A report from the
Deloitte Center for Government Insights

Global Transportation Trends 2025

Empowering resilient, tech-driven mobility

The biennial **Global Transportation Trends report** from Deloitte's Center for Government Insights delivers actionable intelligence on the forces reshaping public transportation. Since its debut in 2020, the report has examined themes around funding mechanisms, the emergence of technology- and AI-driven mobility, and infrastructure innovations shaping public transportation. In 2025, we spotlight five critical priorities for government transportation leaders: pioneering funding models; accelerating adoption of low- and zero-emission vehicles; scaling AI for operations and planning; integrating autonomous mobility solutions; and fortifying resilient, cyber-secure transportation networks. Collectively, these trends chart a pragmatic course toward more reliable, sustainable, and future-ready transportation systems.

Global transportation networks face significant challenges even as they struggle to plan for and integrate innovative technologies and transportation modes. Growing cyber vulnerabilities, antiquated technology, and more frequent and intense weather events are battering an aging network of roads, bridges, rail, runways, and transit lines.[1]

Decades of rising use and deferred maintenance have left transportation infrastructure worldwide in a precarious state. The American Society of Civil Engineers' 2025 Infrastructure Report Card graded most of the US' surface transportation and aviation assets either mediocre, requires attention or poor, at risk, reflecting safety and reliability concerns.[2] Infrastructure in many other countries and regions is equally troubled,[3] marked by collapsing bridges, crumbling roads,[4] and growing sustainability and manmade threats.

Governments face uncomfortable arithmetic. Maintenance backlogs are growing, megaprojects are becoming costlier, and electrification and hybrid working patterns are eroding traditional revenue pillars: fuel taxes and urban fares.[5] Today, increasingly as capital needs surge to make existing infrastructure weather-resilient, public balance sheets are stretched by post-pandemic debt, geopolitical tensions, energy-price volatility and social protection needs.

A wide range of meta-trends shape the future of public transportation

Several long-horizon, cross-cutting forces will condition every decision that public transport authorities take over the next decades. While some of these trends' impacts are gradual, leaders should not wait to begin addressing them.

Growing urbanization: The COVID-19 pandemic was a minor blip in the relentless urban population growth around the globe.[6] Since then, urban population growth has rebounded, albeit slightly differently, with more growth in suburban areas, which has increased urban sprawl.[7] This puts additional pressure on transportation infrastructure planning, investments, and service delivery.

Growing environmental volatility and the need for asset resilience. Heatwaves, floods, and storm surges are already degrading road integrity, undermining bridge foundations, and disrupting coastal ports.[8] Globally, extreme weather events caused an estimated US$320 billion in losses in 2024 alone,[9] with worse forecasted for 2025 and beyond.[10] Transportation infrastructure is particularly vulnerable.[11]

Long- and short-term budgetary challenges. Funding and financing future-ready, resilient infrastructure is costly and can require decades of commitment, and governments have struggled to implement sustainable financing mechanisms. A G20 estimate puts the global transportation investment gap at almost US$8 trillion between 2025 and 2040.[12]

Digital and data acceleration and expanding threat vectors. Many public transportation systems still run on legacy technology that was not designed for today's threat landscape. At the same time, transportation modernization efforts increasingly make transportation assets smart and connected, with AI platforms, burgeoning sensor networks, and ubiquitous connectivity boosting situational awareness and asset-management efficiency. This march toward hyperconnectivity continually widens the cyberattack surface, and agencies must confront ever-more-sophisticated ransomware incidents and phishing attacks.

Constantly changing travel patterns in urban centers. In 2020, the global COVID-19 pandemic reshaped transportation habits, with remote work arrangements reducing the number of vehicles on the road and radically shifting millions of workers' daily commutes and transportation infrastructure use. Now, as some employers urge workers to return to office, commuting patterns remain in flux, but it seems likely that many organizations will stick with hybrid work for now.[13] These changing travel patterns and preferences will make it difficult for transportation planners to understand demand and finalize public transit investments and funding models.

These meta-trends do not occur in siloes and in fact, are largely interdependent: Urban travel preferences can affect transportation patterns and funding, while reduced funding puts more pressure on future infrastructure investments. Digital transformation in transportation can enable resilience and create new vulnerabilities. Understanding their combined effect is a prerequisite to directing scarce resources toward maximum public value.

Five trends reshaping public transportation in 2025

Amid this complex landscape, this global transportation trends report focuses on five key trends that are top of mind for public transportation leaders.

Diversifying and innovating transportation funding models. As fuel-tax receipts plateau, some agencies are piloting road user charges and other innovative funding mechanisms. Oregon's OReGO program charges high-efficiency vehicles by the mile rather than by the gallon, pointing toward a technology-agnostic "user pays" future.[14] Mature congestion-pricing schemes—London remains a benchmark, cutting congestion time and improving air-quality metrics[15]—can generate both revenue and behavioral change. In parallel, some agencies are finding private-sector partners for projects, signaling that infrastructure investors still view transport as an attractive, long-term asset class.

Advancing low- and zero-emission vehicles. Buyers worldwide purchased more than 17 million EV cars in 2024, as improved battery technology and rising competition lowered prices.[16] Notwithstanding rising adoption, the EV market continues to face long-term challenges around public charging infrastructure, price-subsidy tradeoffs, and battery supply chain challenges. Transportation leaders are looking to develop ecosystems that support a wider set of options, including hybrids, hydrogen, compressed natural gas, and other alternative fuels.

Scaling AI in transportation. AI-enhanced operational platforms are shifting from pilots to production. AI applications are helping to cut congestion times, improve predictive maintenance capabilities, offer insights into commuter behavior, and monitor transportation infrastructure in real time. A key challenge lies in finding ways to scale innovations beyond pilots and experiments, creating mature, robust systems that keep pace with evolving user and operational needs.

The promise of autonomy. Autonomous vehicle technology is edging into commercial service, with driverless robotaxi pilots on the streets in several cities.[17] Government planners and policymakers worldwide are assessing how to safely integrate AVs—including autonomous trucking—into transportation ecosystems. Navigating the complexities of regulatory and public acceptance hurdles—along with practical barriers like coping with harsh weather and terrain, and securing insurance—the policy frontier is closely linked to building public trust, integrating AVs with fixed-route transit, and helping to ensure the equitable distribution of safety benefits.

Future-proofing transportation infrastructure. As transportation assets are more connected, they also risk being more exposed to cyber threats. Cyber incidents—ransomware, phishing, and more sophisticated attacks—continue to illustrate operational risk and ever-growing threat vectors. Physical infrastructure hazards due to extreme weather events further amplify those vulnerabilities. Agencies are therefore embracing advanced technologies, data analytics, and cybersecurity from the design stages, modular design, and harnessing innovations in material science to build long-term resilience. The result is a shift from incident response to continuous readiness, aligning infrastructure stewardship with 21st-century threat landscapes.

#Trend 1: Transportation funding

New transportation modes and technologies could eventually bring savings for both governments and citizens. However, putting these new systems in place, not to mention keeping current infrastructure operational during the transition, can be challenging. Traditional fuel tax revenues won't cover the cost of expanding and modernizing public transportation systems, upgrading aging systems, and transitioning to cleaner forms of energy.[18]

Changing vehicle preferences, declining fuel tax revenues, and economic and social shifts have downstream effects on public transportation funding, and it falls to government to make the numbers add up. Transportation agencies are responding to the changes by exploring a range of finance mechanisms and long-term revenue models that promise to be more sustainable, including road usage charges, congestion pricing, and public-private partnerships.

Fuel tax revenues explained

Fuel tax revenues once covered the lion's share of public transportation outlays. As consumers purchased ever more cars and drove ever more miles, agencies could count on gas taxes bringing in steadily increasing revenues. But conventional vehicles have become more fuel-efficient over the last two decades,[19] hybrids use even less fuel, and, of course, EVs use no fuel at all.

In 2023, the shift to EVs led to an estimated US$12 billion loss in fuel tax revenues, a gap expected to exceed US$110 billion by 2035 (figure 1).[20] By 2030, EVs are projected to reduce global daily oil demand by more than 5 million barrels,[21] with taxes falling in tandem. Despite declining revenues and forecasts, tax-averse lawmakers have been hesitant to assess new levies to make up the difference.[22]

Figure 1. Global fuel tax revenues will continue to fall over the next decade

Source: International Energy Agency

Indeed, worldwide, few transportation agencies' revenue models are sustainable. Some leaders are beginning to grapple with trends and models for future EV-driven budget shortfalls, with a handful of agencies thus far adopting a data-driven approach to quantify gaps before looking to develop alternative funding streams.[23] In the US, California adopted a data-driven approach to analyze the impact of rising zero-emission vehicles on transportation funding. California's Legislative Analyst's Office estimates that transportation revenue will decline 31%—US$4.4 billion annually—over the next decade and even further if the state's plan to end gas-powered passenger car sales by 2035 remains in effect.[24]

Economic and societal shifts have further impacted fuel tax revenue, with, for example, following the COVID-19 pandemic, remote work arrangements have eliminated many daily commutes. In the US, overall, employees now work more than one-quarter of paid days remotely, up from 7.2% in 2019.[25] While many large organizations, including government agencies—particularly in Asia Pacific[26]—have moved to urge or even require a full-time return to office work,[27] many will likely settle for hybrid work arrangements, given employee preference.[28]

Diversifying transportation funding

Public transportation agencies are diversifying their revenue streams to address funding shortfalls that will widen without intervention. Strategies include adjusted gas tax rates, fees on EV purchases, road-user charges, asset recycling, and public-private partnerships.[29]

Levying EV taxes and fees

The increasing popularity of EVs and hybrid vehicles presents opportunities and challenges for transportation funding. Low- and zero-emission vehicles contribute to reducing greenhouse gas emissions and dependence on fossil fuels, but they inflict many of the same external costs—for instance, wear-and-tear to roads and bridges—as traditional Internal Combustion Engine (ICE) vehicles. Agencies no longer benefiting from fuel taxes must still account for EVs' impact.

