Merging physical and digital engineering can help transportation agencies work smarter and faster

Some transportation departments in the United States are acknowledging that this shift is no longer optional to deliver on their mission. Here's how others can get started.

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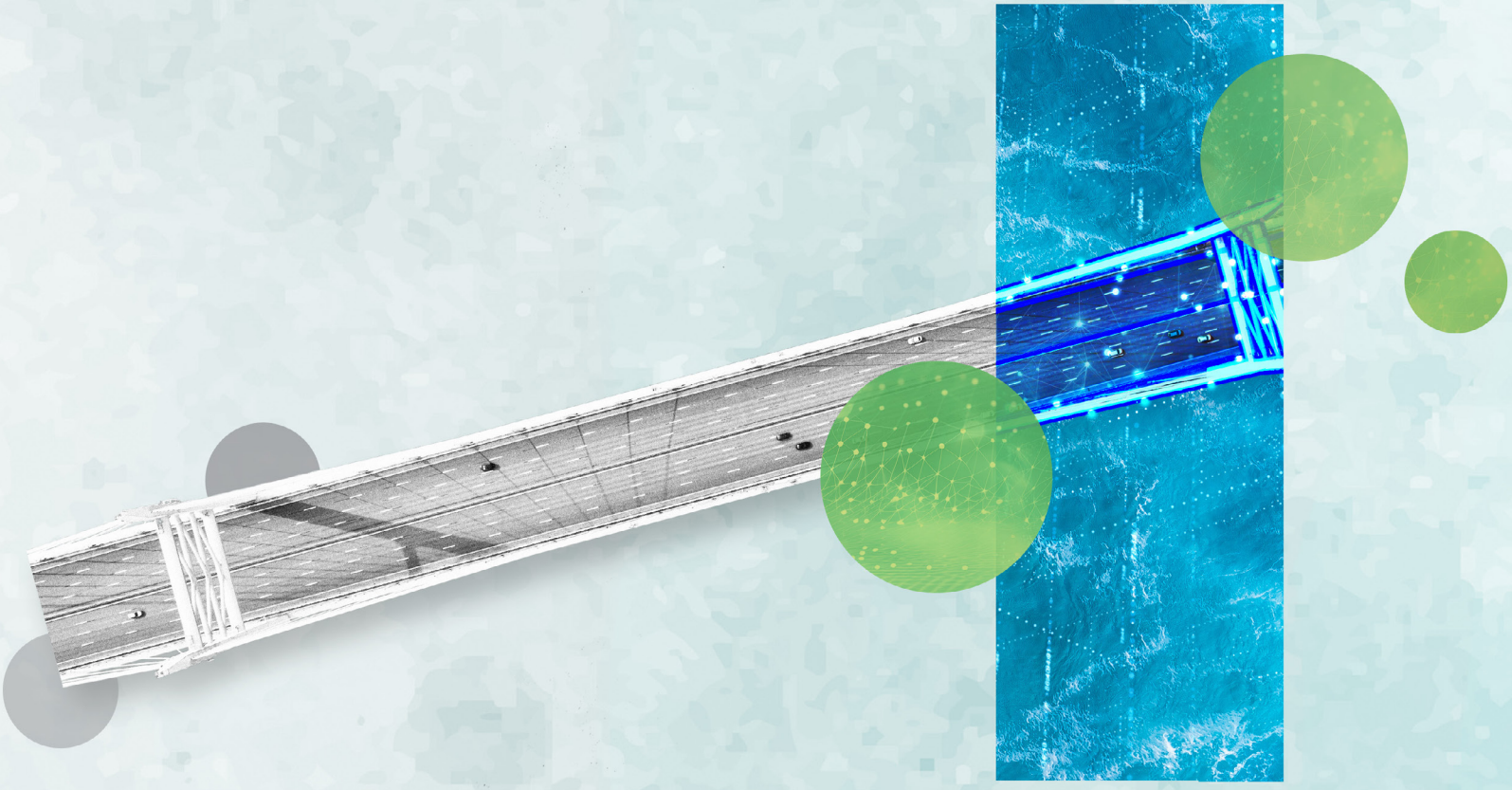

