

Catalyzing Scale: 10 Factors to Help Close the Pilot-to-Scale Gap

Kickstarting scaling momentum and helping deployers avoid “scale fail” in the connected intelligent mobility ecosystem.

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Date: September 2026

Time to Read: Approx. 15 minutes

In this second brief, we take a closer look at the factors that can help transportation leaders build scaling momentum, avoid “scale fail” and move emerging technologies from limited deployments to system-wide adoption.

Ten Ways to Accelerate Scale

The following 10 factors can help connected, AI-enabled and autonomous transportation move out of the messy middle and into the mainstream.



1. Digital Infrastructure as a Core Transportation Asset

Transportation agencies have traditionally defined infrastructure in physical terms: roads, bridges, pavement and signals. But a new technological layer is forming on top of the physical network: the sensing and learning layer where data, communications, AI and automation operate. This layer includes connected vehicles, intersections and corridors; roadside and industrial sensors; high-definition roadway mapping and visual inventories; advanced simulation and digital twins; cloud and edge computing; machine-readable traffic control and work-zone data; curb management; and secure, interoperable data-sharing architectures. Without this layer, even the most advanced vehicle, operating agency or transportation management center is essentially “driving blind.”

This is where much promising technology stalls. Today, the digital infrastructure layer is too often built in pieces: one pilot, one grant and one demonstration at a time. To catalyze scale, transportation leaders need a different mindset. Digital infrastructure must be planned, funded, maintained, secured and governed with the same discipline as physical infrastructure. Agencies already understand lifecycle management for physical assets; they now need equivalent models for data, software, communications networks, algorithms and digital services.

That shift brings practical questions into the mainstream. What digital assets does a corridor need to support connected and automated mobility? How are they procured, owned, maintained, secured and updated? How are they integrated with operations and evaluated for performance? When those questions move out of the innovation office and into long-range plans, corridor studies, TSMO plans, asset management plans and capital programs, digital infrastructure stops being an early-adopter experiment and becomes a stable foundation for scale. That is when the future stops being a demonstration and starts becoming an integrated transportation system.

STRATEGIC IMPLICATION: Digital infrastructure must be treated as core public infrastructure: planned, funded and lifecycle-managed for the long term. Agencies that make this leap will be better positioned to move connected and automated mobility out of perpetual pilots and into everyday travel.

2. Connected Infrastructure and V2X Ecosystems Accelerate Mobility AI and Autonomy

We tend to imagine the autonomous vehicle as a self-contained and independent thing: perceiving its surroundings, interpreting conditions, planning its path and executing every driving task on its own. That vision is powerful but incomplete. A vehicle, however intelligent, cannot see around a corner, through a truck, past a work-zone barrier or beyond a weather-obscured horizon. The transportation system becomes far more capable when vehicles are not left to interpret the world in isolation.

That is what vehicle-to-everything (V2X) connectivity provides. It lets vehicles, roadside infrastructure and other road users exchange the information that a single sensor suite on one vehicle can never capture on its own, such as corridor signal phase and timing, downstream queues, work zones, emergency vehicles, road weather, roadway hazards and vulnerable road users, delivered as real-time warnings and alerts. Connectivity reduces uncertainty for a vehicle operator or traveler, and reduced uncertainty is what turns a promising prototype into a system safe and reliable enough to scale. Autonomy stalls in the messy middle when every vehicle must solve the entire world alone; it accelerates when the roadway itself helps vehicle and traveler decision-making.

Crucially, this foundation of connectivity delivers value long before full autonomy arrives, which is exactly what makes it a catalyst rather than a bet on the distant future. Signal priority, emergency-vehicle alerts, work-zone warnings, freight-corridor information, transit operations and vulnerable-road-user applications all pay off today, in mixed-fleet environments, with human drivers still on the road. Agencies do not need to wait for full AV market penetration to justify the investment in connectivity. They can build the connected, interoperable, securely governed corridors now and, in so doing, quietly assemble the digital and operational foundation on which scalable autonomy will ultimately depend.

STRATEGIC IMPLICATION: Mobility AI and AV readiness increasingly depends on roadway digital readiness. Agencies can prioritize connected corridors and interoperable digital ecosystems before full autonomous vehicle deployment, capturing near-term benefits today while preparing their networks for scaled autonomy tomorrow.

3. AI-Augmented Operations Can Create the Fastest Path to Value

Much of the public conversation about AI in transportation focuses on futuristic scenarios. But for practitioners, the most immediate value may be emerging somewhere more practical and more powerful: the transportation management center. TMCs, maintenance operations, transit control centers, emergency operations centers, asset management programs and integrated corridor management programs make high-volume, time-sensitive decisions every day. They interpret field data, detect incidents, assess and predict congestion, coordinate responses, manage work zones and issue traveler information as conditions change by the minute. This is exactly where mobility AI can help.

