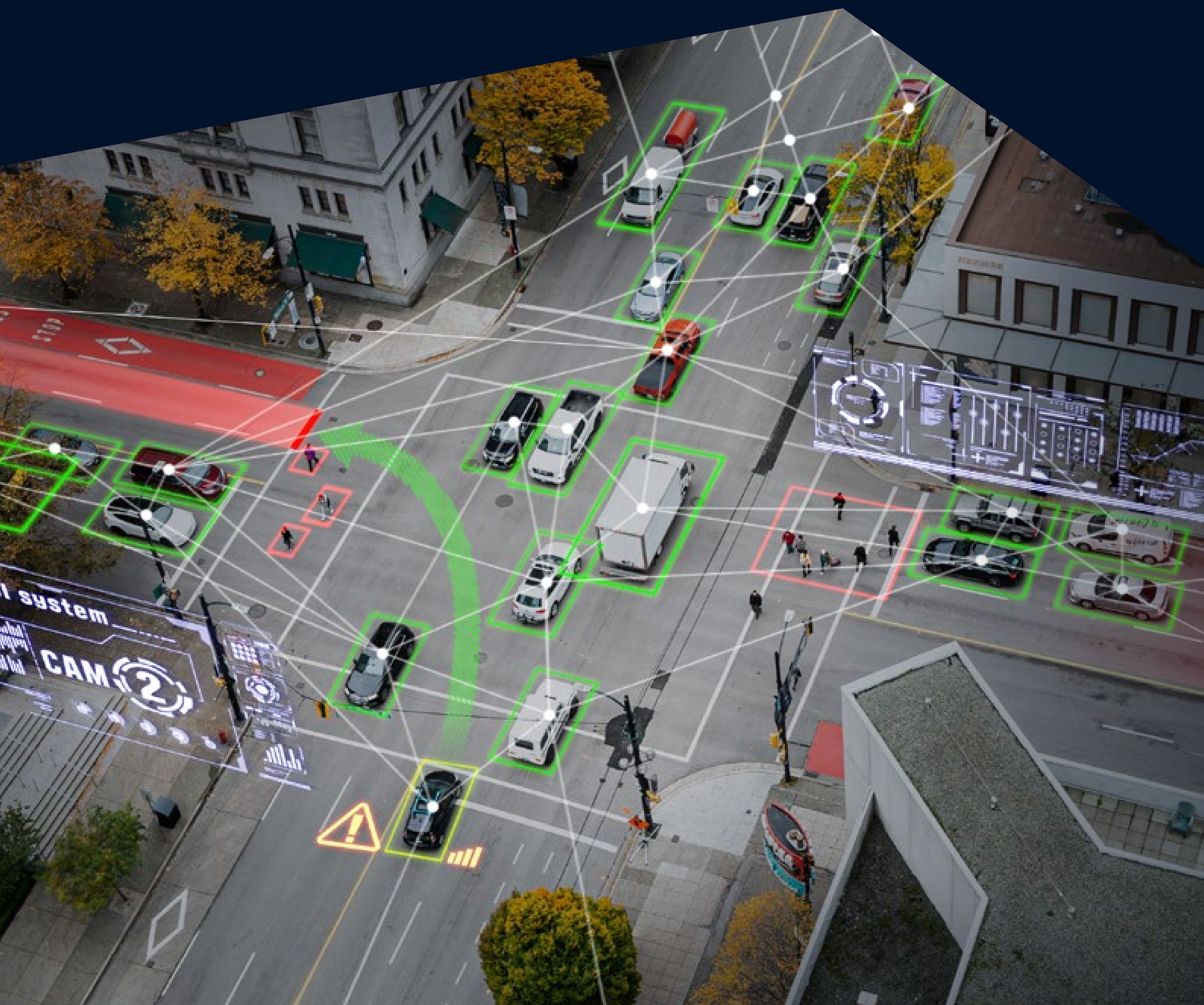
Digital Infrastructure Strategy Report

Shaping the future of transportation in the United States



Contents

Foreword

The Intelligent Transportation Society of America (ITS America) is grateful for the opportunity to publish this report based on the work of our Digital Infrastructure Working Group in collaboration with Cambridge Consultants. ITS America is the only organization in the country that represents all sectors of the transportation industry – public, private, academic, and non-profit – to advance transportation technology. Our membership includes state and city departments of transportation, transit agencies, metropolitan planning organizations, automotive manufacturers, technology companies, engineering firms, automotive suppliers, insurance companies, and research and academic universities. Our vision is one of a better future transformed by transportation technology and innovation. Safer. Greener. Smarter. For all. Our work accelerates the deployment of technology that saves lives, promotes sustainability, and advances more equitable transportation. We believe that digital infrastructure deployment is an essential component of our vision, and that connectivity, automation, data, code, and software will allow the industry to manage and operate our nation's physical assets more safely and effectively. It is our hope that this report will encourage such a deployment, and we look forward to working with USDOT to realize the potential that digital infrastructure has to bring about the next generation of transportation infrastructure.

Cambridge Consultants (CC) is delighted to have contributed to this timely report, and proud to have made that contribution in collaboration with ITS America, the leading advocate for the digital transformation of transportation. CC is a very particular kind of technology consultancy in that our outlook is broad and multidimensional. We don't carry a torch for any one solution, rather our focus is on outcomes – specifically the business, economic and societal value of breakthrough digital transformation. This approach, infused with our track record in creating, developing and deploying original technology innovation, dovetails neatly with the bold, modernising vision of ITS America. Our collective and agreed hope is that this report will help pave the way towards safer, greener, smarter environments for everyone. We hope you find it valuable.

Executive summary

The role of technology in transportation has grown exponentially, and digital infrastructure (DI) innovations have the potential to radically improve our nation's transportation system. The US Department of Transportation (USDOT) urgently needs to devise a comprehensive digital infrastructure strategy to guide and support the deployment of these technologies. This strategy should leverage digital infrastructure's ability to support the broader USDOT objectives, which include enhancing safety, boosting economic value, addressing climate change, and ensuring equity in all transportation modes. However, formulating a strategy in the transportation sector is complex. It involves coordinating with a vast array of stakeholders, from transportation departments to technology providers and the general public, each having distinct interests and capabilities. Additionally, the rapidly evolving technological landscape, marked by progress in areas such as AI, IoT, 5G, and blockchain, requires a detailed grasp of their applications and implications. Different regulatory frameworks across states and transportation types adds further challenge to the integration of digital technology and compliance.
These factors both complicate the formation of a clear digital infrastructure strategy and underscore the importance of Federal leadership in the deployment of these solutions.

In the face of this complex ecosystem, this report aims to facilitate the discussion on digital infrastructure and offers recommendations for defining and implementing a national digital infrastructure strategy. These recommendations are framed by examining definitions of digital infrastructure, assessing digital infrastructure in the context of specific use cases, pinpointing key stakeholders, and suggesting concrete actions for USDOT to implement. It is our hope that this report serves as a useful resource for USDOT as it conducts the important work of leading the way for a nationwide deployment of digital infrastructure for the benefit of all road users.

Defining digital infrastructure

Defining digital infrastructure is a crucial step for USDOT. Establishing a common definition allows a unified vision and ensures all involved parties are aligned in their objectives and efforts. A consensus around digital infrastructure would encompass critical technological advancements and innovations, allowing for strategic planning and adaptation. Equally vital is the establishment of an agreed-upon reference architecture and relevant standards, ensuring consistency, interoperability, and a benchmark for quality. By identifying key stakeholders within this definition, USDOT can ensure inclusivity and collaborative decision-making. Lastly, by setting clear priorities and goals, USDOT can create a roadmap that guides efforts and investments, ensuring optimal outcomes for the nation's transportation needs. Without a shared understanding of digital infrastructure, the risk of fragmented approaches and missed opportunities increases.

Digital infrastructure in the context of use cases

USDOT should identify and continue to foster innovative initiatives through industry use cases with the most significant impact. This will help prioritize actions and align strategy with clear and measurable outcomes. These initiatives should be designed to align with defined milestones and an end vision, to avoid projects operating in silos. In parallel, there is a need to agree and define the data sharing strategy within the reference architecture. A fully defined architecture will serve as a comprehensive blueprint for implementing key actions derived from the relevant use cases.

Identifying and collaborating with key stakeholders

In this complex transportation ecosystem, it is crucial for USDOT to engage with all stakeholders and understand whose needs must be satisfied, compared to those who should be actively engaged, monitored, or kept informed. For instance, State DOTs represent key stakeholders in this process and require active engagement, given their direct involvement in spearheading specific implementation projects. Also, the voice of road users, both public and private, should be brought more fully into the conversation and involved in policymaking.

Taking decisive action

The immediate next steps that USDOT should take are the following:

- **Establishing a realistic and achievable vision**
  USDOT should define a national digital infrastructure vision that consists of ambitious, yet achievable and measurable goals. In doing so, it will help prevent siloed work and ensure that everyone is working towards a common end vision. We expect this vision will reflect key USDOT priorities, including the National Roadway Safety Strategy goal of approaching Vision Zero,[1] USDOT's 2022-2026 Research, Development, and Technology Strategic Plan,[2] and USDOT's 2022-2026 Strategic Plan more broadly.[3]

- **Establish a roadmap with defined milestones**
  This roadmap should guide the actions needed for scaling implementation projects, proof-of-concept initiatives, and use case developments and include realistic milestones. These milestones should clearly define what is to be achieved, and there should be a mechanism in place for quantitatively assessing whether the milestones have been reached.

The rise of technology in transportation necessitates a well-defined approach to digital infrastructure. Decisions made by USDOT today will influence the transportation sector's future. By utilizing the recommendations in this report and collaborating with stakeholders, a future emphasizing safety, equity, and sustainability can be achieved. Uniting under a shared vision and acting decisively will pave the way for a brighter transportation future.

1 https://www.transportation.gov/sites/dot.gov/files/2022-02/USDOT-National-Roadway-Safety-Strategy.pdf
2 https://www.transportation.gov/sites/dot.gov/files/2023-01/USDOT%20RDT%20Strategic%20Plan%20FY22-26_010523_508.pdf
3 https://www.transportation.gov/sites/dot.gov/files/2022-04/US_DOT_FY2022-26_Strategic_Plan.pdf

1 Introduction: a transportation system in flux

1.1 Where are we now?

The US transportation system is on the brink of urgent transformation, moving to embrace a much more digitally orientated architecture of sensors, data, software, and connected systems. This evolution has been driven by major economic and societal trends as well as a rapidly evolving technology landscape that offers significant advantages if implemented. These inevitably pose a series of challenges to transportation – primarily concerning safety, mobility, sustainability, and operational efficiency of the transportation network.

In the US alone, NHTSA estimates that 42,795 people died in motor vehicle traffic crashes in 2022. The US Energy Information Administration (EIA) estimates that in 2022, motor gasoline and diesel fuel consumption in the US transportation sector resulted in a total of about 1,476 MMmt of CO_2. There is much to be improved in increasing the safety, efficiency, and effectiveness of the transportation system. That said, transportation is being driven by advances and rapid deployments in a broad and connected set of digitally enabled technologies such as edge computing systems, artificial intelligence (AI), accelerated wireless connectivity, mobility-as-a-service, and new forms of energy.

Regardless of the complexity of evolving transportation enterprise, data sharing protocols, technology capability gaps and ecosystem collaboration, industry leaders recognize that the future of transportation requires a more balanced approach to supporting infrastructure, in which the physical assets will merge with digital layers into a unified solution.

Successful implementation of this digital layer requires an overarching vision: a thoughtful and in-depth strategy and planning approach that all industry stakeholders in the public and private sector will rally behind. It must be clearly communicated and demonstrate value that supports industry business models and public infrastructure.