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Introduction

Many forward-looking departments of transportation across the United States are beginning to look and work very differently than they did a decade ago. Some are rolling out generative AI pilots to flag pedestrian safety risks. Others are rebuilding their business systems to unify planning, budgeting, and project delivery. In places like Broward County, Florida, transportation planners are using digital twins to make better planning decisions.[1]

These aren't just upgrades; they mark a deeper shift, from physical-first operations to a digitally fueled system-of-systems digital infrastructure backbone, where data, digital tools (such as AI, 3D models, and digital twins), and real-time intelligence work in sync to address key transportation problems. The goal is richer situational and operational awareness, with the help of systems that can sense what's happening across the network, share that insight across departments and jurisdictions, and guide faster, smarter decisions.

Why now? Because the traditional model (building bridges, resurfacing highways, maintaining critical infrastructure) isn't keeping up. Demands on infrastructure routinely exceed DOT resources across all categories. Costs are rising, delivery is getting more challenging, staff capacity continues to shrink, and the issues DOTs face—from rising congestion and road safety to uneven growth and regional planning—are substantially more complex and interconnected. Fortunately, DOTs have a wealth of data that can be leveraged through digital engineering to unlock deeper insights and more efficient and targeted solutions.

The physical infrastructure backbone remains critically important, but it is no longer sufficient. DOTs need a new way of working that connects core engineering with digital intelligence across the infrastructure lifecycle (see "Defining and integrating digital engineering in transportation operations"). As the Intelligent Transportation Society of America observes, "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."[2]

We explore how DOTs across the United States are beginning to make that shift and what it will take for others to follow.

DEFINING AND INTEGRATING DIGITAL ENGINEERING IN TRANSPORTATION OPERATIONS

Although the US Department of Transportation has not formally defined digital engineering across the department, it does allude to it through terms like digital delivery, Building Information Modeling for infrastructure, and the Advanced Digital Construction Management System. However, the Department of War defines digital engineering as "an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal."[3]

In transportation, digital engineering means replacing fragmented, siloed, and domain-centric processes with a unified set of data and models that connect domains such as civil, structural, environment, geospatial, operations, and asset management. The digital tools enable input from one domain to be transformed and used by another, thus improving performance, safety, cost efficiency, deeper insights, and resilience across the transportation ecosystem.

Why DOT leaders need a system-of-systems approach to drive this transformation

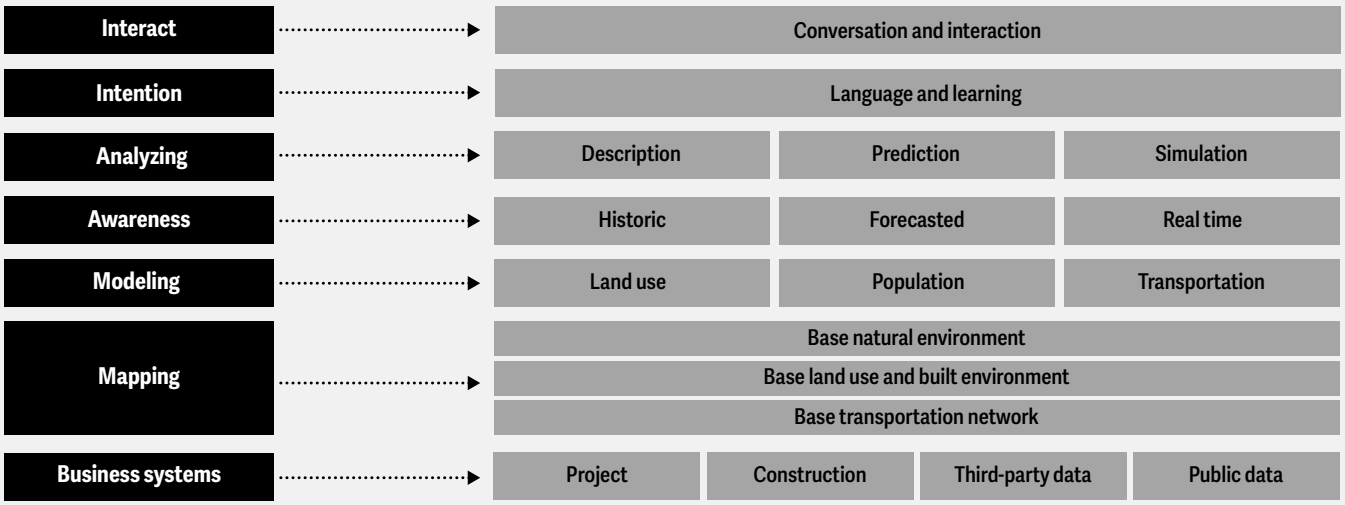
No single system can address the complexity of today's transportation challenges. Agencies must bring together multiple systems—applications, internal and external data sources, and analytic models—and make them work as one. By integrating these components and analyzing the combined data, transportation leaders can gain the insights they need to act with greater precision and impact.