In the TSMO context, AI can detect incidents, predict congestion, flag abnormal traffic patterns, prioritize maintenance, support signal optimization, analyze video feeds and recommend operational responses. Because data is the fundamental building block of AI, strong data governance and management are essential. Operational AI also creates a practical bridge between today's ITS environment and tomorrow's autonomous ecosystem. Agencies can adopt AI first as a decision-support tool, building trust, training staff, developing governance and evaluating performance before delegating higher levels of authority to automated systems.

The framing here is human-centered by design. AI in transportation operations should never be sold as replacing operators; it augments human judgment in increasingly complex mobility conditions. Operators remain essential precisely because transportation is not a purely technical system but a public service shaped by safety, policy, weather, human behavior, emergency response and local context. AI becomes far less threatening, and far more scalable, when agencies experience it first as a partner to human decision-making rather than a substitute for it.

STRATEGIC IMPLICATION: Transportation operations may become the industry's primary proving ground for scalable mobility AI. Agencies that learn to use AI responsibly in this context can capture measurable benefits today while building the organizational confidence needed to govern automation across the network.

4. Standardized Data Ecosystems Are the Foundation of Scale

It is tempting to think the hard part of transportation AI is the algorithm. The harder challenge is often the data environment around it. Transportation data remains scattered across DOTs, cities, MPOs, transit agencies, ports, toll authorities, law enforcement, emergency responders, weather providers, freight operators and private mobility firms. Each organization has its own systems, requirements, formats and rules. AI cannot optimize what it cannot interpret and connected and autonomous systems cannot coordinate when data is inconsistent, incomplete, inaccessible or untrusted. Data fragmentation is one of the most significant barriers to scale.

Solving that challenge requires a more mature data ecosystem: common standards, interoperable APIs, secure data-sharing agreements, metadata practices, privacy protections, clear governance models and enterprise platforms that integrate many sources into shared operational awareness. When standards stabilize, products become more interchangeable, vendors can invest with confidence and agencies can stop building one-off solutions corridor by corridor. The quality, scale and management of transportation data determine whether AI systems deliver reliable results.

This is another place where so many deployments and AI programs stall in the messy middle. An agency makes a massive investment/commitment, pilots a promising AI/AV system/tool, it works and then it dies at the edge of the corridor, because the surrounding data environment isn't mature enough (or similar enough) to carry it any further. Data gaps, inconsistent definitions, proprietary systems, limited access and unclear ownership quietly can prevent a successful pilot from ever becoming a scaled deployment. Technology didn't fail; the data foundation was never built to support it.

STRATEGIC IMPLICATION: Data governance may become as central to transportation modernization as engineering design. Agencies that treat data as a managed enterprise asset, one that is standardized, interoperable, secured and trusted, will be better positioned to lift mobility AI and AVs out of local deployments and scale them across the network.

5. Institutional Readiness and Workforce Transformation Can Determine Adoption

Technology can scale faster than institutions can adapt. Transportation agencies were built to plan, design, build, maintain and operate physical infrastructure. They are now being asked to manage data platforms, software systems, AI models, cybersecurity risks, digital services and complex public-private technology ecosystems. That shift requires new capabilities. The gap between what transportation technology can do and what an agency is built to absorb is one of the most common reasons promising deployments stall in the messy middle.

Closing that gap requires new institutional capacity: AI literacy, data management expertise, cybersecurity awareness, systems engineering capability, procurement flexibility, operational analytics, performance management and cross-functional decision-making structures. It requires agency leaders who can bridge transportation policy, technology, operations and public accountability. It requires a transportation workforce able to connect applied AI research to real operational deployment and a workforce able to build responsible AI frameworks that address data-quality limitations, algorithmic bias and nondeterministic system behavior. Just as important, agencies need a culture of continuous learning, because technology will keep evolving long after any single tool is first installed.

Workforce transformation therefore can't be treated as a side issue; it is a primary determinant of whether next-gen mobility technology scales at all. Transportation agencies need staff who understand not only what AI can do, but when it should be used, how it should be governed, how its output should be validated and how human judgment stays embedded in operational decisions even when AI is involved. AI adoption is not fundamentally about buying tools or creating agents; it is about building the organizational capacity to use them safely, responsibly and effectively.

STRATEGIC IMPLICATION: Human capital investments may produce greater returns than technology investments alone. Agencies that build mobility AI literacy, digital leadership and cross-functional governance, and treat workforce transformation as core rather than peripheral, will be better prepared to scale innovation responsibly across the transportation ecosystem.

