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Infrastructure technologies: Challenges and solutions for smart mobility in urban areas

Smart mobility solutions can transform city living and improve quality of life—but are difficult to implement at scale. A collaborative, ecosystem approach could be the way ahead.

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Traffic jams, long commutes, noise, and pollution have become major blights on urban life. As the global population grows and becomes increasingly urbanized, these problems are likely to escalate. Already, 56 percent of the world's population live in cities; by 2050, nearly seven in ten people will do so.[1] Even cities without projected population growth grapple with transport volumes that put pressure on urban space and infrastructure.

By leveraging technology to manage existing transport infrastructure efficiently, cities can protect or build back neighborhoods to ensure they remain vibrant spaces. Several forward-thinking cities are looking at ways to ease road congestion, decrease emissions, and safeguard neighborhoods and green spaces—thereby improving quality of life. Hundreds of projects have been designed to enhance transport systems at city level around the world, as explored in McKinsey's report *Urban transportation systems of 25 global cities*. Such projects include developing public-transport infrastructure, digitizing transport-system processes, and expanding pedestrian and cycling infrastructure.[2] For example, the city of Amsterdam—that made the strategic decision to reduce the use of private cars as far back as the 1970s—is now planning to implement mobility hubs that integrate different transport modes with shared mobility options such as electric bikes or scooters.[3] And the city of Paris plans to add 180km of segregated bicycle lanes and triple the number of bike parking spots throughout the city.[4]

Solving for urban mobility is a pressing challenge, and a highly complex one, as it involves multiple transport modes—including road infrastructure and public transport networks—and a diverse set of stakeholders such as governments, municipalities, city councils, and service providers. What's more, what works in one city may not work in another. Solutions are often city specific and bespoke which means that they are difficult to replicate and scale. Moreover, the application and protection of the equity principle, requiring the transport system to provide all the population with the same level of access without any discrimination, is of foremost importance when addressing mobility challenges.

This article examines recent trends affecting urban mobility, and highlights the digital technologies and infrastructure advances that can respond to these trends to address the issues that many cities face. It also details the key challenges of implementing technologies and innovations at scale—keeping in mind that the process of connection and/or data exchange between infrastructures and users must comply with local privacy and data protection regulations that change according to specific geographies. As there is no one-size-fits-all solution, the article concludes by providing case examples that could help stakeholders to identify the best way forward for their specific context.

Three inter-related trends are shaping the urban mobility landscape

Cities enable social interaction and spur innovation. As a result, they are an integral part of the global economy—generating more than 80 percent of global GDP. Consequently, the urban road network is an essential enabler of economic growth and access to services. But density and urban sprawl put pressure on resources. Cities represent two-thirds of global energy consumption and account for more than 70 percent of greenhouse gas emissions.[5] Given the transport network's size, any sustainability-related changes have significant potential to reduce emissions, pollution, and congestion.

However, traffic systems are becoming more complex to orchestrate. Three major trends are shaping the urban mobility ecosystem.

Traffic volumes are increasing

OECD projections indicate that total demand for urban passenger transport will more than double by 2050, compared to 2015.[6] Additionally, recent

[1] "Urban development," World Bank, October 6, 2022.
[2] "Urban transportation systems of 25 global cities: Elements of success," McKinsey, July 2021.
[3] "Smart urban mobility," Amsterdam Institute for Advanced Metropolitan Solutions (AMS) website.
[4] Feargus O'Sullivan, "Inside the new plan to make Paris '100% Cyclable'," Bloomberg, October 22, 2021.
[5] "Urban development," World Bank, October 6, 2022.
[6] *ITF Transport Outlook 2021*, OECD, October 2021.

COVID-19-related changes in consumer habits have posed significant challenges on urban roads, specifically the increase in last-mile delivery vehicles as a consequence of the e-commerce boom.

As transport infrastructure capacity becomes more constrained, and traffic volumes increase, stakeholders may have to prioritize road safety awareness, and accident reduction. And as consumer preferences continue to influence delivery patterns, infrastructure may need to be adjusted to accommodate freight and single-parcel delivery option such as electric vehicles, e-scooters, and e-bikes.