Around the globe, agencies are exploring a range of measures to offset at least a portion of declining fuel taxes.[30] The UK, New Zealand, Israel, and some US state governments are introducing tax changes and charges on EVs and hybrid vehicles, from registration fees and road usage charges to taxes on public charging points.[31] Germany, New Zealand, Sweden, and France have slashed their subsidies for EV purchases.[32] And at least 39 US states have enacted special registration fees on EVs, with 32 also assessing fees on hybrid vehicles.[33]

Adjusting fuel tax rates

While most vehicles are still ICE, some governments have looked to incrementally raise fuel taxes— not a permanent solution to the problem of declining gallons used, but a potential stopgap. In 2024, the Australian government raised fuel excise taxes to over 50 cents per liter, with proceeds earmarked for maintaining and developing infrastructure and roads throughout the country.[34] As of January 1, 2025, seven US states raised their fuel tax rates, ranging from less than 1 cent to 3.3 cents per gallon. (Four states reduced fuel taxes.)[35]

Exploring road usage charging systems

From expanding traditional tolls to experimenting with more sophisticated technologies, governments are looking to road user charging (RUC) models as an alternative revenue model. In 2024, New Zealand expanded its distance-based RUC program—in effect for heavy trucks and diesel vehicles since the late 1970s—to include electric vehicles and plug-in hybrid electric vehicles. Revenue collected is directed to the National Land Transport Fund, used for new roads, improvements, maintenance, public transport, road safety, and walking and cycling.[36] In the past year, RUC charges from EV use contributed nearly NZ$80 million.[37]

Singapore is considering upgrades to its existing gantry-based Electronic Road Pricing (ERP) system by introducing an AI-powered camera system that can read vehicle registration plates and automatically charge tolls. The pilot program will be tested until October 2025, with cameras tracking each vehicle's route and assessing potential charges based on the distance covered.[38] Agencies need to ensure proper governance and controls are in place, given the potential privacy considerations associated with such technology.

Agencies in many regions have struggled to successfully implement RUC pilots, due less to technological hurdles than to administrative cost and complexity, especially compared to a straightforward fuel tax structure. Instituting and implementing an RUC program that calculates and assesses tax owed by each driver would entail significantly higher administrative and equipment costs. Transportation agencies have also found it difficult to define the value proposition for different stakeholders, considering urban/rural parity in usage charges, data governance burdens on vehicle manufacturers and dealerships, privacy and bias concerns, political support, and the need to build public trust in these systems.[39]

Some states are trying to reduce the administrative burden by leveraging existing vehicle-safety checks to track mileage. Hawaii, as part of its annual "safety check" inspections, is now recording odometer readings for electric vehicles to inform how many miles were driven.[40] There are some other low-tech solutions being experimented with, like Utah RUC[41], which allows drivers to upload photos of odometer readings quarterly, and New Zealand requires drivers to buy pre-paid blocks of 1,000 kms called distance licenses.[42]

Leveraging congestion pricing

Congestion pricing can be a powerful tool for helping manage traffic and easing urban congestion while contributing funding to cash-strapped urban centers. Programs have helped London, Singapore, and Stockholm reduce congestion by 13% to 30% and greenhouse gas emissions by 15% to 20% through these schemes.[43]

In January 2025, New York City launched its first congestion pricing program[44], charging passenger vehicles, trucks, and buses a flat fee to enter the business districts during peak hours, with charges reduced by 75% at night. The program aims to reduce traffic and travel time, cut emissions, improve quality of life, and raise revenue for public transit improvements.[45] As with its counterparts overseas, New York's program was unpopular at launch but rapidly built support as the outcomes became clear: dramatically faster bus and commute speeds, higher public transit ridership, and more city visitors.[46] The toll raised US$216 million in its first four months of operation, well on target to reach US$500 million in net fees in 2025.[47]

Reimagining public-private partnerships

Many transportation agencies are looking to tap private-sector capital to build and maintain highways, roads, and bridges. After all, businesses rely on functioning infrastructure as much as other interests. By collaborating with the private sector, agencies can share the risks and rewards of large-scale projects.

Dubai Roads & Transport Authority is harnessing private expertise to expand and modernize its metro line, delivering on future-ready infrastructure. The agency is working with a consortium of three companies to construct a 30 km metro line, a US$5.6 billion project that involves building 14 stations, both elevated and underground. The project supports Dubai's urban and economic plans, aims to cut congestion by 20%, and aims to be the city's first platinum-grade green transport project.[48]

In the US, a growing number of states operate managed lanes—typically highways with pay-to-use express lanes—to alleviate road congestion and generate revenue, often financed and maintained by public-private partnerships.[49] Texas has more than 100 miles of TEXpress lanes on eight North Texas roadways.[50] The projects have proven financially successful, especially in typically tax-averse states, to encourage more private sector participation.[51]

Most recently, Tennessee has been looking to create its own "choice lanes" using dynamic tolling. With initial funding provided by the state's Transportation Modernization Act, the state's proposal calls for a private-sector partner to design, build, finance, operate, and maintain the program. This would give commuters a choice between convenience and congestion on I-24 routes between Nashville and its suburbs.[52]

Utilizing transportation bonds and dedicated financing

Transportation bonds represent another strategic approach to funding public transportation infrastructure projects. In 2015, Transport for London issued the first green bond to fund low-carbon transportation projects, with proceeds used for station upgrades, low-emission hybrid buses, and cycling infrastructure.[53] A number of countries continue to issue green bonds to help finance low-carbon transportation and other environmentally targeted projects,[54] though such bonds are largely unavailable to developing economies.[55]

Transportation agencies are tapping a range of sustainable finance strategies to fund low-carbon projects, including public, private, or alternative funding for mitigating and adapting to extreme weather. Bogotá, Colombia, purchased 401 electric buses with US$134 million from the Inter-American Development Bank and private sources.[56]

Land value capture and asset recycling

Some agencies have explored land value capture as a mechanism to help bridge funding gaps by tapping the boost in property values that new transportation projects, such as roads or transit lines, often create. Agencies in France, Korea, and the UK have used land value capture to help fund subways and railroads.[57]

Hong Kong's Mass Transit Railway Corp. has successfully implemented a "rail plus property development" model, partnering with the government to secure long-term development and air rights near new stations at pre-development land values. These rights are tendered to private developers, who fund construction and share profits. This partnership has successfully financed metro expansion and is now applying the approach to other major transport projects.[58]

Asset recycling is another strategy that can allow public transportation agencies to generate revenue and capital expenditure by leasing or selling public assets such as toll roads, airports, or utilities to private investors. Agencies then reinvest the proceeds from these transactions into new transportation infrastructure. In 2022, Dubai made a significant move by partially privatizing its toll system. Salik, Dubai's exclusive toll gate operator, sold a 24.9% stake through an initial public offering, generating approximately US$1 billion in revenue for the government[59] and turning a steady toll revenue into immediate capital for new projects. Dubai, at the forefront of the asset recycling trend, has sold stakes in other transportation infrastructure, such as public parking and taxi services.[60]

#Trend 2: Advancing low- and zero-emission vehicles

Transportation planners have long looked to a future where vehicles are fueled by clean energy. With escalating fuel prices, deteriorating air quality, and dwindling fossil fuel reserves (in some countries), the transportation sector is under increasing pressure to innovate. Furthermore, as a major contributor to global greenhouse gas emissions, accounting for 13.7% in 2021, the sector is at a critical juncture.[61] Public transportation agencies are looking for ways to transition to a long-term low- and zero-emission transportation ecosystem that uses clean energy sources. And consumers around the world are increasingly going electric.

But the road ahead isn't as smooth and free of obstacles as many agencies might prefer. To build a transportation system that's resilient, cost-effective, and as seamless as possible, policymakers and planners should look forward, taking cues from examples of agencies and countries piloting and adopting low- and zero-emission transportation alternatives.

It helps that electric mobility is no longer a niche experiment but a worldwide phenomenon.[62] The global EV market, including battery and plug-in hybrid vehicles, is growing , up 25% from 2023 to 2024, with 17.1 million EVs sold in 2024.[63] Drivers in some European countries are increasingly enthusiastic, and interest is also growing with North American drivers, though China still sets the pace, registering nearly two-thirds of the EVs sold globally last year, with a 41% sales increase in 2024.[64]

However, there's congestion ahead. Many see EV adoption momentum slowing in upcoming quarters, with subsidy cuts in Germany[65] and the US.[66] Some major questions should be resolved before millions of car owners lose their reluctance, and before most transportation ecosystems can fully incorporate EVs.

Clearing the roadblocks to EV adoption

It's up to national, regional, and even local stakeholders to address key challenges:

Charging infrastructure. The surge in vehicles on the road is outstripping the availability of public charging stations. Operators installed 30% more chargers globally for light-duty vehicle charging in 2024, but EV growth was faster still. But the growth is also uneven. Almost two-thirds of the growth in public chargers since 2020 has happened in China, which also has 65% of the world's public charging stock.[67] In mature EV markets, drivers continue to confront a lack of fast chargers on inter-city highways[68] and there are access problems in some apartment blocks.[69]

Some regions struggle to upgrade distribution feeders and connect chargers to the grid, with lengthy installation timelines—up to 12 months for multiple or high-powered units and up to 18 months for ultra-fast chargers,[70] making access scarce. Standardization across charging stations and networks has been a challenge, though increasingly less so, with Tesla opening its expansive Supercharger network[71] to non-Tesla EVs.[72]

Breaking the price-subsidy tradeoff. Economists have seen EV purchase subsidies for passenger cars pay real dividends: In one US study, every US$1 in government subsidies helped generate economic benefits of US$1.87, though three-quarters of subsidies were claimed by consumers who would have bought an EV even without incentives.[73] Still, abruptly removing subsidies can sap consumer interest in EVs. For example, Germany's move to end incentives in late 2023 brought a 27.4% drop in sales in 2024.[74]

Battery technology and supply chains. Batteries, accounting for about one-third of EVs' total cost, largely drive vehicle prices today. The equation is shifting: Advances in technology continue to reduce the cost—from over US$1,200 per kWh in 2010 to US$115 in 2024[75]—and will therefore likely lower batteries' contribution to EVs' cost to about 19% by 2030.[76] Trade may introduce challenges, since battery manufacturing costs vary across geographies.[77] Critical minerals, both mining and processing, an important element in the broader battery manufacturing supply chain, are another critical choke point.