6. Regulatory Agility and Risk-Based Governance Are Essential

There is an inescapable tension at the heart of transportation technology: regulation, law, governance and policy move slowly and deliberately, while AI moves fast and keeps changing. That mismatch is real, and it matters because highly automated vehicles and AI-enabled systems raise genuine questions about safety, liability, transparency, accountability, cybersecurity, privacy, human oversight and performance monitoring. Agencies cannot ignore those questions. But if AI regulation and governance are too rigid, mobility innovation stalls in the messy middle, trapped between a successful pilot and a rulebook that has simply not kept pace.

The path forward is adaptive, risk-based governance. AI risk in general is complex and systemic, emerging from the interactions among algorithms, sensors, infrastructure, operators, users, policies, data, maintenance practices, cybersecurity environments and real-world conditions. Governing it therefore calls for tools built for evolution rather than prescription: performance-based and outcome-based oversight, regulatory sandboxes, pilot-to-scale evaluation frameworks, independent verification and validation, AI assurance and continuous operational monitoring.

AI assurance is particularly important. AI assurance involves measuring, evaluating and communicating the trustworthiness of AI systems and is a continuous process that monitors AI throughout its lifecycle, ensuring the AI remains reliable, ethical and compliant as it learns and adapts over time. It provides documented evidence that AI systems are fair, transparent, accountable and safe for use. Without AI assurance, organizations and the general public may hesitate to adopt or accept AI and AVs due to uncertainty about performance, potential risks or other issues. By providing structured, ongoing assessment and evidence of reliability, safety and ethical compliance, AI can be deployed responsibly. AI assurance is essential for justified trust in mobility AI systems, particularly for systems in the public domain that affect people's safety and well-being. In transportation, this is an absolute priority. It is therefore critical that mobility AI oversight and governance evolve and mature alongside the technology instead of lagging a decade behind it.

STRATEGIC IMPLICATION: The objective is not to eliminate AI risk; it is to enable mobility innovation while managing risk responsibly. Transportation agencies that adopt adaptive,

performance-based AI governance can say “yes” to promising technologies with greater confidence and provide the clarity needed to move connected, automated and AI-enabled systems into trusted, scaled deployment.

7. Public Trust Must Be Earned Through Demonstrated, Measurable Benefits

Transportation agencies operate in a public trust environment, and that changes how technology scales. Most people do not evaluate traffic signals’ AI algorithm or study the inner workings of autonomous vehicles. They judge whether trips become safer, more reliable, more accessible and easier. Leaders decide whether to invest based on whether that value can be demonstrated consistently over time. Public trust is therefore not only a communications issue; it is a performance issue.

To earn that trust, transportation agencies must be able to show that mobility AI and automation produce measurable public value: fewer crashes, faster incident response, better travel-time reliability, lower operating costs, longer asset life, workforce efficiencies, greater network resilience during disruptions, safer work zones, improved access for all and more efficient use of existing infrastructure. Just as important, trust requires honesty about limitations. AI in transportation, whether in operations or in vehicles, can be powerful, but it can also fail, misread conditions, reflect gaps in its data, or behave unpredictably in novel environments. Agencies build durable credibility when they explain not only what a system can do, but also what it can’t do and how these capabilities are evaluated, monitored and governed. Mobility AI and AVs that operate only inside a technological “black box” erode public trust and make value difficult, if not impossible, to assess. This is another factor that can carry next-gen ITS technology out of the messy middle: a promising deployment spreads only when the public and the leaders who fund it can see, transparently and independently, that it delivers consistent benefit.

STRATEGIC IMPLICATION: Public trust should be treated as a strategic asset, not a communications afterthought. Agencies that demonstrate measurable, transparent and independently evaluated benefits will be better positioned to earn the public and political confidence needed to move connected, automated and AI-enabled systems into everyday mobility services.

8. Procurement Must Evolve for Software-Defined Transportation

Traditional transportation procurement was built for physical infrastructure. Requirements are specified, bids are evaluated, contracts are awarded, projects are delivered and assets are maintained. It is a model with a clear beginning and end. AI-enabled systems do not fit that model neatly. They require iterative design, frequent updates, evolving requirements, ongoing performance monitoring, data integration, cybersecurity patching, model refinement, user feedback and continuous improvement. Software-defined transportation is never truly “finished,” and a procurement model built to buy finished assets struggles to support systems that keep changing.

This mismatch is one of the most consequential and often most overlooked barriers to scale. When transportation agencies procure AI using traditional contracting, they risk locking themselves into obsolete requirements before deployment is even complete. But the deeper trap is often financial, not contractual. Traditional funding programs are built to finance capital projects assets that are purchased once and depreciate over decades, not technology systems and services that require continuous investment to stay current. When funding covers the initial purchase but not operations, maintenance, software licensing, cybersecurity and model refinement over the full lifecycle, agencies can successfully pilot a tool and then watch it wither because there is nothing in the budget to sustain it in the long term. This is the funding-and-procurement version of the messy middle: the technology works, but the financial and acquisition machinery around it cannot carry it past the pilot or cannot do so for very long.

