SmartCitiesWorld Trend Report 2022

Urban Mobility

- Electrification of transport
- Integrating mobility services
- Network video technology in mobility
- Developing new business models
- Connected and autonomous vehicles

In association with AXIS COMMUNICATIONS

By Carol Schweiger, Schweiger Consulting

With contributions from:
Andreas Göransson, global marketing manager, and Andrea Sorri, business development director, smart cities, Axis Communications
Luke Antoniou, senior editor, SmartCitiesWorld

SmartCitiesWorld Trend Reports are a series of annual reports that are designed to highlight best practice from city leaders and administrations and showcase innovative technologies from across the five key verticals that make up our coverage of the sector. With the publication of these reports over time, we will be able to track the progress that cities are making and how their priorities change. Here, we're assessing the current trends in urban mobility in which progress is set to determine the path forward to more sustainable and smarter transportation.

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Introduction

Moving people and goods from A to B is – and always has been – one of the most significant challenges that cities face. The shape of our cities is so informed by our roads that if we were to begin again, the urban environment would be scarcely recognisable.

In this report, SmartCitiesWorld is breaking down the challenge facing cities around mobility to assess the trends that are moving urban transport development forwards, considering the travel experience, the need for more sustainable services and business models, and the future of connectivity and autonomy across urban transport networks.

Against a backdrop of pandemic recovery where traffic levels bounced back to normal but left shared modes of transport still recovering ridership, sustainability is key. In this report we focus on electrification as a basis for progressing the sustainability agenda, assessing the progress that cities and their transportation authorities have made to date.

Electrification is only part of this story, however; there's also assessment of the state of integrated shared mobility services, the idea that they can provide genuine alternatives to personally-owned car journeys, and the impact that could have on citizens' behavioural change to reduce congestion and improve mobility. As part of this shift, mobility users need to feel that they're safe and that they can rely on new modes of travel; connected and autonomous mobility is a crucial part of that equation for the future, and the report focuses on some of the groundwork that's being laid to ensure a more connected and autonomous future can be achieved.

Electrification of transport

While electrification and the shift toward alternate fuels in the transport industry are being touted as a way to reduce greenhouse gas emissions, we recognise that the use of alternate fuels may not completely address other issues that significantly impact mobility. The picture that many transport professionals paint regarding electrification is that if more personal vehicles are electrified, that alone will not solve our most serious transport problems including congestion. However, electrification and the use of alternate fuels can make a positive impact on the environment. This, in conjunction with an increase in the use of shared mobility, can improve life in cities. Also, if electrification and the use of alternate fuels are extended to vehicle fleets, such as those operated by public transport and other municipal agencies, the result can be even better for urban mobility.

In terms of electrifying public transport fleets, there are several exemplary programmes across the US. One example is the Massachusetts Bay Transportation Authority's (MBTA's) Bus Electrification Strategy. The overall goals of this strategy are to "centre rider benefits through focus on equity, service, reliability, and sustainability". This includes converting the bus fleet to zero emissions technology in support of the Commonwealth of Massachusetts' carbon reduction goals, and modernising all bus maintenance facilities to improve conditions for the MBTA workforce to support their efforts to keep MBTA services competitive for passengers. As part of that process, they will transition to a more uniform bus fleet replaced on a predictable, annual timetable in support of fleet reliability for the passengers, plus allow for an increase in fleet size to position the MBTA's bus network redesign to meet the needs of growing ridership.

This strategy involves not only converting the bus fleet to zero emissions technology, but also replacing and upgrading facilities to ensure that the following needs are met:

- **Equity** – operating zero emissions buses in transit critical communities and on routes with high ridership
- **Fleet** – lining up facility replacements with the retirement of specialty bus fleets (for example legacy diesel, trolleybus, compressed natural gas [CNG])
- **Systemwide capacity** – replacing facilities that could be moved to a new location first, to open up swing space.

Number of:	2022	2027	2030	2040
Maintenance facilities	9	9	9	9
Facility capable of housing all electric fleet	1	3	5	9
Buses	1,100	1,223		
Percentage of electric buses	3%	30%	>30%	100%

Table 1

The MBTA's bus electrification goal is to have full bus electrification by 2040. This goal consists of battery electric buses (BEBs) with depot charging, parallel electric and hybrid bus procurements and a final hybrid purchase target of 2027. Table 1 shows the progression of electrification throughout the period between 2020 and 2040.

Decarbonisation at the MBTA does not only involve electrifying buses and rebuilding facilities to handle electric vehicles, but also includes assessing various alternatives for electrifying the commuter rail system. Electrification of the commuter rail system will involve replacing diesel locomotives, building new and updating existing maintenance facilities, and implementing new and updated power supply, electric catenary, and power systems.

Given the momentum in addressing climate change in Massachusetts, various groups have been interested in accelerating the electrification of the MBTA commuter rail system. Fortunately, this interest encouraged the adoption of specific amendments to climate change legislation. On 14 April 2022, the Massachusetts Senate passed S.2819: An Act Driving Climate Policy Forward. While transportation decarbonisation is a significant portion of this bill, one amendment specifically addresses the electrification of the commuter rail system: #13 Commuter Rail Electrification, which requires all commuter rail procurements to be electric by 2031 and requires the MBTA to establish short-term, medium-term, and long-term plans for each commuter rail line and how they fit into the state's emissions reductions goals.