1.2 What are the goals & needs?

The USDOT's RD&T Strategic Plan[4] and goals focus primarily on safety, economy, sustainability, equity, and driving transformation and organizational excellence:

- **Safety:** Make our transportation system safer for all people
- **Economic Strength and Global Competitiveness:** Grow an inclusive and sustainable economy
- **Equity:** Support and engage people and communities to promote safe, affordable, accessible, and multimodal access to opportunities and services while reducing transportation-related disparities, adverse community impacts, and health effects
- **Climate and Sustainability**: Substantially reduce greenhouse gas emissions and transportation-related pollution and build more resilient and sustainable transportation systems to benefit and protect communities
- **Transformation:** Invest in purpose-driven research and innovation to meet the challenge of the present and modernize a transportation system of the future that serves everyone today and in decades to come
- **Organizational Excellence:** Establish policies, processes and an inclusive and innovative culture to effectively serve communities and responsibly steward the public's resources

ITS America's digital infrastructure vision aims to support these goals, by ensuring that digital infrastructure allows us to provide, in real time, valuable information to help make better decisions towards a safer, resilient, sustainable, and equitable future.

"The US transportation system is on the brink of urgent transformation, moving to embrace a much more digitally orientated architecture of sensors, data, software, and connected systems"

4 https://www.transportation.gov/sites/dot.gov/files/2023-01/USDOT%20RDT%20Strategic%20Plan%20FY22-26_010523_508.pdf

1.3 ITS America's vision

ITS America set out an initial vision to drive the industry forward and accelerate digital infrastructure deployments. As the vision states, "The industry will use digital infrastructure, data, information and insights to advance our Vision Zero goals to reduce fatalities, to progress US Net Zero emissions reduction goals, to grow the US economy by providing market certainty for industry and provide underserved communities more affordable, accessible, and reliable access to transportation."

To achieve this vision, digital infrastructure requires a fundamental shift towards a more interconnected and data-driven transportation ecosystem that better meets the needs of all stakeholders. ITS America is working with government, public safety, private industry, researchers and nonprofits to create a uniform, interoperable structure, including guidance and best practices, use cases, stakeholder roles and responsibilities, performance measures, and guidance for a reference architecture.

The industry is looking forward to re-energizing the concept of infrastructure with emerging technologies and exciting, innovative solutions that also draw in a new generation. Hence, ITS America and their member organizations have taken various steps since 2022 towards a more interconnected future through forums, workshops, and strategy sessions to help build the next generation of infrastructure.

Last year, ITS America started a national campaign specifically on digital infrastructure and launched a working group across industries and sectors to bring together key voices from leading technologists, engineers, planners, public agencies, researchers, and community nonprofits. The goal of this work is to advocate for technology investment by defining what 'digital infrastructure' means to us, crafting the transportation technology industry's vision for the future, and developing a strategy for the modernization of the US transportation system. This working group will also work together with USDOT to help support their leadership and vision for digital transformation.

1.4 This Digital Infrastructure Report

Since the creation of the ITS America Digital Infrastructure Working Group, for the first time ever, the USDOT has now included 'digital infrastructure' in its Research, Development and Technology Strategic Plan,[5] noting:

"The transportation system of the future will integrate digital technologies and infrastructure to support safe, reliable and convenient multimodal travel."

The ITS America Digital Infrastructure Working Group has identified key areas that are crucial to achieving this strategic plan. This report will elaborate on each of these areas, namely:

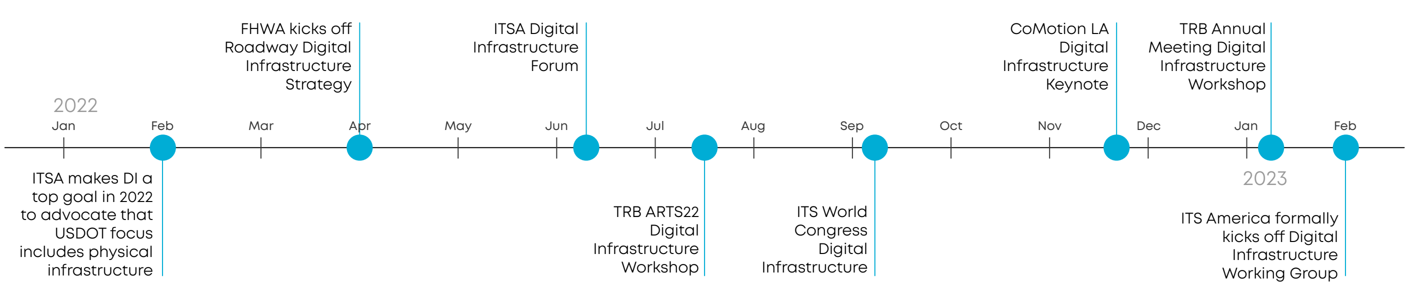
- **Section 2: What is digital infrastructure?**
  Define digital infrastructure and identify the primary components that make up digital infrastructure

- **Section 3: Evaluating through the lens of use cases**
  Identify and prioritize use cases that will set the foundation for digital infrastructure and assist USDOT in understanding where it should direct resource allocation, time, and expertise

- **Section 4: Stakeholder participation and collaboration**
  Architect a comprehensive and inclusive stakeholder map with their roles, responsibilities, and inter-dependencies

- **Section 5: Turning strategy into action**
  Key actions for USDOT to begin shaping a national digital infrastructure strategy

The insights and guidance in this report have been drawn from a large corpus of in-depth ITS America working group meetings, forums, and workshops – particularly from the April 2023 Digital Infrastructure workshop, held during the annual ITS America conference. This serves as a summary record of information from all these discussions which have included hundreds of voices representing DOTs, MPOs, OEMs, public and private sector entities, and more.



5 https://www.transportation.gov/sites/dot.gov/files/2023-01/USDOT%20RDT%20Strategic%20Plan%20FY22-26_010523_508.pdf

2 What is digital infrastructure?

2.1 Defining digital infrastructure

There is no dictionary definition of digital infrastructure; however, through wide-ranging stakeholder discussions facilitated by ITS America, there has been a growing consensus towards a working definition which has been used to underpin some of the previous ITS America work:

"Digital infrastructure is the public and private technology assets that create, exchange or use data to provide information and insights to advance transportation safety, sustainability, equity, access and opportunity. Digital infrastructure is the data, communications systems, servers, routers, hardware, sensors, software applications, and computing to share information through data exchanges and platforms. Digital infrastructure includes the transfer, storage and processing of digital information shared through communications networks across users, companies, devices and public agencies"

This definition is still under development; however, there are key components that must be considered when formulating a formal definition of digital infrastructure, with a holistic view of what digital infrastructure encompasses:

Digital Infrastructure	
Technology & innovation At its core, digital infrastructure is composed of technological systems and processes. Incorporating the aspect of 'Technology & Innovation' in the definition ensures that it remains adaptive and contemporary, considering not just existing technologies but also innovations that will shape the future of the infrastructure. Without a constant eye on technology and innovation, the infrastructure could become obsolete.	1. **Connectivity:** Enhance and expand 5G connectivity across transportation networks, including highways, railways, airports, and ports. This will ensure reliable and high-speed internet access, enabling connected vehicle technologies, real-time data exchange, and communication with infrastructure. 2. **Dynamic transportation systems**: Promote the deployment of the next generation of Intelligent Transportation Systems (ITS) technologies, such as intelligent multimodal traffic management systems, smart traffic signals, and vehicle-to-everything (V2X) communication and incorporating advanced multimodal traffic performance. These systems can improve traffic flow, enhance safety, and reduce congestion by leveraging real-time data and automation. 3. **Continuously emerging technologies**: Embrace the ever-emerging technologies such as connected and autonomous vehicles (CAVs), drones, and electric vehicles (EVs). Develop policies, regulations, and infrastructure to accommodate these technologies and their associated infrastructure needs, including charging stations for EVs and dedicated drone landing zones.
Standards and reference architecture Standards serve as the guidelines and norms that govern the construction, implementation, and interoperability of digital infrastructure components. They ensure a level of quality, reliability, and safety in digital infrastructure systems. Without incorporating standards, the definition of digital infrastructure would lack the structural integrity needed for scalable and consistent performance.	1. **Data sharing and integration:** Establish protocols and standards for data sharing among transportation stakeholders, including government agencies, private companies, and researchers. Enable seamless integration and analysis of transportation data from various sources to support informed decision-making and foster innovation. 2. **Cybersecurity:** Develop robust cybersecurity measures to protect critical transportation infrastructure and systems from cyber threats. This should include implementing secure communication protocols, encryption, intrusion detection systems, and regular security audits to safeguard against potential vulnerabilities. 3. **Interoperability and standardization:** Promote interoperability and standardization of digital systems and technologies within the transportation ecosystem. Encourage the adoption of common protocols, data formats, and communication standards to enable seamless integration and compatibility across different modes of transportation.

Digital Infrastructure	
Stakeholders Digital Infrastructure doesn't exist in a vacuum; various parties like governments, businesses, and consumers interact with and rely on it. Including 'Stakeholders' in the definition acknowledges the range of interests and requirements that the digital infrastructure must serve. It is the stakeholder's needs and expectations that ultimately define the value and efficacy of the DI.	1. **Public-private partnerships:** Foster collaboration between the public and private sectors to leverage expertise and resources. Encourage partnerships with technology companies, telecommunications providers, and infrastructure developers to accelerate the deployment of digital infrastructure and ensure efficient implementation. 2. **User-centric solutions:** Prioritize user needs and experiences when designing and implementing digital infrastructure initiatives. Consider the perspectives of commuters, freight operators, public transit riders, and other transportation users to create user-centric solutions that improve accessibility, efficiency, and overall satisfaction.
Priorities & goals Every digital infrastructure initiative is driven by a set of priorities and goals, whether it is enhancing safety, increasing efficiency, improving accessibility, or ensuring data security. These aims help to guide the design, deployment, and governance of the DI. Including 'Priorities & Goals' in the definition helps ensure that the infrastructure is purpose-driven and meets specific objectives, making it more than just a collection of technologies.	1. **Future-proofing:** Anticipate future technological advancements and design the digital infrastructure strategy with scalability and adaptability in mind. Account for emerging technologies, potential shifts in mobility patterns, and changing user demands to build a flexible and future-proofed digital infrastructure framework. 2. **Sustainability and environmental:** Incorporate sustainability principles into the digital infrastructure strategy. Encourage the use of clean energy sources for powering digital infrastructure, support electric vehicle adoption, and explore innovative approaches to reduce transportation-related emissions and environmental impact. 3. **Safety:** Define the full vision for safety. While reducing fatalities and crashes is an important aspect of safety, a more complete vision of safety for all road users is needed. 4. **Mobility and equity:** Define key objectives that will ensure a transportation system that enhances mobility, is accessible, and includes under-represented communities.

"Every digital infrastructure initiative is driven by a set of priorities and goals, whether it is enhancing safety, increasing efficiency, improving accessibility, or ensuring data security"

3 Evaluating through the lens of use cases

3.1 Ten use cases

In April 2023, ITS America's Digital Infrastructure Working Group convened to identify and prioritize ten critical digital infrastructure use cases to meet safety, equity, economic strength, and climate objectives. These use cases, which were prioritized with input from conversations with USDOT staff, represent an initial blueprint for demonstrating digital infrastructure capabilities within our transportation system. They do not represent an exhaustive list of the possible use cases that digital infrastructure could support, but rather a starting point from which USDOT can measure the potential and progress of digital infrastructure deployment while achieving meaningful results for the traveling public.
The suggested use cases are as follows:

1. Traffic signal integration
2. Connected vehicle data
3. Cybersecure systems
4. AAM
5. Interoperability
6. Curb data
7. EV charging stations
8. Sharing weather data
9. Digital policy
10. Reliable transit

These use cases are driven by:

- Ensuring the safety of all road users, reducing traffic fatalities and decreasing emergency response times
- Improving safety, which can reduce healthcare costs, insurance premiums, and other economic costs associated with accidents
- Increasing the efficiency in infrastructure planning, operations, and investment decisions, ensuring that road networks are designed and maintained to meet USDOT's strategic goals
- Preventing accidents caused by cyberattacks on trains, planes, vehicle sensors, software, and communication links
- Transporting goods faster than traditional methods, leading to increased productivity and lower costs
- Reducing congestion through efficient, data-driven systems
- Reducing carbon emissions by using clean energy alternatives for vehicle operations
- Encouraging and incentivizing new business models through more open data, enabling a competitive marketplace
- Speeding up deployment to realize all benefits sooner
- Assuring transportation equity and justice across all community groups (race, income, age, and ability)

"there was a unanimous agreement on the immediate need for a coherent vision and swift implementation of the identified actions"

3.2 Use cases as the bedrock for discussion

The April 2023 Digital Infrastructure workshop, held during the annual ITS America conference, attracted a diverse group of stakeholders, including USDOT representatives, State DOTs, MPOs, OEMs, and private sector entities. The primary purpose of the workshop was to gather expertise and knowledge from these participants to contribute to the development of a national digital infrastructure strategy.