Modernizing that machinery is achievable, at least in theory. On the procurement side, it may include modular contracting, agile acquisition, outcome-based performance measures, staged pilot-to-scale deployment, open architectures, interoperability requirements and contract structures explicitly designed for continuous improvement. On the funding side, it may include dedicated and sustainable funding streams, budget models that treat software lifecycle and technology O&M costs as ongoing operational commitments rather than one-time capital expenses, financing approaches that support continuous improvement and the deliberate embedding of digital and technology costs within capital programs and long-range plans. It also demands tighter coordination among procurement offices, budget and finance staff, IT

departments, operations staff, legal counsel, cybersecurity teams and program/project managers.

STRATEGIC IMPLICATION: Funding and procurement reform together may become one of the most important enablers of transportation innovation. Agencies that adopt agile, modular, outcome-based acquisition and fund the full technology lifecycle through sustainable, recurring financing will be better able to move mobility AI and AVs out of pilots and into sustained, scaled operation.

9. Sustainable Business Cases Will Separate Pilots from Programs

Transportation agencies face constant pressure to justify investment, and that pressure is what separates a pilot from a long-term program. Many technology efforts succeed technically but fail economically. The tool works in a demonstration, but no one can clearly explain what it costs, what it saves, what return it delivers or what value it creates at scale. Decision-makers increasingly need evidence, not enthusiasm. A technology that cannot explain its value in operational and financial terms will struggle to survive the next budget cycle, no matter how sophisticated it is.

That is also why a strong business case is not just a paperwork exercise. It is the mechanism that carries technology across the messy middle. Agencies need to understand clearly where mobility AI produces value, what cost it reduces, what risk it mitigates and what new capabilities it enables. Potential mobility benefits are real and varied: reduced crashes, faster incident clearance, improved travel-time reliability, reduced congestion, better maintenance planning, improved asset utilization, greater workforce productivity and increased network resilience are among them. But these benefits earn their credibility only when tied to specific transportation use cases and concrete operational performance measures grounded in value-based framing that turns a promising mobility idea into a defensible investment.

The distinction is simple but important. Transportation technologies that showcase technical capability alone are the ones that tend to stall as one-off demonstrations or local pilots. Technologies that solve a significant operational problem and can prove it in repeatable, quantitative terms build the momentum and the funding justification to spread from a single

corridor to a whole network. The business case is what converts a successful experiment into a sustained programmatic investment.

STRATEGIC IMPLICATION: The future belongs to business cases, not pilots. Agencies that anchor mobility AI and automation in measurable, repeatable economic and operational value will be better positioned to scale the technologies that improve long-term transportation performance.

10. Public-Private Ecosystem Orchestration Will Be the New Delivery Model

Transportation depends on a wide mix of agencies and partners. State DOTs own and operate major infrastructure; cities manage local streets, signals, curbs and multimodal networks; MPOs shape planning and investment; transit agencies run critical mobility services; telecommunications firms provide connectivity; cloud providers support data platforms; automakers and technology companies build vehicles and automated systems; universities contribute research and training; engineering firms translate concepts into reality; and public safety agencies support real-time operations and response. No single organization can scale autonomous and AI-enabled transportation alone.

This is why scaling demands ecosystem orchestration, a fundamentally different discipline from traditional project delivery. Where classic delivery hands off a finished asset, ecosystem orchestration sustains a coalition: shared objectives, governance structures, data-sharing agreements, interoperability frameworks, funding strategies, stakeholder engagement and clear performance accountability. It is the connective tissue that keeps dozens of independent actors moving toward the same outcome. The messy middle is, in many ways, what happens when this orchestration is absent: when promising deployments fall apart or fragment because no one is aligning the players, the data, the money, the rules and the accountability across organizational lines.

That reframes what agencies should look for in a partner. In an orchestrated ecosystem, the highest value comes not simply from building a component, but from helping align the whole. In other words, protecting the public interest while weaving research, connectivity, data, vehicles, governance and operations into a coherent, scalable system. The most valuable partnership is composed of actors that emphasize trusted transition from research to

operations, independent evaluation and responsible deployment. Partnership becomes a capability.

STRATEGIC IMPLICATION: Partnership maturity may become a key performance indicator of transportation innovation. Agencies that learn to orchestrate complex public-private transportation ecosystems, rather than deliver isolated projects, will be better positioned to move connected, AI-enabled and autonomous mobility into system-wide scale.

Read part 3 of this series: *Catalyzing Scale: 7 Barriers to Closing the Pilot-to-Scale Gap*, where Battelle explores ideas related to scaling systems via the use of federated data architectures.

Contact us to learn how Battelle helps decision-makers bridge the pilot-to-scale gap with evidence-based solutions that move transportation technology from proven to deployed at scale.