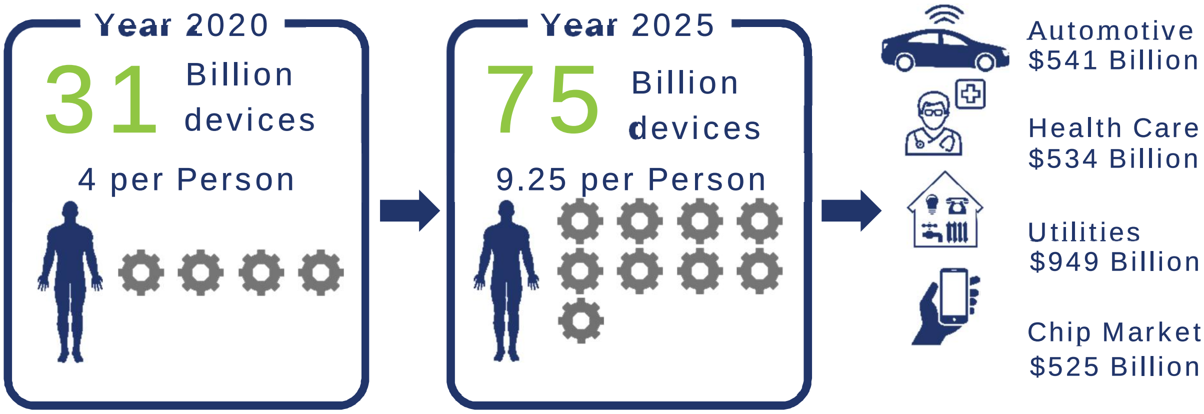
Appendix E:

Technology

Introduction

Technology is woven into peoples' daily lives. It's a part of the way everyone lives, works, plays, and communicates. The advancement of technology will have significant impacts on future cities and the infrastructure that supports them. Preparing for emerging transportation technology will be critical to those tasked with municipal and regional planning. Agencies will need tools that allow them to assess the volume of possibilities and manage the most effective implementation strategies in support of those prioritized possibilities. The transportation system of the future will be built on a foundation of digital infrastructure known as the Internet of Things (IoT). The IoT is an umbrella term that refers to connected physical and digital components. IoT components can send data without the assistance of human actions. Each IoT component has a Unique Identifier (UID) that makes it recognizable. Originally coined in 1997, IoT has grown in size and scope over the past decade. Devices such as smartphones, wearable technology, connected vehicles, and home appliances can communicate with each other without humans initiating the transfer of information. IoT is expected to continue to grow over the next five years. Currently, there are 31 billion devices that are connected to the IoT, an average of four devices per person. By 2025, the IoT is projected to grow to 75 billion devices worldwide, an average of 9.25 devices per person, Figure 1.

Figure 1: IoT Growth Projections (2020 versus 2025)



Preparing for future technology is not a one-size-fits-all approach. Each jurisdiction will need to identify policies, procedures, and infrastructure that needs to be updated to respond to future transportation technology. Additionally, jurisdictions will need to develop a flexible framework that accommodates a range of agency sizes, while also providing agility that allows each agency to respond to evolving technology. There are two foundational questions each jurisdiction address:

Assessing an agency against these two questions can provide multiple benefits. As jurisdictions evaluate their preparedness to respond to future technology, it allows them to review their current practices, capture areas of success, and identify areas that need improvement. This also allows jurisdictions to identify technology enhancements that can make their day-to-day operations easier and more efficient, ultimately saving time and money. Additionally, establishing a foundation for IoT device interactions will help jurisdictions implement large scale transportation advancements that rely on robust communication networks. Building a foundation that is IoT ready does not require large financial investments or doing away with tried and true systems. A solid foundation will build upon existing best practices, add digital infrastructure to streamline processes, collect and communicate data, and connect jurisdictions with the citizens they serve. Agencies are not required to predict the future in order to embrace the possibilities of future technology. Understanding emerging transportation technology, as well as the infrastructure and systems that support this future, is a learning process. This chapter will explore avenues to assess an agency or region's placement within that learning curve and provide a process for preparing for those technologies.