While this legislation is ensuring decarbonisation of public transport, an amendment that was rejected would greatly enhance the electrification of other municipal fleets: #88 Fleet Electrification, which would have set interim targets and required all public fleets including state, municipal, and school bus fleets to be electric by 2035. Also, it would have required that the Massachusetts Department of Energy Resources design an incentive programme to encourage the transition of private fleets to electric vehicles. So while this legislation showed a commitment to actions that would address climate change by electrifying public transport, it falls short by not requiring electrification of municipal fleets. This exemplifies how critical it is for

policy and legislation to go hand-in-hand with technological improvements to provide the greatest impact on the environment.

In Massachusetts, Governor Baker issued an Executive Order in 2021 called "Leading By Example," which set goals for state agencies to reduce their greenhouse gases associated with the burning of on-site fossil fuels at buildings and in vehicles by:

- 20 per cent in 2025
- 35 per cent in 2030
- 60 per cent in 2040
- 95 per cent in 2050.

Further, Massachusetts has the overall reduction goals of 50 per cent by 2030 and 100 per cent by 2050. The MBTA's overall electrification strategies are meant to coincide with these goals as well as those mentioned in S2819.

Looking more broadly at the use of other alternate fuels, public transport decarbonisation can include the use of hydrogen fuel in addition to electrification. As the US Department of Energy explained in a February 2022 article: "In battery-only electric vehicles, electricity charges the battery directly. In hydrogen fuel cell-powered vehicles, hydrogen is stored as a fuel in a tank. The hydrogen stores energy, flows into a fuel cell, reacts with oxygen from the air, and creates electricity that powers the electric motor. Instead of a combustion engine, hydrogen-powered vehicles have hydrogen fuel cells, which convert energy to electricity more efficiently. Fuel cells convert a fuel's chemical energy to electrical energy and can be two to three times more efficient than internal combustion engines."

In the US, the Hydrogen Fuel Cell Bus Council (HFCBC) is a coalition of public transit agencies, manufacturers, and suppliers working together to advance the hydrogen fuel cell electric bus economy and its applications in the public transit sector. Formed in January 2022, 12 public transport agencies are members of the HFCBC along with energy companies and other industry partners.

In other parts of the world, hydrogen fuel cell buses are being assessed and operated by public transport authorities. For example, CaetanoBus, which is the first bus company in Europe to use Toyota's fuel cell technology, has sold buses to Transports Metropolitans de Barcelona (TMB), which is the main public transport operator in Barcelona, Spain; and moBiel GmbH, a public transport company in Bielefeld, Germany. As of the end of 2021, there are 85 hydrogen-powered buses, 70 owned by the city of Tokyo and 15 owned by the private sector. Hydrogen-powered buses will be the norm in Tokyo as the city intends to equip more than 300 buses with hydrogen fuel cells by 2030. In South Korea, a total of 624 hydrogen buses are to be put on the roads of the port cities of Busan and Ulsan and the province of South Gyeongsang by 2025 as a replacement for buses with combustion engines.

Actionable insights

Fleet renewal is set to play a significant role in delivering cleaner transportation to the masses. Electrification will be a costly endeavour for many and those pursuing it should look to:

- Combine electrification strategy with modal shift and infrastructure considerations to gain a fuller picture of their local transportation landscape over the next 5-10 years

- Explore battery electric and hydrogen options for fleet renewal – dependent on existing infrastructure, total cost of ownership over the long term could be significantly higher or lower for one over the other

- Tie electrification into city and/or state climate action and emissions reduction plans which may help in securing further funding for fleet renewal

Integrating mobility services and developing new business models

While there have been numerous attempts at improving mobility in urban areas prior to the introduction of mobility-as-a-service (MaaS) and mobility-on-demand (MoD) concepts, it is only recently that improving urban mobility is recognised as the only way to facilitate key life activities such as education, healthcare, jobs, shopping and entertainment. The way that many urban areas have evolved has been hindering these activities for residents and travellers – increased traffic congestion, lack of integrated shared mobility options, increased pollution, and lack of urban space. Fortunately, in the last eight to 10 years, urban mobility improvements are beginning to be made to facilitate better access to these activities.

According to SAE JA3163, MaaS is defined as "a concept envisioning integrated mobility where travellers can access multiple transportation modes over a single digital interface. MaaS primarily focuses on passenger mobility allowing travellers to seamlessly plan, book, and/or pay for travel on a pay-as-you-go and/or subscription basis". While several US transit agencies are moving toward MaaS, no US agency truly offers it. MaaS has been implemented in a small number of agencies and cities outside of the US, but several of these are pilot deployments. While MaaS has been touted since its conception in 2014 as an ideal mobility solution that will lead to travellers giving up their personal automobiles in urban areas and more generally will change travel behaviour, neither of these premises have been proven absolutely yet.