New mobility paradigms have emerged

Shared mobility, and electric and autonomous vehicles have disrupted urban mobility. Depending on customer acceptance of shared mobility, regulations in each country, and the progress of technology, spending on shared-mobility services could reach $500 billion to $1 trillion in 2030.[7] In parallel, the future of the automotive industry is looking increasingly electric, due to shifting consumer behavior, ongoing improvements in battery and charging technologies, and regulatory moves.[8] For instance, the *Advanced Clean Cars II* regulations mandate that all new passenger cars, trucks, and SUVs sold in California will be zero emissions by 2035.[9] As far as autonomous vehicles are concerned, consumers may want cars with more advanced autonomous functions (including L2+, L3, and L4) which give the autonomous system greater control. L3 and L4 systems for driving on highways will likely be commonly available in the private-passenger-car segment by around 2025 in Europe and North America, although steep upfront costs may limit such advances to premium vehicles.[10]
These developments have implications for urban mobility infrastructure ecosystems. Growing use of shared mobility services, with the associated increase in fleets of these modes, has added to congestion. Transport infrastructure will likely become more constrained as space will have to be allocated for electric vehicle charging infrastructure (EVCI) and parking facilities dedicated to micro-mobility and/or shared mobility.

Greater attention, and public funding, is being focused on sustainability and decarbonization

The transport sector is responsible for around one quarter of global energy-related CO_2 emissions.[11] And McKinsey estimates that more than half of transportation emissions are generated by passenger cars.[12] Governments and institutions around the world are setting decarbonization goals, for example, the European Union aims to be climate neutral by 2050, an objective at the heart of the European Green Deal, in line with commitments to the Paris Agreement.[13] The US government set the same goal, aiming for net-zero emissions by 2050.[14] Businesses, too, are embracing decarbonization. Currently, more than 4,000 companies are working to reduce emissions by setting science-based targets and commitments.[15] Given the role transport plays in emissions, these shifts have significant implications for urban mobility.
As these trends unfold, cities are growing and evolving, and their citizens' needs are changing: Livability and quality of life will become increasingly important and shifting consumer preferences may shape the cities of the future. McKinsey research indicates that leading cities expand transport networks and infrastructure, and provide good road networks, bike lanes, and pedestrian infrastructure. Furthermore, increasing the number of dedicated public-transport lanes, optimizing bus routes, completing road construction or modernization projects, and implementing digital upgrades all help improve the commuter experience in such cities.[16]

Most importantly, as more people switch to new transport paradigms, there will be a greater need

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[7] "Shared mobility: Sustainable cities, shared destinies," McKinsey, January 5, 2023.
[8] "Why the automotive future is electric," McKinsey, September 7, 2021.
[9] Kira Bindrim, "NY implements 2035 all-EV plan after California clears the way," Bloomberg, September 29, 2022; "Advanced Clean Cars II regulations: All new passenger vehicles sold in California to be zero emissions by 2035," California Air Resources Board website.
[10] "Autonomous driving's future: Convenient and connected," McKinsey, January 6, 2023.
[11] "Global energy-related CO_2 emissions by sector," IEA, October 26, 2022.
[12] *Net-zero Europe: Decarbonization pathways and socioeconomic implications*, McKinsey, November 2020.
[13] "2050 long-term strategy," European Commission website.
[14] "Navigating America's net-zero frontier: A guide for business leaders," McKinsey, May 5, 2022.
[15] "Companies taking action," Science Based Targets initiative (SBTi) website, accessed December 2022.
[16] "Building a transport system that works: Five insights from our 25-city report," McKinsey, August 11, 2021.

to collaborate, coordinate, and synchronize decision making and visibility across the transport ecosystem. The need for coordination already exists—many cities face a pressing need to manage vehicle flows, as well as volumes of pedestrians and cyclists, that make up urban life.

Infrastructure technologies already provide the tools and solutions to address urban mobility challenges

Advances such as the Internet of Things (IoT), data analytics, artificial intelligence, and cloud computing create a mix of connectivity in cities that can enable solutions for reshaping the urban mobility landscape. Several actors from different industries have invested in mobility digitalization and new technologies. The range of business across the mobility value chain include established technology companies, systems integrators, tech and mobility startups, original equipment manufacturers (OEMs), digital platforms, providers of software and hardware components, and payment companies.

