers to using public transportation, especially when direct connections are lacking or options are inconvenient. By providing a single app, a complete trip platform improves efficiency and convenience for travelers that need to take multiple forms of transportation to make a complete trip.

KEY STAKEHOLDERS

Public Agencies:

Provide data feeds (using e.g., General Transit Feed Specification (GTFS), General Bikeshare Feed Specification (GBFS)[5]), provide and integrate multimodal options, and support seamless trip planning across different transportation modes. Oversee regulatory compliance, funding, and strategic planning for multimodal trip solutions; coordinate among various transit providers. Set and collect payments, handle fare eligibilities.

Technology Providers and Platform Developers:

Design, maintain, and update centralized trip planning and payment platforms; ensure interoperability and data accuracy across systems.

Users and the General Public:

Use the complete trip platformtoplan, book, and pay for multimodal journeys; providefeedback to im- prove accessibility and user experience.

Transportation Network Companies (TNCs) and Third-Party Mobility Providers:

Manage rideshare, microtransit, micromobility, taxi, or volunteer driver programs. Integrate with the platform to expand travel options and coverage for users. Provide data feeds for integration in platform.

Healthcare Providers and Social Service Agencies:

Collaborate on specialized trip solutions for populations with unique mobility needs, such as non-emergency medical transportation, paratransit, and on-demand transit.

COMMON IMPLEMENTATION CHALLENGES

Integration of Multimodal Transportation Data

One of the most prominent issues is the seamless integration of multimodal transportation data. Providers often utilize a range of technologies and adhere to different data standards, making it complex to unify disparate data sources into a single, cohesive platform. However, this integration is key to ensuring door-to-door coverage by complete trip platforms.

Data Interoperability

Achieving data interoperability across various systems requires the development and support of open data standards and specifications, universal application programming interfaces (APIs), and the establishment of strong data governance practices. These measures are essential to ensure that information shared between providers remains consistent, accurate, and reliable for users.

Reliable Telecommunications Connectivity

Reliable network connectivity for both agencies and platforms users is another critical factor, as it underpins the delivery of real-time updates that are vital for effective trip planning. Any interruptions or inconsistencies in network performance can undermine the user experience and the functionality of the platform.

Privacy

Safeguarding user privacy presents significant challenges that must be carefully addressed during implementation. Protecting sensitive personal information is vital, particularly when integrating data from multiple transportation providers and managing real-time updates. Comprehensive privacy practices, including robust data governance and secure data handling procedures, are essential to maintain user trust and comply with regulatory requirements. Ensuring the confidentiality and integrity of rider data helps create a secure environment for users, promoting trust and lowering barriers to use.

DEPLOYMENT EXAMPLES

Wisconsin and Michigan

"CatchaRide" applications, currently deployed in communities in Wisconsin and Michigan, provide illustrative examples of complete trip platforms, aggregating multimodal transportation options for riders.[6] The apps comprise a variety of types of providers, including public transit, micro transit, TNCs, taxis, small business and non-emergency medical transportation services, and volunteer driver programs. Catch a Ride ap- plications vary by region and may include a mix of local and national services.

Heart of Iowa Regional Transit Agency (HIRTA)

A second example is the HIRTA's Health Connector project, a complete trip platform focused on improving access to healthcare for those in Dallas County.[7] In collaboration with partners like the Dallas County Hospital, the initiative addresses transportation challenges for rural residents, older adults, veterans, and individuals with disabilities or limited English proficiency.

[3] Venter, C. J. (2020). Measuring the quality of the first/last mile connection to public transport. Research in Transportation Economics, 83, 100949.

[4] Hu, L., & Schneider, R. J. (2025). Panacea or band-aid? First-/last-mile connection in public transit systems. Journal of the American Planning Association, 91(2), 278-285.

[5] Shared-Use Mobility Center. (2025, January). The role of data specifications in creating an interoperable transportation system. https://learn.sharedusemobilitycenter.org/casestudy/the-role-of-data-specifications-in-creating-an-integrated-transportation-system/

[6] Feonix. (2023, September). Waupaca County Catch-a-Ride provides 4,000 trips for rural access to employment . https://feonix.org/waupaca-county-catch-a-ride-provides-4000-trips-for-rural-access-to-employment/
Make the RIDE Happen. (2023, September). Waupaca Catch-A-Ride. https://www.maketheridehappen.org/services/new-london-catch-a-ride/;
The Catch a Ride Network. (2025). Connecting communities through transportation. https://www.catcharide.org/.

[7] DOT Intelligent Transportation Systems Joint Program Office (2025). Heart of Iowa Regional Transit Agency. https://www.its.dot.gov/research-areas/ITS4US/deployments/iowa/

REAL-TIME TRANSIT INFORMATION

Real-time transit information systems utilize digital signage installed at stations, along roads, at key population centers (e.g., libraries, apartment buildings), and inside transit vehicles to deliver timely public transportation updates to riders. These digital signs display crucial information, including arrival times, service changes, and route updates, delivered under standards such as GTFS, enabling travelers to stay informed throughout their journey.

To deliver accurate and timely updates, real-time transit information systems utilize TDI components. Transit vehicles must be equipped with GPS sensors and robust network connectivity to enable automatic vehicle location (AVL) and computer-aided dispatch (CAD). Operators then aggregate available data, distributing them across multiple channels including digital signage and online platforms. The reliability of the communications network is essential in ensuring that information is delivered promptly to riders, allowing them to make timely decisions and efficiently catch their buses or trains.

By providing up-to-date details in visible and accessible locations, these systems can help riders make informed decisions and improve their overall transit experience.

BENEFITS

Real-time transit information systems play a pivotal role in improving the overall rider experience by increasing awareness of service connections and timing. This is particularly beneficial for individuals who do not have access to mobile devices, as information is readily available through digital signage in public spaces. When integrated with complete trip or other transportation platforms, these systems help minimize wait times and reduce uncertainty by providing actionable information to riders about when their bus or train is expected, thereby lowering friction associated with transit use and empowering travelers to make more informed trip decisions.

KEY STAKEHOLDERS

Transit Agencies and Operators:

Responsible for deploying, maintaining, and updating real-time information systems. They aggregate data from vehicles, make schedules and routes, manage digital signage, and ensure accurate, timely updates for riders. Operators must coordinate with multiple transit providers to integrate data across modes and regions. Maintenance and operations teams are responsible for the upkeep of digital signage, sensors, and communications infrastructure, ensuring uninterrupted service and reliable delivery of real-time information.

Technology Providers and Vendors:

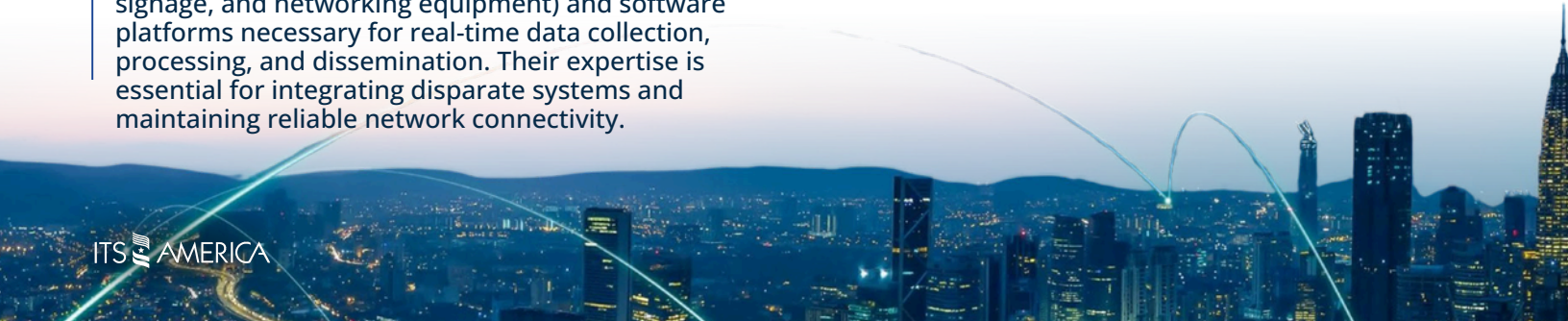
Supply the hardware (e.g., GPS sensors, digital signage, and networking equipment) and software platforms necessary for real-time data collection, processing, and dissemination. Their expertise is essential for integrating disparate systems and maintaining reliable network connectivity.

Local, Regional, and State Transportation Authorities:

Oversee regulatory compliance, funding, and strategic planning for transit information systems. They play a key role in setting standards, coordinating among different transit operators, and ensuring access to information.

Riders and the General Public:

End users benefit directly from real-time transit information, which improves trip planning, reduces uncertainty, and enhances the overall transit experience. Their feedback and usage patterns help agencies refine and improve system performance.



COMMON IMPLEMENTATION CHALLENGES

Integration and Dissemination of Transit Provider Data

Large transit hubs commonly display signage from a variety of transit providers. These signs often include essential information (e.g., schedules, delays, elevator and escalator availability, usage guidelines, and payment instructions) to assist travelers in navigating complex transportation networks. Deploying a real-time transit information system in such settings presents substantial challenges, primarily related to the integration and coherent dissemination of accurate, current data from numerous providers and transportation modes. Different providers often utilize distinct technologies and data standards, making seamless integration a technically demanding process; adoption of common standards would facilitate integration.

Updates and Access

Coordinating regular updates (i.e., pushing new information to signs) and maintenance schedules for software and hardware among multiple agencies can be difficult given the diversity of systems and responsibilities involved. Additionally, it is important to consider the needs of users who do not have access to mobile devices, as limited access to real-time transit information remains a significant barrier to broad and effective adoption of transit systems. Ideally, information should be furnished to users by a variety of channels to reach the widest possible audience.

Network Connectivity

Maintaining consistent network connectivity and supporting the hardware required for real-time information (e.g., digital signage, sensors, V2X, and robust communications infrastructure) across a broad geographical area, including underground areas, further adds to the complexity and cost of implementation. Expanding these systems throughout a region also results in increased maintenance demands, as agencies must ensure uninterrupted power, reliable communications systems, and the upkeep of industrial-grade displays.

DEPLOYMENT EXAMPLES

Los Angeles Metropolitan Transportation Authority (LA Metro)

Digital signage with real-time transit information provides a modernized and user-friendly transit experience, facilitating the delivery of reliable service. LA Metro, for example, has deployed hundreds of real-time bus arrival signs at bus stops and shelters with the highest ridership.[8]

Washington Metropolitan Area Transit Authority (WMATA)

In Washington, D.C., WMATA is also installing newer, efficient digital passenger information displays at bus stops and throughout the metro system. This program, known as Better Bus, provides schedule and arrival information, enabling commuters to better plan and schedule their trips.[9]

Chicago Transit Authority (CTA)

CTA has recently announced a partner with Papercast via its Innovation Studio program.[10] In this pilot, real-time bus arrival information will be displayed on solar- and battery-powered e-paper displays. The displays are further equipped with text-to-speech buttons, increasing accessibility.

[8] Los Angeles City Planning. (2023). LA Metro - transportation communication network. https://planning.lacity.gov/plans-policies/metro-tcn

[9] Washington Metropolitan Area Transit Authority. (2025). Better bus: Digital passenger information displays and modernized technology. https://www.wmata.com/initiatives/plans/Digital-Passenger-Information/

[10] Papercast. (2024). Papercast selected for Chicago Transit Authority pilot for solar and battery powered real-time displays. https://www.papercast.com/customer/papercast-selected-for-chicago-transit-authority-pilot-for-solar-and-battery-powered-real-time-displays/

INCENTIVIZATION TO REDUCE VEHICLE MILES TRAVELED (VMT)

Promoting a shift from single-occupancy vehicle use to other modes, including public transit, biking, walking, or carpooling, remains a significant challenge, particularly in areas with limited alternatives. Where multiple transportation options are available, encouraging a true mode shift toward multimodal travel often depends on innovative digital strategies, including the use of commute management platforms.

To address this, many transportation agencies and businesses have adopted incentivization strategies, often involving gamification techniques, within mobile apps and integrated benefit platforms. These tools support travel demand management by making multimodal travel more engaging and rewarding, aiming to reduce overall Vehicle Miles Traveled (VMT). By leveraging principles from behavioral science, these applications motivate users to alter their travel habits through elements of competition, achievement, and satisfaction.

Unlike traditional owner-operated TDI, these mobile solutions primarily utilize smartphone capabilities to monitor and communicate travel choices. They can also connect with real-time data feeds from transit providers, ensuring users receive the most relevant and efficient travel options for their needs.

BENEFITS

Incentivization can offer several benefits in efforts to reduce Vehicle Miles Traveled (VMT). By incorporating gamified elements (e.g. challenges, rewards, and leaderboards) into travel apps and platforms, users are incentivized to opt for other transportation modes like public transit, biking, or carpooling. This approach can make the travel experience more engaging and enjoyable while leveraging behavioral science to reinforce positive travel habits. Additionally, data collected through these platforms can help agencies tailor incentives and strategies to maximize participation and impact.

KEY STAKEHOLDERS

Local, Regional and State Transportation Agencies: Adopt and promote commute management platforms, integrate real-time transit data, and design incentive programs to encourage multimodal transportation options and traveler choice.

Major Employers: Implement incentivization programs for employees, support regional transportation demand management, and partner with agencies for commuter rewards networks.

Technology Providers & App Developers: Design and maintain mobile applications and platforms, leverage behavioral science to create engaging challenges and rewards, and ensure integration with transit data feeds.

Transit Agencies & Regional Transportation Authorities: Supply real-time data feeds, support interoperability across modes and jurisdictions, and collaborate on integrated solutions.

End Users (Commuters & Travelers): Participate in incentivization programs, provide feedback, and help drive adoption and effectiveness of mode shift strategies.

COMMON IMPLEMENTATION CHALLENGES

Sustained Engagement

Achieving widespread user adoption and maintaining sustained engagement are key challenges in deploying gamification-based incentive schemes to encourage traveler choice, particularly in areas where multimodal transportation options are limited. Ensuring that these platforms are appealing and accessible to a diverse user base is critical for success.

Seamless integration with real-time data feeds from multiple transit providers is also a crucial requirement. This integration can be technically demanding, often necessitating robust interagency cooperation to synchronize data sources and maintain accurate, up-to-date information for users. Without strong collaboration and unified data standards, the effectiveness of these digital strategies may be compromised.

Privacy Concerns

Additional barriers include privacy concerns associated with tracking users' travel behaviors, the ongoing need to provide incentives to keep participants engaged, the potential for incentives to supplant intrinsic motivations related to mode choice, and disparities in access to smartphones. Addressing privacy issues requires transparent policies and secure data management practices. Sustaining engagement demands a continuous supply of attractive rewards and challenges, and poorly calibrated rewards or challenges can lead to a feeling of being manipulated or bought, thus triggering user resistance, disengagement, or lack of trust. Disparities in smartphone ownership and digital literacy can further limit the reach and inclusivity of these programs.

DEPLOYMENT EXAMPLES

Georgia Department of Transportation (DOT)

Public agencies andmajor employersacrossthe United States have deployed commute management software applications with elements of gamification, leveraging Federal tax incentives. Large-scale regional transportation demand management (TDM) programs, such as Georgia Commute Options (GCO), use the commute management technology platforms to help residents explore commute alternatives.[11] The GCO incentive programs require minimal data from users on signup to confirm eligibility, including contact information, typical transportation mode, and number of days commuting to work per week. Users log trips to earn rewards on the MyGCO app, which may also collect location data to match users for carpooling.