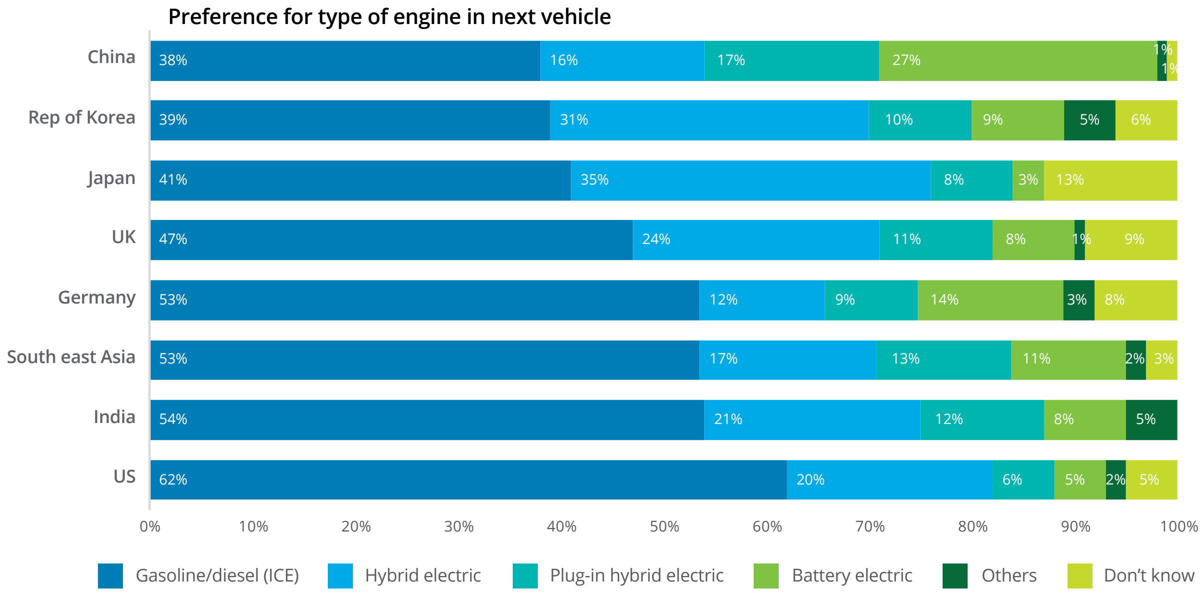
Freight electrification. Electrifying freight is hardly frictionless. A possible movement in freight will be around electrifying short-haul, last-mile, and local delivery vehicles, and solutions for long-haul will likely center around hydrogen and biofuels in the future. And there are clear reasons for such a differentiation. Large, heavy battery packs in vans and trucks steal payload capacity, and grade heavy routes—think the Andes, the Alps, or the Rockies—sap range and strain brakes on descents.[78] While engineers are experimenting with lighter lithium metal cells, in-motion charging lanes, and hybrid hydrogen range extenders, these solutions raise fresh cost and infrastructure questions.[79] Another challenge with heavy-duty and long-haul vehicle electrification is the steep upfront cost and no clear subsidy landscape in many countries.

The transition from Internal Combustion Engines (ICE) to Zero Emission Vehicles (ZEV)

With a range of short-term production and technological challenges affecting battery electric vehicles, and consumer sentiment wavering, governments and other transportation stakeholders are looking for ways to maintain the Battery Electric Vehicle (BEV) growth of the last several years.

This would mean reversing a trend: Deloitte's Global 2025 automotive consumer study indicates a shift in consumer sentiment away from BEVs.[80] Drivers in several markets are increasingly interested in solutions combining reduced fuel costs and lower emissions without relying on charging infrastructure, specifically, full hybrids and range extender technology that do not require external charging plugs (figure 2). Indeed, global sales of hybrids, including plug-in models, have almost tripled over the past five years, from 5.7 million to 16.1 million units annually.[81]

Figure 2. Consumer preference for hybrids has increased in many countries in the past year



Note: Other includes vehicles with engine types such as compressed natural gas, ethanol, and hydrogen fuel cells; percentages may not add up to 100 due to rounding.
Q41. What type of engine would you prefer in your next vehicle?
Sample size: n = 939 [China]; 1,306 [Germany]; 882 [India]; 637 [Japan]; 906 [Republic of Korea]; 5,028 [Southeast Asia]; 1,314 [UK]; 937 [US]

Source: Deloitte 2025 Global Automotive Consumer Study

Hydrogen-powered vehicles take off—slowly

Particularly for commercial vehicles, hydrogen holds significant potential, offering rapid refueling times, driving ranges comparable to traditional ICE vehicles,[82] and the possibility of low emissions.[83] But challenges continue to hinder widespread adoption, from hydrogen's flammability to its proneness to leakage due to its small molecular size.[84] Critically, clean production methods remain expensive and energy-intensive,[85] with most production reliant on fossil fuels, resulting in approximately 830 million tons of annual carbon dioxide emissions, comparable to the combined carbon dioxide emissions of the United Kingdom and Indonesia.[86]

Still, with many agencies and vehicle producers committed to phasing out fossil fuels, interest in hydrogen as an alternative energy source is growing.[87] Numerous pilot projects are testing the operational efficiency of hydrogen fuel cells and other low-emission fuels. Analysts see the market expanding from US$10.78 billion in 2023 to US$165.34 billion by 2030.[88]

Globally, governments have boosted investment in hydrogen energy research, development, and pilot projects.[89] The UAE's national hydrogen strategy aims to position the country as a leading producer of low-carbon hydrogen by 2031, targeting a 25% global market share.[90] And several collaborations across Europe are focused on accelerating hydrogen adoption in transportation, particularly for heavy-duty vehicles. Thirteen partners are working with the H2Accelerate project to deploy hydrogen trucks with a network of refueling stations; funded by the Clean Hydrogen Partnership, the project aims to deploy 150 fuel cell trucks across nine European member states by 2029.[91]

Hydrogen transportation projects are both nationwide and local. In another initiative—part of the H2goesRail project—German Railways Company plans to replace its 1,300 diesel locomotives with hydrogen-powered trains by 2050.[92] Canadian cities are also moving forward, with fleets in the provinces of Ontario and Alberta piloting hydrogen-powered buses.[93]

Canada's national government, too, is working on hydrogen programs, for trucking in particular, advancing zero-emission technologies through Transport Canada's Zero Emission Truck Testbed. A pilot is testing three hydrogen fuel-cell electric vehicles and one Class 8 heavy-duty battery electric vehicle on two Alberta and British Columbia routes to evaluate their performance in demanding urban environments and on long-distance commuter routes. These test vehicles—collecting data with an eye to addressing challenges with broader use—operate under varying conditions, loads, driver profiles, routes, and geographic conditions across all four seasons.[94]

Clean energy fleets

Government agencies are building out clean energy bus fleets—an easier lift than many other transportation modes, considering buses' fixed driving patterns, routes, and shorter travel distances. In the US, California is at the forefront of deploying zero-emission buses, setting a target for all public transit agencies to transition to 100% zero-emission buses by 2040.[95]

As part of Canada's broader Greening Government Strategy, which aims to reduce emissions from federal operations and transition to low-carbon mobility solutions, the government has begun limiting light-duty fleet purchases to ZEVs, with the goal of the light-duty fleet to comprise 100% ZEVs by 2030.[96] Similarly, UK cities are expanding their hydrogen bus fleets, owing to government initiatives, policies, and a supportive regulatory framework to transition from diesel to hydrogen.[97]

Some European agencies are also buying more hydrogen buses, particularly for long-distance commuter routes. Regionalverkehr Köln GmbH, the regional public transport agency in Cologne, Germany, operates more than 100 hydrogen-powered buses and aims to have 160 by the end of 2025.[98]

Beyond hydrogen

Transportation agencies are moving beyond a singular focus and adopting a portfolio approach; they are carefully evaluating the strengths and limitations of various technologies and fuels in relation to their specific operational needs, geographic context, and sustainability goals. This diversified strategy allows for a more resilient and adaptable transition, helping to ensure that public transportation continues to provide essential services while minimizing its environmental footprint. Both public and private sectors are looking to a range of alternative energy sources to supplement or replace fossil fuels in transportation:

Compressed natural gas. Some countries are looking to compressed natural gas (CNG) to help transition to low-emission energy sources. CNG, often based on methane, produces fewer harmful emissions than diesel, including reduced levels of carbon dioxide, nitrogen oxides, and particulate matter. India is increasingly using CNG to reduce urban air pollution, especially in terms of transportation.[99] With refueling infrastructure for passenger and commercial vehicles rapidly expanding, India's CNG vehicle count has increased threefold, reaching 7.5 million units over the past eight years.[100] Delhi converted its entire public-sector bus and private auto-rickshaw fleet to CNG.[101]

Italy has moved to convert buses to low-emission public fleets powered by natural gas, CNG, and methane.[102] Similarly, the Greek Ministry of Infrastructure and Transport is replenishing its Athens bus fleet with 300 CNG buses by the end of this year.[103]

Ethanol. Brazil has used biofuels for almost half a century and remains a leader in ethanol-based transport, particularly with fuel ethanol derived from sugarcane. Some 93% of the country's vehicles are designed to operate on flexible fuels, 100% ethanol, or a mix of gasoline and ethanol. With sugarcane bioelectricity—generated from agricultural "waste" in ethanol production—contributing significantly to the national electric grid, Brazil looks to serve as a model for sustainable transportation in developing countries.[104]

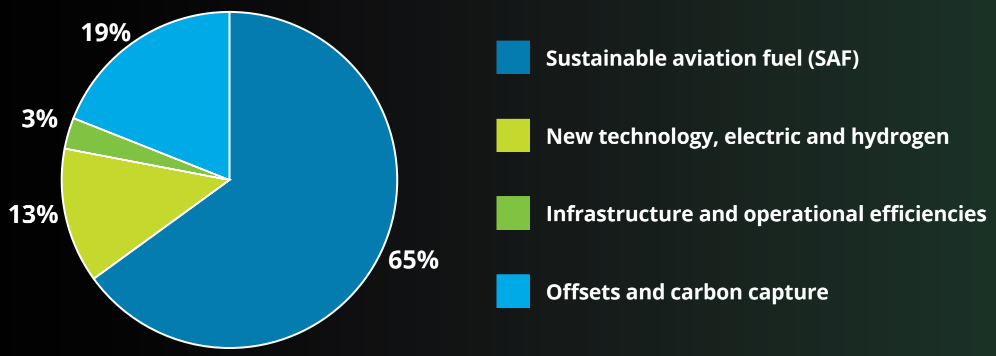
Renewable natural gas. By capturing methane from organic waste sources, renewable natural gas (RNG) offers a sustainable, low-emission alternative for public transportation fleets, one with infrastructure often more established than hydrogen refueling networks. In 2024, North America had more than 400 RNG facilities, with public-private collaborations aiming for 5,000 facilities in place by 2040, producing RNG from landfills, wastewater, and agricultural waste.[105] Several US public transit agencies have signed new deals or extensions of existing agreements to fuel their fleets with clean-burning RNG.[106]

TransLink was Canada's first public transportation authority to use RNG to fuel its bus fleet,[107] and the country is experimenting with other modes of transit as well. In 2022, Ontario launched a carbon-negative garbage truck powered by RNG derived from cow manure, with about half the cost of an electric truck and performance similar to diesel, including in cold weather. The province has more than 30 RNG projects in various stages of development or construction.[108]

Innovations for sustainable air transportation

Public transportation agencies are transitioning their fleets, on both roads and tracks, to low-emission energy sources and are exploring a sustainable alternative for air travel. Aviation contributes 2.5% of the world's carbon emissions, and the aviation industry is aiming for net-zero carbon emissions by 2050 (Figure 3).[109]

Figure 3. Achieving net-zero CO2 emissions in Aviation by 2050 will require a combination of technologies



Source: International Air Transport Association

Several countries are supporting research and development of sustainable aviation fuel (SAF) as a long-term solution for reducing flight emissions: Governments are implementing favorable policies, providing funding, and collaborating with researchers to help advance SAF technology and production.[110] However, in the short to medium term, the aviation SAF strategy will be challenged by bottlenecks in production, feedstock supply chains, and carbon trading mechanisms.

