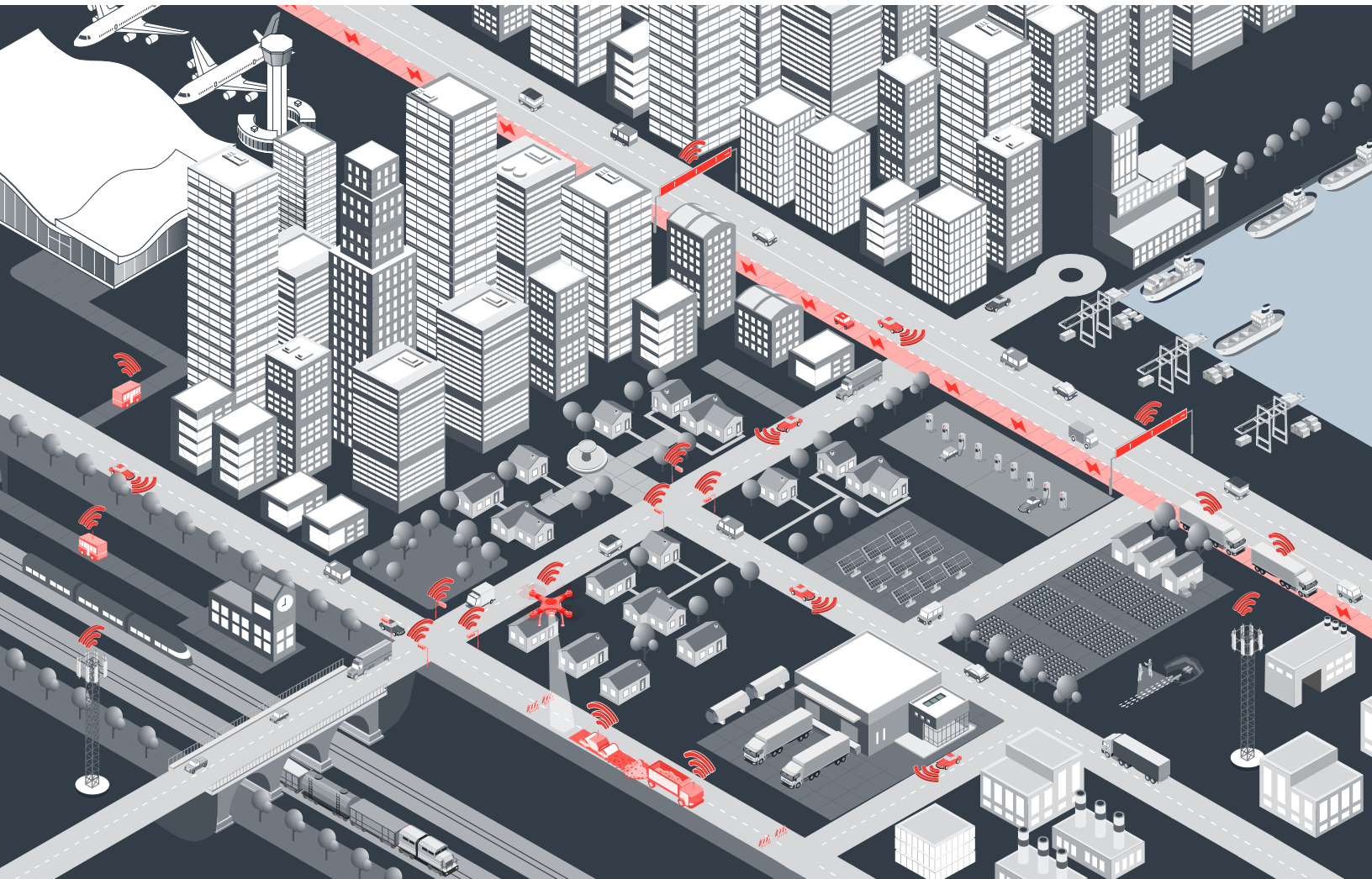
Digitalization of **Road Transport Infrastructure**

Establishing collaborative pathways to deliver the benefits of data-driven systems



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Connect with WSP experts

We would be delighted to share more of our insights with you; please do get in touch with our team via globalt&i@wsp.com or contact the team members noted at the end of the paper.

Foreword

People often take for granted the road transport system since it is omnipresent, but smooth operation depends on the interplay of multiple elements within the built environment. The increasing digitization of system components provides opportunities to address transport-related challenges, including road congestion and accessibility, through the integration of technology and data to create digital transport solutions. A comprehensive understanding of the interaction between the elements, with people at the core, is necessary to realize the potential benefits of digitalization—including enhanced safety, efficiency, inclusivity and sustainability.

In this paper, our technical experts and advisors apply a holistic perspective to explore pathways that government and regulatory bodies, road authorities and infrastructure operators, and solution and service providers can adopt to bring the greatest outcomes for all users.

Digital Transport Infrastructure encapsulates the integration of elements within transport systems through a digital lens, focusing on how stakeholders can leverage technology and data-driven approaches to meet policy goals and customer needs.

The performance of road transport infrastructure is facing ever-increasing demands, fuelled by steady population growth, rising urbanization rates, the adoption of more connected and automated vehicles, and more frequent extreme weather due to climate change.

Implementing system-wide digitalization requires a vision that seeks to implement the goals of digitalization through a whole-system perspective, strategic investment and a willingness to embrace continuous change. Collaboration across industries, disciplines and nations is essential to break down siloes and build resilient and adaptable transport networks for current and future generations. This process also calls upon those who advise, design, engineer and operate road infrastructure to prioritize the provision of inclusive, equitable and accessible digitized systems, making the benefits of digital transformation available to all.

Thank you for taking the time to explore our insights and guidance throughout this piece. We look forward to discussing your Digital Transport Infrastructure needs and collaborating to shape your successful journey.

Eric Peissel
Global Director, Transport and Infrastructure

The Road to Digital Transport Infrastructure

The evolution of road transport spans thousands of years, beginning with the invention of the wheel and progressing through significant technological milestones.

The wheel revolutionized transport by enabling the movement of goods and people over greater distances with reduced effort. Early roads were rudimentary, often little more than beaten paths, but they gradually evolved into more structured networks as civilizations advanced.

The arrival of the combustion engine in the late 19th and early 20th centuries marked a pivotal shift in road transport. Cars and trucks powered by internal combustion engines became the dominant mode of transport leading to the development of formalized road networks and basic traffic control and management systems. This era saw the introduction of paved roads and regulatory frameworks designed to manage the growing volume of vehicles. The fundamental principles of road transport remained relatively stable during this period, characterized by a more sophisticated system of vehicles, people and infrastructure working in tandem but largely as separate entities, with limited reliance on technology and data.

The late 20th century brought about a digital revolution that began to transform road transport. The integration of digital technologies introduced a level of complexity and interconnectivity previously unimaginable. Advanced computing, telecommunications and data analytics began to merge with traditional transport infrastructure through Intelligent Transport Systems (ITS) that were implemented to improve the operational capabilities of transport systems. Innovations such as real-time navigation and traffic monitoring emerged, enabling more efficient and responsive management of road networks.

Today, the boundaries between vehicles, roads, communication networks and the users themselves have blurred, creating a dynamic, evolving ecosystem. Gone are the days when vehicles and infrastructure function as separate entities. The synergy between technology, infrastructure and users will continue to drive innovations in road transport, especially as transport data becomes ubiquitous and more accessible. The success of these innovations—to facilitate the development of safer, greener and equitable transport systems—will greatly depend on the adoption of a whole-system approach that considers the interdependencies between technology, infrastructure and people.

This paper explores the next phase in the evolution of roads, outlining how Digital Transport Infrastructure can support enhanced outcomes and transform the way we all use our road transport networks. Our analysis recommends clear and robust pathways for stakeholders to realize this change.

Issues confronting road infrastructure projects

Driving the need for change and underpinning the areas to be addressed on the journey to digitalization are challenges and complexities of todays transport systems.