The Bay Area Metropolitan Transportation Commission

Some agencies have partnered to create an integratedcarpool and commuter rewards network allowing seamless access to ride-matching and gamified trip incentives. For example, the Bay Area Metropolitan Transportation Commission and its county part- ners developed a new partnership in 2022 to support customers looking to improve their commutes by providing seamless access to carpool and vanpool ride-matching, plus eligibility-based trip rewards. The new seamless regional carpool and commuter net- work is the first in the nation to link multiple independent agency programs, each powered by the same commute management technology platform.[12]

[11] Georgia Commute Options (2024). Georgia commute options: Cleaner, healthier, better commutes. https://gacommuteoptions.com/

[12] Metropolitan Transportation Commission. (2021, March). Forward commute initiatives. https://mtc.ca.gov/operations/programs-projects/ forward-commute-initiatives

UNIVERSAL PAYMENT SYSTEM

Payment for public transportation often relies on fragmented, closed-loop systems that require riders to navigate multiple fare cards, apps, or cash payments for different modes and operators, even within the same region. This complexity creates confusion, increases transaction times, leaves users with unusable leftover balances, and can discourage people from using transit, especially those unfamiliar with the system or lacking access to specific payment methods. Universal payment systems are integrated platforms that allow users to pay for various modes of transport, including buses, trains, subways, ferries, bikeshare, and ride-shares, operated by different entities using a single payment method or account. Ideally, they are also open-loop systems, allowing users to pay for transit via commonly accepted means (e.g., a debit card) without engaging with proprietary systems for passes or fares. A universal payment system allows travelers to pay for all participating modes through one integrated platform, streamlining the user experience, reducing barriers to entry, and thereby increasing ridership.

To operate effectively, universal transportation payment systems rely on robust TDI. This includes enabling payment at all points of access, including transit stations, buses, and trains, and leveraging scalable computing platforms and high-speed networks to ensure rapid, reliable transaction processing. TDI can also allow transit operators to determine special fare eligibilities (e.g., for students, veterans, low-income users, etc.) while protecting user privacy.

BENEFITS

Universal payment systems can simplify travel, optimize operational processes, promote public transit use, and enhance the overall user experience across different transit modes and networks. For transit operators, universal payment systems reduce reliance on proprietary fare media, minimize the need for ticket machines, and decrease customer service demands related to fare card management. These systems are also highly scalable and flexible. They support robust anonymized data collection to facilitate data-informed decision-making and transit agency funding submissions, and seamless integration with third-party payment and customer service platforms.
By making public transit more affordable and accessible, universal payment systems also help remove barriers to mobility and enhance quality of life for individuals without access to private vehicles.

KEY STAKEHOLDERS

Transit Agencies and Operators

Deploy and maintain payment readers, manage fare structures, and coordinate integration across multiple modes and providers.

Technology Providers and Vendors

Supply hardware (fare boxes or gates, networking equipment) and software platforms for transaction processing, data integration, and system scalability.

Local, Regional, and State Transportation Agencies

Oversee regulatory compliance, funding, and strategic planning for integrated payment systems; facilitate collaboration among transit operators.

Financial Institutions and Payment Processors

Enable secure transactions, support mobility wallets (integrated digital receptacles for fare payments and passes) and direct bank card payments, and ensure interoperability with existing financial systems.

Riders and the General Public

Use the universal payment system for seamless travel across modes; provide feedback to improve user experience and accessibility.

Third-Party Mobility Providers

e.g., bike share, ride-hailing): Integrate with the universal payment platform to expand coverage and convenience for multimodal travelers.

COMMON IMPLEMENTATION CHALLENGES

Seamless Integration

A major challenge to deploying universal payment systems in transportation is achieving seamless integration across multiple transit operators, modes, and jurisdictions, each of which may use different legacy technologies and fare structures. Coordinating these systems requires significant technical investment, strong interagency collaboration, and agreement on data standards and privacy protections. Achieving interoperability demands substantial upgrades to hardware and software, robust real-time data connectivity, and coordinated efforts to standardize APIs and ensure data security across networks. Demands for data interoperability and system integration may differ for those using closed- and open-loop payment systems.

Access

Ensuring that all users can access universal payment systems, including individuals with disabilities, without smartphones, or the unbanked, remains a persistent barrier. Many members of the public may be excluded from seamless travel experiences if these barriers are not addressed. This ongoing challenge highlights the need for solutions that consider varying circumstances and resources of all potential riders. Addressing access issues is critical for the universal payment system to deliver benefits across system users.

Privacy

Universal payment systems introduce privacy issues related to the movement of individuals. As these systems collect and process data on users' travel patterns and payment transactions, there is an increased risk of exposing sensitive information. The aggregation of travel histories can make users vulnerable to tracking and profiling, raising concerns about how their data is stored, used, and shared among agencies, third-party providers, and financial institutions. Addressing these privacy challenges is essential to ensure user trust and compliance with data protection regulations.

DEPLOYMENT EXAMPLES

Major metropolitan areas around the United States have started to implement regional universal payment systems that rely on direct pay with bank cards or mobility wallets, eliminating the need for a proprietary fare card or cash. Some regional implementations will support additional modes beyond traditional public transit or micromobility, such as bike share. Major metropolitan regions including Chicago, New York, San Francisco, Portland, Los Angeles and Miami each operate a universal payment system for public transit and, in some cases, other mobility modes.[13] Key data includes encrypted payment token, transaction amount, timestamp, location ID, device ID, fare structure, fare cap information, merchant information, amount aggregation, unique IDs for passenger privacy, and API utilization.[14]

[13] Ventra. (2024). How it works. https://www.ventrachicago.com/howitworks/; OMNY. (n.d.) How OMNY works. https://omny.info/how-omny-works; San Francisco Municipal Transportation Agency (2017, May 2). Fares. https://www.sfmta.com/getting-around/muni/fares; Tri-County metropolitan Transportation District of Oregon. (2025). Fares. https://trimet.org/fares/#howhopworks; LA Metro. (2017). Fares. https://www.metro.net/riding/fares/; Miami-Dade County. (n.d.). Transit Pass. https://www.miamidade.gov/global/transportation/transit-pass.page CAL ITP. (n.d.). A modern and consistent transportation experience throughout California. https://www.calitp.org/

[14] "Open-Loop Transit Payments Summary – SUMC Mobility Learning Center." SUMC Mobility Learning Center, 3 Apr. 2025, learn.sharedusemobilitycenter.org/casestudy/open-loop-transit-payments-summary/.

3 Movement of Goods

Freight movement is a complex process that involves transporting goods from their point of origin to their final destination using a diverse array of transportation modes, such as maritime shipping, railways, air cargo, and roads. Efficient movement of goods is a cornerstone of modern commerce, requiring coordination across various transportation networks and logistics providers. By leveraging TDI, agencies and businesses can enhance freight operations, optimize routing, and improve delivery reliability, ensuring that shipments, from bulk cargo to small packages, reach their destinations smoothly and on time. This section demonstrates how TDI can streamline freight logistics, from long-haul shipments to first-mile/last-mile logistics, ensuring efficient and reliable service for businesses and consumers.

USE CASES INCLUDED IN THIS SECTION:

- **Port of Entry Optimization for Trucks:** TDI-enabled port of entry optimization provides expedited or fast-track pathways for freight trucks going through ports of entry and crossing borders.
- **Truck Parking Availability:** These solutions facilitate informed routing decisions and improving efficiency and safety by providing drivers and dispatchers with up-to-date information on truck parking locations, space availability, and capacity along freight corridors.
- **Freight Corridor Signal Prioritization:** Freight signal corridor prioritization reduces the number of stops and conflicts on roadways for freight vehicles and enhances shipment reliability by giving freight vehicles priority at traffic signals along key transportation routes.

PORT OF ENTRY OPTIMIZATION FOR TRUCKS

Wait times at international ports of entry continue to pose significant challenges for freight and trucking. Although some crossings have modernized their information systems, many still lack pre-verification processes. Furthermore, real-time updates on delays and recommendations for alternative routes are generally unavailable. Access to such information on an hourly or daily basis would be highly beneficial to reducing port of entry wait times. TDI-enabled port of entry optimization can provide expedited or fast-track pathways for freight trucks going through ports of entry and crossing borders.

BENEFITS

Reducing port of entry wait times for trucks delivers significant efficiency gains across the freight and transportation ecosystem. By integrating real-time data from roadside devices, weigh stations, and virtual weigh-in-motion (WIM) installations, agencies can provide timely updates on delays and alternative routes, reducing congestion and minimizing unpredictable wait times at ports of entry. This increased transparency enables freight providers and recipients to better plan shipments, allocate resources, and fulfill commitments with greater reliability. Drivers also benefit from more efficient routes and reliable port of entry information, which improves productivity and job satisfaction while contributing to safer and more predictable travel conditions.
The advantages extend to government agencies and regional planners, who can leverage improved data to enhance traffic flow, support short- and long-term planning, and optimize capital improvement programs. Reduced congestion at ports of entry also lowers fuel consumption and minimizes wear and tear on vehicles and infrastructure, resulting in cost savings for both freight companies and public agencies. Furthermore, efficient border management helps ensure regulatory compliance and safety for people and cargo. Ultimately, border wait time optimization strengthens the resilience and competitiveness of the national supply chain, benefiting all stakeholders involved.

KEY STAKEHOLDERS

Freight Providers:
Seek detailed data on aspects including the number of containers or freight units moved each day, allowing them to optimize operations and maximize throughput.

Freight Recipients:
Depend on accurate insights regarding expected delivery times, which enables them to better plan and fulfill their own commitments.

Drivers:
Rely on the availability of efficient routes and reliable throughput at border crossings or checkpoints. Improvements in these areas directly affect their productivity and job satisfaction.

Border Crossing and Customs Officials:
Responsible for processing each vehicle that enters or exits a country. Enhanced efficiencies at these crossings through streamlined procedures or improved information sharing can help reduce congestion, particularly at high-traffic locations, benefiting both officials and travelers.

State DOTs:
Handle a range of priorities, but throughput and safety consistently remain at the forefront. Reducing backups at crossings improves traffic flow and minimizes delays for drivers, contributing to safer and more predictable travel conditions.

Regional Municipal Agencies, Including Metropolitan Planning Organizations (MPOs) and Counties:
May serve as either the origin or final destination for freight shipments. Greater transparency and access to information about incoming and outgoing freight allow these agencies to enhance both short- and long-term planning, particularly through budgeting and capital improvement programs.

COMMON IMPLEMENTATION CHALLENGES

Data Interoperability

Effective border wait time optimization relies on the seamless integration of real-time data from various roadside devices, weigh stations, and virtual weigh-in-motion installations. Achieving interoperability between different systems and agencies, especially at international borders, requires substantial technical investment and coordination. Many crossings still lack modern information systems or pre-verification processes, making real-time updates on delays and alternative routes difficult to provide.

Interagency Collaboration and Standardization

Strong collaboration among federal, state, and local agencies, as well as private sector partners, is essential. Each stakeholder may use different legacy technologies, data standards, and operational procedures. Standardizing data formats and protocols across jurisdictions is a persistent challenge, and without it, information sharing and system integration can be fragmented.

Data Accuracy and Reliability

Ensuring the accuracy and reliability of data is critical for providing actionable insights to freight providers, drivers, and border officials. Inconsistent or outdated data can lead to inefficiencies, increased congestion, and reduced trust in the system. Maintaining high-quality data requires ongoing investment in infrastructure, regular updates, and robust data governance practices.

Privacy and Security Concerns

Collecting and sharing detailed information about truck movements and driver behavior raises privacy concerns. Agencies must address these by implementing strong data protection measures and transparent policies. Additionally, cybersecurity risks associated with connecting multiple systems and sharing sensitive information must be mitigated to prevent unauthorized access or disruptions.

Stakeholder Engagement and Change Management

Gaining buy-in from all stakeholders, including freight providers, drivers, customs officials, and regional agencies, is essential for successful implementation. Resistance to change, lack of awareness of benefits, and concerns about operational impacts can hinder adoption. Clear communication, demonstration of tangible benefits, and inclusive planning processes are necessary to build trust and encourage participation.

Scalability and Adaptability

Solutions must be scalable to accommodate varying traffic volumes and adaptable to changing regulations, technologies, and operational needs. Piloting new systems at select crossings before broader deployment can help identify and address unforeseen challenges, but scaling requires careful planning and resource allocation.

DEPLOYMENT EXAMPLES

Florida DOT

The Florida Department of Transportation (FDOT) is partnering with HNTB to develop FDOT's Freight Operations Exchange (FOX).[15] This platform is a centralized management and exchange platform that helps facilitate safe and efficient movement of freight throughout the state. The data management platform verifies commercial vehicle information with state and federal databases for safety and credentials, and is expanding to include goods movement data from traffic sites and major freight hubs like ports and terminals.[16] FOX uses data from various roadside devices, including statewide weigh stations and virtual weigh-in motion installations, to identify inbound drivers and reasons for arrival, allowing freight drivers to bypass inspection stations once the roadside devices verify vehicle information. The FOX hub lets users monitor performance measures in real time to improve safety and mobility. It also connects facilities and partner agencies, including the intelligent transportation network, permit system, and analytics network.[17] While this is a statewide initiative, agencies can adopt and integrate these platforms at international borders to expediate the crossing process and mitigate delays.

[15] HNTB. (2025, January 8). Freight operations exchange: Facilitating safe and efficient movement of freight. https://www.hntb.com/projects/freight-operations-exchange/

[16] Ibid.

[17] Ibid.

TRUCK PARKING AVAILABILITY

Truck parking availability remains a persistent challenge across the freight industry, with drivers often struggling to find safe and legal parking spaces, especially during peak hours or in high-demand corridors. This issue is compounded by inconsistent data sources, rapidly changing weather and capacity conditions, and the lack of real-time, integrated information across states and private parking operators. The need for accurate, up-to-date parking information is critical, as drivers face regulatory limits on driving hours and must plan rest stops accordingly. Without reliable data, drivers may be forced to park in unsafe or unauthorized locations, increasing the risk of crashes and legal violations, while also contributing to inefficiency on major freight routes.

TDI solutions can help overcome these challenges by integrating data, both on origination and while enroute, from various sources, including roadside sensors, dynamic message signs (DMS), smartphone and in-cab applications, and public and private parking operators, to provide real-time truck parking availability information. By leveraging predictive models and robust data-sharing platforms, TDI enables drivers and dispatchers to identify parking locations, availability, and capacity for freight vehicles, facilitating informed parking decisions across regions, reducing time spent searching for spaces, and minimizing congestion in high-traffic areas.

BENEFITS

Integrating TDI for truck parking provides significant advantages to the freight industry by addressing key safety and operational challenges. Real-time parking data helps drivers avoid unsafe or illegal parking locations, thereby reducing the risk of crashes. Additionally, TDI minimizes the time spent searching for available parking, which in turn lowers fuel consumption and operational costs. Reliable parking information is invaluable for drivers and freight operators, as it enables more effective route planning and ensures compliance with legal requirements regarding driving hours and rest stops. Access to accurate data contributes to greater road safety and improved overall efficiency in freight operations. State DOTs and private parking owners also benefit from shared data, as it allows for optimized resource allocation and helps to alleviate congestion in high-traffic areas.
Warehouses and distribution centers experience fewer delivery delays and benefit from improved scheduling and logistics efficiency due to predictable truck parking availability near destinations. This predictability streamlines freight movement and enhances supply chain performance. State and local agencies gain access to accurate parking data, which supports better infrastructure management and informs effective policy planning. Truck parking availability solutions driven by TDI strengthen safety, operational efficiency, and resiliency throughout the transportation network, benefiting drivers, operators, agencies, and freight destinations alike.