In 2021, the US launched the SAF Grand Challenge to boost annual domestic SAF production to three billion gallons by 2030. Since the launch, the task force has increased production to 30 million gallons; it continues to coordinate stakeholders and align interagency research and development efforts.[111] In Canada, the Canadian Council for Sustainable Aviation Fuels (C-SAF) was created by 60 airlines operating in Canada to work collaboratively with government and other industry stakeholders to accelerate the production of low-carbon and SAF in Canada.[112]

In 2023, the European Union adopted ReFuelEU Aviation, which mandates a gradual increase in the share of SAF blended into the conventional aviation fuel supplied at EU airports.[113] Some countries are also exploring the use of electric aircraft for short-distance travel. For instance, Air New Zealand is partnering with private-sector companies to introduce electric aircraft into its fleet.[114]

As transit agencies aim to advance toward zero emissions, leaders recognize the need for a multifaceted approach to effectively transition their operations. The collective efforts of players—including transit agencies, governments, manufacturers, technology providers, alternate fuel providers, and fleet providers—are key to making this transition successful.

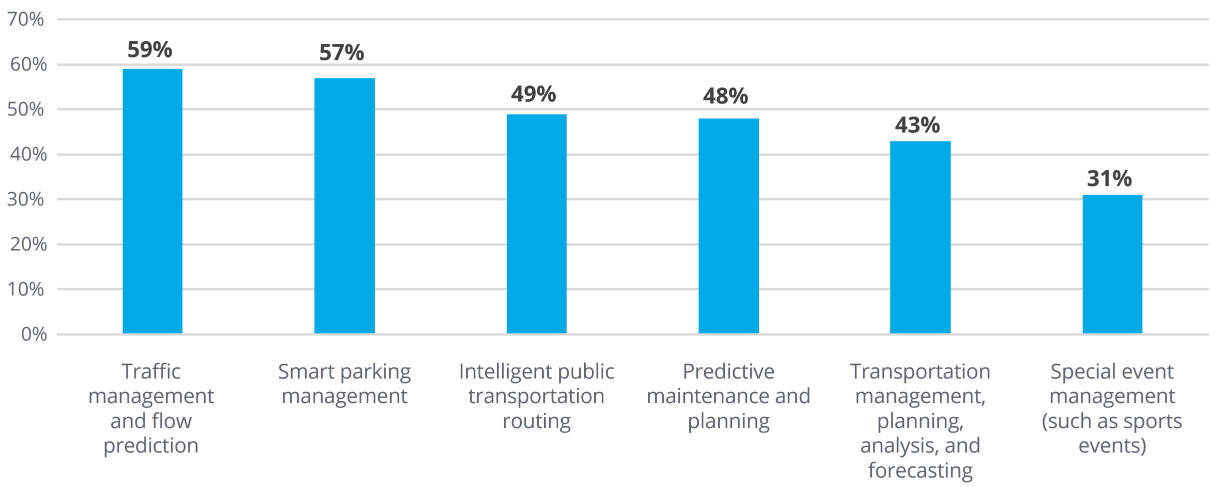
The optimal technology mix will likely vary across regions and transit systems, emphasizing the importance of tailored solutions and ongoing innovation. Ultimately, the journey toward zero-emission public transportation is nuanced and context-dependent, requiring a comprehensive and collaborative effort. Challenges will persist—technological, logistical, and political—but continuing innovation, and examples from around the world, point the way to new low- and zero-emission transportation ecosystems in cities and everywhere else.

#Trend 3: Scaling AI in transportation

Ideally, every journey, whether a daily commute or an interstate road trip, should be a seamless experience: safe, flexible, and convenient. Public transportation agencies, exploring innovative ways to realize this vision, are increasingly looking to AI, capable of processing vast amounts of data, learning from travel patterns, and tapping into sensor data. Leaders are already seeing smart technologies enhance the quality of services and improve operational efficiency.

AI-based analysis can offer insights into what riders and drivers need, helping transit agencies to tailor services and programs. The technology can help monitor road conditions and transportation infrastructure in real time, helping to ensure that any incidents are addressed promptly or even preemptively. A recent Deloitte-ThoughtLab survey of 250 global city leaders found that cities are using AI primarily in traffic management, smart parking management, transportation planning and forecasting, and intelligent routing (figure 4). And AI's convergence with other technologies—including digital twins, data analytics, biometrics, and cloud computing—is only boosting its potential.[115]

Figure 4. Global city leaders use AI for a variety of mobility and transportation uses (Percentage of city leaders surveyed)



Source: Deloitte-ThoughtLab 2024 Global City Leaders Survey

Effective AI development and deployment rely on voluminous data and computing power. Many government agencies have data in spades but struggle to liberate useful information from departmental silos, standardize it, and convert it into actionable insights.[116]

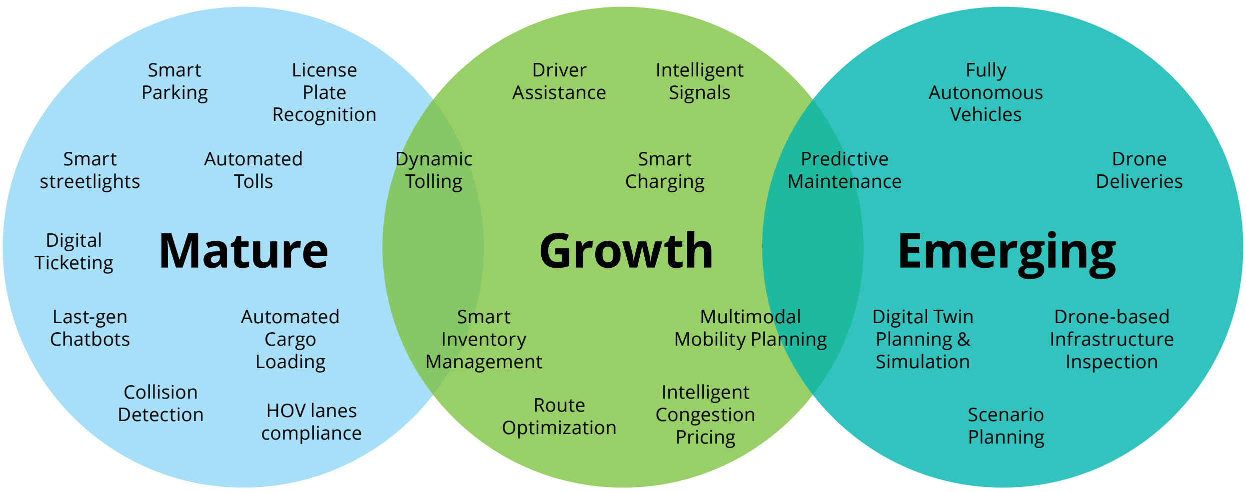
Transportation leaders and planners recognize the benefits that AI offers, and many agencies have pilot projects and proof-of-concept initiatives underway. The challenge now lies in finding ways to scale innovations beyond pilots and experiments, creating mature, robust systems that keep pace with evolving user needs.

AI creating value for transportation agencies

Beyond the most common uses for AI in transportation—including smart parking, smart signals, route optimization, and traffic compliance—leaders are looking to advances in data management and AI technologies for new capabilities. Agencies aim to build predictive capabilities, improve planning and design, and make more dynamic and accurate real-time decisions.

At a broader level, AI usage in transportation can be organized into three intersecting categories by their maturity levels: mature, growth, and emerging (figure 5).

Figure 5: Growing maturity of AI applications in transportation



Source: Deloitte Analysis

Mature

Smart parking: The recent surge in traffic congestion in many global cities[117] is prompting transportation agencies to rethink urban parking infrastructure. The earliest smart parking innovations began with sensors placed in various parking lots to gauge space availability. Today, advanced AI technologies can analyze real-time traffic and occupancy data and historical parking patterns to help agencies respond to congestion by adjusting parking fees dynamically.

In the Swedish city of Linköping, the smart parking app LinPark 2.0 offers digital navigation to direct users to the nearest available car parks or on-street parking areas. Integrated digital signage efficiently directs drivers, saving fuel and reducing congestion. While streamlining users' parking experiences, the system gathers data and provides insights into user patterns and peak times, helping agency leaders to plan better in the future.[118]

Compliance: Barcelona is piloting an AI-based system to improve bus circulation by enforcing bus lane and stop regulations. On two lines, cameras installed in the front of buses detect vehicles committing violations, such as disrupting bus operations by blocking or parking in reserved lanes. The system aggregates and analyzes the collected photographic and video data along with the context, helping planners identify ongoing challenges with traffic flow and repeated violations.[119]

Safety: To boost Singapore's public transport's safety and efficiency, government agencies have incorporated AI technology into a number of systems. In 2018, smart camera sensors were installed on buses to detect objects at the front and sides, addressing blind-spot hazards. The Land Transport Authority upgraded surveillance systems on 10,000 buses with AI-powered features, including advanced driver assistance and blind spot detection, improving safety by alerting drivers and pedestrians, reducing traffic risks, and promoting safe driving habits.[120] And Changi Airport uses AI-based technology with proper controls and oversight for baggage screening and behavior recognition during immigration clearance, helping to improve border security and enhance the travel experience.[121]

Growth

Smart signaling: Arlington, Texas, authorities use a platform that taps into data from sensors and cameras to sync traffic signals with real-time conditions, adjusting them as needed. For example, it can lengthen yellow lights or prioritize emergency vehicles. The system also provides planners with detailed traffic data that can help them respond quickly to new challenges.[122] In a two-month pilot project in Redlands, California, a similar system tested at just two intersections saved 900 commuting hours and cut 11 tons of vehicle emissions.[123]

Predictive maintenance: New York's Metropolitan Transportation Authority is extending its TrackInspect prototype using advanced AI to detect subway track defects. Smartphones retrofitted with sensors and microphones in subway cars capture vibrations and sound patterns, sending this data in real time to cloud-based systems. AI and machine learning algorithms generate predictive insights, guiding human inspections to detect defects, confirm problems, and help the model keep learning. A GenerativeAI (GenAI) layer allows inspectors to ask natural-language maintenance questions. The initial pilot ingested and analyzed 335 million sensor readings, 1 million GPS locations, and 1,200 hours of audio; the system identified 92% of the problems that inspectors found.[124]