A system-of-systems approach in which "system elements … interact to provide a unique capability that none of the constituent systems can accomplish on its own" can enable this integration (figure 1). It is a method for "integrating and networking systems in a coordinated way for specific goals such as robustness, cost, [and] efficiency."[4] Some transportation agencies are using this approach to bridge the digital and physical worlds, increasing the value of their technology investments and elevating mission impact. Such an approach is akin to an air traffic control system that fuses inputs from radar, pilots, weather feeds, and sensor data to provide real-time intelligence, allowing controllers to diagnose issues and quickly intervene.

Take safety, for example. Identifying vulnerable road users and proposing options to avert collisions requires analyzing historical crash records with live feeds from signals, sensors, and traffic cameras, and then adding external data on mobility, traffic patterns, weather, and more from third-party data providers to create a complete picture. Then other systems can be built over the data to help analyze and provide intelligence that allows better decision-making by transportation and safety engineers.

Figure 1

A system-of-systems approach can help accelerate value for transportation agencies



Source: Deloitte analysis.

Case studies: Early moves by some state DOTs show what's possible

Some DOT pioneers are charting the path forward, experimenting with AI-enabled safety tools, predictive maintenance, and digital twins to reduce costs and delays. Early results suggest that incorporating smart technology into DOT systems isn't just achievable but necessary.

Utah DOT is modernizing its business systems to build faster with tighter cost controls

Modernizing an agency's business systems can help address frequent cost overruns and schedule delays. The Utah Department of Transportation (UDOT) is replacing several legacy systems with integrated, cloud-based software solutions to better manage capital planning, project management, rights of way, and contracting.

UDOT is also reorganizing and standardizing data across processes to ensure project updates and records are accurate, accessible, and consistent. Design, inspection, and construction workflows are being modernized to reduce paperwork and improve data accuracy. Centralized and digitized data will allow teams to use existing models rather than repeat surveys, while tools like digital twins will augment decision-making throughout the infrastructure life cycle.[5]

The potential benefits are multifold. Eliminating paper speeds up access to construction details and avoids duplication; digital models enhance design review, reduce human error, and support safer, smoother construction; data captured during construction becomes a valuable asset for future maintenance and planning. Connecting digital tools with established workflows accelerates project delivery and creates trustworthy enterprisewide, interoperable data that can improve insights and thereby decision-making. Moreover, UDOT is positioning itself for the continued adoption of open standards and emerging digital innovations. The workforce, in turn, is freed up to focus on high-value tasks and activities, providing the agency with the agility to match resources with high-priority demands.