In this context, Intelligent Transport Systems (ITS), urban congestion charging, and Mobility-as-a-Service (Maas) platforms are among the most advanced systems and solutions currently in development:

ITS refers to systems in which technologies are applied in the field of road transport— including infrastructure, vehicles, and users—and in traffic management and mobility management.[17] For ITS to work, both hardware and software components are needed. Hardware includes IoT devices like road-side units, sensors, detection cameras, controllers, traffic lights, and toll booths. Examples of software include packages that enable advanced traffic management, environmental traffic management, vehicle-to-everything (V2X) communications, adaptive traffic control, advanced traffic planning and simulations, and data analytics.

ITS can play a significant role in improving road safety, reducing congestion, optimizing transport efficiency, enhancing mobility, and reducing energy use and environmental impacts. A European Commission report found that the largest cumulative socioeconomic benefits of ITS include reduced travel times and increased efficiency (66 percent), reduced accident rates (22 percent), and fuel consumption savings (11 percent).[18] Furthermore, ITS can help to smooth mobility demand at peak hours and provide a way to optimize freight transport through better capacity management.

Urban congestion charging mechanisms work thanks to digital cameras that are able to identify license plates and classify vehicles in urban areas. By surcharging or restricting private car access to congested areas—typically city centers—regulators aim to reduce traffic congestion and improve other recurring issues, like air quality and noise pollution.

MaaS platforms combine urban transport modes and services—for example, public transport, shared mobility services, urban rail services, and parking facilities—by leveraging data and information to integrate planning, booking, payment, and customer-service processes. Municipalities, transport companies, technology startups, and payment companies have been investing in MaaS due to the dual benefits for passengers and urban areas. Consumers benefit from superior transparency over travel options and pricing, with all transport offerings available ad hoc on a smart phone. Cities benefit from better traffic flows and overall improvements in a transport system that also incentivizes environmentally friendly alternatives.

These three technologies are often implemented in conjunction with other initiatives or urban architecture projects such as developing

[17] *Directive 2010/40/EU of the European Parliament and of the Council on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport*, Official Journal of the European Union, July 7, 2010.
[18] *Study on the deployment of C-ITS in Europe: Final Report, European Commission*, 2016.

dedicated lanes for public transport or bicycles, establishing restricted access areas, or enforcing on-street parking payments. Even though these technologies act as fundamental enablers for solving urban mobility challenges and boosting cities' livability, their implementation at scale is struggling to take off.

Why it's challenging to implement technologies at scale

Implementing technologies at scale is a complex and challenging process because: i) there are multiple stakeholders involved as transport system upgrades by nature involve the overlap and integration of multiple layers and components; and ii) each initiative is project-based and not fully scalable to other cities.

The issue of mobility is managed by many actors, each with different objectives, budgets, sources of funding, and legacy technology (see sidebar, "Stakeholders in the urban mobility environment"). Communication and coordination across these stakeholders can be difficult and may pose challenges to implementation.

International examples show that urban mobility projects are often unique and cannot be directly replicated and scaled. Indeed, cities require tailor-made solutions. Needs vary according to factors such as the maturity level of the system already installed, the budget allocated for the project, and targets to be achieved. A solution that works in one city is difficult to replicate or scale to others as it was designed to solve specific challenges in a particular context.

In addition, solutions for smart mobility depend on the mix, and integration, of multiple layers—and each component has to be adapted to local standards and tech protocols. Elements include hardware and IoT devices, software to collect and synthetize data from multiple sources, and third-party providers who install and maintain the hardware and software. Furthermore, any solution will likely need to be compatible with all kinds of legacy applications that are still in operation.

Adopting an ecosystem approach provides a way to achieve scale

Due to the complexity of urban mobility systems, and the required interconnection of multiple stakeholders, an ecosystem approach can increase the chances of success when implementing digital technology at scale. In this approach, every actor plays a critical role in successful implementation and the resulting impact.