Route optimization: Germany's hybrid urban-suburban rail network, S-Bahn, uses AI-based technology in operation centers to boost train traffic efficiency and help dispatchers swiftly address disruptions by simulating potential developments and continuously analyzing live operations. This proactive approach minimizes delays, improves traffic flow, and creates capacity for additional trains, optimizing existing infrastructure. The German Railways Company is testing the AI-based program outside the S-Bahn network, expanding to encompass different kinds of dispatched traffic, including cargo as well as regional and long-distance trains.[125]

Emerging

Transportation infrastructure planning: In seeking value in AI technologies, transportation agencies are looking to digital twin in particular. This approach—using detailed digital replicas of infrastructure such as roads, bridges, tunnels, and transit systems—allows for real-time monitoring, simulation, and optimization. By integrating data from various sources, including sensors and historical records, digital twins can offer a comprehensive view of these assets' current and future state.[126]

In Florida, the Broward Metropolitan Planning Organization is developing a digital twin that aims to improve infrastructure planning by merging data on housing, zoning, population, and climate, allowing planners to employ geospatial visuals to develop ideas. SMART METRO looks to forecast congestion and flood risks while simulating impacts on transportation and land-use impacts. The agency hopes to use the program to guide redevelopment projects, improve roadways, and determine optimal locations for transit stops and routes.[127]

Drone-based deliveries and inspections: With too few specialists to adequately inspect South Korea's aging underground urban highways, the Korea Institute of Civil Engineering has pioneered drone inspection technology to monitor construction and maintenance. The GenAI-based system can synthesize comprehensive images of damage scenes from limited information, with AI-powered drones navigating inside tunnels and effectively replacing manual inspections in hazardous environments.[128]

Early cases for generative and agentic AI transformation in public transportation

The transportation industry is actively exploring the potential of GenAI, which can automate tasks, analyze mountains of data, and create and edit text, video, and images. In Deloitte's recent survey of transportation and supply chain executives across sectors, over 40% of government and public services executives see GenAI already transforming how work gets done.[129]

In May 2024, the California Department of Transportation issued contracts for pilot programs to test how GenAI can enhance traffic operations and highway road safety. These programs will use GenAI to help analyze voluminous data coming from sensors and real-time camera feeds and make it usable for transportation planners.[128] The first pilot aims to use GenAI to investigate near-miss incidents, identify hazardous areas, and aid workers in brainstorming ideas to protect bikers and pedestrians. The second pilot will aim to help analyze traffic pain points, looking to reduce congestion and enhance crash prevention by generating real-time route adjustments or alerting operators to hazards.[130]

The emergence of agentic AI—AI that can operate independently and make autonomous decisions—is poised to further redefine public transportation.[132] Agentic AI can accelerate the development of intelligent transportation systems, recognizing accidents and immediately rerouting traffic, adjusting signal times using traffic flow data, triggering maintenance workflows in predictive maintenance, and coordinating vehicle-to-vehicle and vehicle-to-infrastructure communication.[133] Of course, these are still early days of experimentation for the technology, with developers and planners working to address important oversight (human-in-the-loop), cybersecurity, and interoperability concerns.[134]

The challenge of scaling AI

In the realm of transportation, effective AI integration hinges on four critical dimensions: strategy, governance, people, and technology (figure 6). Many transportation agencies already possess capabilities in each of these areas, and pilot projects are providing valuable insights and enabling initial experimentation. But the journey toward widespread, scalable AI applications demands a far more integrated and comprehensive approach.

For many transportation agencies, the real challenge isn't the absence of an AI strategy or the necessary technological tools—it's the gap between pilot initiatives and at-scale operational capabilities. The level of expertise, infrastructure, and coordinated governance needed to fully embed AI into transportation processes far exceeds the requirements of early-stage experiments. This disparity underscores the need for a concerted effort to move from preliminary projects to robust, scalable solutions that can drive efficiencies, enhance service reliability, and make a transportation network smarter and more responsive.

By addressing these four dimensions holistically, transportation executives can help ensure that AI initiatives become integral components of a modern transportation system.

Figure 6. The bridge from pilot-level to at-scale capabilities

	Pilot-level capabilities	At-scale capabilities
Strategy	Typically, document published at launch that is seldom referenced thereafter	Living decision-making process, objectives, and metrics tied to the transportation agency's mission built into every step of the process to achieve its stated goals with AI
Governance	Minimal oversight, with perhaps some initial approvals to create a proof of concept	Ongoing governance with tiered bodies and a platform/tool capable of handling prioritization, risk management, and tracking of various AI use cases from ideation through testing, implementation, and ongoing usage
People	A small cadre of self-starters: Progress is driven by those interested enough to learn about gen AI and begin experimenting with it	The right skills for all workers: AI fluency training tailored to the role, level, and job of each individual Transparency and change management training: For those who may be concerned about how AI could impact their work
Technology	A patchwork of sandboxes, testbeds, and subscriptions that work for individual pilots but do not offer enterprise visibility or value	An AI platform that facilitates the easy creation of new solutions and the rapid scaling of successful ones. It includes built-in controls for data protection, and the ability to modify each use case as needed

Source: Deloitte Analysis

#Trend 4: The promise of autonomy

After years of optimistic predictions and often-justifiable skepticism,[135] autonomous vehicles pilots are cruising enough city streets, highways, and industrial sites for government agencies to make AVs central to transportation planning and policy.[136]

The potential economic and social benefits of driverless cars—beginning with improved efficiency, convenience, safety, and mobility—have long been evident.[135] Projections and simulations have illustrated how AVs might help agencies, drivers, and everyone else. One study estimated that using AVs to optimize traffic flow and dissipate stop-and-go traffic patterns would yield a 40% reduction in fuel consumption and a 15% increase in vehicle throughput.[136] A simulation suggested that shared AV taxi and micro transit fleets could drastically reduce a city's congestion, emissions, and required parking space.[139]

Although AVs still face obstacles to wider adoption—from ongoing safety and policy challenges[140] to broad public skepticism about the benefits of AI technology in vehicle systems—however their potential to transform the future of transportation and national economies is growing ever clearer. One study estimates that deploying 9 million AVs in the US during the next 15 years would need 114,000 workers to meet AV production, distribution, maintenance, upgrades, and repairs.[141]

As many autonomous vehicle pilots scale further, transportation leaders and policymakers should determine their key objectives and priorities—such as fewer crashes, less parking demand, improved air quality, less congestion, and economic development—and consider how AVs might contribute to achieving them.

Autonomous technology moving into the mainstream

Automakers and regulators are implementing a wide range of AV experiments and pilots. Analysts expect the global robotaxi market alone to grow at a compounded annual growth rate of 65% between 2023 and 2030 and reach almost US$100 billion.[140] In the US, robotaxi pilots have flourished in cities such as Austin, Phoenix, San Francisco, and Los Angeles.[141] With public acceptance growing, Waymo plans to introduce a next-generation AV equipped with custom sensors and an AI "driver."[144] And notwithstanding some high-profile AV programs closing down,[145] investment elsewhere remains strong.[146]

Countries around the world are increasingly looking at ways to assimilate AVs into their public transportation networks, from laying the groundwork for adoption[145] to full-fledged integration. The Chinese city of Yizhuang is developing a system that integrates data from vehicles, roads, and cloud platforms to create a safer and more efficient transportation network.[146] Seoul has also introduced autonomous buses linking major tourist attractions, integrating into existing transport infrastructures; the initial 2.6 km route stops at five locations every 15 minutes, providing free transfer to passengers.[149]

Robotaxis and self-driving buses may draw most of the headlines, but AV technology is also having a real impact on the freight and trucking industry. Companies around the world are adopting autonomous trucks, particularly in mining, and seeing increased productivity and reduced operating costs.[150] More than 3600 autonomous haul trucks are operating in mines around the world. China has the largest share, followed by Australia, Canada, and Chile.[151] And the market for autonomous construction equipment, most notably AV farm tractors, partly to compensate for labor shortages, continues to expand.[152]

Following on-road autonomous heavy-vehicle pilots in Europe and the US, the Australian city of Melbourne partnered with transportation infrastructure company Transurban to conduct trials of a self-driving truck. Travel on CityLink—the city's smart motorway, equipped with sensors, 600 cameras, and Automatic Incident Detection Systems[153]—sends real-time data directly to the truck's automated driving systems, helping it efficiently navigate the road and traffic. The trials aimed to understand how the vehicle interacts with road infrastructure in real-time traffic and how future trucks can be integrated into the existing transportation network.[154] Transurban plans to introduce more autonomous trucking programs on smart highways in Australia.[155]

A proactive regulatory approach to scale AVs

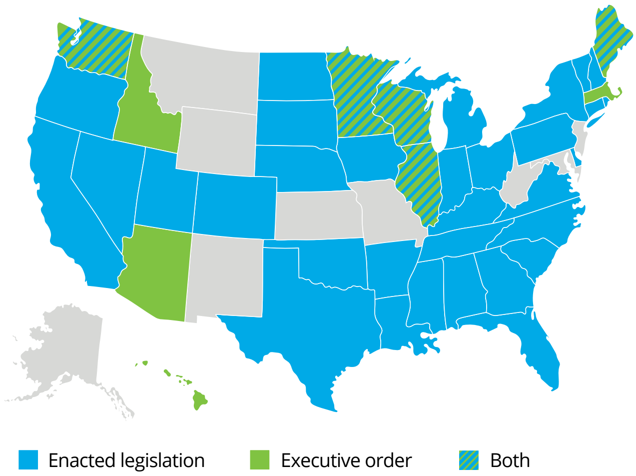
As the AV market continues to expand, governments are setting targets to scale up the technology and encourage new market participants. For instance, the United Arab Emirates' Autonomous Transportation Strategy aims to make 25% of the country's total transportation autonomous by 2030, with the goal of reducing transportation costs by 44%, decreasing accidents by 12%, and boosting productivity of individuals by 13%.[156]

Realizing measurable benefits in any city, region, or country will require a coordinated effort across the broader transportation ecosystem. The public and private sectors should combine their strengths to ensure safety and reliability and nurture public confidence.