Safety performance plateauing

A general plateauing of safety metrics is limiting progress toward Vision Zero (the aim for zero deaths and serious injuries on road networks).[1] Aging infrastructure compounds these challenges as deteriorating road conditions and inadequate maintenance practices undermine the reliability and resilience of road networks. System designers[2] must prioritize proactive risk management strategies, investment in infrastructure upgrades and the adoption of cutting-edge technologies to address the root causes of accidents and improve overall safety performance.

Environmental challenges

The environmental impact of road transport infrastructure poses a significant threat to ecosystem health and human wellbeing through contributions to air and noise pollution.[3] Road transport constitutes the highest proportion of overall transport emissions globally—76% of the EU's transport emissions in 2021[4] and 79% of Canadian transport emissions in 2021.[5] Furthermore, the extensive land use associated with road construction and expansion encroaches upon sensitive ecosystems, disrupting natural habitats and diminishing local biodiversity.

Accessibility and inclusivity

Road transport infrastructure continues to act as a barrier to mobility for marginalized communities, thereby contributing to inequity. Users with disabilities (visible and non-visible), low-income households and underserved communities face disproportionate challenges in accessing transport services, leading to social isolation and economic disparity. Inadequate infrastructure investments in rural and remote areas drive mobility gaps and impede economic development, continuing cycles of poverty and underinvestment—over 1 billion of the global rural population remain unconnected to a good quality road network.[6] This too extends to digital transformation. Where non-digital alternatives are not available for services, such as toll payment or navigation, unbanked and digitally disadvantaged people can become excluded from certain routes and activities.[7]

Urbanization and population growth

Cities are swelling as more people move to urban centres in pursuit of economic, social and personal benefit; overall global population growth and associated urbanization is predicted to continue until at least 2050.[8] As a result, road networks are experiencing unprecedented levels of stress leading to chronic congestion and deteriorating air quality, compromising mobility and exacerbating social inequity. These issues underscore the urgent need for significant interventions that can mitigate the adverse impacts of urbanization and enhance the resilience and efficiency of road networks.

Financial constraints and material shortages

Governments around the world are facing a challenging financial situation with high interest rates and rapidly increasing costs in labour, materials and general service delivery. As a result, road transport infrastructure projects are grappling with constrained budgets and material scarcities limiting the capacity for governments to deliver on ambitious construction plans. Traditional construction methodologies are straining under these limitations causing stakeholders to seek innovative alternatives to navigate the delicate balance between quality, cost and resource availability.

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1 *Reported road casualties Great Britain, annual report: 2022*, UK Government, September 28, 2023.

2 System designers are people who in their professional work influence the planning, design, operation and maintenance of the road transport system. This diverse group includes policymakers, politicians and government officials, planners, engineers, road designers, vehicle manufacturers, trauma and hospital care providers, plus any other provider and enforcer of the road transport system. See the WSP Vision Zero brochure for more information.

3 *Noise pollution is a major problem, both for human health and the environment*, European Environment Agency, March 20, 2020.

4 "Greenhouse gas emissions from transport in Europe," European Environment Agency, accessed July 2024.

5 *Transportation in Canada: Overview Report 2023*, Transport Canada, July 7, 2023.

6 "Sustainable Transport, Sustainable Development," *Interagency report for second Global Sustainable Transport Conference*, United Nations, October 14-16, 2021.

7 Anne Durand et al., "Access denied? Digital inequality in transport services," *Transport Reviews* vol. 42, 07 May, 2021.

8 Hannah Ritchie, Veronika Samborska and Max Roser, "Urbanization," Our World in Data, accessed April 2024.

Transforming Road Transport Infrastructure

What is Digital Transport Infrastructure?

Digital Transport Infrastructure is the term emerging at an international level to highlight the evolution of the digitalization journey, building on historic global developments in ITS that have led to changes in how we perceive the convergence of technology, digitalization and transportation.[9] Currently, there is no consistent definition for Digital Transport Infrastructure due to the natural variance in interpretations and applications of Digital Transport Infrastructure across organizations and geographical boundaries. This has limited the capacity for co-ordinated development of Digital Transport Infrastructure, a topic that has emerged as a matter of discussion at national and international conferences and forums such as ITS America, the ITS World Congress 2022 in Los Angeles, and the ITS European Congress 2023 in Lisbon. ITS America has developed a strategy paper that considers digital transport.[10] Without a shared understanding, the risk of fragmented approaches and missed opportunities increases.

Why Digital Transport Infrastructure?

The priorities and goals for transport strategies today are increasingly shaped by challenges such as climate change and other global trends that impact communities. From government agencies and infrastructure operators to users of the system, the integration of digital technologies is becoming a critical component to shape modern road transport systems as transport authorities strive for enhanced efficiency, improved safety performance, sustainability and seamless multimodal connectivity. As digital solutions continue to evolve, their significance in road transport and other sectors will grow, bringing advanced data-driven decision-making and smarter infrastructure. In this era of rapid technological advancement, applying digitalization in road transport is not merely a matter of adaptation but a prerequisite for staying competitive and supporting sustainable and equitable solutions in an increasingly interconnected world.

For the purpose of examining how to develop modern, sustainable transport networks, we present our evolving definition of Digital Transport Infrastructure:

Digital Transport Infrastructure refers to mobility-related infrastructure shaped by technological and data-driven components, utilized to deliver whole-system outcomes driven by customer needs and policy objectives.

The concept offers pathways to guide transport organizations, operators and policymakers as they embark on or continue their digital transformation journeys.

9 "Intelligent Transport Systems Enable the Decarbonization of Road Transportation," WSP, 07 October, 2021.

10 "Digital Infrastructure Strategy Report," ITS America, 18 September, 2023.

Digital Transport Infrastructure vision

Intelligent Applications and Platforms

Applications and platforms that provide real-time information and services to users, such as navigation aids, traffic updates, and multimodal transport options through Mobility-as-a-Service.

Co-operative, Connected, and Automated Mobility

Infrastructure to support vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-everything (V2X) communications, coupled with automation to enhance vehicle co-ordination.

Intelligent Infrastructure

Infrastructure that integrates fixed and wireless communication technologies, such signals and sensors to improve traffic management, control, and operations.

Intelligent Operations

Hubs converging people and technologies, such as Traffic Management Centers and Security Operations Centers, that manage and operate road networks, while coordinating real-time responses.

ENABLERS

- People and collaboration
- Data and AI
- Cloud computing
- Connectivity
- Automation
- Cybersecurity

OUTCOMES

- Improving safety performance
- Driving greener and more sustainable mobility
- Improving access to services and opportunities; driving inclusivity and reducing inequity
- Improving efficiency
- Multimodal integration
- System resilience

Figure 1 – An emerging vision for Digital Transport Infrastructure

Global technology trends driving Digital Transport Infrastructure

Underpinning digital transformation of road transportation are four key megatrends. These are driving changes across all aspects of society but form an integral enabler to realizing Digital Transport Infrastructure.

Developments in connectivity, data processing and computing

The evolution of wireless communication standards has been critical to increasing data transfer volumes, speeds and latency to the service level needed to support digital road networks. The Internet of Things (IoT) plays a significant role by interconnecting various devices, enhancing data collection and improving real-time responses within transportation systems. Additionally, the adoption of cellular technologies such as 5G is enabling low latency high-bandwidth connections for large-scale vehicle-to-everything (V2X) communications.[11] Satellite and low-power wide-area networks (LPWAN) has extended these technologies to remote areas where connectivity is absent or difficult to obtain. The pace of development shows no sign of slowing; the next iteration in 5G-Advanced is already in development and is anticipated to support advanced applications of AI (such as machine learning, sensing, and robotics) across wireless networks.[12] Furthermore, quantum computing is emerging as a transformative technology offering unprecedented processing power to handle complex computations and massive datasets, potentially revolutionizing data processing and decision-making.