Any change in one area is likely to affect all others. Actors need to work together, across the mobility ecosystem, to upgrade existing public transport systems and road infrastructure, and make traffic more fluid—ultimately increasing people's quality of life.

In the spirit of broadening the debate about how to design and implement smart urban mobility solutions, the following seven examples of real-world challenges and how cities solved them can shed light on how new technologies and an ecosystem approach can lead to positive outcomes.

Embrace a forward-looking approach when tendering ITS solutions

A private operator committed to installing nearly 3,000 traffic controllers to upgrade the traffic-detection infrastructure in Miami-Dade County in Florida. This initiative is part of a seven-year partnership between the private operator and Miami-Dade County, an example of combining global and local expertise.[19]

Boost green forms of transport without causing adverse effects on road traffic

Copenhagen invested in ITS by installing new controllers in traffic signals at the city's intersections. This new technology enabled the city to control traffic and optimize signals in real

[19] "Major milestone in Miami-Dade County ATMS upgrade project," Yunex Traffic, March 28, 2022.

Stakeholders in the urban mobility environment

Broadly, the various actors across the urban mobility landscape can be classified as those that shape the urban system, and those that deliver mobility services (exhibit).

— Stakeholders shaping the urban system

- At an institutional level:

- Supranational institutions set priorities and macro-objectives, like the European ambition to reach net-zero targets by 2050

  » Country governments develop targeted national programs to achieve the objectives set by supranational institutions and allocate, for each program, a budget based on available funds

  » Local cities orchestrate the actual implementation of technologies for mobility and regulate land use and urban design; they may organize themselves in networks like C40

- At consumer level:

  » Users' personal preferences and behaviors are important factors in shaping the system. Research indicates that an external compelling event is often needed to trigger a change in a person's mobility behavior pattern.[1] In this regard, COVID-19 and the climate crisis is prompting people to re-think how they want to live and travel.

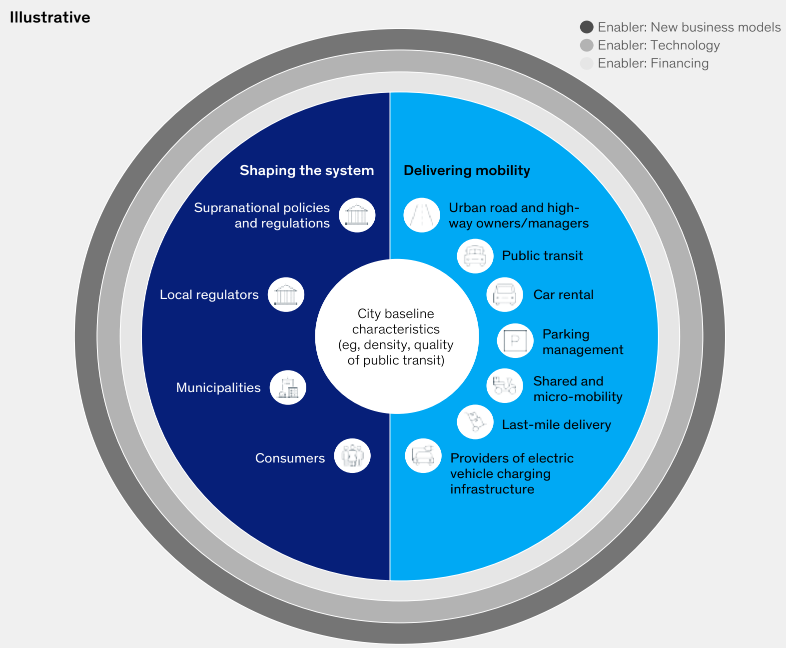
— Stakeholders delivering mobility services

- Established stakeholders include urban road and highway owners/managers, public transit operators, car rental companies, and parking management companies

- New entrants include shared and micro-mobility providers, last-mile delivery services, and EVCI builders and installers

Exhibit

There are two kinds of actors across the urban mobility system.