In 2024, more than 50 countries[157] had or were in the process of creating dedicated autonomous vehicle regulations to implement effective safety standards and build confidence while maximizing AVs' potential benefits.[158] Some geographies have adopted a decentralized approach, with policies for AV deployment tailored to regions, or states. Others, such as the European Union[159] and Canada, have adopted a more centralized approach.[160]

Twenty-five US states allow some level of AV deployment, with varying rules for public road testing to suit local needs. Cities within these states have adopted diverse strategies to integrate AVs while ensuring safe operation, offering policymakers different approaches for optimal deployment (figure 7).[161]

Figure 7. Multiple US states have enacted legislation or issued executive orders related to AVs



State policy

States have embraced AV testing deployment, and adoption on varying levels. Preemption has led some states to enforce official stances uniformly across communities, while its absence enables greater local flexibility.

Local or city policy

Based on statewide policy, some localities can play central roles with industry for deliberate, controlled implementation, while other localities are on the sidelines.

Source: Deloitte Analysis

While framing these regulations, policymakers should address a wide range of complex challenges to unlock the potential of AVs for citizens, businesses, and the environment. Whether the focus is on shared or individually owned AVs, ride-hailing or package delivery, short commutes or long road trips, regulatory authorities and transportation agencies should consider a proactive policy approach to help make the integration safe and effective.

Many transportation ecosystems are so complex that simply grasping the scale and the number of players and stakeholders can be a real challenge. Agencies face so many considerations and unanswered questions that it can be easy to overlook something critical.[162] Some challenges to address include:

- **Licensing, permits, and registration.** How can an agency establish processes for determining operational eligibility for AVs, and what else should be built out?
- **Liability and insurance.** What stakeholders are involved in AV operations, and who is responsible if something goes wrong?
- **Road safety and traffic management.** How should local governments leverage their traditional oversight in traffic management, street design, and curb management to shepherd AV deployment?
- **Data privacy and cybersecurity.** How can AV companies share emerging findings and progress with the public sector while maintaining user privacy?
- **Vehicle standards and environment.** To what extent do autonomous operations require special standards, and what level of stringency will optimize safety and innovation?

Each policy area requires a blend of oversight and collaboration among public and private entities. Collaboration across the ecosystem is key to effectively developing a regulatory framework and advancing autonomous technology. Saudi Arabia has made AV implementation a key part of its Vision 2030, teaming with various public and private partners to establish a unified national AV strategy.[163] Singapore's Land Transport Authority is tapping private partners' expertise to develop a system that will help support regulatory efforts by ensuring AVs' safe and reliable deployment through real-time monitoring and management.[164]

Advanced air mobility

As the number of AVs on land grows, more autonomous drones are filling patches of sky. Companies are testing autonomous drones to deliver packages, food, and other items.[165] Drones operate on little energy, and remote pilots can oversee 20 drones at a time, making the technology a viable option for food logistics companies.[166] A Dublin-based drone company has conducted more than 200,000 successful deliveries in Dublin, Helsinki, and Finland, making around 300 daily deliveries within a 3 km radius.[167] Other companies plan to retrofit existing aircraft with continuous autopilot systems that cover all flight stages, from takeoff to landing, using precision navigation to avoid collisions and manage fuel more efficiently.[168]

Interest in unmanned aerial vehicles is rising as well, with several industry players working on automated, electrically powered advanced air mobility (AAM) aircraft that can take off and land vertically. Deloitte research conducted with the Aerospace Industries Association suggests that the US AAM market could reach US$115 billion annually by 2035, creating more than 280,000 jobs.[169]

Agencies, including NASA and the Federal Aviation Administration, are actively involved in safely integrating and researching on the concept of AAM. FAA is collaborating with NASA to safely integrate AAM into the broader transportation ecosystem, driving regulatory consistency and high safety standards.[170]

Airservices Australia, a federal organization, has partnered with an AAM technology company to introduce air taxis.[171] Brisbane officials plan to introduce air taxi services as part of the 2032 Olympic Games' transportation infrastructure.[172]

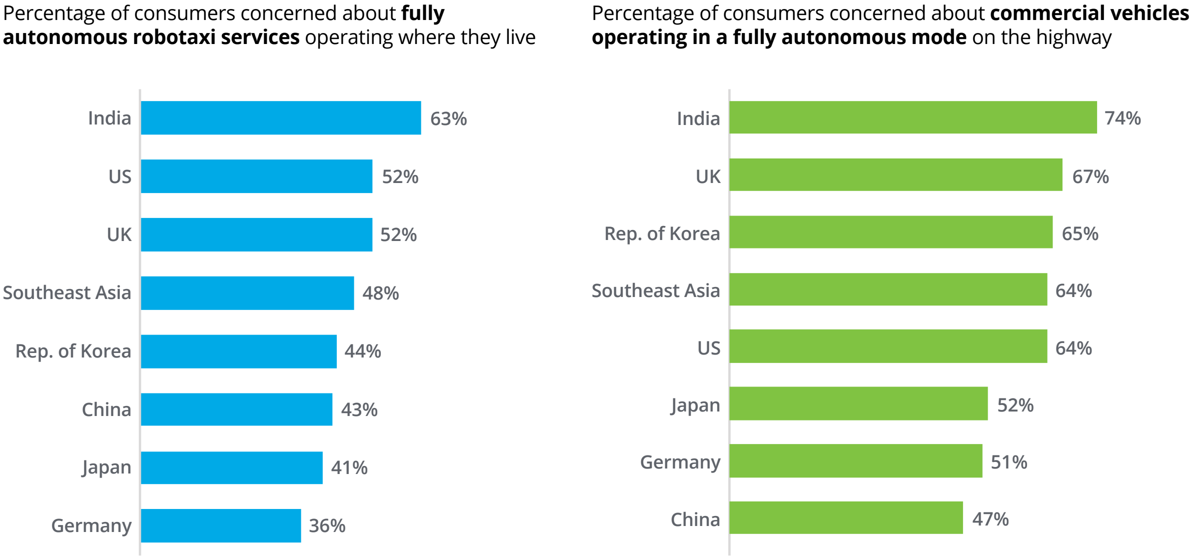
AAM vehicles could offer a viable alternative to traditional helicopters and ground transportation for urban and regional travel,[173] though they're likely to reach the masses only if and when operators can provide per-seat pricing on par with premium taxi services—and if and when demand grows for unmanned aerial taxis.[174]

Building public trust in autonomous vehicles

While research suggests that AVs are safer than human drivers in most road circumstances,[175] it's understandable why the handful of injuries and deaths involving AVs, even when compared to the 1.2 million annual traffic deaths worldwide[176], draw disproportionate news coverage and drive up apprehension.[177] In a 2023 survey, 68% of respondents claimed to be afraid of AVs, up from 55% in 2022.[178]

Deloitte Global's Automotive Consumer study shows a wide variance in AV acceptance across the eight countries surveyed. More than half of the consumers surveyed in India, the United Kingdom, and the US expressed concern about fully autonomous robotaxi services operating where they live. People are more worried about commercial vehicles operating in fully autonomous mode on the highways than about robotaxis operating where they live (Figure 8).[179]

Figure 8: More consumers surveyed are concerned about the use of AVs on the highway than in their neighborhood

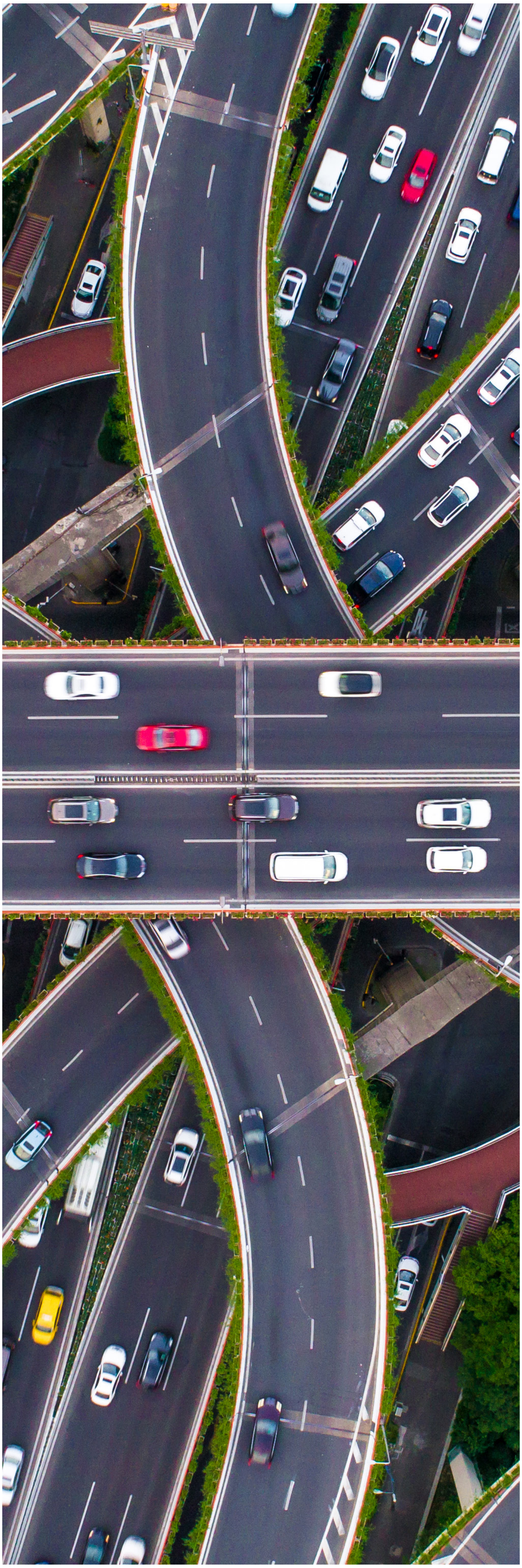


Q56. To what extent are you concerned with each of the following scenarios?
Sample size: n = 939 [China]; 1,306 [Germany]; 882 [India]; 637 [Japan]; 906 [Republic of Korea]; 5,028 [Southeast Asia]; 1,314 [UK]; 937 [US]

Source: Deloitte Global 2025 Automotive Consumer Study

To build trust in automation, transportation agencies can adopt a multifaceted approach of increasing transparency, demonstrating the effectiveness of safety standards and showcasing the technology's benefits to both individuals and the wider transportation ecosystem. Trust can build gradually: Los Angelenos and San Franciscans have become accustomed to seeing driverless cars on the roads, and ever more feel safe calling for and climbing into a robotaxi themselves.[180]

One strategy for agencies is to provide regular public updates on AV policies and regulatory frameworks, including the important subject of data collection and use, since AVs both need and generate voluminous amounts of environmental data.[181] Agencies should clearly communicate how ecosystem players—including government—might use the data that AVs collect[182] as well as how privacy will be protected in a robustly networked system.[183] For AV manufacturers and suppliers, vigilance in keeping cybersecurity protocols up to date is key: One hack or data breach could impact public safety and significantly diminish consumer trust.[184]