KEY STAKEHOLDERS

Freight Operators:
Trucking companies and independent drivers rely on accurate, real-time parking information to plan routes, comply with regulatory limits on driving hours, and ensure safe, legal rest stops. Their participation and feedback are essential for system effectiveness.

Freight End-Destinations:
Warehouses, distribution centers, and wholesalers benefit from improved truck parking availability, which helps maintain delivery schedules and streamline logistics operations.

Technology Providers and Platform Developers:
Companies that design, deploy, and maintain the digital infrastructure, including sensors, data integration platforms, and predictive AI models, play a key role in enabling real-time parking information and system scalability.

Parking Spot Owners and Operators:
Local governments, State DOTs, law enforcement authorities, and private lot owners manage parking resources and provide data on availability and capacity. Their cooperation is critical for integrating public and private parking data into a unified platform.

Local, Regional, and State Transportation Agencies:
These agencies oversee infrastructure planning, policy development, and regulatory compliance. Reliable parking data supports their efforts to manage congestion, enhance safety, and optimize freight networks.

Regional and Multistate Coalitions
Collaborative initiatives, including the I-10 Truck Parking Availability System (TPAS) implemented by the I-10 Corridor Coalition, demonstrate the importance of coordination across states and agencies to deliver consistent, reliable parking information for drivers traveling long distances.[18]

COMMON IMPLEMENTATION CHALLENGES

Data Interoperability

Integration of various data sources is complicated by the diverse systems and formats used by different stakeholders. Further, successful integration requires significant technical investment, as well as agreement on data standards and privacy protections.

Data Accuracy and Reliability

Obtaining consistent and reliable data from both state agencies and private parking owners is a challenge. The variability in how data is collected and shared across different regions hinders the creation of a unified, real-time picture of truck parking availability. Weather conditions and fluctuating parking capacity can create additional roadblocks, impacting the reliability of predictive models and making it difficult to maintain consistent accuracy. Ensuring the accuracy of real-time availability data becomes even more complex when scaling solutions to cover larger geographic areas.

Integrating with Predictive Models

A critical roadblock for this type of TDI is integrating predictive models with existing solutions that track or update wait and queue times. Achieving seamless integration requires technical coordination and collaboration that can be difficult to establish.

State Collaboration

Furthermore, state-level differences in truck parking policies and priorities pose a challenge, necessitating deeper collaboration among states, agencies, and private stakeholders.

DEPLOYMENT EXAMPLES

I-10 Truck Parking Availability System (TPAS)

The I-10 TPAS is a multistate technology system that will detect, monitor, and provide real-time truck parking availability information to truck drivers, dispatchers, and other interested stakeholders.[19] Once implemented, the system will monitor and report on the availability of approximately 550 truck parking spaces at 37 public rest areas in California, Arizona, New Mexico, and Texas. To facilitate this, a real-time data stream of currently used parking spaces will be generated. Using roadside dynamic message signs, smartphone and in-cab applications, websites, and other traveler information sites, truck drivers and dispatchers can make informed parking decisions that will help improve safety, efficiency, and mobility while reducing emissions along the I-10 corridor.

[18] I-10 Corridor Coalition. (2020). Overview of TPAS. https://i10connects.com/overview-tpas

[19] I-10 Corridor Coalition. (2020). Overview of TPAS. https://i10connects.com/overview-tpas

FREIGHT CORRIDOR SIGNAL PRIORITIZATION

Freight corridors, geographic areas well-known for high levels of freight traffic, can put measures in place to reduce the impact of high freight volume. Freight signal corridor prioritization can reduce the number of stops and conflicts on roadways for freight vehicles as they pass through a corridor. This TDI application utilizes a variety of technologies, including wireless communication systems, vehicle sensors, transponders, and GPS trackers, to detect approaching freight vehicles. Signal timings are then altered to provide priority control to freight vehicles.

BENEFITS

When implemented effectively, freight corridors equipped with signal prioritization technology offer a wide range of advantages. One of the primary benefits is the reduction in travel time for freight vehicles, as prioritized signals help freight trucks pass through intersections with fewer stops. This smoother traffic flow also contributes to improved fuel efficiency for heavy trucks, which in turn leads to lower emissions and saves on fuel costs. Additionally, signal prioritization minimizes the need for frequent braking by heavy freight vehicles, resulting in reduced pavement wear and extending the lifespan of road surfaces. The combined effect of these improvements is greater reliability and predictability in freight deliveries, allowing schedules to be maintained with consistency and enhancing overall operational efficiency for freight companies.

KEY STAKEHOLDERS

Freight Companies:
These companies are continually seeking more reliable and efficient routes for their drivers. With improved signal prioritization, freight companies can benefit from reduced delays and increased route consistency, which is vital for timely deliveries and operational efficiency.

Traffic Management Authorities
Responsible for overseeing the flow of vehicles, these authorities work to keep both freight and local/commuter traffic moving smoothly. Their goal is to minimize interactions between freight vehicles and other road users, ensuring optimal traffic conditions for all.

Local Communities and Businesses
Consistent and predictable freight movement benefits local communities and businesses by reducing disruptions and facilitating better planning. Enhanced understanding of freight schedules allows these stakeholders to anticipate and prepare for freight activity, contributing to a balanced and mutually beneficial relationship between freight operations and the surrounding area.

COMMON IMPLEMENTATION CHALLENGES

Integration
One of the primary challenges involves the technical integration with existing traffic management systems. Misalignment between new and current technologies can hinder, or even completely negate, the effectiveness of signal prioritization within these corridors.

State Collaboration
Balancing the needs of both freight and non-freight vehicles using the corridor requires thorough collaboration and detailed planning among all stakeholders. Achieving this balance is essential to maintaining smooth operations and ensuring that the benefits of signal prioritization are realized for road users.

DEPLOYMENT EXAMPLES

Florida DOT

Florida DOT's integrated freight plan showcases multimodal development and planning dedicated to freight throughout the state.[20] It includes data sharing agreements and a focused effort on highlighting regions and throughputs for freight, including designed freight corridors and potential signal prioritization. Many of the initiatives are collaborative, and require multiple stakeholders as denoted above; the plan lays the groundwork for making the required data available and usable.

Oakland County, MI

The Road Commission for Oakland County partnered with P3Mobility to implement cellular vehicle-to-everything (C-V2X) signal priority for freight.[21] This TDI solution enables agencies to provide subscription-based access to fleet operators, granting them signal priority services. Through this subscription-based model, state and local agencies can generate revenue, and private fleet operators can gain competitive economic advantages by providing faster services.

[20] Cohen, H., & Jules, E. (2023, June). Florida's Freight and Mobility Trade Plan 2024. Florida Department of Transportation. https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/rail/plans/fmtp/fmtp24/d4_fmtp24.pdf?sfvrsn=ec4dfdcf_2

[21] ITS America. (2025, June). Deploying connectivity with unique business models Oakland County, Michigan. In ITS Technology Use Case Library (3rd ed., pp. 25-27). https://itsa.org/wp-content/uploads/2025/06/ITSA-Use-Case-Library-Vol-3-COPY-3.pdf

4 Asset Management and Construction

Asset management and construction play a critical role in ensuring the effective development and resiliency of transportation infrastructure. The following use cases illustrate how Transportation Data Integration (TDI) can be leveraged to enhance asset management and construction processes. By applying TDI throughout the entire lifecycle of transportation assets—from planning and design to construction, real-time monitoring, operation, maintenance, upgrades, and performance improvement—agencies and stakeholders can make data-driven decisions that strengthen infrastructure resilience and reliability. These integrated approaches help maximize asset value, boost safety, and ensure that transportation systems are prepared to meet both current and future needs.

USE CASES INCLUDED IN THIS SECTION:

- **Smart Work Zones:** TDI-enabled smart work zones utilize advanced technologies such as digital mapping and real-time alerts to enhance safety and efficiency for workers and vehicles navigating construction areas.
- **Curb Management:** Curb management solutions streamline the allocation and monitoring of curb space, improving access, reducing congestion, and optimizing the flow of vehicles and goods in urban environments.
- **Digital Twins for Capital Programs, Asset Management, and Transportation Planning:** Digital twin technology creates virtual replicas of transportation assets and systems to support more effective planning, real-time monitoring, and data-driven decision-making throughout the asset lifecycle.
- **Automated Trouble Ticketing**: Automated trouble ticketing systems enable the efficient reporting, tracking, and resolution of infrastructure issues, facilitating prompt maintenance and minimizing service disruptions.

SMART WORK ZONES

Ongoing capital projects present consistent risk for potential safety incidents. TDI-enabled smart work zones, which safeguard workers while maintaining safe and efficient vehicle passage through the area, have increasingly become standard due to their demonstrated effectiveness in reducing incidents. However, it is essential that all personnel also adhere to proper safety protocols and wear appropriate protective equipment within designated zones, ensuring optimal operation of smart work zones. Additionally, larger trucks delivering goods require special consideration because of their reduced maneuverability and increased risk to workers on the roadway.

Smart work zone solutions, including digital mapping, connected vehicle technologies, and real-time alerting systems, can be integrated into existing transportation management systems. Agencies can leverage current infrastructure and technical means to deploy these solutions, supplementing them with new sensors, communications equipment, and software platforms. This integration allows for enhanced safety monitoring and dynamic information sharing among workers, fleet managers, and drivers.

BENEFITS

Establishing more intelligent and secure work zones offers substantial advantages for all parties involved in roadside construction and transportation management. The integration of advanced technologies like digital mapping, connected vehicles, and real-time alerting systems significantly enhances safety by helping to minimize incidents within work zones. Improved visibility into vehicle movements makes it easier to anticipate and address hazards posed by large freight trucks or unexpected changes in traffic patterns, thereby protecting personnel and property. The Work Zone Data Exchange (WZDx) Specification also aims to improve worker safety by providing up-to-date data on work zone activity to help both human drivers and automated driving systems navigate work zones more safely.[22] Beyond immediate safety improvements, intelligent work zones contribute to heightened adherence to safety regulations and standards. Smart work zones can support the consistent enforcement of safety protocols by alerting workers to potential dangers and reminding them to use appropriate protective equipment, further reducing the likelihood of incidents. The reduction in disruptions not only improves project efficiency, but also fosters greater trust among stakeholders, including roadside workers, organized labor, fleet managers, and regulatory agencies. Moreover, data collected from smart work zone technologies can be leveraged by government bodies to inform policy decisions, guide future initiatives, and ensure the continual advancement of safety and operational standards across the region.

KEY STAKEHOLDERS

Roadside Construction Contractors:
Roadside construction contractors consistently prioritize both safety and efficiency. Their foremost objective is to safeguard their workers, ensuring that no delays arise from unsafe conditions or practices within work zones. By integrating smart work zone technologies, contractors can more effectively maintain secure environments and minimize operational disruptions.

Roadside Workers and Unions:
Roadside workers, along with their unions, are required to adhere to strict protocols governed by OSHA and other project-specific safety procedures. The implementation of smart work zones simplifies compliance with these rigorous standards, supporting worker protection and the consistent enforcement of safety measures.

Fleet Managers:
Fleet managers benefit from the enhanced visibility provided by smart work zones. Insights into vehicle movement through these areas enable them to prioritize the safety of their fleet vehicles and drivers, contributing to safer and more efficient transit through construction zones.

Government and Regulatory Bodies:
Government agencies and regulatory bodies seek uniform approaches that ensure safe and efficient operation of all work zones within their jurisdiction. Data generated from smart work zone technologies informs their policy development and decision-making processes, supporting region-wide improvements in safety and operational standards.

Freight Providers:
Freight providers gain critical information from smart work zone data, including insights into movement patterns, delays, slow-down areas, and driver performance. This data helps freight companies optimize routes, minimize disruptions, and enhance overall efficiency as goods are transported through work zones.

COMMON IMPLEMENTATION CHALLENGES

Device Compliance and Standardization
Ensuring compliance and standardization across devices presents another challenge, given the diversity of hardware, software, and communication protocols currently in use. Integration issues may arise, resulting in in inconsistent performance or potential safety gaps. Agencies must work to establish clear, standardized protocols for deploying and operating these devices to achieve seamless interoperability across systems and maintain consistent safety standards.

Cost and Resource Constraints
Financial limitations also hinder the adoption of smart work zone components. The development, installation, and ongoing maintenance of sensors, communications equipment, and digital signage can be costly. Smaller agencies or those with limited budgets may struggle to justify these investments, especially if the benefits are not immediately apparent. Specialized components often add to the expense and can complicate portability and overall deployment, further constraining the implementation of these technologies.

Workforce Adaptation and Training
Effective implementation of smart work zone technologies depends on workforce adaptation. Many construction workers and personnel lack prior experience with these systems, making targeted training and upskilling essential. Providing relevant education and exposure helps enhance workers' skills, facilitating successful interaction with smart work zone ecosystems.

Data Management and Reporting
Robust data management and timely reporting are critical for the success of smart work zones. For example, some states or localities may report data to the Connected Work Zone (CWZ) or Workzone Data Exchange (WZDx) in different formats. Agencies must coordinate across departments and jurisdictions to maintain data accuracy and integrity. This process can be complex and time-consuming, requiring careful oversight to ensure reliable data supports safety and operational improvements.

Lack of Standardized Deployment Protocols
The absence of clear, standardized protocols for deploying smart work technologies leads to uncertainty and hesitancy among agencies considering adoption. Establishing and communicating these protocols is necessary to promote confidence and enable further integration of smart work zone solutions, ultimately creating safer conditions for construction workers.

Operational Maturity and Organizational Readiness
The effectiveness of smart work zone technologies is closely linked to the maturity of work zones themselves. Mature work zones, characterized by established protocols, trained personnel, and robust data management practices, are better positioned to adopt and utilize advanced digital tools. Conversely, less mature work zones may lack organizational readiness, standardization, or resources, limiting their ability to integrate and benefit from smart work zone solutions.

DEPLOYMENT EXAMPLES

Connecticut DOT
Connecticut DOT utilizes HAAS Alert Safety Cloud through Samsara, a digital alerting system, to protect workers by providing advance notification of hazards, such as work zones and emergency vehicles, to freight vehicles and other motorists.[23] These alerts are delivered over cellular networks to navigation applications and vehicle dashboards, ensuring freight drivers have ample time to slow down when approaching a work zone. Digital alerts have been shown to reduce the risk of collisions by up to 90 percent and reduce hard braking near roadside incidents by 80 percent.[24] Roadside workers benefit from an additional layer of protection through digital alerting systems.

North Carolina DOT
Digital alerting also allows drivers to adjust their speed and increase awareness. For example, DriveWyze provides in-cab alerts, including and especially for work zones and potential danger areas, for trucks along many major freight routes across the US.[25] North Carolina DOT found that these in-cab alerts positively impact freight driver behavior, with 70 percent of alerted users reducing speed by along an I-95 work zone.[26] Organizations such as DriveWyze work collaboratively with public agencies to provide drivers with notifications when a freight carrier is approaching a work zone.