Source: McKinsey analysis, expert interviews

[1] Ariella Kristal and Ashley Whillans, "Why it's so hard to change people's commuting behavior," *Harvard Business Review*, December 31, 2019.

time, resulting in more efficient flows of bikes and buses and reduced accidents. ITS will help Copenhagen to achieve its vision to have 75 percent of all the trips in the city be by bike, public transport, or on foot by 2025.[20]

Identify solutions to shave-off traffic peaks during rush hour

London and Singapore successfully implemented congestion pricing mechanisms to reduce traffic congestion in city centers during rush hours. After the first year of operation, the solution deployed in London led to a 15 percent reduction in traffic during charging hours. Additionally, traffic delays were cut by 25 percent, travel speeds increased by 30 percent, and bus reliability and journey time improved.[21] Similar outcomes were achieved in Singapore: The country's electronic road pricing scheme launched in 1998 led to a 24 percent reduction in vehicles a day during weekdays, and a 30 percent increase in average speed.[22] Singapore is currently implementing the second generation of a road pricing scheme that allows for dynamic pricing on individual road segments over the course of a day. In February 2023 the electronic road pricing rates were adjusted in response to traffic conditions observed throughout the previous month.[23] This system will help to smooth traffic peaks, optimize use of road capacity, and support a shift from private cars to public transport.

Favor the implementation of Maas platforms

These platforms that allow travelers to purchase tickets for multiple transport options through a single app are tailored to local contexts. One example is the Jelbi app launched by Berlin's public transport authority, BVG, and the technology company Trafi. Another example is Whim app that provides access to urban modes of transport in some cities in Finland, Belgium, Japan, Switzerland, Austria, and the UK. Local urban transit operators can play a critical role in orchestrating the implementation of MaaS platforms by coordinating mobility players in the area.

Achieve the "15-minute city"

Paris Mayor Anne Hidalgo is one of the most prominent champions of the 15-minute city concept where residents' needs are easily satisfied and are within reach by a 15-minute cycle or walk. Some squares in Paris have been upgraded with more room for pedestrians. Other areas have been repaved with new bicycle lanes. As a consequence, some roads saw triple the number of cyclists. The Mayor has promised to reduce the number of parking spots by 2024, and involve private operators to use smart-city technologies to make car and truck traffic more efficient.[24]

Extract the highest value from Application Programming Interface (API) to orchestrate urban mobility

The Oregon Department of Transportation is designing a cloud-based connected vehicle ecosystem that leverages moving vehicle data and public-agency data. The resulting data-sharing hub is intended to deliver safety and mobility applications over the network and via roadside units using cellular V2X technology.[25]

Take an integrated approach

The U.S. Department of Transportation's Federal Highway Administration is currently rolling out an integrated corridor management (ICM) program that takes into account the fact that traffic conditions on one roadway will affect traffic conditions on adjoining or alternate roadways as well as other modes of transport. In this context, managed lane strategies, alternative routing of traffic, and proactively controlling traffic within freeway corridors are useful approaches that can increase utilization levels of existing roadway capacity, improve travel times, enhance safety, and increase travel reliability.[26]

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[20] "Cities100: Copenhagen—Smart traffic signals boost cycling," C40 Cities, November 2016.
[21] "Lessons learned from international experience in congestion pricing," U.S. Department of Transportation Federal Highway Administration.
[22] "Lessons learned from international experience in congestion pricing," U.S. Department of Transportation Federal Highway Administration.
[23] Sarah Koh, "ERP rates at five locations to go up by $1 from Feb 13," The Straits Times Singapore, February 7, 2023.
[24] Patrick Sisson, "What is a 15-minute city?" City Monitor, October 4, 2022.
[25] *Oregon connected vehicle ecosystem*, Volume 1: Technical application, Oregon Department of Transportation, 2021.
[26] "Corridor traffic management," U.S. Department of Transportation Federal Highway Administration website.

All in all, when designing or implementing an urban mobility system that leverages new technologies, an ecosystem approach can improve its chances of success. City authorities could play a critical role in facilitating the process with relevant stakeholders and orchestrating overall implementation. All stakeholders need to understand the new mobility models available and the impact that they can have, and technology providers could make all stakeholders aware of these products and systems.

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