Caltrans works to prevent road deaths

In 2024, traffic fatalities claimed the lives of more than 44,000 people on US roads.[6] States often struggle to improve road safety but are hampered by limited budgets, fragmented safety data, and the complex interplay of factors affecting safety and of federal and local policies. To make progress in this area, State of California transportation leaders are tapping the power of AI to pursue the state's ambitious Vision Zero goal: eliminating fatalities and serious injuries on state roads by 2050.[7]

The California Department of Transportation (Caltrans) is looking to leverage the data it collects from California Highway Patrol and thousands of roadside sensors, and then use generative AI to analyze crash sites, factoring in lighting, traffic patterns, and road-user behavior to identify high-risk areas and recommend targeted safety measures.

In Broward County, FL, community voices help reshape county plans and investments

With rapid population growth,[8] planners across state, regional, and local agencies face mounting pressure to meet the demand for modern infrastructure, affordable housing, and efficient transportation. Enhancing infrastructure resilience demands interagency coordination—and is routinely thwarted by fragmented data, siloed information, and complex federal rules and regulations.

To tackle this, the Broward Metropolitan Planning Organization in Florida built a digital twin platform called Smart Metro to unify stakeholders and offer a shared view of infrastructure needs and planning decisions. This geospatial-driven system combines housing, zoning, population, and transportation data that was previously scattered across agencies. Planners can now ask plain language questions, run scenario simulations, and visualize long-term impacts.[9]

"The platform shows what the effects of my decisions will be in real time, as opposed to waiting for years for studies to be completed," says San Zuniga, an engineer with the city of Miramar.

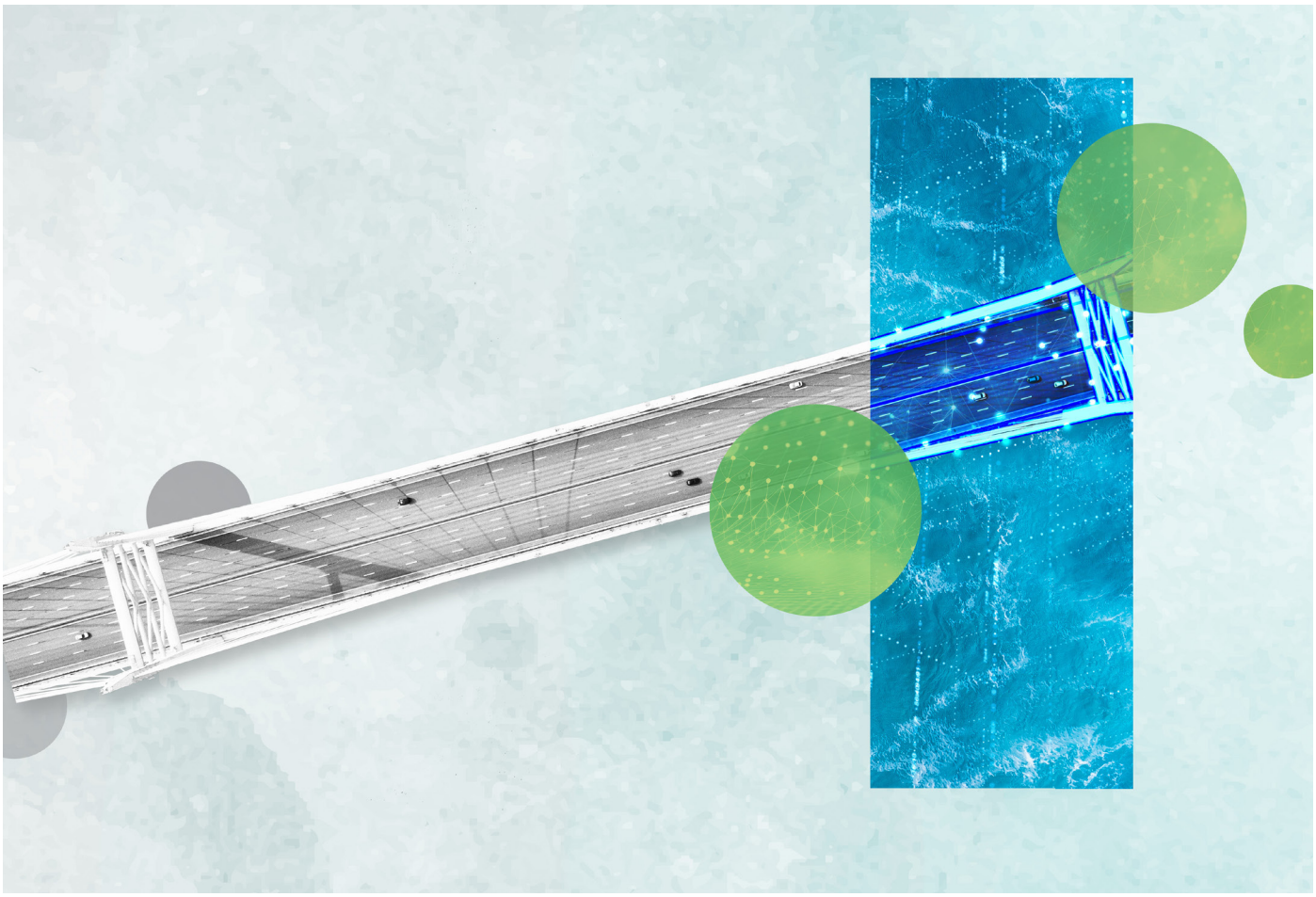
Smart Metro combines analytics and simulation to forecast traffic, predict land use trends, and model flood impacts, while strengthening collaboration through shared data and insights.[10]