[22] USDOT. (2024, April 30). Work Zone Data Exchange (WZDx). Transportation.gov. https://www.transportation.gov/av/data/wzdx

[23] ITS America. (2025). Protecting roadside workers with cloud-based alerts, Connecticut. In ITS Technology Use Case Library (3rd ed., pp. 13-14). https://itsa.org/wp-content/uploads/2025/06/ITSA-Use-Case-Library-Vol-3-COPY-3.pdf

[24] Drucker, C. J. (2013). An epidemiological approach to emergency vehicle advanced warning system development: a two-phase study. [Doctoral dissertation, University of Minnesota Twin Cities]. University of Minnesota Twin Cities Dissertatoins. https://hdl.handle.net/11299/162638.; Sakhare, R. S., Desai, J., Mahlberg, J., Matthew, J. K., Kim, W., Li, H., & Bullock, D. M. (2021). Evaluating the Impact of Vehicle Digital Communication Alerts on Vehicles. Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2021/19. https://doi.org/10.5703/1288284317324

[25] DriveWyze. (2024, October 3). Driver guide: Alerts & advisories. https://drivewyze.com/help/driver-guide-safety-notifications/https://drivewyze.com

[26] ITS America. (2025). In-cab safety alerts for commercial trucks, North Carolina. In ITS Technology Use Case Library (3rd ed., pp. 15-16). https://itsa.org/wp-content/uploads/2025/06/ITSA-Use-Case-Library-Vol-3-COPY-3.pdf

CURB MANAGEMENT

Prioritizing curbside management is essential for improving safety, efficiency, and multimodal access in urban environments. TDI solutions—particularly those enabling real-time data sharing and dynamic curb allocation—offer a transformative approach to managing limited curb space while supporting broader transportation goals. Agencies face growing challenges as curbside demand increases from passenger vehicles, freight deliveries, ride-hailing, and micromobility. Traditional static curb regulations often fail to keep pace with these dynamic needs. Implementing TDI allows agencies to digitize curb assets, monitor usage, and apply adaptive policies that optimize curb space for safety and efficiency.

Digital curb management also strengthens multimodal safety. Real-time curb data helps agencies coordinate passenger pick-up/drop-off zones, freight loading areas, and bike lanes, reducing conflicts between modes. Advanced analytics derived from curb usage data empower agencies to make evidence-based decisions, forecast demand, and proactively address bottlenecks.

BENEFITS

Implementing TDI-driven curbside management solutions delivers several key advantages:

Dynamic Allocation of Curb Space
Digital platforms allow agencies to adjust curb use in real time based on demand, prioritizing loading zones, ride-hailing, deliveries, and transit pick-up/drop-off. This flexibility reduces conflicts and improves throughput for all modes.

Enhanced Multimodal Safety
Real-time curbside data integrated with navigation apps and connected vehicle systems helps protect vulnerable road users—pedestrians, cyclists, and micromobility riders—by reducing unexpected interactions and improving visibility of active zones.

Enhanced Transparency
Digital inventories provide clear curb regulations to drivers, fleets, and app developers.

Congestion Reduction and Efficiency
By digitizing curbside operations, agencies can minimize double-parking and illegal stops, reducing bottlenecks and improving traffic flow. Predictive analytics further enable proactive adjustments to prevent congestion before it occurs.

Data-Driven Decision Making
Advanced visualization tools and actionable insights from TDI platforms support better resource allocation, informed policy development, and long-term planning for curbside infrastructure investments.

Support for Emerging Mobility Services
Digital curb management facilitates integration with TNCs, microtransit, and freight delivery services, ensuring curb space is optimized for evolving mobility needs.

KEY STAKEHOLDERS

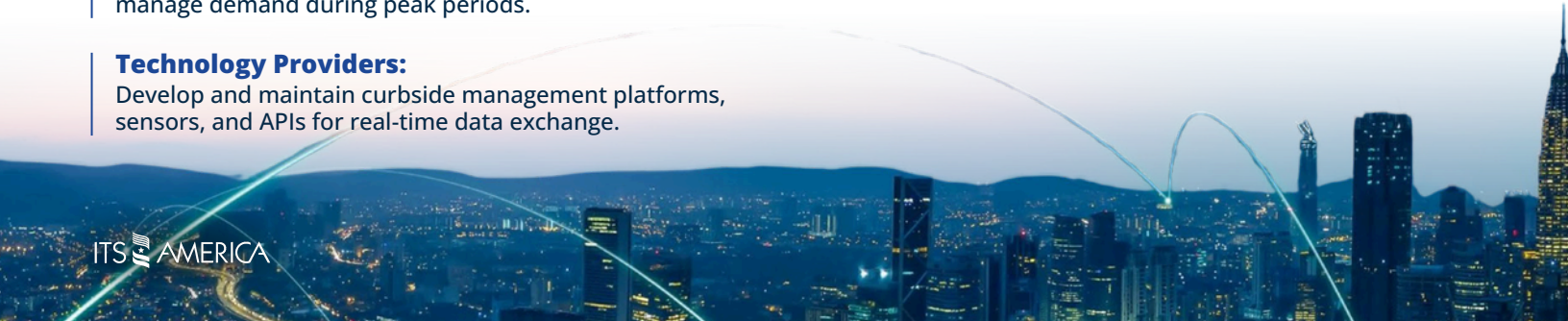
Local, Regional, and State Transportation Agencies:
Oversee curbside policies, deploy digital platforms, and ensure interoperability across jurisdictions.

City Planners and Parking Authorities:
Use curbside data to design access strategies and manage demand during peak periods.

Technology Providers:
Develop and maintain curbside management platforms, sensors, and APIs for real-time data exchange.

Freight and Mobility Operators:
Depend on accurate curb availability data to optimize delivery schedules and reduce dwell times.

Road Users:
Benefit from safer, more predictable curbside environments and improved travel experience.



COMMON IMPLEMENTATION CHALLENGES

Data Standardization and Interoperability

Fragmented curbside data formats hinder interoperability. Adoption of standards like the Open Mobility Foundation's Curb Data Specification (CDS) is essential. Coordinating curbside data with traffic management centers, parking systems, and third-party apps requires robust APIs and governance frameworks.

Change Management

Agencies must align policies and educate workforce and stakeholders to ensure successful adoption and enforcement of dynamic curbside strategies.

Space

Insufficient space next to the right-of-way makes it difficult to load people, goods, or services.

Cost

The expense of acquiring new technologies can be a major barrier for cities and local governments.

DEPLOYMENT EXAMPLES

Washington, D.C.

The District Department of Transportation partnered with CurbFlow to digitize loading zones for delivery vehicles. The pilot reduced double-parking by 64% and improved safety for pedestrians and cyclists by providing real-time curb availability through a reservation system.[27]

Seattle DOT

Seattle uses digital curb management tools to dynamically allocate curb space for freight, passenger loading, and micromobility. Real-time data integration supports congestion mitigation and access strategies.[28]

New York City DOT

NYC DOT implemented the Automated Loading Zone Program, which deployed sensor-based curb management to monitor and enforce loading zones, reducing illegal parking and improving traffic flow in high-demand corridors.[29]

[27] Pyzyk, K. (2019, November 14). CurbFlow pilot reduced double parking in DC by 64%. Smart Cities Dive. https://www.smartcitiesdive.com/news/curbflow-pilot-reduced-double-parking-in-dc-by-64/567268/

[28] Dalla Chiara, G., Maxner, T., Esmaili, A., Wehrmueller, G., Rula, K., Goodchild, A. (2025). Seatle Smart: Digitizing the Last Mile of Urban Goods to Improve Curb Access and Utilization. Urban Freight Lab, University of Washington. https://doi.org/10.6069/TZAS-KG37

[29] New York City DOT. (2024). NYC DOT completes installation of over 500 loading zones in response to public feedback on double parking and blocked bike and bus lanes. https://www.nyc.gov/html/dot/html/pr2024/nyc-dot-loading-zones.shtml

DIGITAL TWINS FOR CAPITAL PROGRAMS, ASSET MANAGEMENT, AND TRANSPORTATION PLANNING

A digital twin, as defined by the ITS America Digital Twinning Decoded White Paper, is a "constantly updating, dynamic virtual model of a physical system or object that can be seamlessly connected to measurement systems via transportation digital infrastructure and continuously updated to reflect changes in the physical world, enabling monitoring, analysis, and optimization of complex systems." [30]

The capabilities and popularity of digital twins have increased substantially in recent years, as they offer efficient and accurate digital representation of key assets and systems within the transportation sector. However, a significant challenge is posed by the requirement to scan all assets and right-of-way items using LiDAR or other technology to generate accurate models. This process is typically labor-intensive and requires considerable workforce adaptation to implement these new technologies.

To address some of these obstacles, emerging technologies now incorporate drones to capture imagery and facilitate asset digitization, enabling Building Information Modeling (BIM)-integrated project delivery as official documentation of as-built conditions. Upon project completion, a final scan using LiDAR ensures the creation of precise digital twins.

BENEFITS

Digital twins present several clear advantages for asset owners and project managers. Through real-time digital representations, digital twins provide enhanced insight into various infrastructure elements, including traffic signals, wayside assets, and signage. This real-time digital representation ensures that stakeholders can monitor and manage these assets more efficiently.

Additionally, digital twins create a comprehensive and continuously updated digital record of all assets related to a project. This facilitates seamless access to critical project and asset data for all authorized parties throughout every phase of project management. By centralizing this information in a dynamic digital format, the likelihood of data loss is minimized, ensuring that essential details are preserved and readily available when needed.

KEY STAKEHOLDERS

Contractors
Tasked with constructing and integrating digital twins into project workflows, ensuring that models accurately represent physical assets and infrastructure.

Construction Field Teams
Interact directly with digital twin data, utilizing it to inform construction activities and document as-built conditions.

Design Teams
Specialists in Building Information Modeling (BIM) and other digital design processes support the creation and refinement of digital elements, contributing essential data to the twin environment.

Local, Regional, and State Transportation Agencies
Use digital twins to analyze scenarios, forecast outcomes, and plan expansions. Digital twin data supports their financial modelling and strategic decisions. These agencies rely on up-to-date maps and asset schedules from the digital twin for daily operations and maintenance.

COMMON IMPLEMENTATION CHALLENGES

Time
One of the primary hurdles is the considerable time investment required to create full-scale digital twins, which varies based on the scope and level of detail needed for the project. This process can be lengthy and complex, especially for larger footprints.

Organizational Uncertainty
On an organizational level, visualizing the benefits and applications of digital twins prior to full deployment can be difficult. This uncertainty may lead to delays or skepticism regarding the effectiveness and necessity of the solution, particularly in departments accustomed to established norms and traditional methods. Building consensus and fostering openness to new technology are important steps in facilitating smooth adoption and overcoming resistance to change.

Workforce Development
Additionally, transitioning to digital twin technology demands that both central and field teams adapt to new operational procedures and workflows. Training and change management are essential to help the workforce effectively shift from legacy systems and practices to those required by digital twins.

Clear Standards
The successful deployment of digital twins relies on the establishment of clear standards, practices, guidelines, and capabilities. Robust data governance frameworks must also be put in place to ensure consistency, accuracy, and security of the digital twin data throughout its lifecycle.

DEPLOYMENT EXAMPLES

Texas DOT (TxDOT)
Through TxDOT's Transportation Programs Support team, Trimble MX-90 mobile mapping systems have been deployed statewide.[31] These vehicles collect high-resolution imagery and LiDAR data on the move in order to identify roadside assets, measure bridge clearances, and document pavement conditions like rutting, cracking, and elevation changes in a fast, safe, and accurate manner.

This mapping system is being used to capture existing roadway conditions to inform design decisions, all without ever slowing traffic. LiDAR point clouds, and photographs with associated geolocations, are used to extract characteristics of roadways, assets, and other infrastructure elements to help identify changes.

Washington State DOT (WSDOT)
WSDOT utilizes digital twins to better manage their assets through a partnership with Bentley Systems. On the Interstate 90 Homer Hadley floating bridge, Internet of Things (IoT) sensors are deployed on this proof-of-technology project to provide near real-time data on bridge conditions, alert operations and maintenance personnel of issues, and provide digital alignment guidance for anchor cable adjustments.[32] Through this TDI application, agencies can collect data about the performance of their hard infrastructure assets, enabling informed, data-driven decision making that will ultimately make roads safer, save agencies time and money, and improve the resiliency of their physical infrastructure.[33]

[30] ITS America. (2025, January). *ITS America digital twinning decoded.* https://itsa.org/wp-content/uploads/2025/01/Digital-Twinning-Decoded.pdf
[31] Selissen, A. (2025, July 23). *Mapping the Future of Texas Transportation*. Linkedin.com. https://www.linkedin.com/posts/anhselissen_mobilemapping-txdot-innovation-activity-7353805901037801472-kLoC?utm_source=share&utm_medium=member_desktop&rcm=ACoAAAb0ZSkB3quK5L_GyAVTglJe02tNIphuswg
[32] ITS America. (2025). Digital twin-aided bridge evaluations, Seattle, Washington. In *ITS Technology Use Case Library* (3rd ed., pp. 72-73). https://itsa.org/wp-content/uploads/2025/06/ITSA-Use-Case-Library-Vol-3-COPY-3.pdf
[33] Ibid.

AUTOMATED TROUBLE TICKETING

Automated trouble ticketing, also known as e-Ticketing or e-Construction, uses TDI solutions to record and transfer information in real time for materials as they move from plant or supplier to construction yard. This process involves the transfer of data to servers for immediate access by stakeholders via mobile devices. The primary challenge addressed by automated trouble ticketing is reducing the time customer support personnel spend on the phone with customers. This system aims to minimize the need for customers to contact their offices directly, thereby improving efficiency and response times.

BENEFITS

Automated trouble ticketing allows agencies and departments to place more focus on long- and short-term maintenance planning and spending. Additionally, it can be integrated into forward looking asset state of good repair, which helps reduce risk of asset failure or decommissioning. Finally, this innovation can help optimize workforce deployment on a variety of issues and needs across the network.

KEY STAKEHOLDERS

Local, Regional, and State Transportation Agencies

Oversee and enable the implementation of automated trouble ticketing by ensuring accurate reporting, efficient resource allocation, and improved maintenance scheduling across transportation assets

Local Asset Owners

Organizations including freight lines, power distributors, and water infrastructure owners can gain a better understanding of their asset needs and maintenance requirements through accessing and inputting data.

Technology Developers

Responsible for providing the physical technology necessary to automate ticketing processes. Additionally, they ensure robust data governance and organization, facilitating seamless system functionality and minimizing operational issues.

COMMON IMPLEMENTATION CHALLENGES

Data Integration

One of the primary challenges is the requirement for properly formatted data, which often comes from dashcams or intersection cameras. Acquiring and implementing these technologies across an entire network can be expensive, particularly when scaling from a small pilot project to a statewide initiative.

Feasibility and Adoption

Whether the automated ticketing system is being tested on a limited basis or rolled out more broadly, success depends on the ability to secure appropriate data sources and ensure that stakeholders are willing and able to adopt the new technology. Agencies must therefore assess feasibility and readiness for adoption when considering deploying automated trouble ticketing.