However, it is advantageous for transport agencies to consider moving toward MaaS to provide travellers in and around urban areas a one-stop shop for their mobility. With many public transport agencies' current suite of technology and mobility services, these agencies are well on their way toward MaaS, but need a strategy and roadmap to identify the process and steps necessary to not only deploy a MaaS platform, but to: firstly, develop the necessary partnerships with other regional mobility service providers (MSPs); secondly, identify the necessary data sharing and fare payment integration between regional MSPs and public transport agencies; and finally, identify the enabling technology and technology integration that will be needed to drive a MaaS platform. Further detail and an example roadmap from Dallas Area Rapid Transit (DART) can be found in the further reading section.

According to The Ws of MaaS paper in IATSS Research, there should be five key aspects in determining an agency's desire to move toward MaaS:

1. Transport services and infrastructure: how prepared the current transport system is for MaaS. This includes the variety of modes available, the density of services, the frequency of services and the integration of services.

2. ICT infrastructure: penetration of MaaS-enabling technologies. This includes internet access and smart ticketing infrastructure.

> *"In the last eight to 10 years, urban mobility improvements are beginning to be made"*

3. Transport operator openness and data sharing: the extent to which transport operators share data and make APIs available to third parties. This includes whether data and APIs are made "open" (freely available to use, redistribute and alter).

4. Policy, regulation and legislation: the extent to which key policies, regulations and laws to support MaaS are in place. These may be at a city level or a national level.

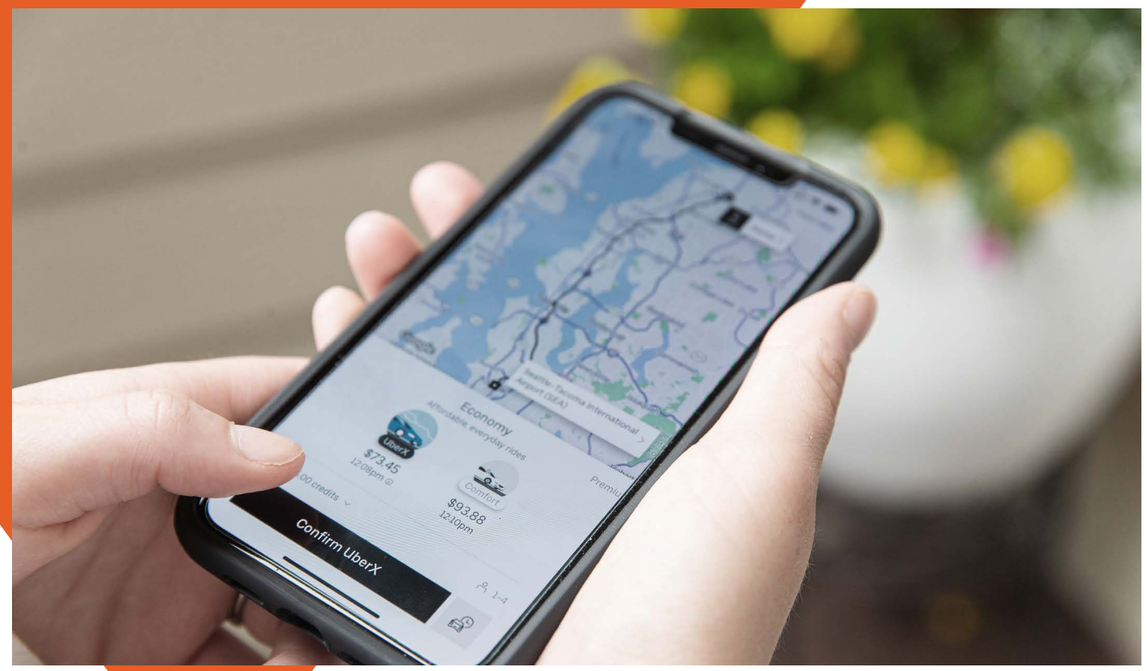
5. Citizen familiarity and willingness: the extent to which citizen lifestyles and behaviour align with a MaaS model of transport provision. This includes travel behaviour and use of MaaS-related technologies.

Focusing on DART's initial approach, the agency set out to develop partnerships with regional MSPs including bikeshare, carshare, regional taxi services, rental car companies, Uber, Lyft, scootershare operators, and any other MSPs in the greater DART area. The goal of these partnerships is to provide travellers with information on the MSPs' services that can be used to connect them with DART services, and eventually exchange real-time and static data that will be used in the MaaS platform to provide travellers with itineraries that include these MSPs, and allow travellers to use GoPass® to pay for an entire trip (rather than paying for each mobility service in an itinerary separately). The partnerships will be necessary to provide a true one-stop shop for all Dallas regional travellers.

Second, as part of the partnership development, DART identified the data sharing and fare payment integration that will be necessary to include the regional MSPs in the MaaS platform. In this step, once partnerships with MSPs are finalised, a number of technology-related activities can be pursued. This includes a regional trip planner incorporating data and information from MSPs and DART. This itinerary planner is considered "level 1" in the MaaS topology devised by Jana Sochor, Hans Arby and MariAnne Karlsson.