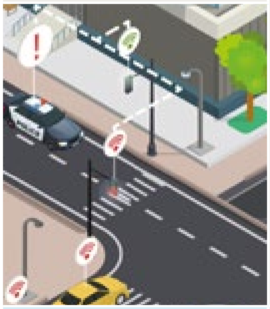
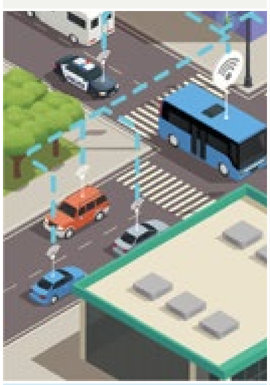
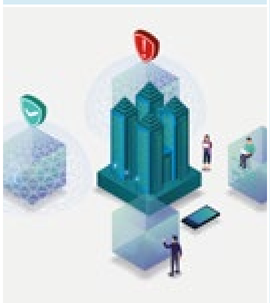
During the workshop, over 300 attendees were present, including representatives from USDOT, State DOTs, City DOTs, technology and infrastructure providers, academia and standards bodies. These attendees were provided with detailed explanations of goals associated with the 10 use cases outlined in 3.1 that covered a wide range of topics and industry challenges. This information served as a focal point for their discussions, enabling participants to identify key stakeholders, determine necessary actions and generate valuable insights about the potential outcomes of success.

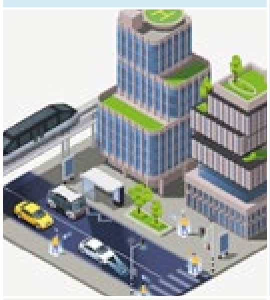
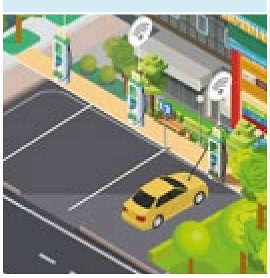
Among the different use cases, device deployment and data sharing emerged as the most significant common threads. The participants saw the need for common standards, security, and privacy across the different use cases. The strategic deployment of assets, as well as their protection and maintenance, were common discussion points too. Most importantly, there was a unanimous agreement on the immediate need for a coherent vision and swift implementation of the identified actions. The frequent call throughout the workshop was clear: **USDOT must take the lead without delay**.

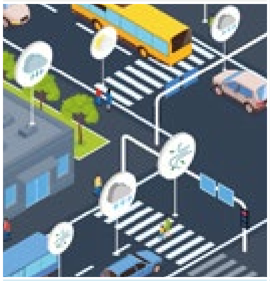
Focusing on a combination of these use case challenges will assist USDOT in understanding where it should direct resource allocation, time, and expertise. The unique insights associated with each use case will also help in defining and establishing achievable milestones, identifying key stakeholders, and also in prioritizing the scaling of the most impactful use cases.

The key takeaways associated with each use case have also been summarized on the following pages. These takeaways will help shape the broader objective of informing and measuring the success of a national digital infrastructure strategy.

3.2.1 Summary of workshop use cases

Use cases	Key drivers	Key workshop takeaways
Traffic signal integration 	▪ Allow authenticated emergency/transit/freight vehicles to pre-empt signals ▪ Enable connected vehicles to drive more safely and prevent accidents (e.g. CAV slows if signal will turn yellow) or plan faster routes ▪ Ensure safer pedestrian road use ▪ Help improve emergency response times (e.g. by prioritizing emergency vehicles) ▪ Improve awkward transport situations (e.g. transit vehicle drop-offs)	▪ Need for systematic implementation of technology standards, interoperable communication, and data systems ▪ Educate and upskill the population on new technologies, and secure funding beyond pilot projects, in order to successfully modernize infrastructure, enhance public engagement, and showcase benefits such as reduced traffic accidents
Connected vehicle data (safety) 	▪ Provide real-time traffic updates, allowing drivers to make more informed decisions about their route and avoid potential hazards ▪ Improve emergency response times by providing more accurate information about the location and severity of accidents and other incidents ▪ Inform infrastructure planning and investment decisions, ensuring that road networks are designed and maintained with safety in mind	▪ There is need for a strategic framework that aligns technology with safety objectives and advocates for robust standards for data exchanges ▪ Promote stakeholder collaboration and foster a shift in mindset to value data exchanges ▪ Digital twin technologies to evaluate the potential impacts and benefits of data exchanges on the ecosystem and optimize decision-making processes
Connected vehicle data (economy) 	▪ Reduce travel times and costs, leading to increased productivity and economic growth ▪ Sharing connected vehicle data can create new business opportunities for private companies ▪ Improve safety, which can reduce healthcare costs, insurance premiums, and other economic costs associated with accidents ▪ Inform infrastructure planning and investment decisions, ensuring that resources are allocated efficiently and effectively	▪ Need for establishing national standards for digital roadway data ▪ Agree and set up privacy policies to ensure OEM and customer trust ▪ Use data to create new economic opportunities ▪ Foster OEM data sharing practices and continuous collaboration among stakeholders ▪ Prioritize infrastructure maintenance and upgrades in parallel
Cybersecure systems 	▪ Preventing accidents caused by cyberattacks on vehicle sensors, software and communication links ▪ Faster and coordinated cyber emergency response from threat detection and monitoring ▪ Giving commerce, the public sector, and users confidence that their data/identities are protected ▪ Cyber-secured access and authorization for safety audit, incident analysis, and safety related monitoring	▪ Need for an encompassing national cybersecurity strategy and related standards ▪ Integrate cyber experts from project inception ▪ Develop compliance frameworks ▪ Develop a funding mechanism for incentivizing cybersecurity compliance ▪ Address liability and accountability concerns

Use cases	Key drivers	Key workshop takeaways
Advanced air mobility 	▪ Efficiencies in moving people and goods by sharing more data between air and ground systems ▪ Transport goods faster than traditional methods, leading to increased productivity and lower costs ▪ Reduced congestion and improved mobility ▪ Autonomous systems to be built with safeties and redundancies which help prevent accidents and reliable delivery of goods ▪ Help reduce carbon emissions by using electric or hybrid-electric propulsion systems	▪ Need to establish a skilled workforce, robust safety and communication systems, clear stakeholder roles, and uniform regulations across jurisdictions for advanced air mobility ▪ AAM needs to target economic growth, zero accidents, time efficiency, seamless integration with existing infrastructure, equitable access, and ensure cost-benefit balance
Interoperability 	▪ New business models due to more open data enables competitive marketplace ▪ Speeds up deployment (realizes all benefits sooner) ▪ Avoiding a 'patchwork' set of features and unknown behaviors of digital infrastructure systems ▪ Encourages consistency/quality of data, which has benefits for future app ecosystem	▪ Develop a standardized and interoperable digital infrastructure, adopting a holistic system approach, fostering trust and collaboration among stakeholders and emphasizing rigorous testing ▪ Interoperability to support the deployment of collaborative Intelligent Transportation Systems, a substantial reduction in lives lost, and a widely accepted standard communication protocol
Curb data 	▪ Improved parking access and space freed up for greenery ▪ Reduce idling time, need for double parking or need to circle to find parking ▪ Speed to delivery accelerates and more packages can be delivered in the same amount of time ▪ Reduce emissions, improve resident safety and equity, management of congestion ▪ Curb digital twins and live data enables seamless coordination and booking of space between multiple user groups	▪ Develop comprehensive standards for data management and an accessible digitized inventory ▪ Understand and optimize dynamic curb management ▪ Success is reliant on clear strategies and KPIs linked to sustainability goals, well-defined design solutions and business models generating self-sustaining revenue streams, and efficient procurement and funding reform
EV charging stations 	▪ Reliable accessibility to charging stations reduces range anxiety and incentivizes switching to electric ▪ Data-informed insights about charging station demand will enable more effective infrastructure planning and policies ▪ Interconnected and interoperable charging stations will support the coordination of renewable energy sources to power charging infrastructure	▪ Ensure the logging and sharing of real-time data for the maintenance of EV charging stations, implementing standardization for ease of use, ensuring grid reliability for station expansion and rethinking data allocation for cybersecurity ▪ Success is to be indicated by grid capacity expansion, integrated mapping of charging stations, and increased EV charging revenue driven by a larger install base and improved reliability

Use cases	Key drivers	Key workshop takeaways
Sharing weather data 	▪ Promote stronger resiliency planning and mitigate impact of disasters and extreme weather ▪ Enhance mobility and distribute services equitably ▪ More efficient traffic rerouting, saving lives and quickly responding to climate events ▪ Help travelers find safer routes ▪ Reduce traffic inefficiencies and thus gas emissions	▪ Deploy localized weather stations, implement a multimodal data integration strategy, enhance weather prediction models with AI, develop universal applications for stakeholders, and increase investment for these initiatives ▪ Aim towards greater weather data density, resource efficiency, disaster resilience, reduction in weather-related incidents, improved transportation service, and prediction model accuracy
Digital policy 	▪ Promotion of transportation equity and justice across all community groups ▪ Ensuring that major investments in digital integration and transformation align with the needs and values of all communities in the travel corridor ▪ Ensuring the benefits of digital infrastructure investments are adequately communicated out to various audiences with varying degrees of digital literacy ▪ Ensuring all neighborhoods within a community are considered when changes are made to the transportation network	▪ Champions or sponsors to carry out the vision and enable the adoption of the strategy and standards that will enable the realization of a digital policy ▪ There is need for collaboration between stakeholders and definition of roles to realize the vision ▪ There is need for data-driven objectives to drive accountability ▪ Incentivizing outcomes through focused funding
Reliable transit 	▪ Enable greater transportation equity by income, age, and ability ▪ Promote increased workforce participation ▪ Improve health by encouraging more exercise in commute ▪ Increase commute efficiency by reducing unknown delays between multimodal transit sources ▪ Increase revenue to municipal areas through increased ridership ▪ Provide access to critical community services	▪ Develop a robust knowledge network through incentivized data sharing ▪ Ensure multimodal trip integration and accessible dynamic route planning solutions, and diversify information distribution ▪ Aim towards improving trip efficiency and safety, with success gauged by the establishment of interoperable standards, creation of inclusive digital payment modes, KPIs tracking operational efficiency and safety, and increased public data availability for innovation

3.3 Actionable insights from two key use cases

There are several common threads among the ten use cases that could serve as starting points for USDOT in shaping the national digital infrastructure strategy. But to provide a contextual understanding of some of these actions, two use cases were selected for further in-depth analysis: **connected vehicle data** and **traffic signal integration**. Moreover, these two specific use cases address significant challenges within the transportation sector and emerge as key areas where prioritization is necessary. The exploration will involve identifying obstacles to success and outlining the necessary steps to mitigate them. And lastly, in order to understand how these use cases can be realized, the report also explores the potential for a **reference architecture which uses a shared data layer**.

3.3.1 Connected vehicle data

Establishing an ecosystem where insights from connected vehicles are optimally utilized to address safety and system efficiency requires a multifaceted approach. Key actions include promoting stakeholder collaboration, standardization, data privacy and security, infrastructure development and maintenance, as well as incentivizing both data sharing and data exchanges.