DEPLOYMENT EXAMPLES

Iowa DOT

Iowa DOT has utilized e-Ticketing in 217 projects in 2024 alone. The digitization of the data and processing procedures provided by automated trouble ticketing have increased job safety for workers by reducing the number of work zone vehicles, saved time by providing real-time access to data while reducing processing times, improved project documentation, and provided standardization of data collection for construction projects across Iowa.[34]

[34] Knapp, K. (2024). *e-Ticketing in Iowa Tech Transfer Summary*. Iowa Local Technical Assistance Program (LTAP). https://www.iowasudas.org/wp-content/uploads/2025/03/e-ticketing_tech_brief.pdf

5 Emergency Preparedness

Effective emergency preparedness is essential for enabling first responders and emergency agencies to successfully plan, prepare, mitigate, adapt, and recover from natural disasters, unexpected disruptions, major incidents, and other critical events. This section explores key use cases that highlight how TDI can support coordinated strategies and emergency personnel in managing a wide range of emergencies, ensuring rapid response and resilient recovery for communities.

USE CASES INCLUDED IN THIS SECTION:

- **Emergency Vehicle Preemption (EVP):** EVP systems use real-time data and AI-based algorithms to optimize traffic signals, granting emergency vehicles priority passage through intersections for faster and safer emergency response.
- **Interagency Video Sharing Platforms:** These platforms facilitate collaboration by allowing emergency response agencies and transportation departments to securely share live video feeds, supporting coordinated decision-making during incidents.
- **Advanced Air Mobility (AAM):** AAM leverages innovative aviation technologies to enable rapid deployment of emergency personnel and resources, improving accessibility in hard-to-reach areas and enhancing overall disaster response capabilities.
- **Emergency Notification Systems:** Emergency notification systems provide timely alerts and critical information to the public and responders, supporting effective communication and rapid action during emergencies.

EMERGENCY VEHICLE PREEMPTION (EVP)

First responders must arrive at an incident scene as quickly as possible. Every second counts during emergencies, when health and safety are at stake. Signalized intersections with conflicting vehicular phases, pedestrians, and bicyclists are some of the most challenging locations en route to an incident scene.

Signal preemption involves an emergency vehicle requesting preemption as it approaches an intersection. This is one of the clearest examples of vehicles-to-infrastructure communication. Next generation signal preemption utilizing the cloud has emerged as a full TDI solution, relying on data networks and advanced AI-based algorithms to optimize traffic signal phases for all types of emergency vehicles.

BENEFITS

Traffic signal preemption is a proven solution that reduces the risk of collisions and clears traffic congestion at the intersection, leading to quicker response times for emergency vehicles.[35] By granting emergency vehicles priority passage through intersections, preemption systems minimize the likelihood of crashes between first responders and other road users. This not only enhances the safety of both responders and the public, but also ensures that first responders can reach the scene of an incident as rapidly as possible, which is critical when lives are at stake.

Additionally, emergency vehicle preemption helps to reduce delays caused by heavy traffic, particularly during peak travel times or in congested urban areas. Clearing intersections for emergency vehicles not only improves their travel efficiency but also reduces stress and confusion for other motorists by providing clear signals and predictable traffic patterns during emergency events. This contributes to smoother overall traffic flow, even in high-stress situations.

Modern EVP systems that leverage advanced data networks and AI-driven algorithms can further optimize signal timing, ensuring that all types of emergency vehicles, including fire trucks, ambulances, and police cars, receive the fastest and safest routes through complex intersections. The resulting improvements in response time can make a significant difference in emergency situations, improving post-crash care and ensuring the overall safety of the community.

KEY STAKEHOLDERS

Emergency Response Agencies
Fire departments, ambulance services, and law enforcement agencies are primary users of EVP systems. Their vehicles rely on EVP technology to safely and efficiently navigate intersections during emergency responses, reducing travel times, and improving public safety.

Technology Providers and System Integrators
Companies that develop and supply EVP hardware, software, and communications platforms play a critical role in enabling reliable, secure, and scalable EVP solutions. Their expertise is essential for integrating vehicle-based systems with traffic signal controllers and central management platforms.

Local, Regional, and State Transportation Agencies
Responsible for deploying, maintaining, and upgrading traffic signal infrastructure to support EVP. These agencies oversee the integration of EVP technology with existing traffic management systems and ensure compliance with safety and operational standards.

Local Government and Regulatory Authorities
Set policies, allocate funding, and establish regulatory frameworks for EVP deployment. Their support is crucial for cross-agency collaboration, public safety initiatives, and long-term system sustainability.

Cybersecurity and IT Specialists
As EVP systems increasingly rely on cloud-based communications and data exchange, cybersecurity experts are needed to safeguard infrastructure against unauthorized access and cyber threats. Their involvement ensures the integrity and resilience of EVP networks.

COMMON IMPLEMENTATION CHALLENGES

Cybersecurity Risks

Transitioning to a cloud-based approach for emergency vehicle preemption (EVP) introduces cybersecurity risks that agencies must proactively address. Connecting secure infrastructure networks, such as those used for traffic signals, to external providers interfacing with emergency vehicles creates new vulnerabilities.

Communications Infrastructure Needs

Advanced EVP systems require high-speed communications between each traffic signal and emergency vehicle. However, traffic signals may lack these capabilities and are unable to receive requests from emergency vehicles. As a result, upgrading communications infrastructure at traffic signals should be a top priority for any city or DOT considering modern EVP solutions.

DEPLOYMENT EXAMPLES

San Jose, CA and Hillsborough County, Florida

Many cities around the United States have deployed newer technology EVP at some or all of their traffic signals. In one recent deployment of note, San Jose, CA upgraded its system by leveraging existing infrastructure and a central control system. Emergency vehicles communicate with the central system, which then preempts signals at intersections based on the vehicles' GPS location and priority. Similarly, Hillsborough County, Florida implemented an EVP system across 600 intersections and 175 emergency vehicles.[36]

[35] FHWA (2025). Traffic signal preemption. In *Traffic Signal Timing Manual.* Retrieved March 6, 2026, from https://ops.fhwa.dot.gov/publications/fhwahop08024/chapter9.htm#9.1

[36] Hillsborough County Florida (2025). Emergency vehicle traffic signal preemption system. https://hcfl.gov/residents/property-owners-and-renters/roads-and-sidewalks/emergency-vehicle-traffic-signal-preemption-system

INTERAGENCY VIDEO SHARING PLATFORMS

Interagency video sharing platforms for transportation and emergency management allow different agencies and organizations (e.g., traffic management centers, emergency services, law enforcement, and media outlets or the public) to share live or recorded video streams from their respective cameras.

BENEFITS

Sharing video between agencies significantly enhances situational awareness by providing real-time visual information from multiple sources. This increased awareness enables informed decision-making during emergencies, as stakeholders have access to a comprehensive view of developing situations. Furthermore, the ability to share video across different organizations fosters cross-collaboration, allowing agencies to coordinate their efforts more effectively. Such collaboration can lead to faster and more efficient responses during incidents and emergencies, which may ultimately be critical in life-or-death scenarios.

One of the significant advantages of an interagency video sharing platform is the reduction in redundant infrastructure investments. By enabling multiple agencies to access and share video feeds from a centralized pool of cameras, the solution eliminates the need for each agency to install and maintain separate cameras at the same intersection or location. This collaborative approach streamlines resource utilization and leads to substantial cost savings, as agencies no longer need to fund redundant equipment.

KEY STAKEHOLDERS

Traffic Management Centers and Transportation Agencies

Responsible for operating roadway surveillance systems and sharing live or recorded video streams with other organizations. Their collaboration ensures that transportation data is available for incident management, traffic operations, and public safety.

Emergency Services and First Responders

Fire departments, ambulance services, and law enforcement agencies use shared video feeds to enhance situational awareness and coordinate responses during emergencies. Access to real-time visual information supports faster and more effective decision-making.

Local, Regional, and State Transportation Agencies

Set policies, allocate funding, and establish regulatory frameworks for video sharing platforms. Their support is crucial for cross-agency collaboration, public safety initiatives, and long-term system sustainability.

Technology Providers and System Integrators

Companies that develop and supply hardware, software, and communications platforms enable reliable, secure, and scalable video sharing solutions. Their expertise is essential for integrating disparate video management systems and maintaining robust network connectivity.

Cybersecurity and IT Specialists

As video sharing platforms increasingly rely on cloud-based communications and data exchange, cybersecurity experts are needed to safeguard infrastructure against unauthorized access and cyber threats. Their involvement ensures the integrity and resilience of shared networks.

Media Outlets and the Public

In some cases, media organizations and the public may be granted access to selected video streams for public information and awareness, especially during major incidents or emergencies.

COMMON IMPLEMENTATION CHALLENGES

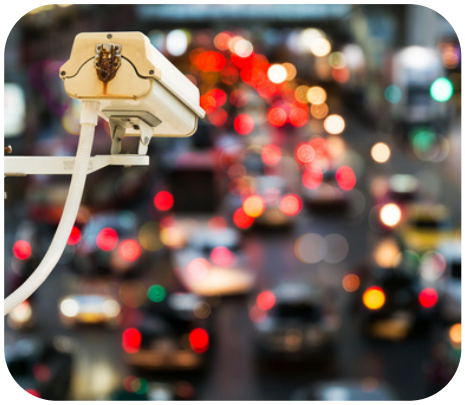
Communications Network
An effective video sharing solution depends on the presence of a reliable, high-speed communications network. Such a network is essential for transmitting large volumes of video data in real time, ensuring that users receive timely and uninterrupted access to feeds from traffic cameras installed along roadways.

Partnership Framework
Beyond technological infrastructure, successful video sharing relies on a well-developed partnership framework among participating agencies. Clearly established rules are necessary to govern how video is accessed and shared, ensuring transparency and accountability. Additionally, strong configuration management practices must be maintained to coordinate the different video management systems in use, enabling agencies to collaborate effectively without compromising security or operational integrity.

Unified Platform and Computing Power
Central to this solution is a unified platform equipped with sufficient computing power to securely manage the various video streams generated by these cameras. This platform must be capable of handling multiple streams simultaneously, while ensuring that access is restricted to authorized users with differing operational needs.

DEPLOYMENT EXAMPLES

State of Maryland
Maryland has implemented a multiagency video sharing platform to assist with emergency management. Since its inception the MView program has worked with numerous public safety organizations, and has expanded to partner with organizations across Maryland, Washington D.C., Pennsylvania, New Jersey and Virginia. Public safety personnel leverage MView to improve situational awareness, manage planned/unplanned events, and to share video across different networks belonging to disparate organizations without impacting existing internal systems or exposing internal networks to unnecessary cybersecurity risk.



ADVANCED AIR MOBILITY (AAM)

AAM is rapidly improving traffic and emergency management by providing an aerial perspective in many areas where traffic or security cameras may not be installed. This enhances both incident management and emergency response. Emergency operations centers personnel are now able to quickly assess damage and recommend actions in close coordination with first responders in the field.
Utilizing AAM in real-time requires robust TDI that can not only support the network bandwidth needed for video, but also interoperable video systems and video walls to be able to display and share information.

BENEFITS

Deploying AAM in traffic and emergency management offers transformative benefits by providing a dynamic aerial perspective that traditional ground-based cameras and sensors cannot provide. In regions where fixed traffic or security cameras are absent, AAMs can rapidly deliver real-time visual coverage, enabling agencies to monitor incidents, assess damage, and coordinate responses with greater speed and accuracy. This capability is especially valuable during emergencies, including natural disasters or major crashes, where immediate situational awareness is critical for effective decision-making and resource allocation.
AAM enhances incident management by allowing emergency operations centers and first responders to quickly evaluate conditions, identify hazards, and recommend actions before personnel arrive on the scene. Their mobility and flexibility enable coverage of hard-to-reach or hazardous areas, supporting rapid assessments that improve safety for both responders and the public.
Additionally, AAM can be used for ongoing monitoring of construction sites, bridge inspections, and damage assessments after events like earthquakes, providing detailed visuals that support efficient maintenance and recovery operations. Further, AAM can help agencies be more proactive in assessing the conditions of their infrastructure, potentially preventing future incidents before they occur and mitigating future high repair costs. By supplementing existing infrastructure with AAM, agencies can optimize response times, enhance operational efficiency, and ultimately strengthen the resilience of transportation and emergency management systems.

KEY STAKEHOLDERS

Emergency Management Agencies and First Responders

Agencies including fire departments, law enforcement, and emergency medical services use advanced air mobility technologies to enhance situational awareness, assess damage, and support rapid response during incidents and disasters.

Local, Regional, and State Transportation Agencies

Leverage AAM for traffic monitoring, infrastructure inspection, construction site management, and real-time assessment of roadway conditions. Their involvement is crucial for integrating AAM data into transportation operations and planning.

Technology Providers and Drone Operators

Companies that manufacture AAM, develop supporting software, and provide operational services are responsible for supplying reliable hardware, maintaining systems, and ensuring data interoperability. Skilled AAM operators are essential for safe and effective deployment.

Regulatory Authorities

Government agencies, such as the Federal Aviation Administration (FAA), set policies and regulations governing AAM usage, airspace restrictions, and privacy standards. Their oversight ensures compliance and safe operation within legal frameworks.

Infrastructure Owners and Project Managers

Owners of bridges, roads, and other critical infrastructure benefit from AAM-enabled inspections and monitoring, which improve safety and efficiency in maintenance and emergency response.

Data Integration and IT Specialists

Professionals who manage the integration of AAM data into transportation management systems, emergency operations centers, and video walls ensure that information is accessible and actionable for decision-makers.

COMMON IMPLEMENTATION CHALLENGES

Workforce Development

Effective AAM deployment in transportation and infrastructure applications requires personnel with specialized skills. Agencies must invest in training programs and educational initiatives to ensure that staff are equipped to operate AAM devices safely and efficiently. This includes developing expertise in AAM technology operation, maintenance, regulatory compliance, and data management. Without a skilled workforce, integrating AAM into existing workflows and maximizing its benefits can be challenging. As AAM technologies continue to evolve, ongoing professional development is essential for keeping pace with industry standards and operational best practices.

Airspace Regulations

In addition to personnel and cost-related challenges, AAM operators must navigate a complex landscape of airspace restrictions and regulatory requirements. Federal, state, and local regulations dictate where and how AAM devices can be flown, and these rules can vary widely depending on the location and intended purpose. In some cases, regulatory constraints may severely limit or even prohibit AAM usage, making it imperative for operators to remain informed about current laws and restrictions to ensure compliance and operational feasibility.

Financial Investment

High quality AAM and accompanying software often requiring substantial initial financial investment. While these expenses can be high, they generally yield cost savings in the long run as AAMs are integrated properly into operational workflows and routinely utilized for inspections and monitoring.

Privacy and Cybersecurity

Deploying AAMs in transportation and emergency management introduces important privacy and cybersecurity challenges that agencies and operators must address. AAM devices collect and transmit large volumes of visual and operational data, often in real time, which can include sensitive information about individuals, infrastructure, and incident scenes. Ensuring the privacy of those captured in AAM footage requires transparent policies, robust data governance, and secure data handling practices. Agencies must establish clear guidelines for data collection, storage, sharing, and retention to prevent unauthorized access or misuse of personally identifiable information (PII).

DEPLOYMENT EXAMPLES

Pennsylvania, California, and Texas

PennDOT uses AAM devices for situational awareness, particularly for incidents where immediate access is difficult.[37] AAM devices can provide real-time information before responders arrive on the scene. Caltrans uses AAM devices for construction site management, monitoring progress, and ensuring safety.[38] AAM devices have also been used for bridge inspections and damage assessments after earthquakes, providing detailed visuals of hard-to-reach areas, enhancing safety and efficiency of maintenance operations. Texas used AAM devices during the recent flooding to view and preliminarily assess sediment, bridge, and washout amounts;[39] these AAM devices were equipped with photo, video, LiDAR, radar, and heat sensors.