The next technological steps also include payment integration among DART and the regional MSPs, which will perhaps be the most challenging activity from a technical perspective. The Federal Transit Administration (FTA) has documented the challenges associated with multimodal fare integration in the Mobility Payment Integration: State-of-the Practice Scan. Adding payment integration to a multimodal trip planner is considered "level 2" in the MaaS topology mentioned above.

From here, data exchange and integration supporting not only multimodal trip planning but also payment may be challenging. Fortunately, there are considerable efforts to standardise the data formats used in a MaaS system, as well as MaaS elements



such as booking/reservations application programming interfaces (APIs). Interoperability for Mobility, Data Models, and API from the MaaS Alliance explains that "exchange of data occurring between different parties in the MaaS ecosystem provides benefit to all parties. For example, local transportation authorities and infrastructure providers can use the exchanged data, when standardised, to evaluate and analyse the usage made of their infrastructure, the stress put upon them by travellers to maintain, improve, or develop them. Similarly, standardised data can be used to cross compare offers from the different providers to build up relevant and insightful data with reduced effort.

One example is the TOMP-API (Transport Operator to MaaS Provider – Application Programming Interface) is a standardised and technical interface between MaaS providers and transport operators. The diagram on the TOMP-API's GitHub page depicts the concept of having a standard-based application programming interface from transport operators to or from MaaS providers. It allows all participating companies to communicate about planning, booking, execution, support, general information and payments of multimodal, end-user specific trips. Using the TOMP-API enhances the interoperability between parties in the MaaS ecosystem.

Finally, DART is continuing to identify the enabling technology and technology integration that will be needed to drive a MaaS platform. There are numerous enabling technologies the agency is exploring:

- Existing DART technologies including the CAD/AVL system; fixed-route and paratransit scheduling software; real-time traveller information (for example, next bus arrives at stop N in x minutes); communications technology (for example, radio and cellular)

- Blockchain technology, which can provide a privacy preserved, transparent and trustless architecture for mobility services

- Intelligent sensor technology can be effective for sensing and collecting real time mobility data from MSPs other than MTTA

- Artificial intelligence (AI)-based algorithms can be developed to provide autonomous decisions on the basis of the data collected from all MSPs as well as future predictions about different mobility related services and entities, such as the conditions of roads, traffic, and streetlights. Additionally, data centric AI algorithms can be used by organisations for customer centric target marketing

- Intelligent geospatial technologies that MTTA already provides accurate information for the tracking and tracing of vehicles and travellers. These technologies, along with scheduling software, can also facilitate alternative routes management in case of emergencies and disasters

- Information processing techniques are applied to data from MSPs so that predictive information and pattern analysis can help them in making decisions. The data sources can include smartphones, data from social networks, vehicle sensors, global positioning system (GPS) and location applications, traffic light sensors and other road locations, public agencies, connected vehicles, and camera feeds.

The technology integration will be dependent on the partnerships developed between DART and the regional MSPs. One critical factor will be whether or not DART deploys only one MaaS platform or allows competitive third-party platforms.

Another critical consideration in the development of MaaS is to ensure equity, accessibility, inclusion and diversity – every traveller should have the ability to use a MaaS platform. This requires that DART explore unbanked customers and customers who do not have smartphones against accessibility and inclsusivity needs, benefits for commuters which can complicate multimodal payments, integration with legacy technologies, and regulations, policies and standards for payment acceptance.

DART recently developed the 2045 Transit System Plan and its plans for MaaS and MoD are integral parts of that plan. The plan highlights that DART is preparing for future mobility by focusing on opportunities under five themes and a set of associated goals. The MaaS goal and action are defined in the Mobility and Innovation theme while MoD goals and actions are described in the Service and Expansion theme.

Another aspect of improving urban mobility can be seen in public transport providing more integrated services. Typically, public transport services are loosely integrated – for example, buses may arrive at a subway station loosely based on the subway schedule). Only recently have some agencies explored or initiated "commingled" services. Currently, commingling is defined as merging demand-responsive transport (DRT) or paratransit with other mobility on demand services, such as microtransit, into one service. One reason for considering commingling is to reduce the typically high cost of paratransit services (for example, in the US, the Americans with Disabilities Act [ADA] requires paratransit services that are complementary to fixed-route services).

Using new scheduling and dispatching software, commingling is now possible and being deployed in a variety of locations, including Lincoln, Nebraska in the US. StarTran, the public transport agency in Lincoln, uses the same fleet of vehicles and drivers to provide both paratransit and microtransit services. Another example of commingling services is being provided by Citibus in Lubbock, Texas.

> *"It is advantageous for transport agencies to consider moving toward MaaS to provide travellers in and around urban areas a one-stop shop for their mobility"*

In terms of new business models to improve urban mobility, transport services are making a concerted effort to connect the first- and last-mile of a trip with other mobility services. Technology is facilitating this service integration. One of the best examples of this service integration is Brightline train service which operates from Miami (Florida) to Ft Lauderdale to West Palm Beach and eventually to Orlando. When users purchase a train ticket, they have the capability to reserve a private ride, shared ride or bikeshare (called BrightBike in the West Palm Beach area), or to board a walk-up shuttle to/from a Brightline station. They can also purchase a parking pass for any of the Brightline station parking facilities. Finally, Brightline for Business provides a corporate travel programme for employers – something that is often contemplated as a substitute for having an employee use a corporate car.