This chapter provides a:

- Review of the IoT devices that assess with transportation devices
- Detailed description of Connected, Automated, Shared, and Electric (CASE) vehicles as the primary framework for discussing emerging transportation technology

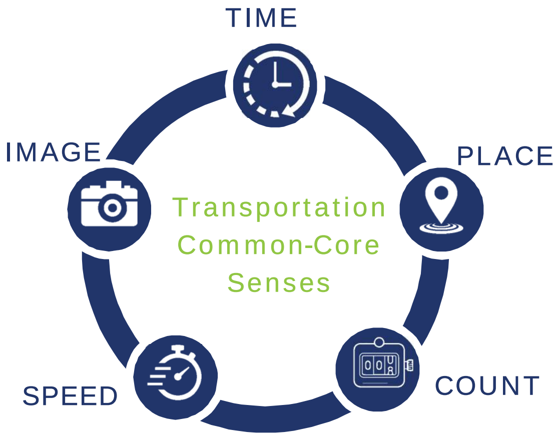
- Brief review of other emerging transportation technology such as Freight and the Connected Curb Lane
- An introduction to the Capability Maturity Model Framework and strategies that support the advancement of a jurisdiction's agility to respond to emerging transportation technology

This appendix provides an in-depth introduction to CASE vehicles and other emerging transportation technology. After establishing a familiarity with CASE vehicles, an agency can focus on a preparedness assessment for emerging transportation technology using the Capability Maturity Model Framework provided in the Right-Sizing Emerging Transportation Technologies section.

The Internet of Things

The Internet of Things (IoT) describes the network of devices used to communicate and share data. IoT devices are used in a wide range of industries, including transportation, health care, utilities, entertainment, and consumer electronics. In the transportation field, IoT devices have five common-core senses as depicted in Figure 2. These senses include time-stamping events, tracking GPS locations, counting quantities, measuring the speed of moving objects, and capturing images/video.

Figure 2: Five Senses of Transportation IoT Devices



These common-core senses are used in both vehicles and their supporting infrastructure. Transportation IoT These common-core senses are used in both vehicles and their supporting infrastructure. Transportation IoT devices communicate this type of information to influence the effectiveness of the transportation system. By leveraging the communication between IoT devices, jurisdictions can improve their responsiveness to changing demands for transportation, curb lane access, commercial delivery, passenger loading, transit, walking, and bicycling.

Infrastructure

The infrastructure that supports CASE vehicles, freight, and the connected curb will play a critical role in the success of emerging transportation technology. Three primary pieces of infrastructure that integrate IoT devices are smart traffic signals, smart light poles, and mobile devices.

Smart Traffic Signals

Smart traffic signals can monitor traffic conditions in real-time through the use of video cameras and radars. Through the detection of vehicles on a roadway, traffic signals can predict when a vehicle will arrive at an intersection. This information is used to develop a timing plan that determines the duration of the green signal phase for each approach. Signal timing plans can be updated in real-time depending on changing traffic conditions. Through a connected network of intersections, smart traffic signals can improve travel times and help to decrease vehicle emissions.

Smart Light Poles

Smart Light Poles are energy efficient streetlights that use LED lighting and motion sensors to save energy and costs. These light poles can be connected into a network of lights through wireless communications and controlled from a central management location. Smart light poles can be equipped with cameras and sensors that monitor parking availability on city streets, detect air quality and emissions levels, and serve as a supporting network for autonomous vehicles fleets. They can also be equipped with LED screens that provide dynamic signage and wayfinding. Lastly, smart light poles can serve as charging ports for electric vehicles.