Energy

The global demand for public EV charging points and the introduction of biofuel and hydrogen stations for public transport operators are adding complexity to the infrastructure that supports road transportation. The energy mix on the road network is anticipated to rapidly diversify, bringing with it new safety and operational considerations.[13] To combat charging worries and range limitations, some areas are experimenting with embedding energy infrastructure into the road environment through new operating regimes such as e-Highways.

Artificial intelligence (AI)

With AI legislation being actively developed and implemented across the world, the legal and regulatory hurdles that face AI are beginning to be addressed, removing many of the limitations placed upon its application seen previously. Noted as a key technology for strategic development by the UK Science and Technology Framework,[14] AI has the potential to transform ways of working across all industry and is already altering user expectations of digital services.

The application of AI has brought early innovations within transport operations that can benefit any activity where pattern recognition is critical, such as traffic monitoring, incident detection, signal control and more.[15] AI can be particularly useful for asset management where applications lie in building a comprehensive picture of asset condition, identifying failure points and the root cause of issues. This helps to plan effective reactive maintenance schedules to improve asset availability and reliability.

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11 "Key technologies to boost the digitalisation of transport," *European Commission: Digital Strategy*, European Commission, accessed April 2024.

12 "5G-Advanced Explained," Nokia, accessed April 2024.

13 "Road transport," *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach*, International Energy Agency, September 26 2023.

14 *Science and Technology Framework*, UK Department for Science, Innovation and Technology, accessed May 2024.

15 "Artificial Intelligence in Proactive Road Infrastructure Safety Management," *ITF Roundtable Reports*, No. 187, International Transport Forum.

Automation

Automation is being leveraged to achieve greater efficiency and cost effectiveness in road maintenance services, notably in snow removal, agriculture, and asset condition investigation.

On a larger scale, automated driving is generating early use cases for businesses, notably in estates and depots, local delivery routes, freight, and public transport and taxi services—before the widespread application to private fleets and personal vehicles. This seismic change in mobility will be driven by business needs, as the private sector looks to solve issues such as driver shortages and safety improvements.

These developments will bring about new linkages and working relationships between governments, their agencies, vehicle manufactures and operators, and road authorities in ways that have not been seen before in the roads sector.

The convergence of automation with advanced connectivity will transform vehicles from isolated machines into interconnected components of a larger network, seamlessly communicating with each other and road infrastructure.

Pathways to Adopt and Implement Digitalization

WSP's defined vision is applied in this paper to enable the achievement of clarity and coherence amid the complexity of the digital transport infrastructure landscape.

Framing the journey through a whole-system approach

As outlined earlier in this paper, the road transport system is becoming even more complex with the blurring of lines between traditional road infrastructure and integrated digital approaches. The transition from analogue to digital road networks requires a whole-system approach to understand the impacts and dependencies between people, processes, place, data, technology and services. This holistic view enables system designers to identify and mitigate adverse impacts, providing for a safer, more equitable and more environmentally conscious system.

Introducing a new technology for example, may create an unintended negative impact in the location it was intended to serve, especially if it has not been considered holistically. Considering technological aspects within the wider whole-system approach sets the stage for achieving of the most beneficial outcomes (Figure 2).

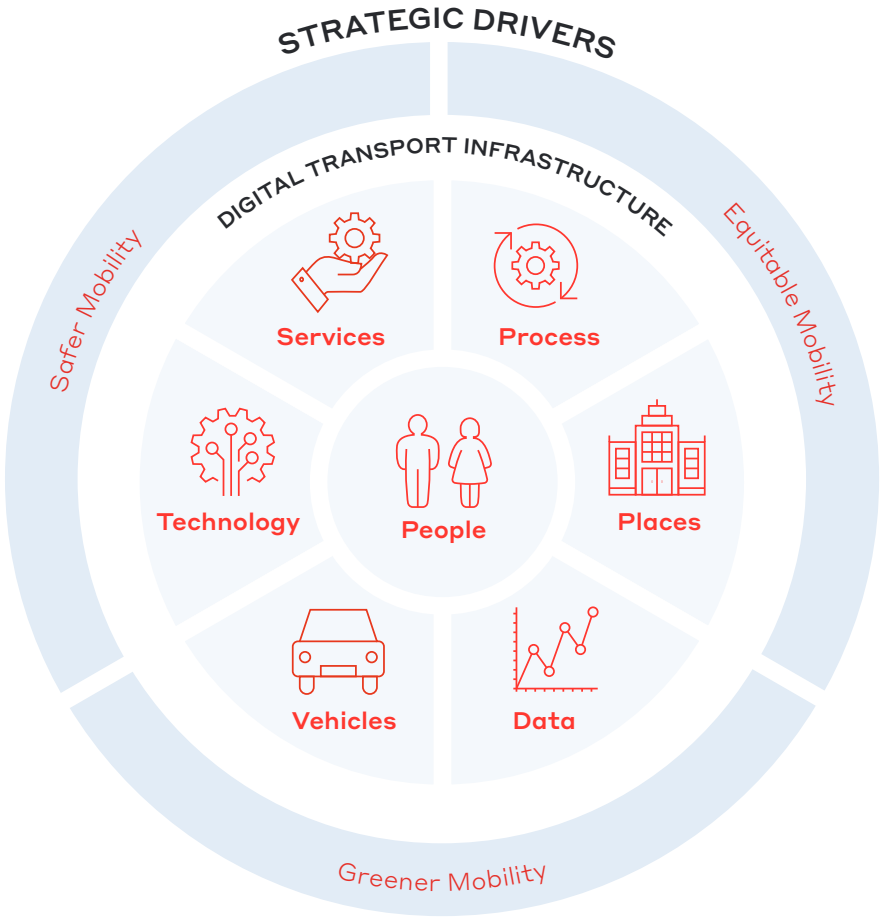
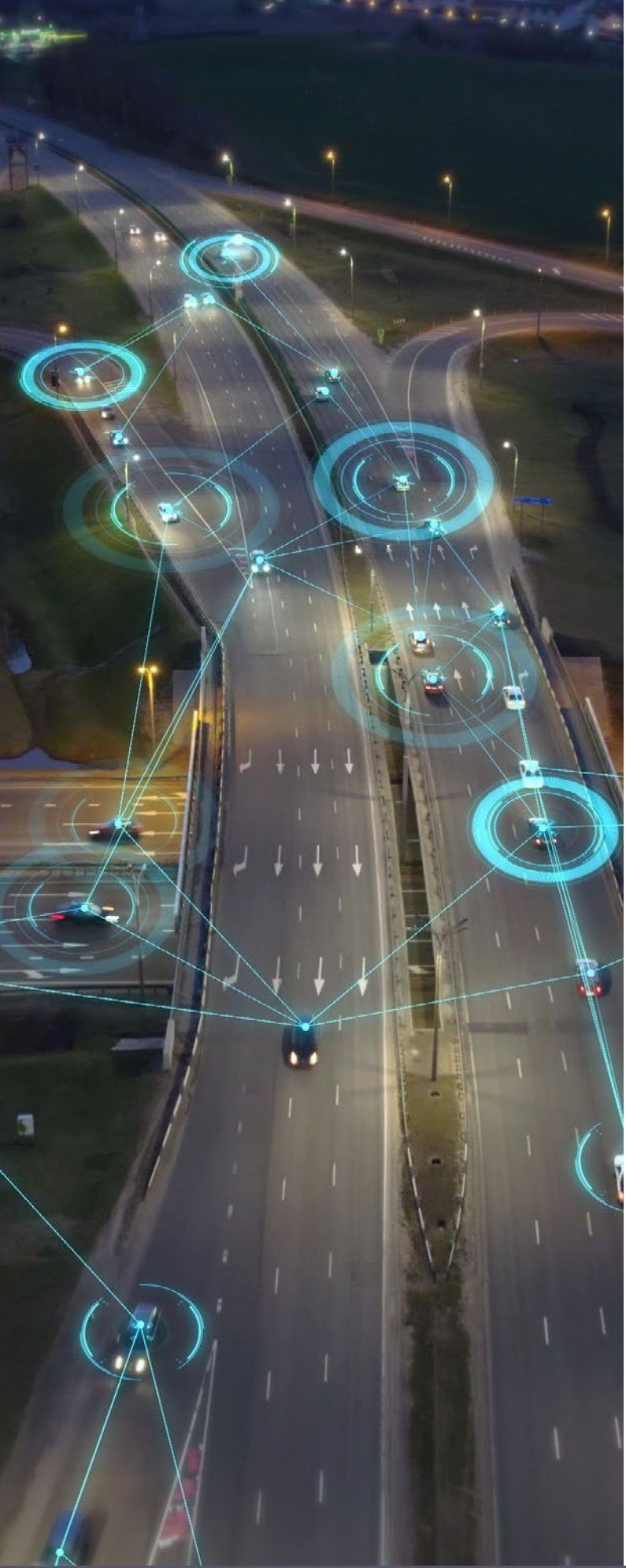