A MaaS app powers Brightline's integrated mobility. Part of its strategy is to have a positive impact on mobility through the following goals:

- Addressing climate change through using clean biodiesel for lower emissions and removing three million cars from roads each year
- Making the facilities and trip greener through using solar power in stations and providing electric charging in their parking facilities
- Implementing mitigation strategies to reduce the environmental impact
- Ensuring inclusivity and equity
- Focusing on health and safety.
- Connected and automated vehicles

Actionable insights

Integrated mobility services and more demand-responsive transport will be critical to encouraging modal shift on the scale required to effectively ease congestion in our cities. Providing services is only part of the solution, however – authorities must also ensure they:

- Educate all citizen groups on new types of service – particularly those that are digitally enabled
- Keep equity and accessibility front of mind in rolling out new services – are they affordable and accessible for those in the community that really need them?
- Do not deploy technology for technology's sake – are new services actually providing a solution to a challenge, both for the authority and/or the customer?

"Getting the right people involved is almost always a critical success factor in overcoming exclusion and promoting a fairer experience for all."

Improving urban mobility with the latest network video technology

By Andrea Sorri, director, business development smart cities; Andreas Göransson, global marketing manager, Axis Communications

In the world of urban data collection, the reputation of video has skyrocketed in recent years as public service authorities have recognised the value that network cameras can bring in terms of insight, monitoring and decision making.

This is especially true of the mobility market, where gaining a holistic view of operations and road networks can help authorities to address wider policy objectives, such as developing safer and more sustainable roads.

Video is just one half of this equation, however – the other is the analytics capabilities that sit alongside the raw data. As the Internet of Things has grown in the last decade, cameras have become smarter, those capabilities can now increasingly be found at the edge, with AI-enabled data analysis happening in-situ on the camera itself, without having to be transferred to a central server.

These advancements in connected cameras have brought numerous benefits to transport and traffic authorities, improving support on real-time traffic management and helping to streamline traffic safety and enforcement across cities to ensure road user and pedestrian safety. What's more, today's cameras can serve numerous purposes thanks to both their connectivity and the AI software built into them, helping authorities to save money by ruling out the need for multiple deployments. For example, today's camera hardware could be used to monitor red light violations and collect mobility statistics without the need to install more than one device.

Monitoring and surveillance of road networks and associated infrastructure, whether it's intersections or rest stops, is critical to maintaining and improving citizen safety on the street. The cameras and video sensors that enable this to be done effectively and

efficiently must now be part of the IoT, capable of capturing and analysing data at the edge regardless of lighting or weather conditions.

The nature of safety itself is also changing – it is no longer only keeping road users and pedestrians safe from traffic incidents, speeding cars and accidents at crossings; it is ensuring that the environment in which these activities are happening is futureproofed, that air quality is good and CO2 emissions are kept to a minimum.

The effective roll out of connected cameras into urban road networks today should actively contribute to citizen liveability, creating a built environment that is greener, safer and simpler to travel through, with improved traffic flow and monitoring contributing to all three factors.

Solving mobility challenges for Metropolitan City of Milan

It was with these challenges in mind that, beginning in early 2021, Axis worked together with system integrator, Safety21, on a project with Metropolitan City of Milan. The project aimed to address three challenges through one rollout: environmental monitoring and security, citizen safety, and monitoring road safety.

The project had four primary objectives that the city wanted to achieve:

- To gather information on road users' driving behaviour and their respect for road laws
- To promote a different cultural and social attitude about environmental issues to protect and further promote safety among vulnerable communities
- To develop a single system for monitoring, safety and traffic
- To promote a more positive perception of public authorities deploying sensor and camera technologies and solutions.

At the centre of all these main objectives was the desire to deliver improved safety for citizens from a roads traffic and environmental perspective. The integrated road safety project also leveraged the principles of public-private partnerships in a unique way to ensure that the local authority would be able to undertake the project – Safety21 required no investment from the public authority, taking on the full potential risk of investment in the rollout themselves. In this scenario, Safety21 only takes returns on investment from the managed service it provides to the city.

"The biggest problem for a smart city project is how you finance it and this includes after delivery because many cities across

"The effective roll out of connected cameras into urban road networks today should actively contribute to citizen liveability, creating a built environment that is greener, safer and simpler to travel through."

Europe do not have the budget to maintain the infrastructure," said Gianluca Longo, founder and CEO of Safety21. "In a private public partnership you can link it to returns on investment – in this case from the violation fines – so you always have a flow of money that can be directed to the maintenance of the infrastructure."