[37] *Unmanned Aircraft System (UAS) Policy*. (2021). Pennsylvania Department of Transportation. https://www.pa.gov/content/dam/copapwp-pagov/en/penndot/documents/public/pubsforms/publications/pub%20832.pdf

[38] *Deploying UAS Innovations for Remote, Autonomous Infrastructure Construction Inspection to Enhance Safety, Save Time, Reduce Costs and Lessen Carbon Emissions*. (n.d.). California Department of Transportation - Smart Grants Program. Retrieved December 4, 2025, from https://www.transportation.gov/sites/dot.gov/files/2024-11/Caltrans_508.pdf

[39] Miles, J. D. (2025, July 11). *Drone pilot navigates chaos to aid rescue teams in Central Texas flood aftermath*. Cbsnews.com. https://www.cbsnews.com/texas/news/central-texas-flood-drone-pilot-search-rescue-efforts/

EMERGENCY NOTIFICATION SYSTEMS

Push notifications for emergency alerts over our cellular networks provide public agencies with a channel to give direct notice to the public to act, thereby helping the public react to natural disasters and major transportation disruptions. This can reduce the chances of harm to the traveling public while helping to manage the larger transportation system under stress.

BENEFITS

Emergency notification systems enabled by transportation digital infrastructure provide critical advantages for public safety and system resilience. By leveraging cellular networks and push notification technologies, these systems enable rapid dissemination of alerts during natural disasters, major transportation disruptions, and other emergencies. Timely, accurate notifications empower the public to take protective actions, reducing the risk of harm and facilitating faster, more orderly responses to evolving situations. For transportation agencies and first responders, these systems enhance operational coordination and situational awareness. Interoperable notification platforms support efficient communication between various agencies, ensuring that emergency messages reach the right audiences and that responders can act quickly and effectively. Additionally, emergency notification systems help reduce stress on the broader transportation network, minimizing congestion and supporting the safe movement of people and goods during critical events. Overall, these solutions strengthen community preparedness, improve emergency response outcomes, and contribute to a more resilient transportation ecosystem.

KEY STAKEHOLDERS

Local, Regional, and State Transportation Agencies

These agencies oversee infrastructure planning, policy development, and regulatory compliance for emergency notification systems. They are responsible for coordinating with other agencies, maintaining system interoperability, and ensuring timely, accurate data and information on emergency events. DOTs and transit authorities also play a key role in integrating notification systems with transportation networks, managing congestion, and supporting the safe movement of people and goods during emergencies.

Emergency Responders and Public Safety Organizations

Rely on notification systems to receive and disseminate alerts, coordinate response efforts, and protect the public during disasters and major transportation disruptions.

Technology Providers and Platform Developers

Companies that design, deploy, and maintain the digital infrastructure, including cellular networks, push notification platforms, and data integration systems, to enable rapid and reliable dissemination of emergency alerts.

General Public

Residents, commuters, and travelers are the end users of emergency notification systems. Their feedback and engagement help agencies refine system performance and improve preparedness.

COMMON IMPLEMENTATION CHALLENGES

Timely and Accurate Data

Emergency notification systems depend on receiving and transmitting timely, accurate data and information related to the emergency. State and local agencies may face challenges in maintaining up-to-date data governance structures, standards, operating procedures, and exercises. Consistent updates are necessary to ensure these systems operate effectively during emergencies.

Interoperability

Another critical challenge is achieving interoperability between various emergency responders, technical systems, and public agencies. Reliable, efficient, and safe operation of emergency notification systems hinges on seamless communication and collaboration between all stakeholders.

DEPLOYMENT EXAMPLES

State of California
California's Earthquake Early Warning system uses a ground monitoring system and alerting methods to deliver warnings to people via cell phones before the strongest shaking arrives. Seconds to tens of seconds of advance warning can provide opportunity to take life-saving actions and put devices into various forms of a safe mode.

Caltrans is also partnering with SiriusXM Radio and automotive OEMs to develop a situational data exchange platform that transmits emergency messages securely and to a wider audience in vehicles.

To help public safety teams find specific at-risk individuals, some states use alerting systems for Amber (child abduction) and Silver (missing senior) Alerts, in addition to displaying vehicle information on traditional dynamic message signs on roads.

6 Special Events

With significant upcoming events in the United States like the 2026 FIFA World Cup and the 2028 Summer Olympics & Paralympics, as well as innumerable concerts and other sporting events, public agencies and event organizers can help enable the movement of eventgoers through multimodal transportation options while simultaneously managing the safety and efficiency of this movement through TDI.

These use cases demonstrate the efficient movement of people around major events that draw not only local attendees but international visitors who may not be familiar with the area and transit systems.

USE CASES INCLUDED IN THIS SECTION:

- **Parking Management:** Parking management during special events uses advanced technologies and strategies to optimize parking availability, reduce congestion, and enhance attendee and community experience.
- **Managed Lanes:** Managed lanes involve the dynamic regulation of specific roadway lanes to improve traffic flow, increase safety, and efficiently accommodate varying travel demands during peak periods and special events.
- **Interagency Traffic Management Data Exchange:** Interagency traffic management data exchange enables real-time sharing of situational and operational data among emergency responders, transportation agencies, and public entities for coordinated event and incident response.
- **Use of Message Signs:** Message signs provide timely updates and critical information to drivers and event attendees, supporting safety, efficient movement, and public awareness during emergencies and large gatherings.

PARKING MANAGEMENT

Effective parking management during special events is essential to ensure smooth traffic flow, public safety, and a positive experience for attendees and local communities. Event venues often have limited parking for attendees. Parking management involves a suite of strategies that range from reducing demand and optimizing travel for those that drive to the event while minimizing the impacts on communities and businesses adjacent to a venue. Transportation agencies must engage in advanced planning, travel demand management, real-time parking availability, access controls, and effective curbside management to facilitate loading and pick-up. These strategies often require TDI to manage the roadside or communicate with the event goers and the broader public.

BENEFITS

Effective parking management delivers substantial benefits for transportation agencies, event sites, and the communities they serve. By leveraging advanced technologies like sensors, smart meters, and real-time data analytics, agencies can optimize parking availability, reduce congestion, and improve traffic flow during special events and peak periods. Dynamic parking management systems enable agencies to adjust pricing, manage demand, and facilitate efficient curbside operations.

Additionally, digital parking management solutions provide choices for attendees by encouraging carpooling and the use of non-driving modes. Real-time information empowers drivers to make informed decisions, reducing the time spent searching for parking and lowering fuel waste associated with idling and circling. These systems also provide valuable data for future planning, helping agencies allocate resources more effectively and design policies that promote better parking access.

KEY STAKEHOLDERS

Local, Regional, and State Transportation Agencies

Oversee the planning, deployment, and ongoing management of parking systems. They may be responsible for integrating advanced technologies like sensors and smart meters and ensuring that parking management aligns with broader transportation and mobility goals.

Technology Providers and Platform Developers

Companies that design, supply, and maintain hardware and software for parking management, including sensors, payment platforms, and data analytics tools, enable the deployment of modern, efficient parking solutions.

Local Businesses and Community Organizations

Businesses and community groups are impacted by parking management decisions and may collaborate with agencies to ensure that parking solutions support economic activity and minimize negative effects on residents and customers.

Local Governments and Municipal Authorities

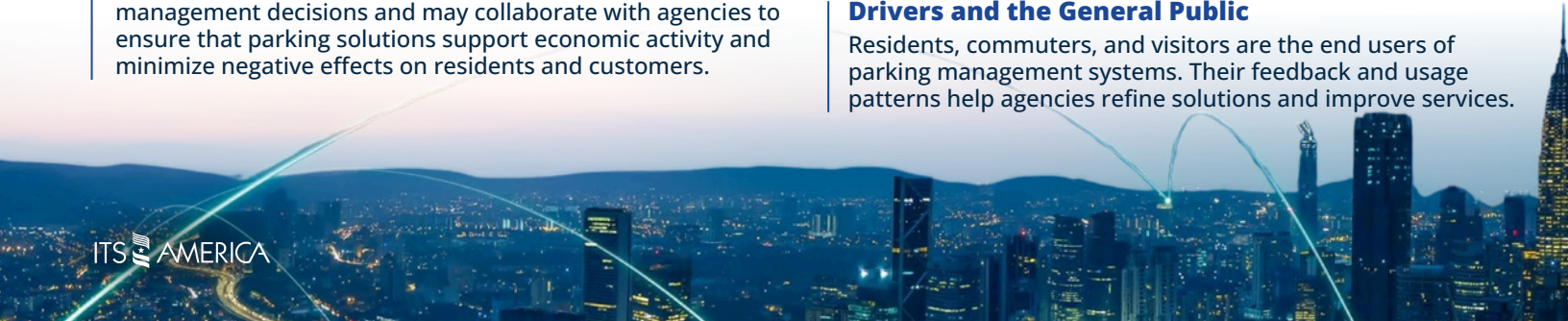
Municipalities set policies, allocate funding, and regulate parking operations within their jurisdiction. Their support is crucial for implementing dynamic pricing, curbside management, and ensuring fair access to parking resources.

Event Organizers and Venue Managers

For special events, organizers and venue managers coordinate with transportation agencies to optimize parking availability, manage demand, and minimize disruptions to surrounding communities. These venues may own the parking itself and may be the ones integrating advanced technologies, sensors, and analytics platforms to manage their parking needs.

Drivers and the General Public

Residents, commuters, and visitors are the end users of parking management systems. Their feedback and usage patterns help agencies refine solutions and improve services.



COMMON IMPLEMENTATION CHALLENGES

Acting on Real-Time Data

A primary barrier is the requirement for advanced technology to collect, process, and act on real-time data. Implementing digital parking management solutions relies on the deployment of modern hardware and software systems, such as sensors, smart meters, and data analytics platforms. These technologies must be capable of capturing accurate, up-to-the-minute information about parking availability, usage patterns, and demand fluctuations. Additionally, robust systems are needed to process this data quickly and provide actionable insights to both agencies and end users. Overcoming this technological hurdle is essential for agencies to make informed decisions, optimize parking operations, and deliver responsive services that meet the needs of drivers and communities.

Time and Resources

Transitioning from traditional, static parking management systems to dynamic, digital solutions necessitates considerable investment of time and resources from public sector agencies. This shift involves not only upgrading physical infrastructure but also retraining staff, updating operational procedures, and engaging with stakeholders to ensure a smooth adoption process.Addressing these challenges is essential to facilitate the broader adoption of digital parking management systems. By overcoming these barriers, agencies can pave the way for more efficient, flexible, and responsive parking solutions that better serve communities and support larger transportation objectives.

DEPLOYMENT EXAMPLES

City and Municipal Parking Management

Dynamic parking pricing for special events means adjusting parking rates before, during, and after these occasions. Parking management systems update rate schedules and connect with parking meters and mobile apps. Some mobile parking applications are managed by cities, while others operate through partnerships with municipalities. In major metropolitan areas like San Diego, San Francisco, Austin, and Seattle, different forms of dynamic street parking pricing are used near downtown event venues to promote carpooling or alternative ways to reach events.

MANAGED LANES

Managed lanes are specialized road lanes designed to enhance traffic flow and ensure reliable travel times. These lanes often incorporate TDI technologies to employ strategies that manage demand and prioritize certain vehicle types. Managed lanes are commonly found on congested roads where commuter demand exceeds capacity, but they can also support special events by designating lanes for buses or other specific vehicles. Lane directions may be adjusted to facilitate movement in and out of venues, with reversible lanes managed either manually by traffic officers or automatically through TDI. Digital infrastructure solutions, including control software, lane control signals, and dynamic message signs, are used to optimize traffic near venues with large crowds.

BENEFITS

Managed lanes offer significant advantages for transportation agencies, commuters, and communities by enhancing traffic flow and ensuring reliable travel times on congested roadways. By employing dynamic lane assignments, demand management, and prioritization for certain vehicle types (e.g., buses, carpools, or event traffic), managed lanes help reduce bottlenecks and improve overall roadway efficiency. These solutions are particularly valuable during special events or peak periods, where lane directions and usage can be adjusted to facilitate movement in and out of venues, minimizing delays for both event attendees and local travelers. Additionally, managed lanes with added fees support more efficient transportation choices by encouraging carpooling and transit use, which can reduce single-occupancy vehicle trips and lower emissions. Digital infrastructure solutions including control software, lane control signals, and dynamic message signs, enable agencies to optimize lane operations in real time, improving safety and compliance without major physical changes to the roadway. Overall, managed lanes can contribute to more predictable travel times, reduced congestion, and a better experience for all road users. Rather than viewing limited right-of-way as a constraint, managed lanes offer a unique opportunity to maximize the utility of existing roadway space. By converting current lanes or reconfiguring roadway use, such as implementing reversible lanes, prioritizing high-occupancy vehicles, or introducing dedicated transit and emergency vehicle access, transportation agencies can significantly enhance capacity and operational efficiency without the need for costly and disruptive roadway expansion. This approach allows communities to make the most of their infrastructure investment, improving traffic flow and supporting broader mobility goals even in space-limited urban and suburban settings.

KEY STAKEHOLDERS

Local, Regional, and State Transportation Agencies

Oversee the planning, deployment, and ongoing management of managed lanes. They are responsible for integrating digital infrastructure, like control software, lane control signals, and DMS, and ensuring that managed lane operations align with broader transportation and mobility goals.

Event Organizers and Venue Managers

For special events, organizers and venue managers coordinate with transportation agencies to optimize managed lane availability, manage demand, and minimize disruptions to surrounding communities.

Law Enforcement and Public Safety Agencies

Help enforce managed lane rules, support traffic flow, and ensure safety for all road users during both routine operations and special events.

Local Governments and Municipal Authorities

Municipalities set policies, allocate funding, and regulate managed lane operations within their jurisdictions. Their support is crucial for implementing lane prioritization, reversible lanes, and ensuring fair access for all road users.

Technology Providers, Platform Developers, and Roadway Managers

Companies that design, supply, and maintain hardware and software for managed lane operations, including lane control systems and DMS, enable the deployment of modern, efficient lane management solutions. Additionally, these companies often own the roads and lanes that were built and designed through public-private partnerships and other contracting methods.

COMMON IMPLEMENTATION CHALLENGES

Initial Investment

The most prominent barrier is the substantial initial investment required for construction, as well as the ongoing maintenance costs associated with keeping systems functional and up to date. These financial considerations can be particularly burdensome for smaller transportation agencies, which may struggle to justify or allocate the necessary resources.

Managed lanes are frequently financed and operated through public-private partnerships (P3s) or contractual agreements with private companies. In these arrangements, private entities provide funding for the construction, maintenance, and management of the lanes and roadway infrastructure. In return, they may receive revenue from tolls or fees, and are responsible for day-to-day operations, technology deployment, and ongoing maintenance. This model enables transportation agencies to leverage private investment and expertise, accelerating project delivery and ensuring efficient lane management, especially in high-demand urban corridors.

Constrained Right-Of-Way

Another limiting factor is the constrained right-of-way available in many urban and suburban environments. This restriction often prevents the addition of new lanes, thereby capping the overall system capacity and reducing the potential benefits of managed lane deployments.