Figure 2 – Considering technological aspects within the whole-system approach to Digital Transport Infrastructure



CASE STUDY

Digital Roads, National Highways, UK

In response to the evolving landscape of the highways sector, National Highways identified the critical need for digital transformation. Recognizing the challenges of achieving ambitious targets such as Net Zero emissions and Vision Zero for road safety, there was an imperative to transform the strategic road network. WSP was commissioned to create a vision for digital transformation of the strategic road network over the next 30 years, setting the strategy that would align the organization and frame transformational change. The project successfully took Digital Roads from concept development stage to public launch with it now forming a flagship program within National Highways and an industry-level vision that draws together clients and suppliers across the highways sector. The benefits of Digital Roads permeate all aspects of design, construction, operation and customer experience and range from enabling safety improvements through to reducing carbon emissions, supporting a safer, smoother and greener road network.

From analogue to digital

Transport infrastructure has been designed, constructed, operated and maintained via well-established standards, processes and methodologies in an analogue world—based on written words, drawings and other physical documents. Developments into the digital world are accepted in areas such as use of 3-D modelling for design, and more recently in construction. Embracing technology and adopting a data-centric approach creates significant opportunities for efficiency and consistency—data created at the start of a project runs through to delivery and operations (often referred to as a "golden thread").

Realizing the benefits from this golden thread relies on changes to behaviours and commercial arrangements, to move away from a reliance on paper-based outputs to a digital environment.

From assets to services and outcomes

The sector is also witnessing a shift from asset-centric to service-led and outcome-oriented approaches to project delivery. As demands for tangible results and measurable benefits from infrastructure investments grow, traditional output-based metrics are increasingly viewed as inadequate measures of project success. Instead, stakeholders are called upon to demonstrate the broader societal impacts and long-term value proposition of transportation projects, aligning project objectives with strategic goals and stakeholder priorities. By embracing outcomes-driven approaches, road infrastructure projects can enhance accountability, transparency, and stakeholder engagement, fostering a culture of innovation and continuous improvement that drives positive socio-economic outcomes and delivers lasting benefits to communities.

As stakeholders navigate the ever-evolving landscape of technological advancements and digitalization to develop digital infrastructure, there is a pressing imperative for a shift in thinking and approach.

Achieving successful outcomes through effective transition requires an understanding of readiness, capability and potential. Underpinned by a whole system, a set of principles can then be established to help stakeholders navigate seamlessly throughout this transition.

Understanding readiness, capability and potential

When embracing digital solutions, it is critically important to recognize and understand the starting point. Embracing Digital Transport Infrastructure can alter how transportation systems are operated, managed and delivered; understanding the current situation across the entire road transportation system is essential to achieve the intended benefits and to mitigate potential risks. Stakeholders must undertake a comprehensive baseline assessment to gauge the readiness of the entire system, evaluate their existing capabilities and understand the potential for digital transformation to solve problems, transforming gaps into opportunities.

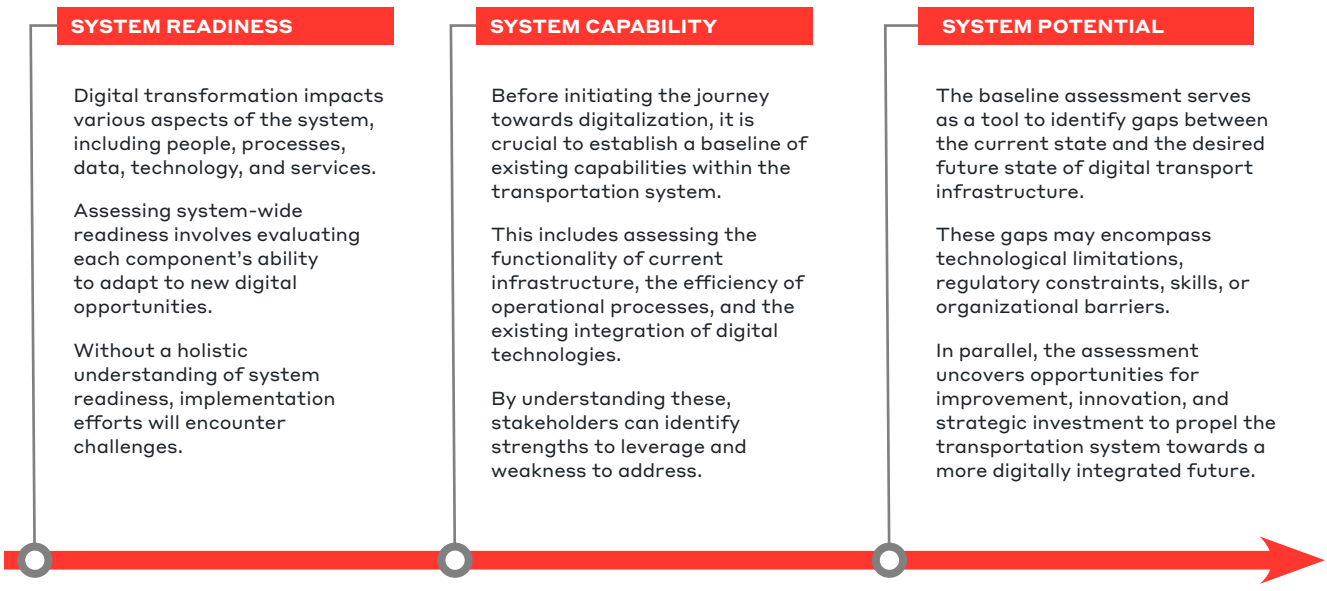


Figure 3 – Establishing the starting point through a readiness assessment

Pathways underpinning the journey

The pathways outlined in this section provide structured approaches for transport organizations, operators and policymakers to successfully navigate their digital transformation journeys. Each pathway offers specific strategies to leverage technological and data-driven components ensuring that Digital Transport Infrastructure aligns with customer needs and policy objectives. Following these pathways will help stakeholders accelerate system-wide development.

The pathways introduced in Figure 4 and explored in the following pages, form a framework to progress the journey to Digital Transport Infrastructure. The following pages build on each pathway to outline considerations and opportunities as an indicative route for digital transformation of road transportation. The pathways are designed to be flexible and adaptable, recognizing some pathways may be emphasized more than others dependent on the different contexts and challenges of the users' specific needs and circumstances.

The numbering represents a way of identifying each as a separate consideration in the journey to Digital Transport Infrastructure, rather than a particular order to follow.

PATHWAY 1

Policy and Regulatory Frameworks
Establishing policies and regulations that incentivise the adoption of Digital Transport Infrastructure. This includes setting standards for digital systems, data privacy, cybersecurity, and interoperability.

PATHWAY 2

Governance and Enterprise Frameworks
Creating a structured framework to coordinate activities among diverse stakeholders from both public and private sectors. This aligns all parties to share objectives and risks, fostering genuine collaboration, mutual accountability, and a balanced approach to financial responsibilities.