Highlighting AVs' social benefits—for instance, how they can help people unable to drive or use traditional public transport due to disabilities, age or other factors[185]—can also foster trust. Detroit is piloting a system of self-driving shuttles for elderly and disabled residents, offering free rides to more than 110 locations throughout the Detroit area, from grocery stores to medical facilities.[186] Eligible residents can book Accessibility-D on-demand rides by phone or app.[187]

To address mobility challenges in less populated areas, local transportation agencies are introducing autonomous shuttles, offering reliable and clean transportation options for areas with limited access to traditional public transit services. Since 2020, operators have run self-driving shuttles in a group of remote towns in rural France[188]; covering 4.5 km every 20 minutes between public places, shops, and businesses. Each Robobus carries around 10 people along with a safety operator.[189] A consortium has built on the experience to expand autonomous shuttles in the region.[190]

Japan, also facing challenges with an aging population, rural isolation, and a shortage of public transport drivers, is expanding the use of various mobility options, such as AVs and ride-sharing. The government is launching several initiatives in collaboration with local partners. Officials have started a demonstration of the first lanes dedicated to AV movement, with a target of deploying Level 4 autonomous driving mobility services into more than 50 locations by the end of 2025.[191]

#Trend 5: Future-proofing transportation infrastructure

On July 19, 2024, nearly 50 million people around the globe found themselves knocked offline as a technology outage hit banks, TV broadcasters, government services, retailers, and more, compromising medical, emergency, and transportation systems. The disruption hit airlines, forcing the cancellation of nearly 4% of all scheduled flights worldwide.[192] Analysts feared a cyberattack, but the cause was more mundane and perhaps more troubling: a fault with a configuration update that impacted software running on a broad network of PCs and servers — a disruption that ultimately cost economies more than $1 billion.[193]

The incident, dubbed "the largest IT outage in history,"[194] highlighted the fragility of essential systems in today's increasingly interconnected digital infrastructure—and how a single point of failure, intentional or not, can cascade throughout the networks on which society depends. Transportation, increasingly online and tech-dependent, is unusually vulnerable to a growing set of hazards, from online glitches and attacks to maintenance failures and rising sustainability concerns. Shippers, travelers, and owners will look to government agencies to keep everything running.

Indeed, transportation faces an ever-expanding range of threat vectors, with the convergence of information technology (IT) and operational technology (OT), which directly control physical devices. Cyberattacks affecting signaling, traffic management systems, tolling booths, and automated ticketing systems can create real-world chaos; autonomous vehicles offer yet more threat vectors.[195]

Transportation infrastructure also confronts physical threats, from overuse, deferred maintenance, and extreme weather events. In many developed economies, the surface transportation network carries more traffic than originally anticipated and requires overhaul. The American Society of Civil Engineers estimates that nearly 39% of major US roads are in mediocre or poor condition, while about half of all bridges are in no better than fair condition.[196] A G20 estimate puts the road transportation investment gap at almost US$8 trillion between 2025 and 2040.[197]

Transportation leaders, facing rising pressure to modernize and revitalize aging infrastructure and build resilience against environmental and cyber threats, are taking steps to help future-proof vulnerable systems while maintaining service and availability. A range of global examples suggests ways to move forward: By embracing advanced technologies, innovations in material science, and data analytics, transportation agencies can safeguard critical systems and help ensure the continuity of essential services after disruptive events.

An ever-changing landscape of cyber threats

The cybersecurity threat landscape for transportation agencies has expanded in both the volume and types of attacks.[198] Ransomware, malware, phishing, distributed denials of service, GPS spoofing, remote vehicle hijacking, and many other types of cyberattacks on transportation networks and infrastructure are becoming increasingly common and ever more sophisticated. Malicious actors have begun to tap the power of GenAI to personalize text-based scams, most notably impersonating government agencies and demanding payment for unpaid tolls and imitating familiar voices and faces in phishing attacks.[199]

Since March 2025, Singapore has seen a surge in phishing scams. Social media accounts impersonated the nation's EZ-Link and SimplyGo payment systems with offers of unlimited public transport rides for a nominal fee of US$2–7. The fraudulent links redirect victims to websites that replicate official portals, ask for credit card details, and use the information for unauthorized transactions, with some in non-domestic currencies. As of April 2025, at least 97 cases were reported, resulting in losses exceeding US$121,000.[200]

The public transportation ecosystem includes diverse stakeholders like service, hardware, and software providers, adding another layer of security concern. Vendors with weak cybersecurity protocols pass on the risk to the transportation agencies they serve. And even after two decades of phishing awareness campaigns, malicious players are only ramping up, seeing transportation networks as likely targets: Between July 2023 and July 2024, phishing attacks on transportation organizations rose by 175%, with attacks made through internal agency email rising by 133.5% and vendor email by 250%.[201]

The rise in autonomous and connected vehicles—which inhabit a data-rich, interconnected domain—intensifies cyber risk, with their continuous exchange of information with the environment and infrastructure creating multiple gateways for unauthorized access.[202] Autonomous vehicles process large volumes of sensitive data, including passenger information and real-time location data. If compromised, these systems could fuel privacy violations or broader safety threats, underscoring the need for robust cybersecurity and resilience in connected platforms.[203] A successful hack could have broad implications including comprising riders safety, crippling critical vehicle functions, disrupting operations which could cause long-lasting loss in public trust in autonomous transit.[204]

Advances in GenAI can create new challenges for the transportation sector. Research shows new GenAI tools are being combined with social engineering efforts to create highly convincing outputs such as fake personas, deep-fake videos, and voice cloning.[205] GenAI is also turbocharging traditional phishing and social engineering attacks. According to emerging research, phishing messages generated by large language models (LLMs) have a higher click-through rate (54%) than emails generated by humans (12%).[206] Commercially available LLMs can now generate phishing emails and websites that imitate well-known brands and deploy evasive tactics that help them elude detection.[207]

Integrated efforts to address IT–OT convergence

Traditionally, IT systems have focused on managing data and information, with OT systems dedicated to controlling physical devices and processes. But as transportation systems evolve and incorporate more connected technology, these two domains are merging.

This integration allows for enhanced operational efficiencies, predictive maintenance, and improved decision-making capabilities. But blending IT and OT systems introduces new cybersecurity challenges: Vulnerabilities in one domain may affect the other, increasing the risk of cyberattacks that can disrupt physical operations.

Transportation planners need to include cybersecurity as a key factor during the design phase of projects, ensuring that both information and physical systems are protected against potential threats. The US federal government is providing various resources to support public transportation agencies with their cybersecurity obligations: The Federal Transit Administration recently introduced a Cybersecurity Assessment Tool for Transit to help transit agencies evaluate their cybersecurity needs and develop their own cybersecurity programs.[208]

Closing the cybersecurity talent gap

As digital technologies play an ever-larger role in critical infrastructure, including public transportation, agencies expect the demand for cyber talent to increase exponentially. Analysts estimated the 2024 global cyber workforce gap at 4.8 million, up by 19% over 2023, with both government and critical infrastructure more likely than other sectors to report a cyber skills gap.[209] To address the increasing demand for cybersecurity professionals in the public and private sectors, the Cyber Security Agency of Singapore posted a guidebook detailing cybersecurity education, career pathways, and training programs,[210] and offering a 12-month program that "aims to effectively build the cybersecurity capabilities in the public sector."[211]

Universities are also working to close the cyber talent skills gap. In Australia, the University of Wollongong and Swinburne University of Technology, along with TAFE NSW, a leading education and training provider, collaborated with the private sector to launch a Cyber Academy that will produce job-ready cyber workers. The three-year blended program will pay participants $40,000 annually for working with industry or a NSW government department.[212]

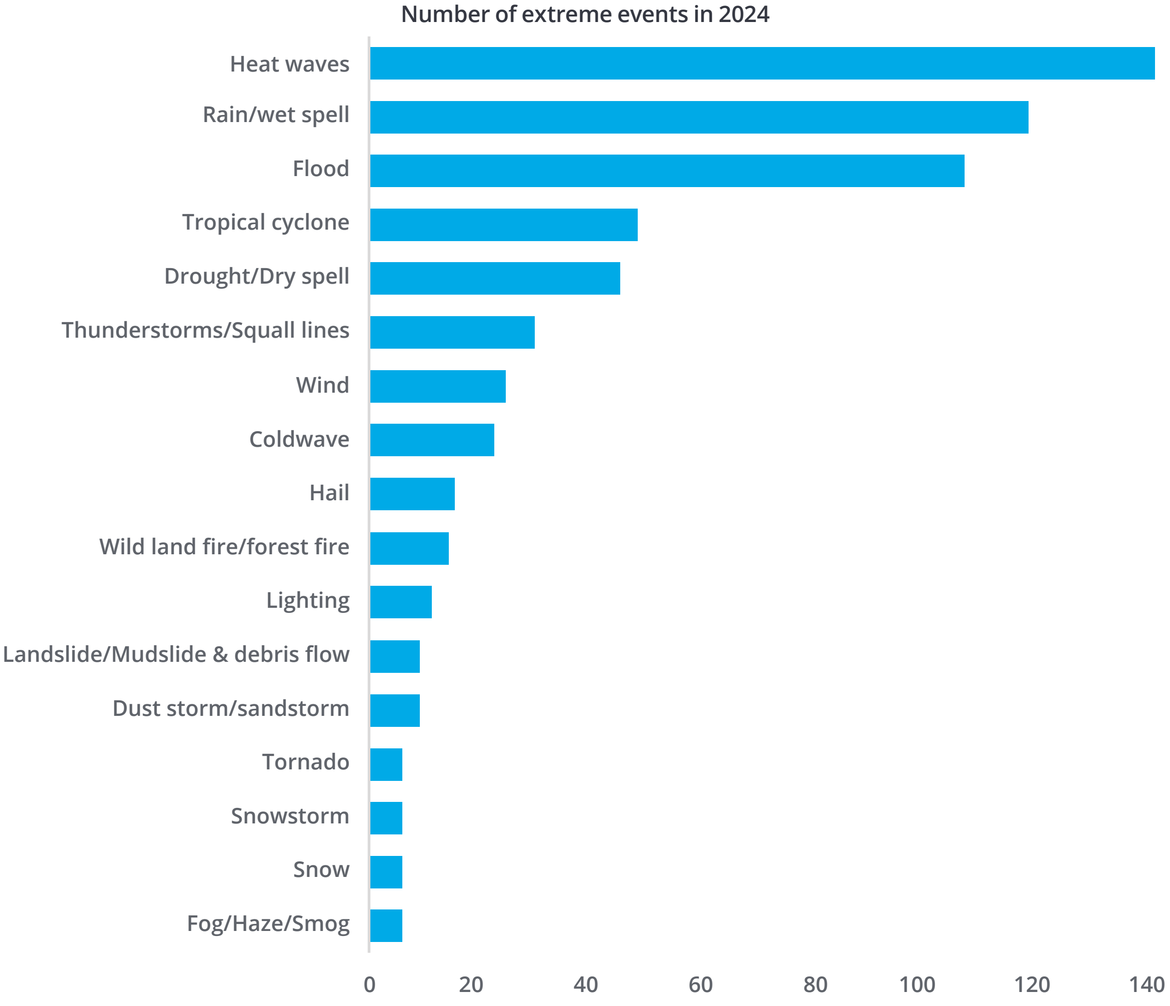
The US National Security Agency has recognized Dakota State University as a Cyber Education Center of Excellence and routinely sends its employees there for specialized learning.[213] In 2023, the South Dakota university entered into a partnership agreement with the agency, allowing students to earn academic credit by working on classified projects. NSA employees can collaborate with faculty and students, acquiring valuable insights and keeping students informed about the latest trends in national security defense.[214]

Mitigating the risks of extreme weather events

The rising frequency and severity of weather events, from heat waves and floods to wildfires and droughts, have made resiliency a top priority for many government agendas, and transportation agencies are on the front lines.