Coordination Among Transportation Agencies

In addition to technical and financial obstacles, the effective deployment of managed lanes depends on strong cooperation and collaboration among transportation agencies, local governments, and the public. Ensuring alignment across these diverse stakeholders is essential for developing operational policies, maintaining compliance, and maximizing the efficiency of managed lanes.
Addressing these challenges is critical to unlocking the transformative potential of managed lanes. Overcoming barriers related to cost, space, and stakeholder engagement will help agencies implement solutions that significantly enhance roadway performance and support broader transportation goals.

DEPLOYMENT EXAMPLES

Cowboy Stadium

For events at Cowboy Stadium in Arlington, Texas, operators can activate reversible lanes controlled by lane control signals on selected arterials. This creates additional lanes to help with traffic flow before and after football games and other events.[40] Real-time signal phase and timing (SPaT) data and vehicle speed data are required to manage signals and move people efficiently.

[40] Office of Communication. (2025, June 13). *Arlington Police Share Gold Cup Game Day Tips for Fans at AT&T Stadium*. Arlingtontx.gov; City of Arlington, TX. https://www.arlingtontx.gov/News-Articles/2024/June/Arlington-Police-Share-Gold-Cup-Game-Day-Tips-for-Fans-at-ATT-Stadium

INTERAGENCY TRAFFIC MANAGEMENT DATA EXCHANGE

Coordination between state and local transportation agencies increases flexibility and responsiveness during special events. Interagency traffic management and data exchange are crucial when coordinating large events between state and local transportation entities to manage traffic signals, traffic incidents, law enforcement needs, transit, and roadway closures. Data exchanges can be set up by establishing interfaces between different ITS and public and private data feeds; data are then made available at operations centers where coordination occurs.

BENEFITS

Interagency traffic management data exchange delivers substantial benefits by enabling state and local transportation agencies to coordinate flexibly and respond effectively during special events, emergencies, and major incidents. By establishing interfaces between different intelligent transportation systems and integrating public and private data feeds, agencies can share real-time information at operations centers, which improves traffic signal management, incident response, law enforcement coordination, transit operations, and roadway closures.

This collaborative approach enhances situational awareness, supports faster and more informed decision-making, and helps agencies implement special traffic plans and closures that improve traffic flow and pedestrian safety around event venues. Interagency data exchanges also strengthen emergency response capabilities, facilitate virtual coordination centers, and ensure that all participating organizations have access to accurate, timely information. Ultimately, these solutions contribute to safer, more resilient, and more efficient transportation networks.

KEY STAKEHOLDERS

State and Local Transportation Agencies
Coordinate traffic signals, incidents, law enforcement needs, transit, and roadway closures by sharing real-time data and collaborating at operations centers to manage special events and emergencies.

Law Enforcement Agencies
Respond to incidents and manage public safety by accessing shared data and collaborating with transportation agencies to implement traffic plans and closures.

Technology Providers and Platform Developers
Design, maintain, and update data exchange interfaces and platforms; ensure interoperability and data accuracy across systems used by multiple agencies.

Traffic Management Centers
Operate centralized platforms for data exchange, incident response, and real-time traffic monitoring; facilitate coordination among agencies and ensure efficient response during events and emergencies.

Transit Operators
Integrate transit data feeds and coordinate with other agencies to adjust routes and schedules in response to real-time traffic conditions and special event needs.

Event Organizers and Venue Managers
Collaborate with agencies to implement special traffic plans, manage closures, and communicate with the public to improve traffic flow and pedestrian safety around event venues.

COMMON IMPLEMENTATION CHALLENGES

Data Interoperability

Interoperability remains a significant barrier to the successful implementation of interagency traffic management systems. The wide range of devices and services used by different agencies often lack standardized protocols, resulting in fragmented and incompatible solutions. This lack of standardization makes it difficult for agencies to share data and coordinate traffic operations effectively.

Addressing interoperability challenges is essential to achieving seamless integration of digital transportation infrastructure. By ensuring systems and devices can communicate and work together efficiently, agencies can maximize the benefits of interagency coordination and improve overall roadway performance.

DEPLOYMENT EXAMPLES

Super Bowls

Recent Super Bowls have shown the importance of managing traffic signals and TDI through coordinated operations centers, as seen in cities like Atlanta, Santa Clara, Arlington, and Inglewood. These centers share information with agencies to implement special traffic plans and closures, improving stadium-area traffic flow and pedestrian safety.

State of Washington

Interagency data exchanges can also support emergency and incident responses. Washington State launched a Virtual Coordination Center for digital incident management between state and local DOTs.[41] This secure, cloud-based coordination system allows agency users to access and share information about traffic incidents and events in real-time. Agencies are able to deploy tools, such as signal adjustments and alternative transit routings, while simultaneously monitoring and managing congestion. This system enables clear, interagency communication and information sharing during

[41] *Report To The Legislature: Virtual Coordination Center (VCC) Proviso Report*. (2023). Washington Department of Transportation. https://wsdot.wa.gov/sites/default/files/2023-11/Virtual-Coordination-Center-Report-December2023.pdf

USE OF MESSAGE SIGNS

Road closures or changes to access during special events can cause congestion and confusion for both residents and visitors. Careful planning to avoid unnecessary closures and ensure smooth traffic flow is critical. Dynamic message signs (DMS) can mitigate the impacts of road closures. When controlled from an operations center, DMS enable transportation agencies to communicate real-time information to drivers, alerting them to upcoming road or lane closures and guiding them to reroute as needed. States, counties, and cities collaborate to deploy DMS throughout event areas. Highway DMS typically focus on regional traffic, advising motorists to avoid congested zones or select appropriate exits, while locally managed DMS help direct traffic through city streets to stadiums and parking locations, many of which are not adjacent to highways.

BENEFITS

DMS play a vital role in modern transportation management by delivering real-time information to drivers and travelers. These signs help agencies communicate important updates about road closures, lane changes, congestion, and special event routing, reducing confusion and improving compliance. By providing timely and accurate information, message signs enable motorists to make informed decisions, reroute as needed, and avoid congested zones, which leads to faster travel times and fewer incidents. DMS can also be used to display messaging related to impaired driving, restraint use, speeding, distracted driving, and other critical safety issues, thereby promoting safer driving behaviors and reducing the likelihood of crashes.

The use of message signs also supports active lane management and enhances safety by alerting drivers to changing conditions, hazards, or emergency situations. Coordinated messaging across agencies ensures that all participants are aware of current operating status, improving interagency visibility and cybersecurity. Overall, message signs contribute to a more reliable and user-friendly transportation experience, supporting efficient traffic flow and better outcomes for both daily commuters and event attendees.

KEY STAKEHOLDERS

Local, Regional, and State Transportation Agencies
Collaborate closely to deploy DMS that relay reliable and accurate messages. State DOTs oversee statewide traffic management, coordinate with local agencies, and provide data feeds for interagency exchange. Local agencies manage city and county traffic operations, contribute local data, and collaborate on incident and event management.

Regional Municipal Agencies and Metropolitan Planning Organizations (MPOs)
Facilitate coordination across jurisdictions, support planning and resource allocation, and integrate regional data sources.

Traffic Management Centers
Operate centralized platforms for data exchange, incident response, and real-time traffic monitoring. These centers also coordinate with transportation agencies and first responders to ensure efficient and seamless response to emergencies and special events.

Law Enforcement and Emergency Services
Use shared data for incident response, traffic control, and public safety coordination during emergencies and special events.

Technology Providers and Platform Developer
Design, deploy, and maintain the transportation digital infrastructure applications and software that enable secure, interoperable data exchange.

Event Organizers and Venue Managers
Collaborate and communicate with agencies to manage traffic flow and coordinate special event operations by raising awareness for ongoing and future events.

COMMON IMPLEMENTATION CHALLENGES

Interagency Coordination

Consistent coordination and timely updates of all messaging across agencies is a challenge. It is essential that every participating agency remains informed of the current operating status to maintain accurate communication throughout the transportation network.

Cybersecurity

Cybersecurity remains a concern for these digital message signs. In the past, bad actors have managed to hack into these systems and display unauthorized messages, which underscores the need for robust protection. By establishing secure data exchange platforms, agencies can enhance interagency visibility, ensuring that all messaging is both reliable and accurate. These platforms also offer an additional layer of cybersecurity, helping safeguard the integrity of the information displayed and reducing the risk of unauthorized access.

DEPLOYMENT EXAMPLES

State of California

To improve traffic flow on the Richmond-San Rafael Bridge, agencies deployed full-matrix DMS at key locations to communicate real-time lane status and operating hours for the third lane. These DMS provided dynamic updates synchronized with Lane Use Signs, ensuring drivers received clear instructions during peak periods. By leveraging this digital infrastructure, operators reduced confusion, improved compliance, and supported active lane management without major physical changes. The result was faster travel times, fewer incidents, and a more reliable experience for motorists.[42]

Nevada DOT

With Las Vegas being a major entertainment hub for tourists, Nevada DOT has undertaken a major infrastructure investment called Project Neon in the heart of Las Vegas.[43] Forty two DMS signs have been deployed across I-15 and US 95 to dynamically manage traffic congestion and improve safety for road users. These signs provide clear, reliable communication to residents and tourists who are unfamiliar with the area. When events in major cities such as Las Vegas occur, leveraging dynamic TDI applications to ensure event attendees have accurate information can reduce confusion, improve travel times, and prevent crashes.

[42] Improving Bridge Travel Times With Lane Management, Richmond, California, ITS Technology Use Case Library Volume 3. (2025). ITS America. (pp. 44-45).

[43] *Project Neon, Las Vegas, Nevada*. (n.d.). Kiewit Corporation. Retrieved December 5, 2025, from https://www.kiewit.com/projects/project-neon/

7 Cross-Industry Integration

Cross-industry integration plays a pivotal role in modern transportation systems by fostering collaboration among diverse sectors such as health, energy, and technology. By seamlessly incorporating expertise and innovations from multiple industries, transportation networks can respond more effectively to large-scale events, automate critical safety actions, and ensure robust information exchange.

This approach enhances safety and operational efficiency while demonstrating how technology-driven partnerships can strengthen multimodal transportation and support vital infrastructure across the nation.

INFORMATION SHARING DURING EMERGENCY SITUATIONS

Florida has implemented a data-focused platform to help better inform residents and businesses during emergencies, specifically during natural disasters like hurricanes. The platform offers multiple ways to track current events, receive communications and alerts, and stay connected even when electricity goes out in an area. The state, in conjunction with FDOT and the Florida Water Management Districts, has leveraged LiDAR and Digital Elevation Data to help better understand flooding.[44]

California has also deployed multimodal, cross-industry TDI applications in the California Earthquake Early Warning System. This system allows for automated actions to be taken in response to earthquake warnings, including stopping elevators and escalators, stopping the Bay Area Rapid Transit (BART) system, and taking over messaging systems in airports and hospitals.[45] This use case emphasizes the importance of cross-industry integration during large scale events by highlighting how technology can automate actions and ensure safety across multimodal transportation and in other sectors.

MARITIME PORTS OF ENTRY

Major maritime ports constitute essential infrastructure supporting the nation's economic strength. Functioning as gateways for international commerce, they enable the import and export of goods vital to domestic industries, consumer markets, and global supply chains. Streamlined port operations increase national competitiveness by lowering transportation expenses and enhancing supply chain dependability. Additionally, maritime ports are central to sustaining energy security, food availability, and manufacturing resources.
After goods arrive at or depart from ports, they often travel across the nation via surface transportation networks. Trucks must operate efficiently and safely on roads to deliver shipments to warehouses, factories, and retail outlets. The transportation sector, including the trucking industry, utilizes information systems to assist drivers and mitigate disruptions within roadway networks. Numerous ITS initiatives undertaken by Departments of Transportation and municipalities focus on disseminating critical information to truck operators, supplemented by digital solutions from logistics companies. Recognizing their role in managing truck traffic, major ports have integrated advanced strategies into their logistics operations. For example, the Port of Oakland has adopted a data-centric approach, leveraging real-time traffic updates, toll rates, and weather forecasts to monitor and optimize the movement of cargo suppliers and delivery partners.[46]

CYBERSECURITY

Cybersecurity presents a constant and dynamic challenge when it comes to any multimodal TDI solution. With a high volume of data moving through TDI systems, cybersecurity needs to be implemented throughout and with constant monitoring. Specific challenges include connecting different agencies and systems for situational awareness while dealing with different cybersecurity standards and systems.

TDI solutions require a strong emphasis on standardized data security and privacy systems to minimize the risk of cyberattacks. Implementing robust standardization simplifies the process of establishing data sharing agreements among regional partners, which in turn supports several of the TDI solutions discussed throughout this White Paper. Innovation zones, such as San Antonio's Smart SA,[47] have created standard requirements to work and operate inside of their region, with a heavy focus on data and cybersecurity requirements.

TELECOMMUNICATIONS

TDI solutions for all modes and functions of surface transportation integrate advanced roadside technologies including sensors, cameras, connected vehicles, signages with real-time data streams, and compute, either in the cloud or at transportation management centers, to improve traffic flow, enhance safety, and support efficient goods movement across transportation networks. The integration is made possible by a resilient telecommunications backbone along our nation's roadway systems. The uses cases highlighted in this document rely heavily on robust, high-capacity telecommunications infrastructure to function effectively and reliably. Broadband of all mediums within the transportation infrastructure continues to grow, forming a backbone for TDI that serves multiple public purposes. Transportation agencies must prioritize the expansion and modernization of telecommunications infrastructure as a foundational element of mobility.

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[44] FDOT Emergency Management. (n.d.). FDOT. https://www.fdot.gov/emergencymanagement/default.shtm
[45] *What is Earthquake Early Warning? | California Earthquake Early Warning. (n.d.). Ca.gov. Retrieved December 5, 2025, from* https://earthquake.ca.gov/about-eew/
[46] *Oakland Portal - Port of Oakland*. (2025). Portofoakland.com. https://oaklandportal.portofoakland.com/#/
[47] Smart San Antonio (SMARTSA). https://smartsa.com/

8 Next Steps and Recommendations

The wide range of TDI solutions provides a near-endless path forward. Funding vehicles both sit at the core of these solutions' deployment and present potential limitations. From our perspective, and recognizing the networked and integrated aspects of these technologies, ideas, and pathways, TDI solutions should be funded from a combination of the following:

- **Certain and Substantial Funding:**
  As outlined in the ITS America 2026 Surface Reauthorization Policy Principles, providing consistent formula-based funding to deploy TDI and transportation technologies is critical to modernizing our nation's transportation infrastructure on a scaled basis beyond one-off pilot projects.
- **Enabling Future Innovation Through Grants and Demonstrations:**
  Federal, or even local, grant programs can help serve as testing grounds for new, emerging technologies within the TDI ecosystem – particularly those solutions that have not yet been demonstrated widely in the field or are nascent (i.e., quantum or blockchain for transportation). Federal programs, such as the SMART Grants, play an important role in demonstrating and validating emerging transportation technologies. From these smaller projects, we can build upon successes and lessons learned, establish new pathways for scaled deployment, and inspire future research and experimentation. This continues a pipeline of research and innovative ideas so that our transportation networks match the ever fluid world of technology.
- **Public-Private-People Partnerships:**
  Public-Private-People Partnerships play a vital role in driving digital innovation within the transportation sector. By leveraging the investment and ingenuity of private firms, these partnerships foster collaboration with the community to accelerate the development and deployment of new technologies. This approach ensures that innovation is fueled by industry expertise in alignment with the needs and aspirations of the public, enabling continued progress in advancing digital solutions across the transportation ecosystem.
- **Federal Leadership:**
  In addition to sustained funding mechanisms, federal leadership is needed to provide a coordinated approach to TDI. The current state of the nation's transportation ecosystem is fragmented, as it is composed of small, pilot-based deployments that vary state by state. While this approach enables innovation, it hampers the overall economic and global competitiveness of the United States. USDOT leadership should advance TDI through inclusion in strategic planning documents and by encouraging states, MPOs, and local governments to deploy these technologies.