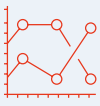
PATHWAY 3

Research and Development (R&D)
Investing in R&D to develop innovative technologies and solutions for Digital Transport Infrastructure. This can include funding research institutions, startups, and technology firms working on digital transportation systems.

PATHWAY 4

Infrastructure Delivery
Upgrading existing road infrastructure to support digital technologies, such as installing sensors, cameras, and communication networks. This also involves integrating digital infrastructure with existing transportation systems.

PATHWAY 5



Data Collection and Analytics
Implementing systems for collecting, processing, and analyzing data from digital infrastructure. This data can be used to optimize traffic flow, improve safety, and enhance transportation planning.

PATHWAY 6

Public Awareness and Education
Educating the public about the benefits of Digital Transport Infrastructure and promoting behaviour change. This can include campaigns to encourage the use of digital tools for navigation, traffic management, and vehicle connectivity.

PATHWAY 7

Capacity and Capability Building
Building the technical capacity and capability of government agencies, transportation professionals, and other stakeholders to plan, implement, and manage Digital Transport Infrastructure effectively.

PATHWAY 8

International Partnerships
Collaborating with other countries and international organizations to share best practices, standards, and technologies for Digital Transport Infrastructure.

PATHWAY 9

Demonstration Pilots and Trials
Launching pilot projects to demonstrate the feasibility and benefits of Digital Transport Infrastructure. These projects can help build confidence among stakeholders and encourage broader adoption.

PATHWAY 10

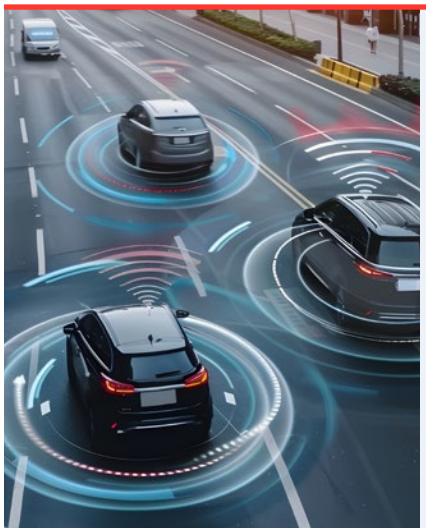
Continuous Monitoring and Evaluation
Continuously evaluating the performance of Digital Transport Infrastructure and making adjustments as needed. This involves monitoring key metrics, soliciting feedback from users, and adapting strategies based on lessons learned.

Figure 4 – Pathways enabling the transition to Digital Transport Infrastructure

PATHWAY 1
Policy and Regulatory Frameworks

Policy and regulatory frameworks play a crucial role in ensuring adherence to defined norms across technologies, systems, processes and people within Digital Transport Infrastructure. While they promote investment confidence, interoperability, compatibility, compliance, safety, security and resilience, they also necessitate careful consideration of potential downsides. These include the time required to establish and implement robust policies, which can sometimes delay innovation. Balancing these aspects is essential to create a stable and predictable environment for market development, enabling long-term planning and investment decisions while fostering innovation within regulatory boundaries.

Theme	Short term	Medium term	Long term
Investment confidence	— To ensure broad support for policy interventions, engage with key stakeholders, including government bodies, private sector participants, and the public. — Gather stakeholder input and seek consensus on proposed measures.	— Foster collaborations between public and private sectors to encourage investment and build certainty around legal and operational aspects.	— Establish mechanisms for continuous monitoring and adaptation of policies to keep pace with technological advancements and challenges.
Interoperability and compatibility	— Identify and establish standards to ensure basic interoperability and compatibility across systems, without hindering innovation.	— Develop migration paths to support the integration of legacy systems with new digital infrastructure.	— Collaborate with international communities to harmonize standards globally, thereby promoting seamless interoperability across borders.
Safety, security, and resilience	— Promote common safety, security and privacy standards, and resilience practices to protect users, systems and critical infrastructure. — Invest in people and skills, deepening partnerships between government, academia and industry.	— Support investment in designing and building resilient infrastructure that can withstand security threats, ensuring minimal disruption.	— Shift industry attitudes from a reactive to a proactive safety and security mindset, while fostering a common language across disciplines.



CASE STUDY

Connected Services Architecture, UK

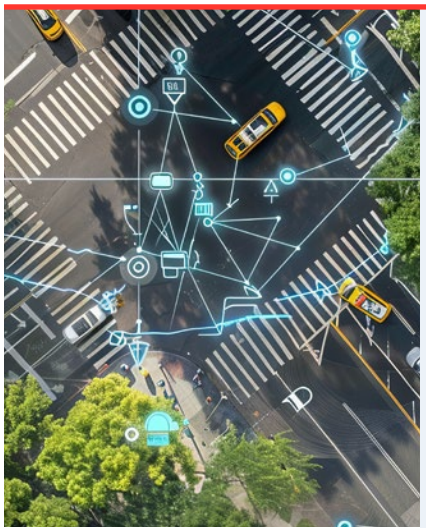
To address the growing need for a robust connected services market, the UK Connected Services Architecture project has embarked on a multi-year research and development journey. Tasked with the crucial role of guiding, standardizing, legislating, and regulating, the UK Department for Transport aims to cultivate a vibrant ecosystem in this domain. A strategic business case is currently in development, focusing on pinpointing interventions that harness vehicle connectivity and digital infrastructure. This initiative aligns with the UK's road policy objectives, aiming to drive advancements that will support a safer, more efficient, and technologically integrated road network.

PATHWAY 2

Governance and Enterprise Frameworks

Governance involves a structured framework that coordinates activities and encourages collaboration among diverse stakeholders. Public-private partnerships (PPP) are particularly effective for Digital Transport Infrastructure initiatives when they operate as true joint enterprises. This model aligns all parties to share objectives and risks, fostering genuine collaboration, mutual accountability and a balanced approach to financial responsibilities, avoiding potential issues seen in models where one party seeks disproportionate financial gain.

Theme	Short term	Medium term	Long term
Structured frameworks and co-ordination	— Establish dedicated governance bodies to oversee development, and outline roles and responsibilities between bodies. — Set the optimal level of private and public sector participation and risk transfer.	— Implement systems and processes to regularly monitor and evaluate the effectiveness of coordination efforts, allowing for adjustments.	— Work toward developing global frameworks for coordination to facilitate international collaboration.
Integration with broader policy objectives	— Set long-term policy goals that integrate Digital Transport Infrastructure with broader transport and societal objectives.	— Conduct periodic reviews of current policies to ensure alignment.	— Promote international policy integration to facilitate global cooperation and standardization.
Co-operation, growth, and stability	— Reduce entry and operational barriers for public and private stakeholders.	— Implement incentive programs to encourage investment and long-term participation.	— Establish institutional stability through long-term agreements and policies that support continuous growth.



CASE STUDY

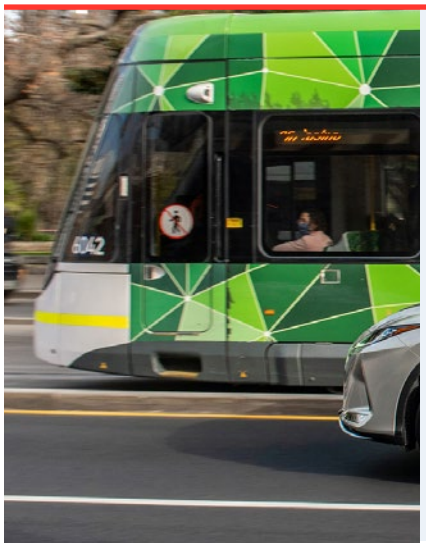
Data for Road Safety, Europe

In response to the evolving landscape of road safety and data management, the Data for Road Safety initiative emerged as a pivotal platform under the EU ITS Directive. Recognizing the necessity of comprehensive data sharing to enhance road safety, this collaborative effort brings together industry partners in transportation, mobility, and traffic data domains alongside public authorities. WSP has been responsible for technical leadership of the digital platform that facilitates the exchange of critical safety-related traffic data, such as collisions and near misses. In doing so, we have contributed to setting a governance model that promotes cooperation across borders and sectors.