Rail lines, airport runways, bridges, and roads often weren't built to withstand today's extreme heat or flood events, potentially jeopardizing their utility at the moment when they're most needed, by people fleeing weather crises. In 2024, more than 600 extreme weather events (figure 9) displaced an estimated 824,500 people worldwide while killing at least 1,700 and injuring another 1.1 million.[215]

Figure 9. Heatwaves, extreme rain, floods, and cyclones are the major extreme weather events affecting the world today



Source: World Meteorological Organization

Routine storms are exacerbating and beginning to shift historical paths to strike unprepared areas. September 2024 saw Typhoon Yagi, the strongest tropical cyclone to hit Vietnam in 70 years, cause over US$115 million in damage to bridges, roads, and railway lines,[216] while in the US, hurricanes Helene and Milton ravaged Florida's west coast and flooded Appalachian towns which were previously unaffected by environmental impacts.[217] Both disasters strained or knocked out transportation infrastructure as people attempted to hastily relocate, with rural areas facing particular struggles: A damaged road or bridge can cut rural residents off from access to food and medicine for extended periods.[218]

With more disruptions likely, public transit agencies are exploring ways to more proactively identify risks and limit damage to transportation networks. Jakarta's Mass Rapid Transit uses various data tools to detect weather-related crises early, including rain gauges in elevated stations to measure rainfall intensity, an anemometer to measure wind speed in the highest station, a seismograph to detect earthquakes early, and water level indicators located in substations.[219]

A data-driven approach can allow officials to plan a future-ready public transit infrastructure. Spain is implementing heat sensors on rail tracks to provide early warnings and heat-reflective coatings and paints to limit temperature increases in the rails.[220] Agencies are considering matters such as rising salinity's impact on bridges and culverts, changing metallurgical requirements for structures, and materials that should be used for coastal roads, which are increasingly subject to flooding.[221]

A Deloitte Global analysis suggests that AI-powered solutions for hazard mitigation and vulnerability reduction could save up to US$70 billion annually in direct disaster costs by 2050, equivalent to 15% of projected average losses. With wider adoption and enhanced AI capabilities, these savings could surpass US$100 billion annually, potentially reducing nearly one-quarter of disaster-related losses.[222]

Tapping into research and innovation in construction and material science

Transportation agencies are looking for innovations in construction and material science to help address the challenges posed by aging infrastructure, changing weather patterns, and increasing urbanization. Composite materials—a blend of different substances to create products with new and enhanced properties—are not only stronger and lighter than traditional options but also more resistant to environmental stressors such as corrosion and extreme weather conditions.[223]

Advanced manufacturing techniques such as 3D printing allow for the rapid and cost-effective production of complex structures, reducing construction time and waste.[224] The use of 3D-printed components in infrastructure is particularly beneficial in areas prone to natural disasters, enabling the quick replacement of damaged parts and the construction of new, more resilient structures.[225]

The University of Maine's Advanced Structures and Composites Center, funded through a National Science Foundation grant, is a good example of how R&D and innovation can drive infrastructure resilience. The center has developed new technologies, including the Composite Arch Bridge System (dubbed the "Bridge in a Backpack"), 3D-printed breakwaters and culvert diffusers, and composite girders that can last more than a century with little maintenance.[226] Innovators designed these technologies to boost transportation infrastructure's durability and resilience, helping it better withstand environmental stressors and reduce maintenance costs.

Using data and digital technologies to improve transportation planning and execution

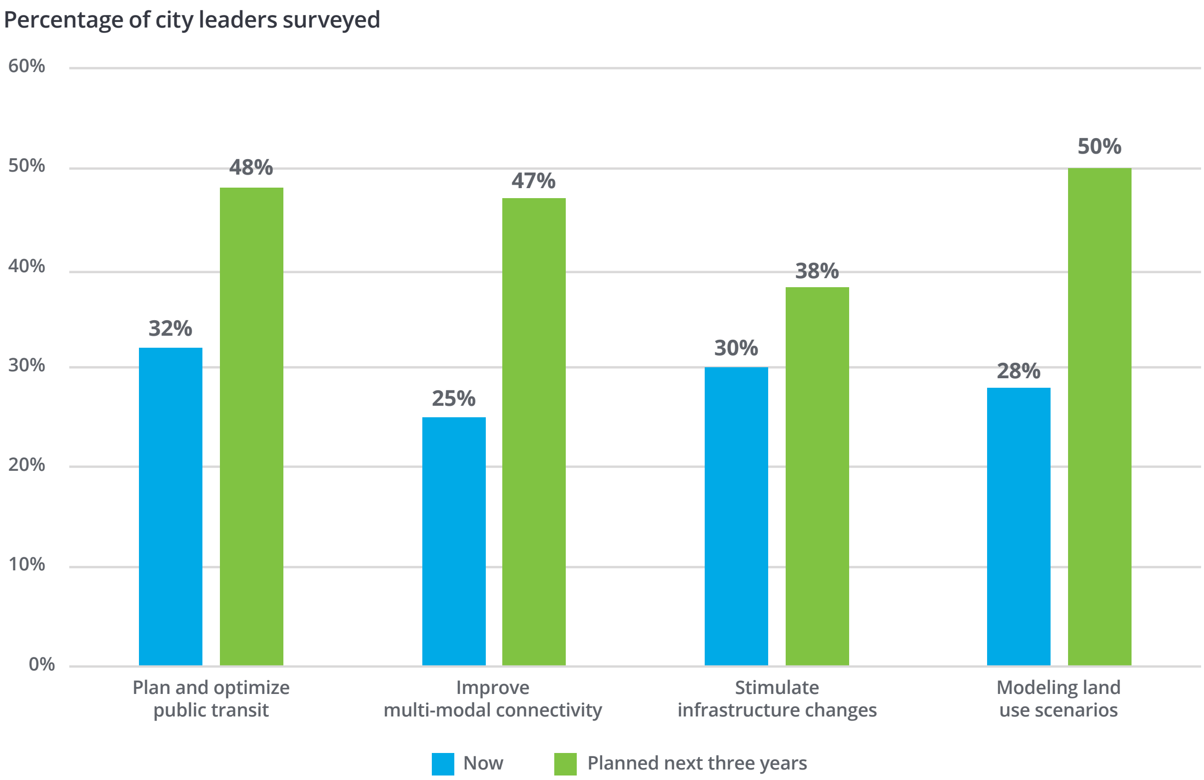
Embedded devices and sensor networks across public transit infrastructure can provide a continuous stream of real-time data for monitoring structural and environmental conditions. The Finnish Transport Infrastructure Agency provides real-time traffic and weather updates through its Digitraffic service, utilizing nearly 500 road weather cameras and more than 350 road weather stations to provide minute-by-minute updates of temperature, wind, precipitation, humidity, and dew. Road weather forecasts refresh every five minutes, and the Traffic Measurement System supplies data on average vehicle speeds and traffic volumes as well as alerts on incidents, roadworks, and restrictions.[227] The agency also makes this data accessible to the public through open APIs. This allows third-party developers to create new transportation services and solutions and better maintain existing infrastructure.[228]

Similarly, in the land down under, the Australian city of Melbourne, through the Smarter Roads program, has introduced various technological improvements to make roads and journeys smarter, safer, and smoother. Over 1,000 cameras monitor traffic, and hundreds of wireless sensors record travel time and detect vehicles. The roads also have live travel signs and over 100 dynamic pedestrian crossings.[229]

Drones and robotic inspection technologies can enhance the efficiency and speed of infrastructure assessments, providing detailed visual and sensor-based inspections. New York's Metropolitan Transportation Authority recently launched a pilot program, based on the TrackInspect prototype, to improve subway track maintenance using AI and sensors. Currently, inspectors walk the track twice a week, inspecting it for defects. In the pilot, subway cars along one line have been fitted with smartphones that use built-in sensors and microphones to capture vibrations and sound patterns; cloud-based systems and AI then capture and analyze this data and flag problems for further inspection.[230] The MTA expects the program to enhance the speed and accuracy of track diagnostics, identifying problems quickly and efficiently.[231]

Transportation agencies around the world are also experimenting with digital twins that simulate various scenarios from routine maintenance to extreme events, helping optimize infrastructure's performance and resilience. Using digital twins to design, plan, and manage connected infrastructure could save cities US$280 billion by 2030.[232] A Deloitte-ThoughtLab survey of global city leaders points toward the growing use of digital twin technology in transportation and urban planning in cities to optimize public transit, improve multimodal connectivity, simulate infrastructure changes, and model land use (figure 10).[233]

Figure 10. Cities are already using digital twin technology; even more have plans to start or continue using it over the next three years.



Source: Deloitte-ThoughtLab survey of global city leaders

Looking ahead

The path toward reliable, resilient, and low-emission mobility will be influenced by both public sector leadership and technological developments. The five trends mentioned in this report represent interconnected approaches rather than separate endeavors. When woven together, these approaches can have multiplier effects: increased revenue streams supporting cleaner fleets and modernization; the application of digital intelligence to optimize asset capacity; and secure, climate-adapted infrastructure maintaining public trust and economic performance.

By pairing bold investments with disciplined delivery, transportation agencies can leave behind a legacy of safer, more inclusive, and better-prepared networks for the uncertainties ahead. Success will be measured not only by the kilometers of new roads or vehicles deployed but also by the resilience of the infrastructure, safety of passengers, and opportunities created for communities and businesses.

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