The key to a project like this is maintaining a good flow of the right information. From an IT architectural perspective, the project utilised an IoT system backed by cloud services. The system is based on Safety21's Titan platform – a cloud platform that facilitated the connectivity of the different monitoring services the city wished to employ. The monitoring services the city wanted to roll out covered a wide range of functions, including:

Monitoring rest stations

The municipality wanted to roll out monitoring at roadside rest stations to help prevent illegal dumping, which is a common problem. The cameras survey these areas 24/7 and allow the traffic control centre to capture the license plates of offenders. The monitoring of these areas can also be useful in response to incidents to enable traffic control to send out a team to clear debris from the road faster and prevent any further incidents, as well as to keep a close eye on vehicles being repaired in the rest stops.

Instant speed monitoring

For Metropolitan City of Milan, monitoring speeding was not only about fining drivers for breaking speed limits, but mitigating speeding in the first instance to encourage behavioural change. Rather than only deploying speed cameras, the city introduced a three-step warning system for speeding drivers, made up of different signage and information to prevent them speeding.

Monitoring pedestrian crossings not controlled by traffic lights

Improving safety at non-traffic-light-regulated crossings was one of the city authority's biggest priorities. To address the issue, they rolled out extra signage and lighting at crossings, which combined with Axis cameras, enabled crossings to detect the presence of pedestrians waiting to cross. This would then trigger the signs and the lights to make drivers more aware of the crossing and the waiting pedestrians.

Red traffic light violation monitoring

In busy urban areas, traffic enforcement at junctions and intersections are critical to maintaining pedestrian safety, which is why Milan also wanted to integrate red light violation detection as part of its safety system. The system uses Axis cameras to detect red light infringements in real time, providing authorities with accurate information and verifiable evidence in the event of an accident.

Case Study

Traffic detection
Detecting traffic and congestion was a key part of the city's plan to keep roads safe. Cameras in this sense is used to collect data and maintain data flow, capturing information about what is happening on the roads and connecting traffic data to CO2 data to enable a drive towards more sustainable road networks.

Average speed monitoring
Milan wanted to use average speed monitoring as a means of ensuring road capacity and occupancy was as efficient as possible. Reducing and avoiding congestion was the primary goal for the city. Once it reaches a point where congestion rarely happens, or only happens to a certain degree in peak hours, the city wanted to achieve a more consistent average speed in non-peak hours to ensure that the road network was operating as efficiently as possible, thereby helping to ease congestion further at peak times.

Axis' technology had a part to play in each of these use cases, either as a core component of the set up or as a companion sensor to help add value for the municipality in terms of the information and data they could draw on in the integrated system. The open and scalable nature of the technology means that cities can integrate traffic monitoring and control into a single platform with more ease, without the risk of creating siloes or vendor lock-in. "In my view Axis' technology is industry standard but also the way in which it can adapt to any environment is key to smart city deployments," says Longo.

This also makes it possible for municipalities to overhaul and streamline their sanctions procedures to protect citizens and law enforcement. Everything is collected in the cloud through the same platform so the local police can analyse video, determine the violation and issue the correct punitive measures. From the edge to the end, the procedure is managed from the same platform. This is also important because not all municipalities have the same law enforcement organisation in place, so openness is key to being able to share critical information between parties.

An integrated system like this also makes managing image and video evidence detection, extraction and storage simpler and more secure. In achieving this, municipalities could then also apply artificial intelligence analytics capabilities on the collected data to surface further insights – for example, correlations between traffic, speeding and average speed statistics and their resulting impacts on traffic or pedestrian incidents.

The system has been in place in Milan less than two years at time of writing and continues to grow. Longo explains that despite some delays due to Covid, the system is performing 200 per cent better than expected. Using open-source technology like Axis' will allow Metropolitan City of Milan to expand the system without concerns over interoperability or siloes. As of May 2022, the system consists of more than 130 devices, enabling a broader and more accurate view to Milan's public authorities of the state of operations on the roads, while improving its record on road and pedestrian safety alongside pushing forward with sustainability goals.

Going forward, Longo believes the private public partnership approach will be key to helping cities to realise their green agendas, especially in the area of smart and shared mobility programmes where payment platforms and other elements have to be managed. He is also keen to demonstrate that the private public partnership approach isn't just for large cities and has recently developed a model for a smaller Italian city that also incorporates Axis technology, which can now be taken to the broader market.

But he highlights the work with Milan as being "revolutionary" for the smart cities movement in general because it is sustainable in terms of finance as well as the technology used: "It is a real-life example of working with a public administration to bring about major change."

Read more about how Axis technology can support smart city initiatives: https://www.axis.com/

Connected and automated vehicles

Discussion on the future of mobility is typically incomplete without reference to the connected and autonomous services that many are banking on to make the future safer, cleaner and more efficient. CAVs are already deep into pilot trials around the world to monitor the safety and efficiency of these technologies ahead of full rollout – or at least the introduction of policy and regulation that will enable full rollout.

One example of these projects is being run by the Jacksonville Transportation Authority (JTA) – an independent agency of the State of Florida governed by a seven-member board of directors. JTA plans, designs and builds roads and bridges, but it also operates Jacksonville's public bus service, downtown automated Skyway and paratransit service. JTA has made a significant investment in automated transit (and now has an Automation and Innovation Division) through its Ultimate Urban Circulator Programme (U2C), a first-of-its kind programme to transform downtown Jacksonville through modernisation and expansion of its downtown circulator (Automated Skyway Express) to accommodate automated vehicles and to extend service to nearby neighbourhoods.