PATHWAY 3
Research and Development (R&D)

R&D, underpinned by innovation, plays an increasingly crucial role in advancing new ideas, solutions and technologies that shape Digital Transport Infrastructure, such as digital connectivity, data platforms, automation and alternative energy. R&D also supports the development and deployment of solutions in a manner that results in better ways of doing things, solving problems and delivering positive outcomes.

Theme	Short term	Medium term	Long term
Targeted research	— Contribute to filling research gaps by identifying high-impact priority problems that require attention.	— Identify future technology trends and new user requirements to develop future R&D portfolios.	— Create partnerships with academia and other sectors to share cross-industry insights and best practice.
Testing to deployment	— Provide seed funding or grants for pilot projects and proof-of-concept studies to kickstart collaborative research and test scenarios. — Participate in technology trials alongside a general improvement in awareness of technology development and possible applications.	— Provide dedicated funding routes and practical environments for the experimentation of innovative technologies and solutions.	— Provide guidance for designing, planning and executing trials, while creating scalable scenarios to inform future deployments.
Innovation journey	— Baseline innovation maturity to identify and obtain the tools and capability necessary to innovate. — Organize joint workshops with partners to identify common research priorities and areas of interest. — Explore business models to support innovation.	— Advance collaborative research projects to define marketplaces. — Create open innovation platforms and centres of excellence, to crowdsource innovative solutions from a global community of researchers and entrepreneurs.	— Fast-track certain innovations to ensure they are put into practice at speed and create a management system for all innovations to be tracked through their stages of maturity.



CASE STUDY

Australian Integrated Multimodal Ecosystem (AIMES), Australia

WSP developed the AIMES in collaboration with the Victorian Government, The University of Melbourne's School of Engineering, and 25 other leading industry partners. The world's first multimodal connected transport laboratory, also known as the 'living laboratory' includes a 6km^2 grid of live streets in Northern Melbourne providing a true-to-life complex environment for testing emerging technologies. Testing focuses on multimodal transportation systems consisting of connected vehicles, connected roadways, connected city logistics, connected public transportation and connected pedestrians and cyclists.

PATHWAY 4
Infrastructure Delivery

In transitioning to Digital Transport Infrastructure, the effective delivery of infrastructure forms a focus for reshaping transportation systems and achieving long-term objectives. Infrastructure delivery as a pathway ensures stakeholders not only build on immediate efficiency gains but also lay the foundation for transformative advancements. This approach underscores the critical importance of infrastructure in fostering sustainable, resilient and inclusive transportation networks.

Theme	Short term	Medium term	Long term
Funding mechanisms	— Utilize PPPs for immediate investments in upgrading existing infrastructure.	— Invest in R&D grants for innovative technologies and develop partnerships. — Embrace commercial and procurement models which incentivize innovation in delivery.	— Invest in research and pilot projects for emerging transportation technologies, including PPPs and venture capital funding.
Design and construction	— Thread data through the delivery lifecycle working toward digital design as the norm.	— Automation of design and construction to become the norm in delivery. — Incorporate internet of things (IoT) and data analytics into assets for proactive and predictive maintenance and management.	— Design flexible infrastructure that can adapt to evolving technology requirements (such as dedicated lanes for automated vehicles). — Embed digital twins into the outset of road transportation projects.
Standardization	— Implement interoperable payment systems and standardize signage and wayfinding for seamless travel experiences.	— Work based on common data standards and protocols that enable interoperability among various smart systems.	— Establish flexible design standards and protocols to accommodate a wide range of future transportation technologies.

CASE STUDY

SMP Alliance Connected Site, UK

Construction, the biggest industry in the world economy, has seen remarkable advancements over the centuries but few productivity gains in recent decades. WSP was commissioned by the UK SMP Alliance to develop and deliver a transformation project for construction of road improvement projects. The Connected Site concept that emerged provided the platform to deliver targeted construction innovations addressing challenges faced by projects limiting productivity. WSP delivered a full end-to-end service ranging from initial research and analysis, through to solution development and deployment. The Connected Site paved the way for a step change in productivity and delivery efficiency, as well as enabling a safer, smoother and greener future of construction. Read more in our paper here.

PATHWAY 5
Data Collection and Analytics

Data plays a pivotal role in shaping the landscape of Digital Transport Infrastructure. Its significance lies in enabling informed decision-making, optimizing operational efficiencies and enhancing user and customer experiences. From traffic flow management to predictive maintenance, data-driven insights empower transportation authorities and service providers to adapt swiftly to evolving demands and improve overall system performance. As organizations recognize the transformative potential of data, there arises a clear appetite for services that use data supplied by multiple systems, bringing forth challenges around privacy, security and trust.

Theme	Short term	Medium term	Long term
Operational efficiency, optimization, and decision making	— Support the pilot and deployment of easy-to-use digital tools and generate early insights for immediate improvement. — Promote, use and make available open-source data where viable.	— Develop real-time data processing capabilities to enable quicker decision making. — Establish a common language for decision makers and practitioners.	— Value data as an asset in its own right alongside physical assets, informing on future investment decisions.
User and customer experience	— Work with users and customers to understand behaviours, needs, and expectations on how they intend to use data and for what purpose.	— Ensure users and customers receive and use data that is fit for purpose relative the desired use case in question.	— Seamlessly integrate various data sources, services, analytics and insights across assets to provide a unified user experience.
Privacy, security, and trust	— Establish and disseminate clear data privacy policies. — Build a data governance framework. — Build a cyber security culture through awareness and action of basic cyber security measures.	— Comply with relevant data protection regulations and industry standards. — Build commercial trust across external interfacing systems and organizations.	— Build capabilities and skills across cyber security and information rights.

CASE STUDY

MaaS Delivery, West of England Combined Authority, UK

In response to urban transportation needs, the West of England Combined Authority, funded by the Department for Transport's £28m Future Transport Zone, is leading a Mobility as a Service (MaaS) solution for the Bristol and Bath city-region. WSP oversees this MaaS programme from inception to operational delivery.

Our customer-centric approach began with a data-driven strategy to map nine typical customer personas. This framework was validated through community engagement, forming a MaaS 'SuperUser' panel to guide requirements, design, security, and delivery. Insights from this analysis identified journey pain points and opportunities for MaaS support, which has resulted on enhancing the customer experience and improving urban transport efficiency.

PATHWAY 6
Public Awareness and Education

Without understanding the needs of existing and future users of the system, it is challenging to build a robust business model for any sort of service-based intervention that is resilient to external forces and change. Public awareness and education can encourage people's behavioural adaptation to new digital technologies, ensuring supporting access while addressing concerns that may hinder desired outcomes. Informed people and organizations are more likely to support policies and investments in digital infrastructure through community engagement, which fosters collaboration and ownership. This pathway allows systems to be designed and delivered in a holistic manner that meets stakeholder needs effectively.

Theme	Short term	Medium term	Long term
Stakeholder engagement and support	— Conduct stakeholder identification exercises and apply a design-led approach. — Develop and maintain engagement channels with stakeholders.	— Conduct public consultations for local and national infrastructure and service delivery opportunities. — Implement transparency initiatives to build trust and create collaboration platforms.	— Develop long-term partnerships with stakeholders through governance models (such as PPP).
Behavioural Adaptation and Equitable Access	— Launch awareness campaigns informing potential users about new digital technologies and the anticipated benefits for communities.	— Identify and address immediate concerns related to equitable access and use of digital technologies. — Embed physical and digital accessibility to design practices.	— Regularly monitor and evaluate the impact of behavioural adaptation and accessibility initiatives to ensure long-term success and inclusivity.