Indiana Department of Transportation revamps maintenance response and planning for the future

Twenty-four states across the United States reported a US$86.3 billion maintenance funding gap over 10 years. These states already expect to collectively spend US$194 billion on roads and bridges under Transportation Asset Management Plans over the next decade and would need to increase spending by 44% to reach the US$280 billion required to close the shortfall.[11]

The Indiana Department of Transportation (INDOT) had a maintenance management system that was not robust enough to capture data accurately, limiting the ability of the maintenance plan and staff response to the state's maintenance needs. The ability to visualize needs and consolidate repair efforts with future planning was a huge victory for the agency. This enables better spending on the critical maintenance dollars for the state. With 11,000 miles of roadway (a total of 28,000 lane miles), every response involving labor, materials, and equipment must be carefully scheduled and reported.

INDOT wanted to move from a siloed point systems to a unified, cloud-based, low-code/no-code work orders management platform that meets all state standards and regulations. The agency sought a robust work order management solution to support both planned and unplanned maintenance activities for key transportation assets.



Five dimensions of change for building a digitally enabled, future-ready DOT

Today's tech-driven transportation planning requires DOT leaders to reimagine their current processes, strengthen data governance, embed AI, and build workforce AI and digital fluency.

Reimagine processes and embed AI thoughtfully

DOT leaders should use AI to reassess *how* work gets done, rethinking workflows around data collection and evaluation, automation, and improved outcomes.

Arizona DOT (AZDOT), for example, is replacing its legacy field office management system and several related subsystems with a next-generation, cloud-based capital project delivery system to enhance security, flexibility, efficiency, and collaboration across project data and delivery.[12]

Embedding AI tools thoughtfully means matching tools to tasks: intelligent optical character recognition for document management software, robotic process automation for rule-based decisions, and generative AI for personalized communications. At Caltrans, generative AI is helping translate crash and congestion data into rapid, plain-language insights for planners.

Hack data silos and governance to lay the foundation for insights and AI

To realize digital technology's promise, transportation agencies must improve data integration and governance. Despite access to abundant data, the challenge for DOTs is turning that data into actionable insights.[13] Breaking down data silos, incorporating external data sets, and sharing machine-readable information across departments are essential.[14] Doing so enables better integration with analytics platforms and improves agencywide decision-making, from smarter parking and traffic signaling to compliance and safety oversight.