TDI solutions are expanding in all areas, especially in the categories outlined in this White Paper. These technologies highlight their impact and success every day by providing safety, efficiency, and economic benefits to the communities in which they are integrated. The landscape of multimodal use cases will continue to grow across the nation as more agencies adopt and deploy innovative solutions to keep their roadways, airways, waterways, and railways moving. To ensure that successful implementations can be leveraged by all those who are seeking to advance their multimodal ecosystem, a coordinated, federal approach and investment is necessary.

Appendix A: Use Cases with Digital Infrastructure Solutions

Movement of People

- **Universal Mobility Wallet Across Modes:** A digital platform that consolidates payment and ticketing for multiple transportation modes, allowing users to seamlessly pay for buses, trains, bike shares, and more with a single account.
- **Seamless Mobility Hubs:** Integrated physical and digital transfer points where travelers can easily switch between different transportation services, supported by real-time data and wayfinding tools to ensure efficient connections.[48]
- **Gamification to Incentivize Using Multiple Modes:** Digital rewards and challenges are incorporated into mobility apps to encourage users to combine various transportation options and reducing congestion.[49]
- **Complete Trip Optimization:** Digital platforms that analyze real-time data to suggest the most efficient or cost-effective routes across multiple transportation modes for end-to-end journeys.[50]
- **Automated Ticketing:** Contactless, digital ticketing systems that automatically issue and validate fares for travelers across different modes, streamlining the boarding process and reducing friction.
- **Mobility On-Demand Services:** Flexible, app-based transportation services, such as ride-hailing, microtransit, or shared bikes, that respond in real time to user requests, enabled by connected digital infrastructure.
- **Ensuring Data Specifications and Standards Across All Modes for One Trip:** The adoption of uniform digital protocols and data standards to enable interoperable trip planning, reservation, and payment across diverse transportation providers.
- **Robotaxis and Shuttles:** Autonomous vehicles operating as on-demand taxis or fixed-route shuttles, coordinated and monitored through advanced digital infrastructure for safe, efficient passenger service.
- **Detour Routing, Dynamic Trip Re-Routing:** Systems that provide travelers with real-time alternative routes or mode options during disruptions, leveraging live data streams and predictive analytics.
- **Vulnerable Road User Safety During Mode Transition (i.e. Loading onto Transit):** Digital solutions such as sensors and warning systems that enhance the safety of pedestrians, cyclists, and other vulnerable users when transferring between modes.

- **AV Shuttles for the Last-Mile Problem:** Autonomous vehicle shuttles provide short-distance connections from transit stops to final destinations, bridging gaps in the transportation network with real-time routing and scheduling.
- **Trip Planning Tool by Different Measures Such as Least Expensive or Most Efficient:** User-friendly digital tools that allow travelers to customize trip planning based on criteria like cost or efficiency, integrating data from various transportation modes.
- **Transportation Demand Management:** Digital tools and policies that influence traveler behavior, such as congestion pricing or real-time incentives, to balance demand across the transportation network and reduce peak congestion.
- **Arrival Prediction Systems:** Advanced analytics and real-time data provide accurate forecasts of vehicle and service arrival times, improving reliability and traveler confidence across all modes.

Movement of Goods

- **Real-time Shipment Tracking:** Digital platforms utilize IoT sensors and cloud-based dashboards to provide continuous, end-to-end visibility of freight location and status for shippers and carriers.
- **Drones for Last Mile Delivery:** Autonomous aerial delivery drones are coordinated through digital control centers for efficient, rapid transport of packages in urban and remote areas.[51]
- **Digital Mapping of Freight Routes to Help with Re-routing:** Dynamic digital maps integrate real-time traffic and infrastructure data to enable rapid re-routing of freight vehicles during disruptions or congestion.[52]
- **Freight Operations Exchange:** Centralized digital platforms connect freight operators, brokers, and shippers to facilitate seamless scheduling, load matching, and communication.[53]
- **Trucking Terminals at Port Facilities and Handoff Between Freight Brokers:** Integrated digital systems manage truck arrivals, departures, and broker handoffs to optimize terminal operations and reduce dwell times.
- **Drayage Optimization:** Digital dispatch and routing platforms optimize short-haul container movements between ports, rail yards, and warehouses for maximum efficiency.[57]
- **Freight Signal Priority:** Intelligent traffic signal systems leverage connected vehicle data to give priority to freight vehicles at intersections, used to extend existing green light phases for approaching trucks, resulting in reduced stops, improved delivery times, and reduced congestion.[54]
- **Freight Corridor Preemption:** Connected infrastructure enables selective traffic signal preemption for freight corridors, taking control of intersections and providing a green light to a specific vehicle, clearing a path for the vehicle and resulting in reduced stops and streamlined goods movement.[55]
- **Sharing Information with U.S. Customs and Border Protection:** Secure digital data exchanges transmit shipment and manifest information to customs authorities, streamlining border crossings and compliance.[56]
- **Platooning:** Connected vehicle technology enables multiple trucks to travel in coordinated, close-formation platoons, improving fuel efficiency and roadway capacity.
- **Truck Parking Availability and Reservation Systems:** Digital platforms aggregate and share real-time parking availability, allowing truck drivers to reserve spaces and reduce search times.

- **Queue Management at Port Security Checkpoints:** Digital queue management tools monitor and control truck flows at security checkpoints, minimizing wait times and enhancing throughput.
- **Port Optimization:** Advanced digital infrastructure coordinates vessel, cargo, and vehicle movements within ports for faster turnarounds and improved resource utilization.
- **Identifying Damage from Trucks on Roads and Bridges:** Embedded sensors and digital monitoring systems detect and report infrastructure damage caused by heavy freight vehicles in real time.
- **Dynamic Rerouting:** Digital platforms analyze live traffic and incident data to provide real-time alternative routes for freight vehicles, minimizing delays.
- **Reducing Delays at Railroad Crossings:** Intelligent warning and scheduling systems communicate train movements to freight vehicles, allowing for proactive rerouting or scheduling adjustments.
- **Differential Tolling Between Passenger Vehicles and Freight:** Digital tolling systems apply variable rates based on vehicle type, time, and route to manage demand and fund infrastructure equitably.
- **Configuration Management for Intelligent Transportation Systems:** Centralized digital tools track and manage the configuration and updates of connected transportation infrastructure for reliability and security.
- **Return Trips and Multipoint Delivery Routes:** Route optimization platforms leverage digital mapping and scheduling to maximize vehicle utilization with efficient return and multipoint deliveries.
- **Data Driven Simulation and Modeling for Optimization and Resilience:** Advanced analytics and digital twin simulations model freight flows and infrastructure performance to inform resilient, optimized operations.
- **Streamlining Freight Weigh Station Operations:** Digital infrastructure helps streamline weigh-in-motion systems, allowing more efficient transportation of freight on U.S. highways and less congestion at weigh stations.[58]

Asset Management & Construction

- **Work Zone Data Exchange for Safety Monitoring, Alerts and Warnings:** Digital infrastructure platforms enable real-time exchange of work zone location and status data, delivering automated alerts and warnings to drivers and connected vehicles to enhance safety and minimize incidents.[59]
- **Asset Tracking and Scheduling:** Centralized digital asset management systems track the location, condition, and maintenance schedules of infrastructure assets, improving operational efficiency and reducing downtime.[60]
- **LiDAR Database of Corridor Conditions:** High-resolution LiDAR data is collected and managed in digital databases, enabling accurate assessment of roadway and corridor conditions for planning, maintenance, and safety analysis.[63]
- **Utilizing Vehicle Sensor Data to Continuously Monitor Asset Conditions:** Connected vehicle sensors transmit real-time data on pavement and infrastructure conditions, supporting proactive maintenance and rapid identification of emerging issues.[64]

- **Lifecycle Cost Management:** Integrated digital analytics tools monitor asset performance and costs over time, supporting data-driven decisions to optimize maintenance, replacement, and budgeting strategies across the asset lifecycle.
- **Digital Twins for Infrastructure Assets:** Virtual digital replicas of physical infrastructure, or digital twins, provide real-time insights for monitoring, predictive maintenance, and scenario planning, enhancing asset reliability and performance.[61]
- **Underground Utility Mapping:** Advanced digital mapping solutions aggregate and visualize subsurface utility data, reducing excavation risks and supporting safer, more efficient construction and maintenance activities.
- **Lane Closure Permit System:** Automated digital permit systems streamline the application, approval, and communication of lane closures, ensuring timely notifications to stakeholders and minimizing traffic disruptions.[62]
- **Standard Rating System for Ancillary Structures:** Digital platforms implement standardized rating systems to assess and catalog the condition of ancillary structures, such as signs and lighting, promoting consistent asset management and prioritization.[65]
- **Validating And Tracking Roadway and Railway Workers to Aid with Alerts:** Digital credentialing and tracking systems verify worker presence and location in work zones, enabling targeted safety alerts and reducing risks of accidents involving personnel.[66]
- **Data Standardization and Harmonization Between Data Providers:** Interoperable digital frameworks ensure consistent data formats and protocols across agencies and vendors, facilitating seamless integration and analysis of transportation data.
- **Automated Inspection of Transportation Infrastructure:** Robotic and AI-powered digital inspection tools capture and analyze infrastructure condition data, increasing inspection frequency, accuracy, and safety while reducing manual labor requirements.[67]

Emergency Preparedness

- **Emergency Vehicle Priority and Preemption System (V2X):** Connected vehicle-to-everything (V2X) platforms enable emergency vehicles to automatically signal traffic lights and smart intersections for prioritized passage, reducing response times during emergencies.[68]
- **ITS for Managing Lane Traffic to Allow for Easy Evacuation/Access for EMS:** Dynamically adjust lane assignments and signage to create clear routes for evacuations and emergency medical services access during critical incidents.[69]
- **Standardizing Data Security to Prevent Cyber Disruptions:** Implementing robust cybersecurity frameworks and standardized protocols across transportation networks safeguards digital systems against cyber threats and maintains operational continuity.
- **Information Sharing Between Traffic Management Centers and Public Safety Units:** Secure, interoperable data exchange platforms connect traffic management centers with public safety agencies to facilitate coordinated responses and real-time situational awareness.

- **Maintaining Operation of Electrified Emergency Responder Services During Grid Outages:** Deploying distributed energy resources and resilient microgrid solutions ensures that electric emergency response vehicles and equipment remain operational during power outages.[70]
- **Using Drones to Evaluate Damages and Aid with Dynamic Response Decisions:** Real-time drone imagery and analytics platforms rapidly assess disaster areas, providing actionable insights for incident commanders to optimize emergency response strategies.[71]
- **Real-Time Feedback Loop to Evacuation Models for Monitoring and Adjustments:** Integrated sensor networks and analytics enable continuous updates to evacuation models, allowing for adaptive rerouting and resource allocation based on evolving conditions.
- **CCTV and Data Analytics:** Advanced video surveillance and data analytics platforms monitor transportation corridors, detect incidents, and support rapid decision-making during emergencies.[72]
- **Integration with 911 Call Centers and Emergency Operation Centers:** Digital infrastructure unifies communication and data sharing between 911 call centers and emergency operations centers, streamlining coordination and accelerating emergency response efforts.
- **Integration of Air, Rail, and Roadway Incident Systems for More Support During Major Evacuations:** Cross-modal incident management platforms consolidate air, rail, and roadway data to provide comprehensive situational awareness and coordinated support during large-scale evacuations.
- **Connecting Data Sets Between Traffic and Weather for Predictive Analysis:** Integrated traffic and weather data analytics enable predictive modeling for proactive incident management and resource deployment during adverse conditions.
- **Flood Detection and Warning Systems:** IoT-enabled flood sensors and geospatial data platforms provide real-time detection, automated alerts, and situational mapping to support timely response to flood events.
- **Disaster Traveler Information:** Digital traveler information systems deliver real-time emergency updates, route guidance, and safety instructions to the public via web, mobile, and roadside platforms during disasters.

Special Events

- **Translation for Tourists Using U.S. Transportation Systems:** Deploying real-time, AI-powered multilingual translation apps integrated with transit kiosks and mobile platforms ensures tourists can easily navigate and access transportation services in their preferred language.
- **Localized Closures:** Dynamic digital signage and real-time notification systems powered by geospatial data provide timely updates on localized closures to both travelers and event coordinators.

- **Coordinating with Modes During Pick-Up and Drop-Off:** Digital curb management and scheduling platforms coordinate various transportation modes to optimize pick-up and drop-off operations and minimize congestion during events.
- **Scheduling and Optimizing Transit and Diversions for Crowd Safety:** Advanced analytics platforms use real-time data to dynamically schedule transit services and route diversions, ensuring safe crowd movement and minimizing bottlenecks during major events.
- **Coordinating 911 and Emergency Centers During Major Events:** Digital platforms that unify communication and data sharing between 911 call centers and emergency operations centers enable faster, coordinated responses during large-scale events.
- **Ensuring Transport of Specialized Equipment to and from Events:** Asset tracking and route optimization software integrated with permit and logistics management systems streamline the movement of specialized equipment for events.
- **Curb Management During Special Events:** Sensor-enabled digital curb solutions allocate and monitor curb space in real time, supporting efficient access for shuttles, ride-shares, and delivery vehicles during special events.

Cross-Industry Integration

- **Sharing Information Between DOT and First Responders Regarding AV Incidents:** Integrated digital platforms enable seamless, real-time data sharing between Departments of Transportation and first responders to coordinate rapid and informed responses to autonomous vehicle incidents.
- **On-Shoring Battery and Chip Manufacturing:** Advanced supply chain management systems and IoT-enabled monitoring support domestic battery and semiconductor manufacturing, enhancing transparency and resilience in critical transportation technology supply chains.
- **Public-Private Partnerships:** Collaborative digital platforms facilitate data exchange, project management, and resource allocation between public agencies and private sector partners, accelerating transportation innovation and infrastructure deployment.
- **Forecasting U.S. Power Grid Needs for Energy Independence:** Analytics platforms forecast transportation sector energy demands, enabling grid operators to optimize resource allocation and support national energy independence goals.
- **Managing Traffic Signal Outages Due to Power Issues:** Digital signal monitoring and automated alert systems detect outages and reroute traffic in real time, maintaining safety and mobility during power disruptions.
- **Early Warning Systems for Natural Disasters:** Integrated digital alert networks leverage geospatial and sensor data to provide timely warnings to transportation agencies and the public, supporting proactive evacuation and response efforts.[73]

- **Adaptive Signals for First Responders, Bus, and Freight:** Smart traffic signal systems prioritize and dynamically adjust signal timing for emergency vehicles, transit, and freight to ensure faster and safer passage through intersections.
- **Digital Curb Management:** Digital curb management solutions use sensors and real-time data to allocate, monitor, and enforce curb space usage, optimizing access for multiple transportation modes and reducing congestion.[74]
- **Connected Vehicle Infrastructure:** Vehicle-to-everything (V2X) communication networks enable continuous data exchange between vehicles, infrastructure, and traffic management systems, enhancing safety, efficiency, and situational awareness on roadways.

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