CASE STUDY

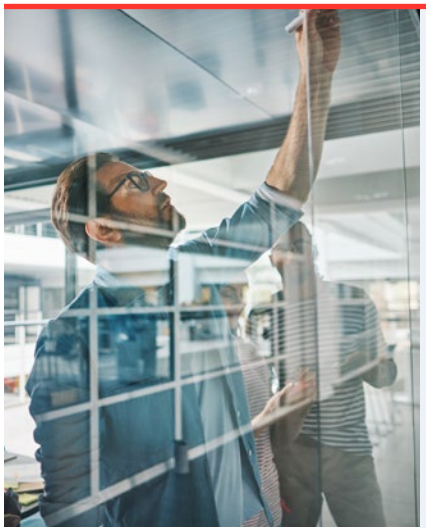
The Utah Transit Authority (UTA) Innovative Mobility, USA

WSP supported The Utah Department of Transportation (UDOT) in creating an innovative mobility strategic plan which incorporated the launch of an automated shuttle demonstration project. Critical to this exercise was the stakeholder planning and engagement that took place. Once identified, targeted surveys were conducted to gain an understanding of local attitudes towards autonomous transportation. The responses helped to mitigate any potential safety concerns and ensured the program was responsive to local needs and procedures. The public engagement on this trial built upon local enthusiasm for autonomy in transportation networks and contributed positively to the overall success of the program.

PATHWAY 7
Capacity and Capability Building

By prioritizing the development of skills and knowledge within the workforce, stakeholders not only enhance the immediate implementation of digital solutions but also cultivate a foundation for long-term success. This emphasis underscores the vital role of investing in human capital to navigate complexities and seize opportunities in the evolving transportation landscape. Empowering individuals and organizations through development of capacity and capability paves the way for a future where innovation drives efficiency, safety and inclusivity across transportation systems.

Theme	Short term	Medium term	Long term
Leadership and change	— Establish clear leadership roles and responsibilities for Digital Transport Infrastructure projects, ensuring alignment with organizational goals and priorities. — Implement change management initiatives to raise awareness, build support, and foster buy-in.	— Create a culture of innovation, adaptability, and continuous improvement. — Invest in leadership development programs to nurture change leaders who can inspire, motivate, and guide teams through digital transformation.	— Embed a culture of continuous learning, innovation, and sustainability. — Establish mechanisms for organizational learning and knowledge management.
Skills development and training	— Identify immediate skill gaps and training needs among individuals involved in Digital Transport Infrastructure projects. — Launch technical training programs to build competency.	— Strengthen technical expertise and cross-functional collaboration skills among practitioners. — Introduce advanced training modules on emerging technologies, regulatory frameworks and strategic planning.	— Develop a learning ecosystem to stay abreast of evolving technologies, regulations and industry trends. — Establish professional certification programs in related disciplines to recognize and validate expertise.
Inclusivity and neurodiversity	— Create an inclusive environment where diverse perspectives and voices are valued and integrated into decision-making processes. — Implement conduct awareness programs to eliminate unconscious bias and stereotyping.	— Promote diversity at all levels of Digital Transport Infrastructure leadership and workforce. — Implement neurodiversity initiatives to increase representation of underrepresented groups in leadership positions.	— Embed diversity and inclusion within workplace cultures, organizational values and practices. — Extend engagement to the wider community, building partnerships and greater collaboration for Digital Transport Infrastructure outcomes.



CASE STUDY

Cyber Futures, National Highways, UK

National Highways launched a cyber security transformation initiative called Cyber Futures. The mission of this programme was to enhance cyber security to facilitate the adoption of secure, digitally enabled roads for customers by delivering innovative and proactive cyber security capabilities. WSP led the convergence of safety and security, aiming to develop a common vocabulary, build awareness and understanding, and adopt best practice from both disciplines. Further to this, WSP control room experts assisted National Highways in creating credible and immersive scenarios to elevate the understanding of operational staff where security is an integral part of decision-making processes.

PATHWAY 8
International Partnerships

By nurturing partnerships across borders, stakeholders not only harness a diverse pool of expertise and resources but also foster a global ecosystem of innovation and best practice exchange. This collaborative approach underscores the interconnected nature of transportation systems and the shared responsibility in addressing common challenges. By working together, nations can accelerate the adoption of digital solutions, harmonize standards and address regulatory barriers, ultimately paving the way for seamless and interconnected transportation networks that transcend geographical boundaries, enhance efficiency and promote sustainability on a global scale.

Theme	Short term	Medium term	Long term
Partnerships	— Identify key international partners for collaboration on Digital Transport Infrastructure. — Host networking events and forums to facilitate connections and initiate discussions among potential partners. — Establish initial partnership agreements.	— Strengthen and formalize partnerships with international collaborators. — Form strategic alliances and consortia to pursue joint funding opportunities. — Establish joint steering committees or advisory boards to provide oversight and guidance for collaborative Digital Transport Infrastructure efforts.	— Sustain and expand partnerships with international collaborators to address evolving challenges and opportunities. — Establish joint ventures or consortia for long-term investment and management of infrastructure and services.
Knowledge sharing	— Share existing knowledge, best practices, and case studies across countries and regions. — Host webinars, seminars and knowledge exchange sessions featuring international experts. — Establish online platforms or repositories for sharing research findings, reports and technical documents.	— Establish mechanisms for ongoing knowledge sharing and collaboration among international stakeholders. — Create a community of practice for Digital Transport Infrastructure professionals to exchange ideas, resources and best practices. — Publish joint publications, reports, research findings and lessons learned from collaborative Digital Transport Infrastructure projects.	— Establish Digital Transport Infrastructure as a global knowledge hub for sharing insights, experiences and best practices in sustainable transportation. — Host international conferences, expositions and summits to showcase Digital Transport Infrastructure innovations and facilitate cross-border learning and collaboration.

CASE STUDY

International Bridges Toll System, USA and Canada

The International Bridges Toll System Project involved three independent international bridge operators with different ownership structures and unique operating tolling configurations. WSP assisted this joint bi-national project to improve communications and establish common technical inter-operability across bridges conforming to differing national and state/regional standards and operating under differing financial regulations. A new mobile app was introduced to streamline toll payment across the international bridges, regardless of the operator or currency used. The project exemplified the administrative, technical and financial challenges to international collaboration in transportation services.

PATHWAY 9
Demonstration Pilots and Trials

Demonstration projects provide tangible examples of the potential benefits and feasibility of digital solutions, fostering buy-in from stakeholders and paving the way for broader adoption. By showcasing successful implementations in real-world settings, demonstration projects not only inspire confidence but also offer valuable insights into the practical challenges and opportunities of digital transformation. Furthermore, they serve as platforms for collaboration and knowledge exchange, enabling stakeholders to learn from each other's experiences and collectively drive progress toward a future of interconnected, efficient and sustainable transportation systems.

Theme	Short term	Medium term	Long term
Facilitating the ecosystem	— Facilitate stakeholder workshops and forums to foster dialogue, identify shared goals and build partnerships. — Establish mechanisms for ongoing communication and collaboration, such as stakeholder working groups and online platforms.	— Nurture existing talent through support programs such as incubators, accelerators, and innovation labs. — Advocate for policies and regulatory frameworks that enable environments for innovation and investment.	— Create collaborative mechanisms and support structures to sustain ecosystem development beyond the lifespan of individual projects. — Gain long-term community support by keeping stakeholders and communities informed.
Delivery framework	— Align the scope, objectives and success criteria of demonstration projects with broader strategic goals. — Streamline project planning and execution. — Establish clear roles and responsibilities.	— Integrate continuous improvement mechanisms, such as performance reviews and post-project evaluations. — Invest in capacity building and training programs to develop project management and technical skills.	— Establish communities of practice and knowledge sharing platforms to facilitate peer learning and exchange of experiences among project practitioners.
Scaling strategy	— Conduct market analysis and stakeholder consultations to identify opportunities and challenges for scaling. — Develop a preliminary scaling strategy outlining expansion pathways, target markets, and resource needs. — Engage with potential scaling partners to build support and alignment for future expansion efforts.	— Conduct in-depth market analysis and feasibility studies to assess scalability. — Develop scaling roadmaps with clear milestones, timelines, and resource allocation plans for expanding successful projects. — Engage with external funding sources, and development partners to secure financing and support for scaling initiatives.	— Execute scaling plans, leveraging lessons learned and best practices from initial demonstration projects. — Forge partnerships and alliances with regional and international stakeholders to support scaling and market penetration.