The Data & Trusted AI Alliance has created frameworks for understanding data trust throughout organizations to maximize transparency and help engender trust in AI systems.

Develop an intelligence and insights layer

Integrated domain-specific data lets DOTs to apply machine learning, predictive analytics, and gen AI to forecast congestion, optimize routes, implement predictive maintenance, and simulate future demand.

A Deloitte-ThoughtLab study found 70% of US city leaders use AI for traffic management and flow prediction; 58% for smart parking management; and 52% for transportation management, planning, and forecasting.[15] The convergence of AI with other technologies such as digital twins, biometrics, and cloud computing further amplifies this potential.

Yet many tools remain stuck at the proof-of-concept level, resulting in a gap between perceived and realized benefits.[16] If this gap persists for long—especially for technology hyped as enthusiastically as gen AI—high expectations can turn to disillusionment.[17] To close that gap, DOT leaders should invest in responsible governance structures and pursue external partnerships when internal capacity is limited.[18]

Some forward-looking agencies are already showing the value of this convergence. Broward MPO, for example, is planning to use its platform to support an upcoming redevelopment project in Miramar, combining flood simulation data with infrastructure planning to inform decisions on transit routes and road investment.[19]

Build digital and AI fluency in the workforce

Workforce fluency is critical for realizing the full benefits of AI; yet most training efforts remain too sporadic and off-target to meet the need. Nearly two-thirds of state and local government employees report receiving no employer-provided AI training.[20] To build meaningful AI capability, agencies should offer employees personalized training recommendations based on role, occupation, and level.

At the federal level, partnerships with academia provide tailored AI training to employees across technical, acquisition, leadership, and policy tracks. Several states and local governments run similar programs.[21] What's missing is a customized and personalized suite of AI training for the government transportation workforce.

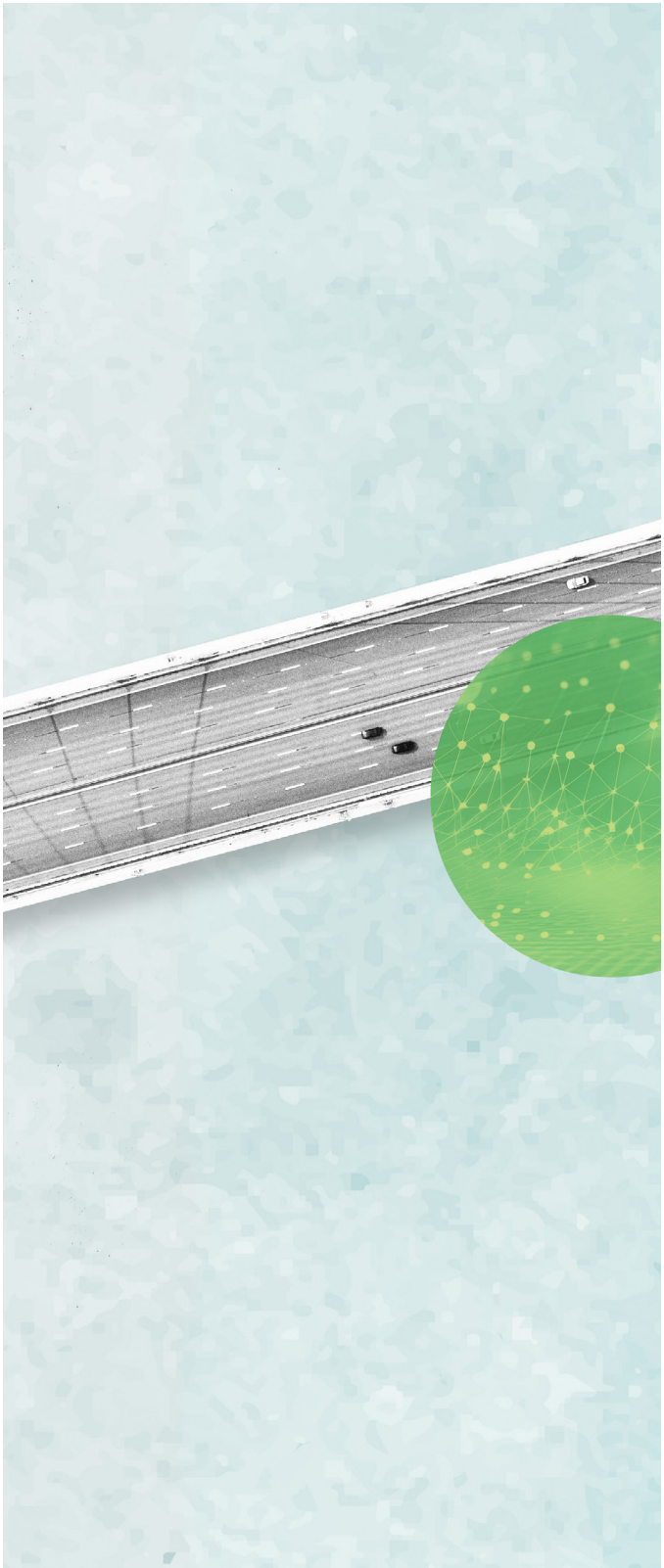
Elevate the chief information officer (CIO) role