Act as a neutral facilitator between stakeholders

A national committee or steering group, comprising representatives from vehicle OEMs, cities, infrastructure companies, technology providers, public safety organizations, data providers, and privacy experts should be formed to capture the hugely diverse perspectives in this sector. Moving forward, this group should act as a united voice, representing all stakeholders. Regular meetings should be held to discuss evolving needs, use cases, standardization issues, and privacy concerns related to digital infrastructure.

A key challenge lies in managing a variety of perspectives and interests, which can make reaching a consensus difficult. Appointing a neutral facilitator, possibly a USDOT representative, can ensure that all voices are heard.

Lead data standardization initiatives

Standardization ensures interoperability and efficiency across the entire digital infrastructure. USDOT should take the lead and work closely with existing national standardization programs such as the NTCIP, as well as with industry, academic, and stakeholder representatives, to develop standards for data exchange and integration. To take advantage of existing cutting-edge systems, increase modularity (for example to swap in future wireless standards), and enable innovation within technology components, it may be important to focus on standardization of data ingress and egress at the 'system of systems' layer, rather than across the entire technology stacks of all the underlying systems and associated industries. USDOT can adopt a crucial role in establishing and monitoring compliance with data standards among all relevant stakeholders, and influencing the enforcement regime that may be required to accelerate change.

The benefits of standardizing need to be relentlessly expressed in terms of stakeholder benefits and value within the different use cases, but at the system level are broadly expected to be:

- Reduced overall cost across the ecosystem
- System level efficiencies and 'seamlessness' in multimodal transport
- Increased innovation and competition (less 'lock in' at key technology layers)
- Increased physical safety, cyber safety, and more consistent equity
- Improved data access, control, quality, ownership, and protections
- Data driven decision making, simulations, and predictive analytics
- Improved transparency, accountability, and performance metrics
- Improved visibility of sustainability performance and impact of net zero policies

Rapid advances in technology can make it difficult to establish and maintain relevant, up-to-date standards. In addition, resistance may arise from industry stakeholders due to the perceived limitation on innovation and the additional burdens of compliance. Implementing an iterative process to update standards will help ensure their ongoing relevance and allow them to benefit from private sector innovation.

There may be large sections of the system of systems where standards are 'de facto' based on public or private sector initiatives, momentum, and majority acceptance. However there are others (for instance making sure data ingress in formats with timeliness and quality that are useful in public safety contexts, or managing overall digital security stance) where public intervention is required.

Leverage simulation and modeling for infrastructure development and maintenance

The development of a robust, interconnected digital infrastructure is vital for the efficient functioning of the transport sector. Promoting joint simulation and test programs, where multiple operators benefit from shared scenarios, should be prioritized. These initiatives could act as an advantageous entry point for data sharing and foster collaborative development, but they would require nationally driven funding and direction.

Subsequent to the development phase, adequate training for maintenance is necessary, accompanied by an established framework for regular upkeep and updates. The significant capital investment required for deployment, along with ongoing maintenance costs, present some of the biggest challenges. To alleviate these financial pressures, public-private partnerships, along with grants and funding from other governmental organizations, can be explored as potential solutions.

Moreover, joint simulation and test programs could play a significant role in optimizing resources and preventing overengineering. For instance, employing more advanced digital twin modeling in these programs could help technical testing of concepts, aid strategic deployment of devices, and support large-scale integration. This approach would potentially reduce waste and lead to a more efficient and cost-effective system.

Develop data privacy and security standards

USDOT should develop comprehensive privacy and security standards for the transportation sector, ensuring the public is well informed about the measures taken to safeguard their data. Similarly, solutions allowing commercial organizations to protect confidential IP should be promoted to enable their investment. These strategies will help bolster public and commercial trust in digital infrastructure, further driving its adoption.

Considering the lifespan of systems being commissioned today, it is important to anticipate that quantum computing may render current authentication and some encryption standards obsolete. Therefore, close attention should be paid to the post-quantum cryptographic standards being selected by NIST and driven from the highest levels of government (e.g., HR 7535 Quantum Cybersecurity Preparedness Act). Particularly, the need for chips capable of specific digital signatures should be integrated into the physical infrastructure layers now, facilitating a gradual transition to post-quantum cryptography over many years.

Ensuring robust data privacy and security can be technically challenging, especially given the rise of increasingly sophisticated cyber threats. Another significant challenge is striking a balance between data collection and usage, and individual privacy rights. Data security technologies can help, but the interfaces to specify, understand, and audit data usage can quickly become complex for enterprise IT and OT departments, let alone end users of transport systems. Each component where data is processed or aggregated potentially creates a new set of access control, and data ownership and liability issues to manage. Strong technology leadership is required to keep the systems manageable while maintaining data security and assigning liability for breaches. Regular or automated security audits can help maintain ongoing effectiveness. Furthermore, promoting systems that improve aggregation, anonymization, and access control assurances will be crucial to maintaining trust with the public, OEMs, and other commercial entities.

In developing safeguards for privacy and security, there will likely be tradeoffs which will impact the data interoperability as outlined in Section 7.1.2. This further highlights the need for strong leadership to make timely decisions about these tradeoffs.

Build trust in data exchanges and ensure their adoption

Naturally, OEMs will be reluctant to share data due to proprietary concerns. However, the development of stringent and transparent guidelines about how and when the data will be used – and ensuring these guidelines comply with local and international data protection and privacy laws – can provide reassurances to OEMs about data safety and user privacy. The obligations, liabilities, and responsibilities that data sharing operators hold should be agreed from the beginning and be legally binding. Furthermore, it is crucial to establish and enforce penalties for the misuse of shared data to uphold trust. While many entities are considering how to implement data sharing systems that give better inbuilt guarantees on protecting confidential IP, there is no de facto solution yet – USDOT has the opportunity to be a pioneer and mandate that data sharing must occur between stakeholders.

Licensing could be another way to promote data sharing among OEMs while addressing their concerns. By establishing a licensing framework, OEMs maintain control over their data usage, specifying its purpose, duration, and any associated conditions. This framework protects OEMs' intellectual property, ensuring their data is not used to infringe upon their patents, trademarks, or other proprietary rights. Licensing agreements can also mandate strict privacy and security standards, providing OEMs with reassurance about the protection of sensitive data. An additional advantage is the potential for revenue generation, as OEMs could charge fees for access to their data, creating a new business model. The clarity provided by these legal frameworks reduces potential disputes and enhances communication between parties. Finally, licensing can stimulate sector-wide innovation. Third-party access to licensed data can lead to the development of new applications, products, or services beneficial to the entire industry, including the OEMs themselves.

Establishing forums or advocacy groups to educate both industry and consumers about the value of data exchange – especially its potential in preventing fatalities and improving transport efficiency – will support a shift in mindset, enabling broader adoption and support. This is inherently a slow process, but clear and consistent messaging that emphasizes the benefits of data exchange can help shift mindsets. Publicizing case studies that demonstrate success is also key to building public confidence and trust. As part of an effort to shift the industry mindset, the government could also offer tax breaks or other financial incentives to encourage OEMs and other stakeholders to share data.

These key actions not only support connected vehicles but also have relevance across a number of other use cases. The significance of these actions underscores the importance of focusing on this particular use case and reinforces the need for concrete actions in implementation.

3.3.2 Traffic signal integration

Integrating traffic signals to improve safety and enable city-wide optimization bears similarities to the creation of a connected vehicle ecosystem. Actions such as standardization, ensuring safe data-sharing practices, and infrastructure development are equally critical for the successful implementation of smart signaling systems. However, this specific use case will necessitate some unique actions as well in order to ensure its success.

Transformation of traffic signal integration and dynamic traffic control strategies

Traditional traffic control strategies include fixed-time, vehicle-actuated, and adaptive signal control. Fixed-time control utilizes historical traffic data to calibrate pre-set signal parameters such as phase sequences, cycle lengths, and green splits. Vehicle-actuated and adaptive signal control apply infrastructure-based detectors to collect real-time traffic data and adjust signal timings according to time-variant traffic demand.

For this transformation, connected and autonomous vehicle (CAV) technologies, communications between vehicles (V2V), and between vehicles and infrastructure (V2I) provide a new source of data for traffic control. This communication makes it possible to convey traffic information (e.g., signal timings or speed advisory) from intersections to vehicles in real time for trajectory planning as well as collect detailed vehicle trajectory data (e.g., speeds and locations) for signal control. This means capturing, processing and storing new data, robust communication networks, prompt exchange of information, and new ways of designing real-time traffic control.

These issues are challenging in themselves as they are suggesting an overall transformation of how traffic signal integration and dynamic traffic control at strategy level needs to be materialized at operational level, which implies change management at different levels. Engagement with different stakeholders and change management experts involved in this top to bottom transformation and a roadmap with concrete actions is fundamental to make this necessary change a reality.

Funding

Funding is the major enabling resource that can catapult new traffic signal integration forwards. In urban areas, traffic engineering departments are often competing for funding with high profile agencies such as police and fire departments, or more tangible capital improvements. Cities might not see an obvious return on investment for adaptive traffic-control systems. That could delay the transition to traffic signal integration and adaptive traffic management. It is only a matter of time before cities would be required to install distributed and connected traffic management tools for AVs. Innovative funding mechanisms, so that every city has the means to be ready for this new technological change, need to be in place.

Introducing innovative funding mechanisms is key but is not an easy task. A way of widening ideas might be to examine successful initiatives in particular cities or estates – or even from other industries – to see what lessons were learned. It would also reveal insights into how different funding initiatives were introduced to ensure that everyone is included in the transformation and implementation of enabling solutions such as traffic signal integration.

Data/time sensitivity challenges in traffic signal integration

Challenges with just-in-time data integration

Typically, transportation data collection and use has been siloed by transportation agencies. However, advances in technology and more sophisticated management of transportation systems are beginning to require real time, cross-agency data integration. This in turn, will require the review of data standards for data capture, storage, and exchange.

Challenges with time sensitivity

There is a need to standardize the frequency of data updates and refresh rates to respond to time dependency and a predictive nature of queries and adaptative traffic signals.

Addressing these challenges needs to be a priority when considering procurement. Implementation of solutions for traffic signal integration, timing of data capture, data processing, and actionable information are key for successful and safe deployment. Technological providers need to engage with City DOTs and key end users such as first responders to understand user needs at operational and response levels to ensure efficiency and safety.

Data standards need to be in place

Transportation data sources cannot be converted to a new 'final' schema overnight. The data sources will continue to produce data in their respective schemas – and continue to evolve – so a different architecture and integration approach is needed. Equally, transportation datasets are highly heterogeneous, with operational (i.e., transactional), streaming, and archived data. Standards and solutions about how this data need to be stored and processed must be decided.

Although there are already data standards in place, standards and specifications need to be developed for all types of data (traditional and new data coming into the market) to enable its effective use. Successful standardization efforts need to break down the complexity of all the data and data exchanges happening at traffic signal integration level into simple elements that are easy to implement. This means that that some existing standards might need to be reviewed and new ones created. The sooner this happens, the more clarity City DOTs and industry will have to move forwards to create and implement solutions.

Sensing technology providers need to create solutions that can fit new and old systems

Integrated traffic signal systems will require that emerging sensors not only use new technology, but also convey new information to the existing control systems. This backwards compatibility needs to be incentivized so that new providers create solutions that also can adapt sensors, protocols, data ingestion, and processing into existing systems. This would be for cities that cannot afford to upgrade all technological changes that are needed all at once.

A stepwise integration approach is needed, engaging technology providers and encouraging them to work with City DOTs to understand current operations and current infrastructure, acknowledge City DOTs current roadmaps for digital transformation and agree on what types of upgrades and solutions can be incorporated at different levels and stages of the development roadmap. This engagement is crucial for guaranteeing equity of opportunities to incorporate traffic signal integration solutions that provide stepwise advancements.

Guaranteeing the reliability of V2X communications and computational capability at application level

This is one of the critical factors that may influence the performance of traffic signal integration and traffic dynamic control. 5G communication should be one of the supporting pillars for the next generation of traffic signal integration, due to its speed and transmission range. Provision of such infrastructure and incentives needs to be in place for telecommunication companies in order to cover as much territory as possible and assure equity of service and opportunities.