CASE STUDY

Smart Columbus, USA

WSP led the systems engineering, design, procurement support and test activities for autonomous vehicle and connected vehicle projects within the Smart Columbus programme. Two separate trials were conducted. Firstly, the Smart Circuit linked downtown visitors with cultural attractions and acted as a test bed for project members and partners to learn about the capabilities of new smart city technologies and services. And secondly, the Linden LEAP which worked to solve first/last mile challenges in freight and delivery services.

PATHWAY 10
Continuous Monitoring and Evaluation

Monitoring and evaluation are crucial for projects or interventions driving significant change. They serve as key mechanisms to provide evidence that the change is beneficial, optimal and directly linked to the intervention. Effective monitoring relies on well-defined governance structures and analytics, allowing swift corrective action. Evaluation generates evidence on successful approaches, lessons learned and areas for improvement. In times of resource constraints, it becomes even more critical to ensure that public and private investments in digitalization are supported by evidence of actions that work well.

Theme	Short term	Medium term	Long term
Monitoring and Evaluation Plans, Governance and Culture	— Identify Key Performance Indicators which will be evaluated against. — Develop a monitoring and evaluation plan that is proportionate to the size of the initiative or change. — Assess adequate data sources suitable for monitoring purposes. — Develop consistent tools, processes, and guidance to aid in monitoring and evaluation. — Establish appropriate policies and structures to incentivize the delivery of good quality monitoring and evaluation.	— Diversify data collection with additional digital tools and sources where appropriate. — Publish monitoring outputs publicly for transparent operations. — Appoint monitoring and evaluation champions. — Embed outcome validation into the culture of project delivery.	— Establish resilient infrastructure with live condition monitoring influencing live scheduling of operations and maintenance.

CASE STUDY

City of Toronto Economic Impact Analysis Taxicabs, Limousine and Private Transportation Companies, Canada

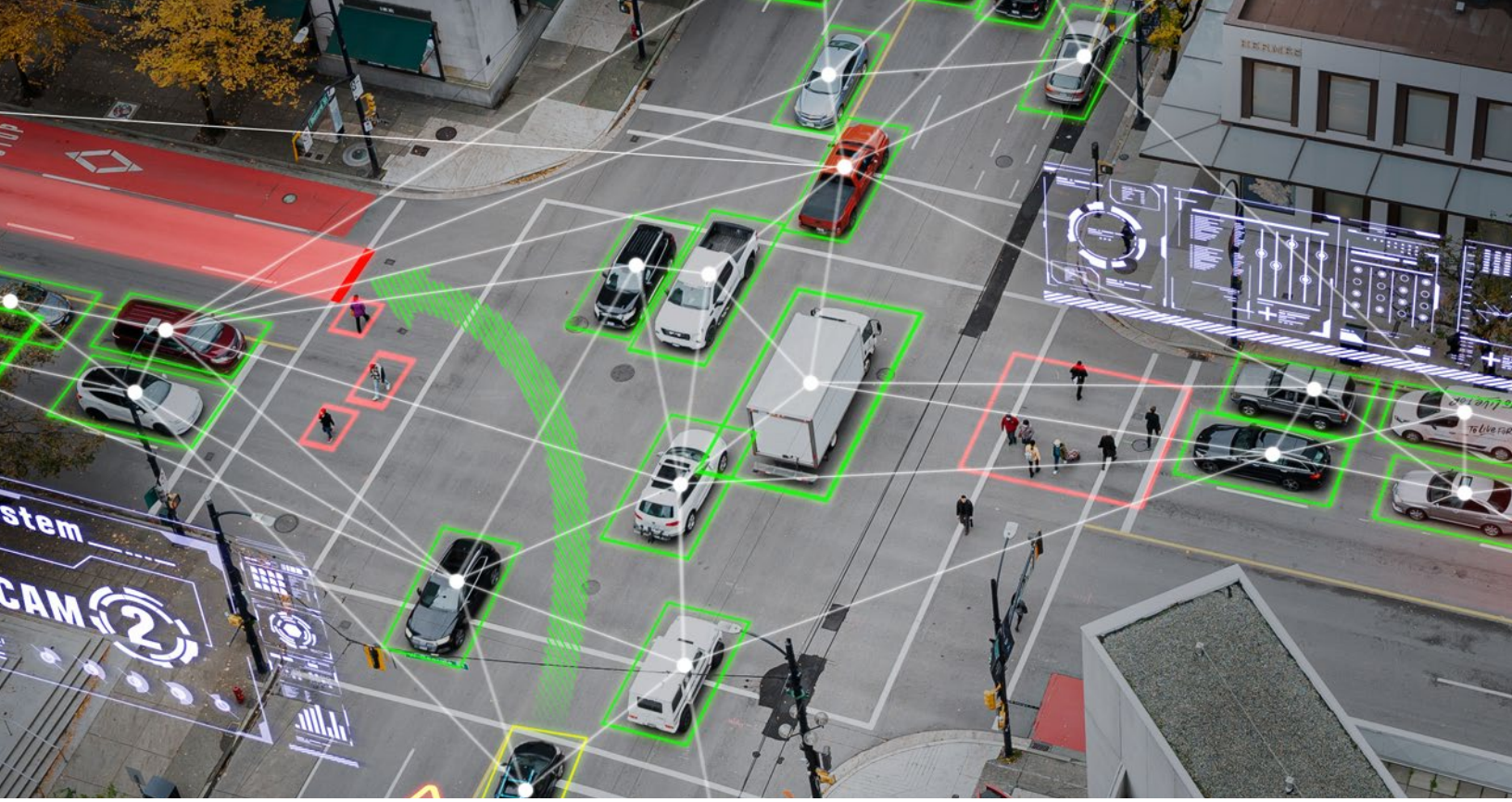
WSP was contracted by the City of Toronto to complete a monitoring and evaluation study to identify the economic impacts of private transport company operations on Toronto's local economy. The study made use of diverse data sets to review economic and social changes affecting residents—data sets were validated to be comparable across a number of North American jurisdictions. Key measurement metrics were identified and included: quality of life, consumer choice, access, tourism, and environmental changes in the city. Stakeholders across the city and industry were consulted to understand perceptions of regulations, industry accessibility and to collect data on ridership and revenue. The full report is available on the City of Toronto website.

Conclusion

Road transport has witnessed significant and rapid changes in recent years, brought about by an increasing reliance on technology, data and digitization throughout society. This shift reinforces the need to apply systems thinking to holistically consider system components and their interdependencies within geographical contexts impacted by a range of factors. Increasing demands from population growth, rising urbanization, the adoption of connected and automated vehicles, and more frequent extreme weather events due to climate change are placing increasing pressure on stakeholders. Decarbonization and advancement toward a safe worldwide road transport system necessitate global and local collaboration to effect meaningful change.

Implementing Digital Transport Infrastructure represents an opportunity to progress the development of modern networks that can effectively respond to these diverse challenges. The journey calls for strategic investment and a willingness to embrace continuous change by a range of stakeholders across disciplines, industries and nations.

Also essential to succeeding in this dynamic landscape is knowing how to focus efforts to achieve road transport digitalization that supports the needs of diverse places. This is where collaborative stakeholder pathways come into play. Depending on contextual needs and challenges, certain pathways may be emphasized, but always toward a common goal: shaping safer, greener and equitable transport networks, future-proofed to support the development of sustainable communities and regions around the world.



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