Transportation CIOs play a critical role in aligning technology initiatives with an agency's strategic goals. As their responsibilities evolve, they must balance innovation with cost management and demonstrate how IT investments drive measurable business value.

- **Understand and engage stakeholders.** CIOs should build strong relationships across the agency, assess the operating environment, and clearly communicate how IT supports both immediate and long-term needs. Reframing IT initiatives in terms of business impact builds trust and buy-in.

- **Develop and prioritize strategic road maps.** Reaffirming mission goals guides the evaluation and prioritization of IT investments. These road maps help communicate IT's value, define future capabilities, and focus on transformative initiatives while effectively managing stakeholder expectations. The key is to build credibility on larger projects by driving early delivery of visible solutions.

- **Optimize costs and invest strategically.** High-performing CIOs continuously review budgets, eliminate inefficiencies, and redirect savings toward innovation. Strategic collaboration with leadership is necessary to ensure IT budgets align with business priorities and are backed by performance metrics and key performance indicators.



Getting started

Make the transformation a leadership priority. Ensure executive buy-in to build support and commitment toward the broader transformation vision. Leaders will need visibility into financials, project selection, progress, and workforce impact.

Choose the right approach. There are multiple ways to begin the journey, from pilots that build confidence to businesswide transformations. Regardless of the path, aim for an impactful and quick win that is visible across the agency in a core business area.

Assign a transformation leader. Designate a leader who is both tech-savvy and familiar with the agency's business and functional areas. This leader should secure an executive sponsor who owns outcomes and clears roadblocks. The transformation leader should also understand the agency's tech stack, its gaps, and how maintenance, construction, and planning actually work.

Find the right partner. DOTs need partners beyond the traditional architecture and engineering firms, partners who can turn abundant data into actionable decisions at scale. Look for expertise in data engineering, AI, and change management to ensure insights inform everyday operations.

Focus on change management. DOT leaders should pair the craft of civil engineering with digital engineering. Show how the shift makes daily work safer, faster, and more rewarding. Elevate early adopters as champions, maintain tight feedback loops, and simplify adoption with practical tools and training.

Looking ahead

The convergence of digital and physical systems is a strategic imperative for transportation agencies. By integrating AI and digital tools, DOTs can significantly enhance safety, efficiency, and cost-effectiveness. Examples from UDOT, Caltrans, Broward MPO, and AZDOT illustrate how early adopters are improving delivery, safety, and resource use. With digital fluency and strong data governance, agencies can unlock new levels of operational excellence.

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