Computational capability of traffic control systems needs to be improved, expanded and incentivized. If not, information collected by CAVs might not be fully collected/processed in a timely way to improve traffic efficiency, or respond to the prompt changes of traffic demands. This could be emergency services priority at intersections using traffic signal integration, for example.

The thrust of all this is about assuring robustness of the communication systems and the capability of traffic control and traffic signal integration systems to deal with potential exponential increment of data capture. Processing and communication at speed is a must for any solution to be effective and safe. This requires engagement with technical providers and City DOTs to work on simulating, testing, and validating all components, interactions, risks assessments, edge cases, and safety nets in case of failures.

Real Time Situational Awareness for public safety and various other use cases may have their own tight requirements on latency, for instance having the system enable network transport paths directly between operational control centers and infrastructure components (in parallel with waiting for data to be received, analyzed, and processed into a shared data system which may have a lower 'refresh' rate).

USDOT and State DOTs to standardize and apply common communication and application layer protocols

The standardization of messaging protocols between traffic management systems is essential for achieving interoperability and improving safety and optimization. An obvious challenge will be to get all stakeholders to agree on standard protocols and ensure that existing systems can be upgraded to comply with these new standards. USDOT and State DOTs will need to keep a balanced and phased implementation approach so that standardization can be applied by City DOTs and their stakeholders and technology providers.

At the same time, promoting the development of standardized interfaces for traffic management applications is just as important. This could involve setting guidelines for how applications should interact with each other within a traffic signal integration setting. Close collaboration between technology providers, communication channels, USDOT, and State DOTs needs to be in place so that the standards are kept up-to-date with rapid technological advancements.

This could also involve agreement on a subset of easily standardized 'basic information' to be made freely and easily available (such as vehicle location, speed, direction) with more enriched 'value-added information' behind a paywall.

Cybersecurity standards need to be established

Resilience is just as important as a robust traffic signal integration approach. Cybersecurity is at the top of priorities on any solution that involves collection, processing and communication of critical safety data.

As well as standards for data and communication protocols, cybersecurity should be at the forefront of critical actions to address issues such as privacy protection of individuals and the security of vehicles and integrated traffic signal systems. Standards for ITS and traffic signal integration need to be in place from USDOT at national level, aligned with the National Cybersecurity Strategy.

The main challenge is that this is time critical. Dedicated resources need to be put in place to create standards so that City DOTs and industry can be sure that their solutions are secured and compliant now. At the same time, this should be a continuous process with quick updates added as new potential threats are identified.

3.3.3 Digital infrastructure architecture

This section will aim to define a shared data layer as part of a potential reference architecture, which will serve as a comprehensive blueprint for implementing the key actions identified from the use cases. Eventually, USDOT will need to agree on a fully defined reference architecture which will aim to offer guidance on standard protocols, system design, and best practices. This will be a crucial tool in aligning the use cases with the overall vision of the national digital infrastructure strategy. In this section, we offer some initial suggestions of what a shared data layer might look like and what might be required to achieve it.

The term 'reference architecture' is used in this context with a perspective similar to that of ARC-IT: it serves as a common framework and language for planning, defining, and integrating intelligent transportation systems. The belief is that this should include mandatory standards for data exchange and security, but it should not dictate any specific implementation methods for utilizing those standards. This definition differs from the one commonly used in industries like the semiconductor field, where a reference architecture may provide a complete blueprint for deploying a particular product into a broader system.

A shared data layer is ready for action

Successful digital infrastructure for US Transportation will be a system of systems – that is to say there will be no central specification that describes everything, and no single decision point where 'the digital infrastructure' is approved and commissioned. This is due to the huge variety of purchasing decisions, KPIs and potentially conflicting requirements among stakeholders.

The variety of purchasing decisions means the standardization focus should be on data exchange, rather than mandating all layers of the technology stack right down to link layer and physical data carriers across the entire system (as is possible in more centralized and monogamous systems like some healthcare and smart metering environments).

This also acknowledges significant previous and ongoing financial investments in current (successful and/or safety critical) systems that hold data that is valuable to digital infrastructure use cases. It can be tempting to describe these as legacy systems that simply need to be replaced, but a more palatable approach may be to acknowledge them and work on ways to make it easy and beneficial for owners of existing systems to integrate with, supply data to, or acquire data from the more widely connected system.

Given the stakeholder needs, there is clearly an increasing appetite for services that use data supplied from multiple systems at once.

In this section we propose a staged strategy for data standards for digital infrastructure that can be adopted now, driving towards a vision of a shared data system that enables a 'digital twin of twins'. It has an innovative app ecosystem providing valuable public services, relying on reliable, secure, and trustworthy data feeds.

This is proposed from an independent perspective – with the intention of driving discussion – rather than with a particular solution in mind.

What is a shared data layer?

There are many levels at which national standardization could occur. Not all of them are needed for all use cases, and some will provide a higher return on investment than others. Many standards used in the combined system will, or already have, come together organically. But there is a clear opportunity to step in and accelerate specific parts of the process to achieve the stakeholder aims. Operating the system outlined here involves operational costs (e.g. network transport costs, storage, hosting, and compute costs) which will not happen without funding being in place.

A potential strategy that enables the articulated stakeholder visions of digital twins and app ecosystems is to define a 'shared data layer', with the intention of a new ecosystem of innovative applications that accesses the shared data to run algorithms, analytics, visualizations, and simulations, feeding back into decision making and ultimately digitally intervening to influence what happens in the real world.

Individual data systems feed real time (or delayed and audited/approved) data into the shared data layer, and in return can take feeds contributed by others that help them optimize their own functionality.

At the application level this provides a new trusted set of holistic real-time data that applications can use for cross cutting applications like first response, overall safety, and so on. Instances of these applications may run on premises or cloud systems operated by entities such as ECCs, Traffic Operation Centers, Emergency Operation Centers (Emergency Management Agencies), Operation Control Centers (Transit Agencies), Real Time Crime Centers and so on.

This data layer approach mirrors other international efforts such as EONA-X within the European GAIA-X framework – for the US it becomes even more important to retain autonomy at the data system layer and standardize at the layer above, given the regional ownership of the datasets and systems.

The data layer helps entities announce and discover each other's data, access it, and exchange it. This is consistent with the 'integration layer' of the DHS Information Sharing Framework [ISF] for public safety. The latter also references specific networking for endpoint access such as NPSBN (FirstNet).

The data does not have to actually be a direct copy of existing data – in some cases it may be a set of endpoint connectors that can stream data directly from the source systems (reducing latency and improving consistency). This may be particularly important for real time situational awareness in public safety situations – for instance where multi-jurisdiction multi-agency information sharing is required – in cases where low latency is critically important the shared data layer might be used simply to announce or discover relevant real-time data feeds (and maybe to get approval to access them) – and then they might be accessed directly, rather than waiting for other shared data layer services to retrieve or analyse them.

A vehicle/OEM data section of the shared data layer is shown as it may have special requirements or need extra control or ownership by OEMs. This goes in parallel with a potential mindset shift in OEMs that the safety of their vehicles, and in turn customers, may now start to depend on third parties a lot more. This might be data from other vehicles or a smart traffic signal, or assurances about C-V2X coverage, for example. OEMs have been used to significant control over safety, and are likely to want more control than other parties over data that their vehicles need to trust. This is reasonable if they are likely to take the ultimate liability for safety impacts on the vehicles and passengers themselves.

The shared data layer diagram is silent on what technology is used for network transport. This aims to recognise that individual systems may be using different network access routes to get to the data systems/aggregators (for instance state deployed broadband networks, commercial networks, cellular, etc.). Within the 'individual system' layer even more communications standards and transport layers may be in use (C-V2X, in-vehicle connectivity, etc.), and at the front end, users such as first responders may be using dedicated transport layers such as NPSBN (FirstNet). However, the broad concept is that the shared data layer is internet facing on both sides, to enable maximum public and commercial benefit and maximum uptake by data owners and application providers.

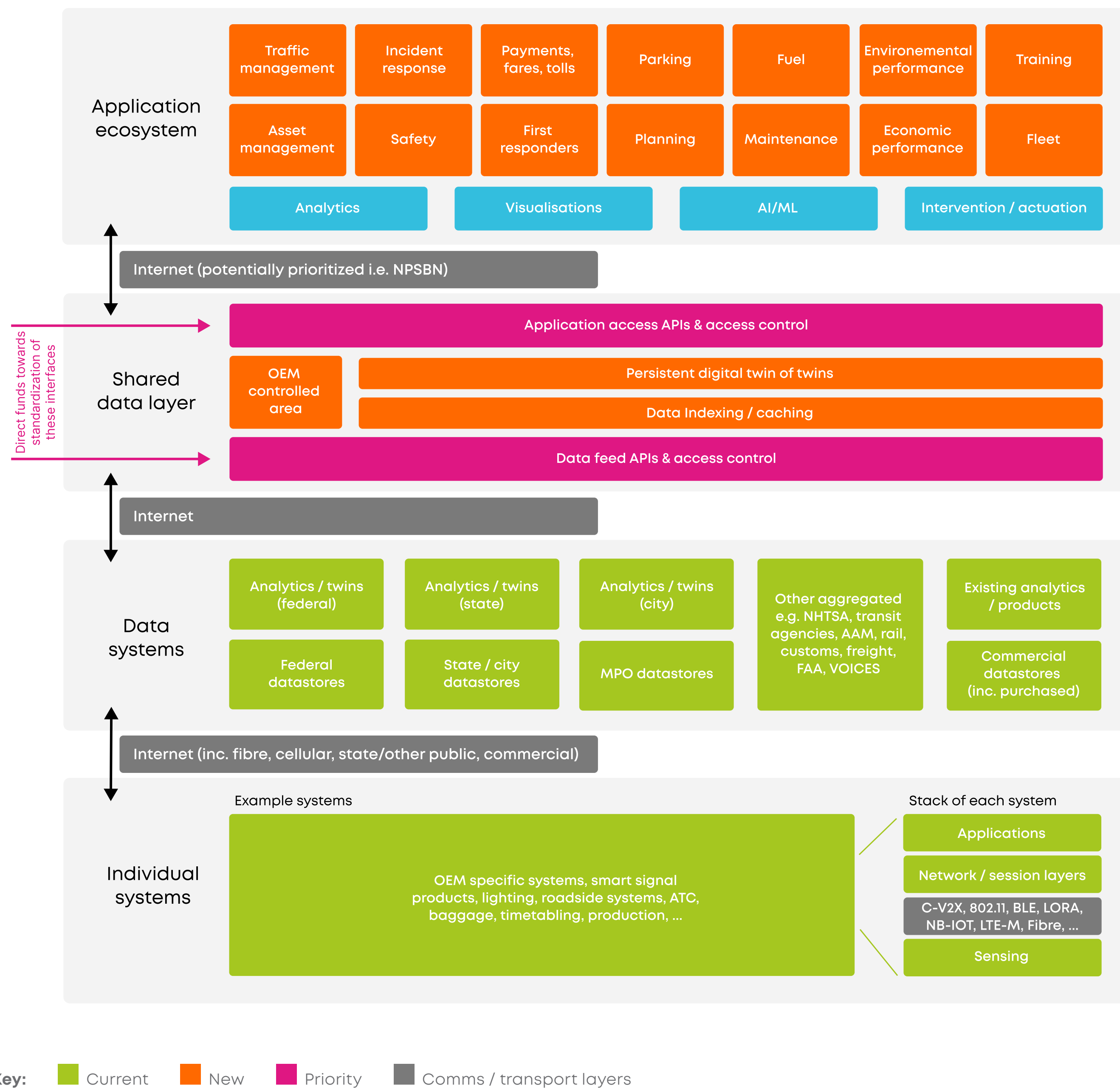


Figure 1: How a shared data layer contributes to the system of systems

Data in the shared data layer ('twin of twins')

The basis for predictive analytics, data-driven decision making, simulations, ML/AI, and adaptive optimization is a persistent digital twin – an 'always on' digital representation of what is happening right now across the combined systems.