The U2C autonomous transportation network will utilise and leverage multiple existing federal investments, including the elevated Skyway Automated People Mover (APM) infrastructure and street-level roads through the urban core. The existing Skyway is a 2.5-mile system, with eight stations, an operations and maintenance (O&M) centre and crosses the St Johns River on the Acosta Bridge. The envisioned system will convert the existing system and expand to approximately 10 miles by combining the at-grade and elevated infrastructure. This will also include the deployment of autonomous vehicles with modern stations and provide more frequent service with improved access for all customers.

There will be an approximately 10-mile system that will be developed in the following phases, according to JTA resources:

- **Bay Street Innovation Corridor (Phase 1 – Active Status) –** The first phase of the U2C me is the Bay Street Innovation Corridor (BSIC). This route is the East Corridor and extends beginning at the current terminal of the Skyway's Central Station, east to the Sports/Entertainment District/TIAA Bank Field. The federally funded project will be the initial phase of the U²C programme and will introduce autonomous vehicles along a key transportation corridor in Downtown Jacksonville.

> *"JTA has made a significant investment in automated transit (and now has an Automation and Innovation Division) through its Ultimate Urban Circulator Programme"*

- **Skyway Conversion (Phase 2 – Active Status) –** the full conversion of the existing Skyway Superstructure and eight stations into an elevated roadway for autonomous vehicles. The current bi-directional tracks run approximately 2.5 miles in each direction. Launching from the Jacksonville Regional Transportation Centre at LaVilla (JRTC), the U2C elevated sections will stretch to four additional stations on the Downtown Northbank, and across the St Johns River over the Acosta Bridge to three stations on the Downtown Southbank. Phase II also includes the street level connection to Phase I, the Bay Street Innovation Corridor.

- **Neighbourhood Extensions (Phase 3) –** advance the design of the Bay Street Innovation Corridor. A Transit Concepts and Alternatives Review (TCAR) planning exercise was completed in FY 2020 that identified alternatives for each of the proposed Skyway corridor extensions including:

  - **Southwest Corridor:** Brooklyn and Riverside host large office towers just over the edge of Downtown and melt into a blend of historic homes and eclectic shops and restaurants Redevelopment in the northern portion of the corridor is bringing more places to live, work, shop and dine. Planned autonomous vehicles will help to connect future residents to areas within the corridor as well as invite them to explore nearby neighborhoods, reachable by the U2C programme

  - **Southbank Corridor:** the Southbank portion of the corridor boasts medical, office and residential towers. The historic San Marco neighborhood has charming homes and small businesses

  - **North Corridor:** the historic Springfield area was once served by streetcars along Main Street and has undergone a renaissance with new and renovated homes and shops. The area's residents and business owners are highly engaged in the community and host neighbourhood festivals and events.

According to an RFI from JTA, the initial phases will include the development and/or expansion of the supervisory system and route technology necessary to support an autonomous vehicle network as well as deployment of vehicles and station modifications or new at grade stops. All programme components will also include both physical and cybersecurity best practices.

Why is this unique programme an example of using technology to improve urban mobility? It is stated well in an early description of this programme as it was envisioned in 2017 as well as it is described in 2022 by JTA: "Live, Work, Shop, Eat, and Play. Our goal is to provide compact, walkable, pedestrian-oriented, mixed-use communities centered around access to JTA's multi-modal transit options. This makes it possible to live a lower-stress life without complete dependence on a car for mobility. The ability to inter-connect micro-mobility and transit options to your desired destinations within Jacksonville improves our health, economy and environment."

Transit-oriented development (TOD) is a significant part of the U2C programme to meet the overall goal of creating vibrant, livable, sustainable communities in the greater Jacksonville urban area. JTA highlights that "TOD provides compact, walkable, pedestrian-oriented, mixed-use communities centered around transit stations. This makes it possible

to live a lower-stress life without complete dependence on a car for mobility. The ability to walk, bike and take transit to your desired destinations across the city improves our health, economy and environment."

JTA's transit-oriented development process for U²C

- Identification of the benefits and impacts of TOD
- Identification of similar public transport systems that address JTA's use of TOD to "revitalise the downtown and equitably increase its residential population"
- Analysis of demographics and the real estate market in downtown Jacksonville and five U2C corridors
- Define the phases of TOD implementation
- Identification of financing and value capture mechanisms
- Identification of ongoing and regular interagency coordination necessary to successfully implement the U2C system.

The implementation of TOD has three key elements:

- Assessment of six corridors encompassing 21 proposed stations. The corridors and station areas are evaluated to identify demographic, travel demand and growth trends; land use and zoning; multimodal accessibility; and real estate market demand. Stations are given a primary typology and TOD Desirability & Readiness rating
- Establishing TOD goals, measures, targets and secondary typologies. Proposed stations have been evaluated for TOD potential. Six stations were selected for more detailed station area planning. Virtual meetings were held to review these station area frameworks
- Identifying TOD regulations, financing, equity and implementation strategies. Key stations were selected for more detailed planning using a public engagement process.