The datasets in the shared data layer form the inputs into this 'twin of twins'.

Individual existing systems are likely to operate their own digital twins and analytics – those do not need to be replaced, but provide data streams that help form the wider connected twin of twins.

Applications that run above this dataset might include rendering and visualization of the data in 3D format – either the existing state or audit/forensics of historical data. Alternatively, snapshots of the current state of the twin of twins can be taken into the application layer for non-real time 'what if' operations such as simulations, predictive analytics, and planning. There is also a host of other non-3D applications that can use the same data (analytics, optimization, user apps, information, sustainability tracking, data driven decision making, etc.).

Some potential feeds into the shared data layer are shown here. The intention is that the system can grow and include cross checks to enable higher data quality as new data feeds become available.

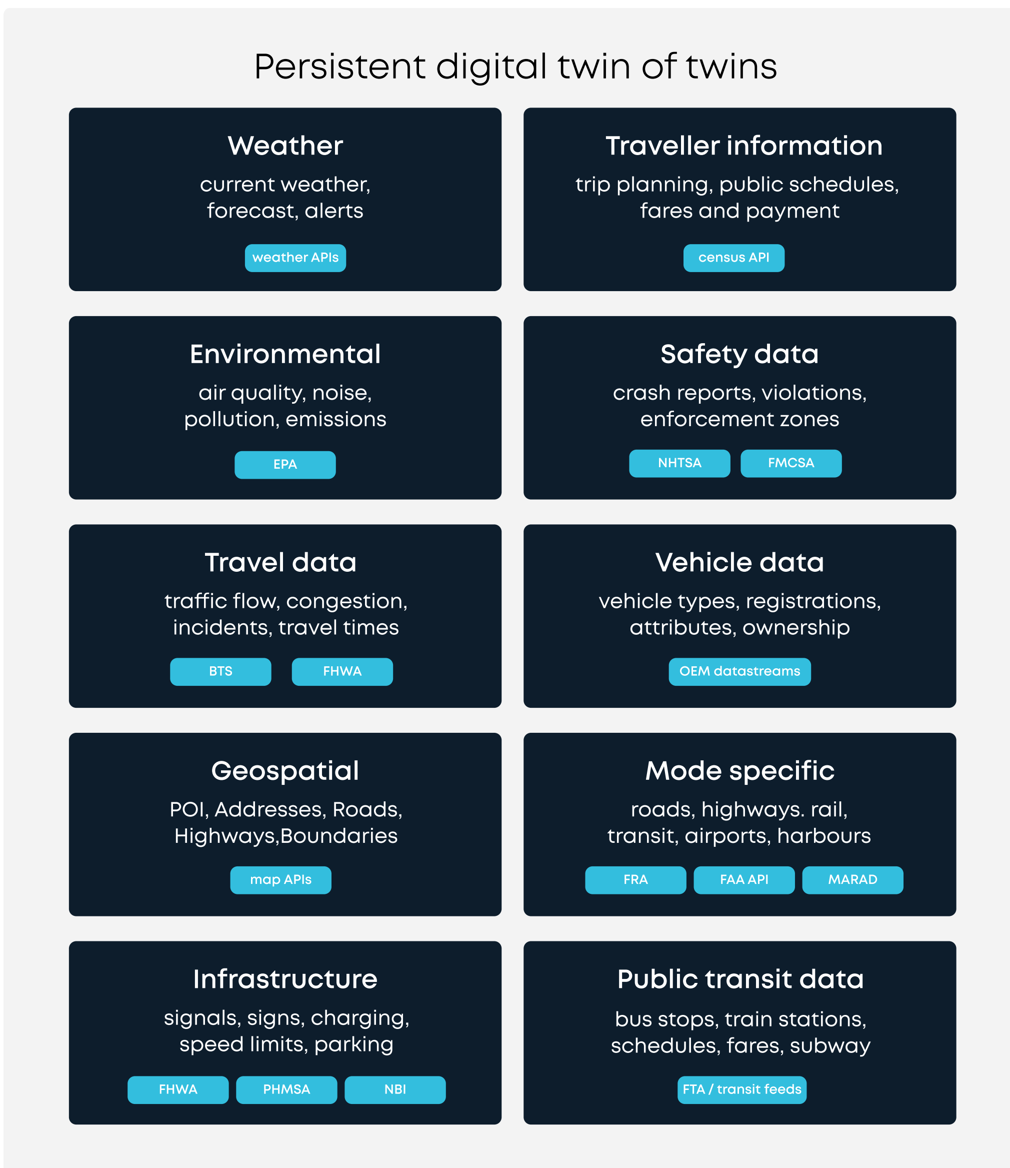


Figure 2: Example Twins

Key: Example data feeds

Why have a shared data layer?

The shared data layer is the key to interoperability of existing systems. Obviously this is important for multimodal transportation and presenting a 'seamless' view to transportation users. But it also enables other new services that are otherwise hard to achieve.

It removes a barrier to scaling individual PoCs that don't make it to larger scale deployment – by enabling multiple suppliers, regions, and PoCs to jointly build the shared data system in a collaborative, interoperable way.

App ecosystem
This is a central pillar of a competitive innovative app ecosystem – rather than an app developer having to consider hundreds of interfaces to underlying systems to achieve a user facing output, they have one place to go for 'known good' trusted data.

Partnerships
It enables public private partnerships by acting as a clear framework for services and defining who owns data when – while also enabling market competition to provide the systems and services underneath the data layer, the services that operate the data layer, and the app ecosystem on top of it.

Collaboration
The data together is more than the sum of its parts – for the first time there could be holistic views of sustainability, safety performance, equity, and economic performance in one place. This in turn allows a whole new suite of data driven decision making at the transport system level.

Security
This approach enables digital security controls that were not there before – for instance by mandating in the API that incoming data is digitally signed, suddenly transparency and accountability for datasets and their quality is vastly improved, ultimately reducing the cost of litigation. It is also a place to enforce privacy measures that reassure both commercial entities and users about confidentiality of their data.

Scaling and efficiency
Finally, this approach allows the clear appetite for scaling of PoCs into regional and national solutions, unlocking investment in component and system design that is interoperable across regional boundaries and providing system wide efficiencies, cost savings, and future proofing.

How a shared data layer enables two example use cases

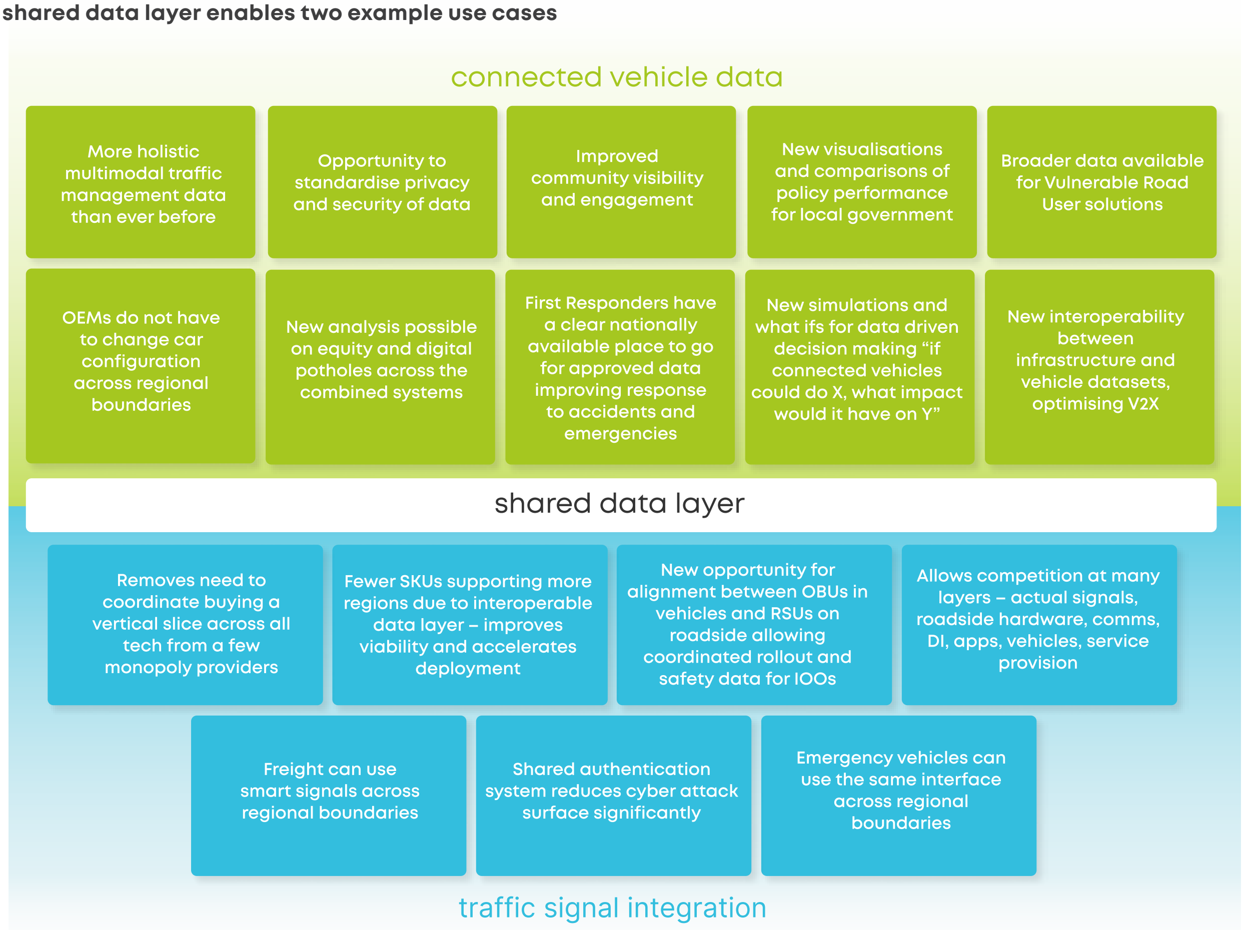


Figure 3: Benefits of a shared data towards two use cases

Declare the ambition and candidate first actions

Market signal for standardizing a shared data layer (Twin of Twins)	
Define data ownership, liability, and privacy policies	Standards and processes to give assurances to 1) commercial entities about what their obligations, responsibilities, and liabilities are on feeding data into the system, and how data ownership will be assigned (including for processed data), and 2) users on personal data anonymity, particularly for equity applications where personal data might be useful, safety data that might identify cars or drivers, or payment data. Unlike some personal data approaches, the future use cases of the data in an innovative app ecosystem might not be known at data collection time, so this might lead to a stronger case for anonymity earlier in the data management process. This work is key to deployment but also acquiring high quality, reliable, accountable, and trustworthy data.
People and process guidance	Given these standards/processes, updated guidance is needed on what skillsets are expected to be required in organizations (public and private) to be able to comply with them. This covers audit, IT, developers, security policy management, governance and so on.
Define APIs for data layer	With agreement that the shared data layer will exist, work can start on defining access and datatypes to stream data in and out of it, with some lead use cases and integration of key data sources (e.g., FHWA, NHTSA) to pipeclean the process, data agreements, and (competed) service contracts.
Definitions to make services competitive	There is a desire to keep provision of digital infrastructure services competitive, rather than one or two systems dominating. Work could be carried out to define the obligations and interfaces to particular data layer services (e.g., providing storage, providing hosting, providing compute) so that they can be competitively procured and provided in an interoperable way. This could include evaluating current digital infrastructure solution providers for how well they would fit a competitive approach, as well as defining rules for allowing services and data to be moved from one provider to another. It could include templates or standards to refer to for procurement.
Refine impact assessments (of 'shared digital infrastructure' on environment, equity, public safety)	A short assessment could be carried out to measure impacts of a shared 'data layer'. A) Sustainability, stacking emissions of associated datacenter processing against potential benefits of having a holistic and quantitative view of sustainability across DOT transportation to inform policy and decision making. B) Impact on equity of being able to enforce specific data useful to equity projects and use cases. C) Benefits and risks to public physical and cyber safety. D) Economic benefit to the US.
Make it easy to procure	Processes should be defined to help public sector organizations match potential digital infrastructure related projects with a shared data layer architecture, while meeting their own goals. This might include a new lightweight process that recognizes that procurement of digital systems or apps does not require the same safety and environmental impact assessments as more traditional transportation procurements. Support is required to give consistency across the procurement process – for instance having specific standards on what makes a system 'shared data compliant' that can be called up in ITTs.
Enable the app ecosystem	App ecosystems happen faster if they have a low barrier to entry, if data access is simple (well defined, published, with language independent APIs or supporting libraries) and if there is a clear route to being paid. Funds could be directed to kickstart app development in specific areas of interest or 'super' use cases.

4 Stakeholder participation and collaboration

One of the key steps towards alignment in a digital infrastructure strategy is acknowledging the stakeholders within the ecosystem. Failure to deliver on a cohesive digital infrastructure will risk the safety of all users and put operational functionality, reliability, and security of the national transportation system at risk. Industry stakeholders will be challenged to provide economic, social, and sustainability benefits to society. This means that it is essential to understand the complex stakeholder map within the digital infrastructure ecosystem and articulate the value each stakeholder receives and brings.

The mapping below (Fig. 4) identifies group categories with a stake in digital infrastructure (from working group sessions thus far and reiterated at the April 2023 digital infrastructure workshop) identifying how information or influence flows between them. Note that it omits any indication of monetary flows and is not fully comprehensive.

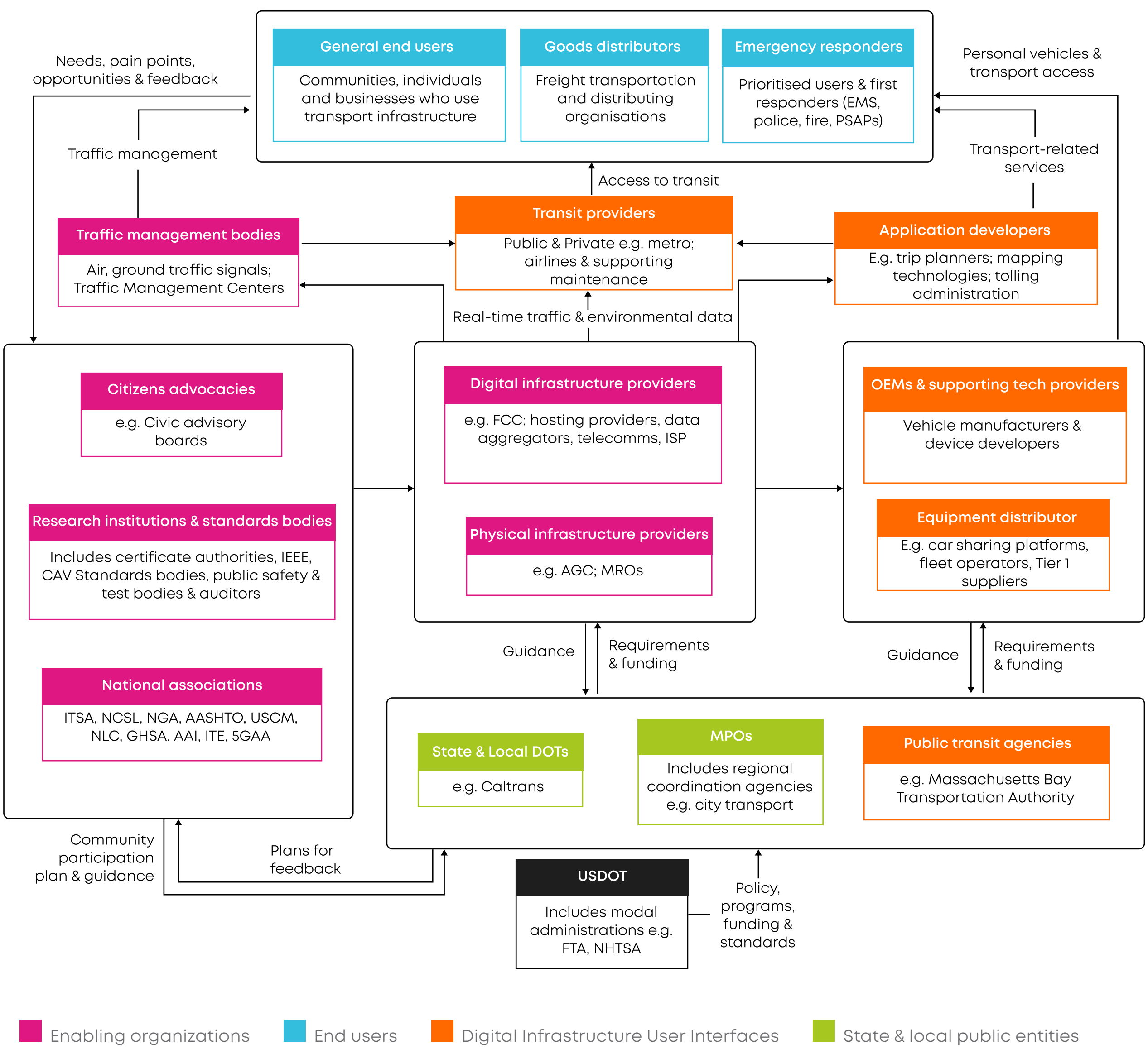


Figure 4: Stakeholder Map

We assume that **end users** are businesses or individuals who may use or operate a range of transportation methods (public, commercial, shared, or personal), or public entities including emergency responders who would need specific consideration regarding traffic management. There are a number of entities that are responsible for the **digital infrastructure (DI) user interfaces**, such as OEMs, supporting technology providers, equipment distributors, application developers, and transit providers. This stakeholder group effectively create the digital infrastructure and the interfaces by which users access transportation, whether that is via a transportation planning application, creating a supply chain plan, leasing a vehicle, or coordinating a delivery slot. These digital infrastructure interfaces are reliant on information, guidance, and infrastructure from a number of **enabling organizations** who contribute to and draw from shared data (e.g. vehicle, weather), or otherwise support the deployment of digital infrastructure. A flow of influence through policy-setting, standards, funding, and project-commissioning across departments of transportation and associated agencies (**state and local public entities** and **Federal officials**) enable the foundations from which the transportation system is shaped. Ensuring that this collaboration is well-informed through insights from research programs, citizen and other end-user advocates, plus technical guidance from providers, is a key component to the success of digital infrastructure deployments.

The next section briefly describes a suggested strategy around engagement with digital infrastructure stakeholders.

4.1 Stakeholder engagement strategy

Mapping the stakeholder groups against the prioritization matrix below (Fig. 5) lays out our assumptions on how heavily each group is impacted by digital infrastructure. This classic analysis technique ensures that we are maintaining an appropriate and realistic level of engagement with each stakeholder group, and are communicating key information or seeking influence from the right voices at the right time.

It also outlines why USDOT should prioritize the needs of users first, ahead of other stakeholders, whilst actively acknowledging the importance of all impacted groups. Note: all groups are important voices in the conversation, but they might be kept engaged in different ways as part of influencing the digital infrastructure strategy overall.

4.1.1 Level of influence on digital infrastructure

Through the mechanisms of the current ecosystem, stakeholders with a high degree of influence on transportation digital infrastructure are likely to be solution providers and OEMs, as they are already actively engaged in using and generating data from the transport system, and state DOTs/MPOs through the specification of projects and programs.

4.1.2 Degree of impact from digital infrastructure

Transportation end users and freight transporters are most impacted by transportation digital infrastructure as they are directly affected by the quality of the system and its ability to meet their immediate needs. For example, if data sharing is not efficiently implemented between transportation entities, this could affect the efficiency of a public transit system and ultimately reduce its value to end users of the system.

4.1.3 Stakeholder collaboration strategies

Bearing this landscape in mind, we should align our engagement strategies with each stakeholder group to match their level of influence and impact against digital infrastructure.

Meet their needs

Ensure that providers and developers are well enabled to both contribute and gain value from a more collaborative and, where necessary, shared digital infrastructure – e.g. through standardization of protocols and accessibility of data. Providing a strong and open-minded basis for creative development to third parties ideally maximizes value.

As digital infrastructure develops, communities of data consumers and owners (including, for instance, connected vehicle OEMs and ATMS systems) need to be established and cultivated to build comprehensive discourse and feedback loops on data standardization needs. Notably, the ITS America Digital Infrastructure Workshop in April 2023 had low representation from end user groups, with only 0.3% of attendees classified as end users. This indicates a need for more intentional engagement with end users or representative bodies.

Actively engage

Empowering those who are most heavily impacted by the outcome of digital infrastructure strategy makes sense. Ideally, citizen advocacies/research bodies are valuable representatives for the collective voice of end users and research-informed guidance on what needs digital infrastructure must meet. Additionally, it is vital to enable continuous active engagement as directly as possible on strategy at the top level, rather than simply collecting feedback on specifically planned initiatives.

In particular, addressing the USDOT goal of increasing equity, increasing and maintaining efforts to engage historically marginalized and underrepresented communities when refining policy and enabling feedback loops around planned updates is vital.

Engaging representatives of freight transporters and public safety organizations which coordinate the nation's emergency response services is important.

Monitor

Ensure at key touchpoints that the enabling infrastructure and equipment is working efficiently with the current and intended digital infrastructure.

Show consideration

Enablers of digital infrastructure need to be well informed by the requirements of providers, developers, and technology to be able to deliver what they need (and ultimately why) in terms of user needs.

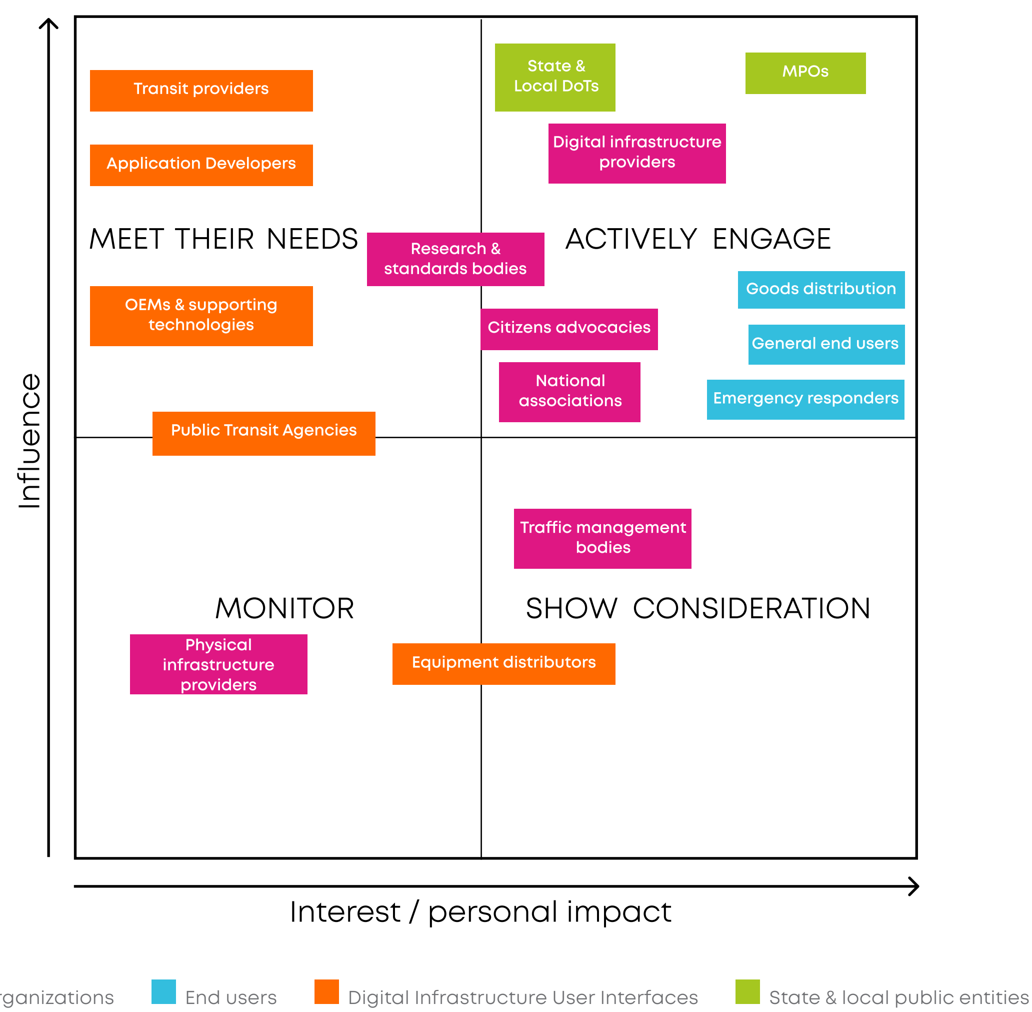


Figure 5 Stakeholder Matrix

5 Turning strategy into action

The growing consensus among stakeholders is clear: **USDOT must take the lead without delay.**

In Section 3, specific actions associated with two example use cases were presented. Some of those actions are not limited to a single use case and can be applied more broadly across other use cases as well. Additionally, below is a summary of the high-level actions that the USDOT should take concerning Digital Infrastructure.