In an interview, JTA staff detailed that ongoing research from WSP showed that TOD yield for the U2C project could be around 15 million in gross square footage, encompassing 11,000 residential units, 1.4 million in commercial-retail square footage, 1.5 million in office square footage.

From a technical perspective, JTA identified 20 key features and capabilities of the autonomous vehicles that will be used for the U2C. These features are called the "Golden 20". Their development was required for two reasons: firstly, there are no existing "standard" transit AV requirements in Jacksonville; and secondly, JTA has specific requirements due to the environment in Jacksonville where these vehicles will operate. The requirements are as follows:

1. Full Americans with Disabilities Act (ADA) compliance
2. Buy America/Buy American compliance
3. Cybersecurity
4. Remote route programming with low latency
5. National Highway Traffic Safety Administration (NHTSA) approval to operate on public road
6. V2I and V2X capabilities (DSRC & 5G)
7. Traverse slope of ± 12 degrees w/ full passenger load (sustained acceleration/deceleration)
8. Operate bi-directionally up to 35mph
9. ≥12 hours of battery life
10. Operate at speeds of 15mph within ± 1 foot of stationary object and operate at speeds of 15mph within ± 3 feet of moving object
11. May operate during inclement weather (rain, fog, wind, and extreme heat)
12. Internal cab – environment control with rapid cool capability and sustained temperature with full passenger load
13. Ability to be towed; push/pull and steer AV manually or towed via another AV
14. Crash worthy up to 35mph
15. Ability for fast charge/opportunity charging
16. Ability to regulate passenger capacity
17. System for recording/storing video for at least 30 days (black box)
18. Emergency button to contact authority/ agency control centre
19. Remote command and control operations of vehicles with low latency
20. Complete vehicle monitoring system, including health monitoring.

In terms of connected vehicles and their impact on urban mobility, results from another trial by the Tampa (Florida) Hillsborough Expressway Authority's (THEA) Connected Vehicle (CV) Pilot include the fact that "Tampa Bay's population, tourism, and economic development vastly increased. The city is transforming with new urban environments, transportation offerings, and a heightened focus on Vision Zero implementation to eliminate traffic fatalities and severe injuries. [The Pilot's] Phase 4 lessons learned for the transportation sector regarding connected technology [include the fact that] this technology can truly assist in transforming grid systems throughout the U.S. into smart cities."

Actionable insights

CAVs will undoubtedly have their part to play in the future of urban passenger mobility, and as seen in the Jacksonville example, will primarily contribute to shared mobility initiatives as opposed to becoming a new mode of individual travel – thereby tying into the strategies covered in the integration section of this report.

Transport authorities and operators need to work in conjunction with city and state authorities to ensure that policy and regulations supports CAV pilots and the eventual launch of full-fledged services

- Pilot projects should adopt a "fail fast" approach to bounce back from any adversity and ensure that lessons inform policy development decisions

- A clear mission statement about CAV projects will help to engage not only citizens but also potential partners – critical when considering the potential impact of new services on local economies and their development

Summary

Assessing the current trends in urban mobility provides a glimpse into what our future could look like – and in some cases, especially around electrification and sustainability, what that future needs to look like if cities are to mitigate their most significant challenges.

Sustainability is the common thread to many of the issues discussed in this report; it is not only environmental sustainability we must consider, but the sustainability of emerging business models in making agencies and operators profitable, and the use of technology to ensure that transport users are central to long-term planning where digitally-enabled solutions are being considered.

These existing trends, many of which are still at a relatively nascent stage of development, demonstrate the importance of strategic planning at a time when – emerging from the pandemic – ridership is down and finances are stretched. Local, state and national transportation agencies and authorities primarily have a common goal and vision for the future of mobility, but a more joined-up approach to reaching it will be required – enabled by cross-party information and data sharing and further standardisation of both technology and approach.

The case studies covered in this report are among best practice examples that illustrate the thoroughness and care with which agencies and authorities must plan pilots and programmes, as well as develop policy, in order to drive toward that shared vision.

Beyond technical requirements, the approaches that transportation organisations take from here must be citizen centric and show a clear understanding of citizen needs and requirements – for now, in the immediate future, and beyond. Without citizens at the heart of systems thinking, inequity and inaccessibility gaps will be allowed to grow unchecked, not only in transportation but at a citywide level.

Further reading and resources

Hydrogen's role in transportation – US Department of Energy

Hydrogen will fuel more than 300 of Tokyo's public buses by 2030 – Arab News, Japan

South Korea to acquire 624 H2 fuel cell buses by 2025 - Electrive

Taxonomy of on-demand and shared mobility: ground, aviation, and marine – SAE International

DART's MaaS efforts – Transportation Research Board

The Ws of MaaS: understanding mobility as a service from a literature review – Science Direct

Mobility payment integration: state-of-the-practice scan – US Federal Transit Administration

Transit Operator to MaaS Provide (TOMP) API – GitHub

DART 2045 transit system plan - DART

Tampa CV pilot testing paves the way for creating smarter, safer cities – Roads & Bridges