1. **Setting a common vision:** Clearly articulate the goals and objectives of the digital infrastructure strategy. Identify the specific outcomes and benefits that the strategy aims to achieve, such as improved efficiency, enhanced safety, and increased connectivity.
2. **Establish a roadmap with defined milestones:** Develop a detailed roadmap that outlines the timeline, milestones, and actions required to implement the strategy. Break down the implementation into manageable phases, prioritizing critical initiatives and ensuring a systematic approach to deployment.
3. **Define the digital infrastructure:** Come to a consensus around the definition of DI. Some of the aspects which this definition needs to include are:
    - Technology and innovations of importance
    - An agreed reference architecture and related standards
    - Key stakeholders
    - Priorities and goals
4. **Prioritize relevant industry use cases:** USDOT should identify and continue to foster innovative initiatives through industry use cases with the most significant impact. This will help prioritize actions and align strategy with clear and measurable outcomes. These initiatives should be designed to align with the defined milestones and the common end vision, to avoid projects operating in silos.
5. **Allocating funding for technology:** Create dedicated funding programs specifically aimed at the implementation and advancement of transportation technologies, including digital infrastructure, is imperative. The suggestion is not necessarily to increase overall funding but to divert a portion of resources from traditional projects toward technology investments. This reallocation could pave the way for a sustainable and future-proof transportation system. Such funding could support initiatives like digital traffic management systems, intelligent transportation networks, electric vehicle charging infrastructure, and data-driven transportation planning.
6. **Policy and regulatory framework:** Develop supportive policies and regulatory frameworks to facilitate the implementation of the digital infrastructure strategy. Address legal, privacy, and security considerations, and establish guidelines for data sharing, interoperability, and emerging technologies.
7. **Start making a difference:** While Proof of Concepts (PoCs) serve a role in exploring new technologies, the focus should now shift toward implementing changes that yield direct and meaningful impacts on citizens' lives. The emphasis should be on scaling up new technologies in real-world settings through proven methodologies, such as Scaled Agile, which strike a better balance between risk and progress. Adopting this approach ensures that taxpayer dollars are spent efficiently and delivers tangible benefits to communities.
8. **Emphasizing citizen-centric changes:** The ultimate goal of any transportation infrastructure should be to enhance the quality of life for citizens. By adopting digital solutions, such an infrastructure can improve accessibility, encourage multimodal transportation options, offer real-time information to commuters, and create a seamless, convenient travel experience. USDOT should prioritize projects that directly address citizens' needs and aspirations to ensure their satisfaction and well-being. Public awareness campaigns should be conducted to educate both stakeholders and the general public about the benefits of a digital infrastructure strategy. It is also important to seek feedback and input from users and communities to ensure that their needs and concerns are addressed during implementation.
9. **Leverage industry associations to foster collaboration:** Leverage industry associations like ITS America to encourage collaboration among various stakeholders, including government agencies, private-sector entities, academic institutions, and other industry associations. Promote regular communication, knowledge-sharing, and coordinated efforts to achieve alignment and synergy in the strategy's implementation.
10. **Partnerships and collaboration:** Foster partnerships and collaborations with technology providers, telecommunications companies, academia, research institutions, and other relevant stakeholders. Leverage their expertise, resources, and innovative solutions to accelerate the implementation of the digital infrastructure strategy.
11. **Review and adapt:** Regularly review the digital infrastructure strategy to assess its relevance and adapt it to evolving technological advancements, user needs, and policy changes. Embrace a flexible approach that allows for adjustments and updates as the transportation landscape continues to evolve.

6 Next steps

Numerous actions have been identified in the previous sections of the report. While all these actions are relevant, it is crucial to phase them correctly to ensure their complementary nature and alignment with a common goal.

As immediate next steps, USDOT should concentrate on two primary actions:

1. **Setting a common vision** – develop an overarching digital infrastructure vision for the transportation sector and ensure that all stakeholders are aiming towards the same result.
2. **Establish a roadmap with defined milestones** – create a way to measure progress towards this ambitious vision, thereby creating a constrained roadmap. This framework will guide stakeholders and direct the scaling of the use cases and reference architecture, thus, ensuring that different state initiatives are not siloed and all work towards a common goal.

The figure on the following page envisions a potential framework that will assist the USDOT in shaping their national strategy.

Wider scale actions for USDOT

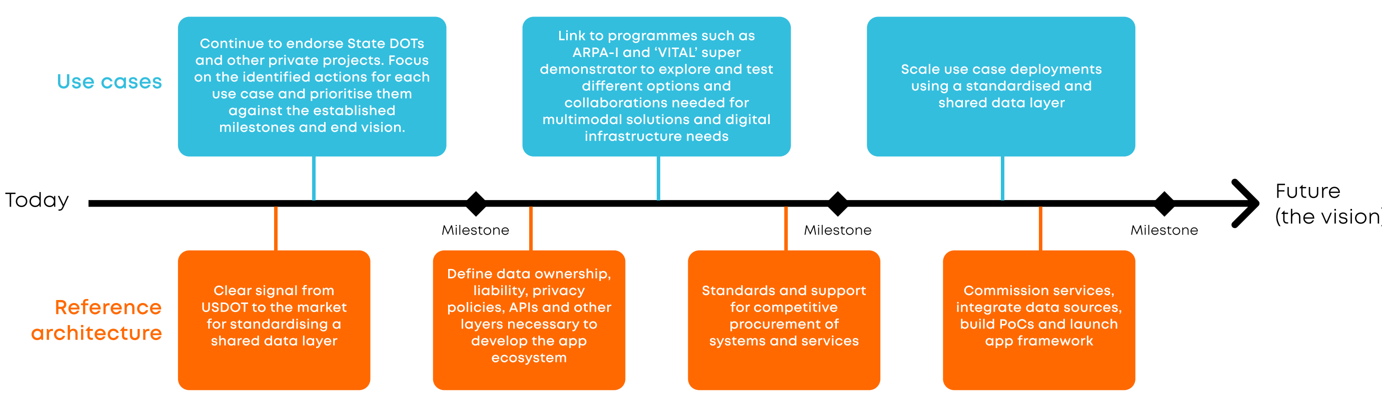
Vision

This will also include Vision Zero goals, however, in order to provide clearer guidance for years to come the vision should comprise of a realistic, achievable, and measurable goal that underpins all proof-of-concept initiatives, use case developments, and milestones. This vision should be agreed upon with stakeholders and serve as a reference point from the very beginning, towards which all efforts are aimed. Given the extended timeframe, the vision must also be adaptable to changes in technology, societal needs, and global conditions.

Roadmap

Similar to the vision, the roadmap with milestones also needs to be agreed upon with stakeholders. These milestones should clearly define what is to be achieved, and there should be a mechanism in place for quantitatively assessing whether the goals have been reached. It is crucial that these milestones are not only ambitious, but also achievable and subject to regular monitoring. State DOTs will be key stakeholders in this process, as they will be directly involved in distributing federal funds to specific implementation projects. A directives-based approach to the milestones could be a suitable method for engaging State DOTs. This would ensure an equal, nationwide commitment to achieving these milestones.

Short term actions not solely for USDOT (next 1-3 years)



7 Conclusion

The era of digital transformation within the transportation sector presents both immense opportunities and significant challenges. USDOT is at a pivotal juncture where the actions it takes today will significantly influence the trajectory of the US transportation sector for decades to come.

To successfully navigate this complex landscape, it is imperative for USDOT to promptly design and implement a comprehensive digital infrastructure strategy. This strategy should be grounded in a realistic and achievable vision, underpinned by measurable milestones. USDOT must also take a proactive approach to engaging key stakeholders, understanding their needs and incorporating their input into strategic decisions. Additionally, USDOT should prioritize those industry use cases with the highest impact and continue to foster innovation in these areas by promoting key national and state-driven projects. Establishing a defined reference architecture will provide crucial guidance on standard protocols, system design, and best practices, serving as a blueprint for scale-up and future initiatives.

In the development and deployment of this strategy, the creation of an ecosystem and landscape for scaling digital infrastructure is paramount. This ecosystem, built on cooperation, interoperability, and data-sharing, will accelerate the deployment of Intelligent Transport Systems (ITS) on a national scale. ITS will pave the way for more integrated, efficient, and safe transportation solutions, promoting equitable access to mobility and reduced environmental impact. By embracing open data and standardized protocols, this approach allows for greater innovation and inclusivity, ensuring a digital infrastructure that is adaptable to future changes and responsive to users' needs.

What is more, this digitally-enhanced transportation landscape presents significant economic opportunities, fostering job creation, industry growth, and infrastructure modernization. Thus, scaling up the digital infrastructure not only aligns with the vision of safety, equity, and sustainability but also serves as a powerful engine for economic development.

In this light, we urge USDOT to act decisively. The decisions made and actions taken in the immediate future will set the course for the transportation industry's evolution in the US, with broad implications for safety, efficiency, sustainability, and end user experience. By following the outlined steps and maintaining a forward-looking, inclusive approach, USDOT can shape a future where digital technology plays a transformative role in transportation, delivering immense benefits for all stakeholders. The present moment calls for firm action and courageous leadership.

ITS America stands ready to support USDOT in this work and will continue to convene digital infrastructure stakeholders to identify best practices, additional use cases, and appropriate milestones for digital infrastructure deployment, among other issue areas. ITS America firmly believes that USDOT is well-positioned to successfully lead these efforts, and that ITS America's membership is ideally situated to support the delivery of the next generation of digital transportation infrastructure.

About ITS America

The Intelligent Transportation Society of America was founded by Congress to advise the federal government on digital transformation in transportation and is the only organization that brings together private industry, government, researchers, non-profits, and communities to advance the deployment of intelligent transportation technologies to save lives, promote sustainability, and increase access and opportunity for all communities. Our vision is a better future transformed by transportation technology and innovation that is Safer, Greener, and Smarter for All. For more information, please visit www.itsa.org.

About Cambridge Consultants

Cambridge Consultants has an exceptional combination of people, processes, facilities and track record. Brought together, this enables innovative product and services development and insightful technology consulting. We work with companies globally to help them manage the business impact of the changing technology landscape.

We're not content to deliver business strategy based on target specifications, published reports or hype. We pride ourselves on creating real value for clients by combining commercial insight with engineering rigor. We work with some of the world's largest blue-chip companies as well as with innovative start-ups that want to change the status quo fast.

With a team of around 800 staff in Cambridge (UK), Boston, San Francisco and Seattle (USA), Singapore and Tokyo, we have all the inhouse skills needed to help you – from creating innovative concepts right the way through to taking your product into manufacturing.

cambridge consultants
Part of Capgemini Invent

UK — USA — SINGAPORE — JAPAN

www.cambridgeconsultants.com

Cambridge Consultants is part of Capgemini Invent, the innovation, consulting and transformation brand of the Capgemini Group. www.capgemini.com

Lit-R-017 v0.4 '2023 ITSA report'