Mobile Devices

Mobile devices, while traditionally not considered to be infrastructure, will be at the center of emerging transportation technology. As IoT devices interact with each other, people will experience the IoT system through mobile devices, computers, and other consumer electronics. Mobile devices can also act as a tool to communicate pedestrian activity and origin/destination data.

CASE Vehicles

Connected, automated, shared, and electric (CASE) vehicles will play a major role in the future transportation system. Technology improvements will help to increase the feasibility of widespread adoption of these advanced vehicles. As the existing vehicle fleet is replaced with new vehicles equipped with this technology, the transportation system will see an increase in safety and a decrease in negative environmental impacts. CASE vehicles, and the infrastructure that supports them, will play a key role in achieving transportation goals such as Vision Zero. Vision Zero is a national and local effort to have zero transportation-related deaths and serious injuries on the Nation’s highways and roadways.

Connected Vehicles

Connected vehicles have the ability to communicate with other vehicles (cars, buses, and commercial vehicles), personal devices, and roadside infrastructure. The ability to communicate with other vehicles and infrastructure is critical to automated safety detection and driver alert systems. There are multiple communications connections that can be accommodated by a connected vehicle and each connection provides different benefits to drivers, passengers, and pedestrians. The possible connections include communication from Vehicle to Infrastructure (V2I), Vehicle to Vehicle (V2V), Vehicle to Everything (V2X), Vehicles to Cloud (V2C), and Vehicle to Pedestrian (V2P). An example of each connection type and the associated benefits are provided below.

Vehicle to Infrastructure (V2I)

Through V2I technology, a connected vehicle can communicate its approach to a traffic signal. Once aware of the vehicle’s presence, the signal phase can automatically update to allow the vehicle to pass through the intersection without stopping. In addition, the traffic signal can communicate its current phase and remaining time to red, so the vehicle can react in time and reduce the likelihood of a crash. In an environment with connected vehicles, traffic signals can adjust signal phasing in real-time to minimize idling and increase efficiency and vehicles can adjust their travel speeds and braking mechanism to improve safety.

- Benefits: Increased efficiency, reduced travel times without increased travel speeds, reduced emissions due to less idling at traffic signals, increased safety.

Vehicle to Vehicle (V2V)

The V2V connection allows connected vehicles to alert each other of their presence. This connection is particularly important in safety detection and driver alert systems. In a scenario where an approaching vehicle can be involved in a collision, the driver will receive a warning about the hazard through the connected vehicle. This warning can decrease the driver’s response time and reduce the chance of a collision. It also can alert the vehicle to implement safety precautions such as emergency braking.

- Benefits: Increased safety, reduced chance of collisions, assistance in reaching Vision Zero.

Vehicle to Everything (V2X)

This connection allows a connected vehicle to communicate with other IoT devices. Through this connection a connected vehicle can alert traffic management centers about roadway conditions that present potential hazards to motorists. Jurisdictions can use information gathered from connected vehicles to prioritize resources for roadway improvements.

- Benefits: Enhanced awareness of driving conditions, improved monitoring of vehicle performance, advanced control of vehicle operations and maintenance.

Vehicle to Cloud (V2C)

The V2C connection assists with vehicle cyber security as well as user experience and interface. V2C helps to organize, monitor, and manage vehicle fleets in conditions where connectivity is intermittent. The V2C connection also allows for the processing of fleet data to increase awareness of fleet operations.

- Benefits: Enables the management of a connected vehicle fleet, provides opportunities to improve the user experience, allows for in-vehicle advertisement and promotions.

Vehicle to Pedestrian(V2P)

This connection leverages a vehicle's ability to connect to cell phones, indicating the presence of a pedestrian or cyclists. Similar to the V2V connection, V2P informs connected vehicles about potential collisions with pedestrians and provides alerts to the driver and to pedestrians. This connection can help jurisdictions decrease pedestrian fatalities and reach Vision Zero goals.

- Benefits: Increased safety

Automated Vehicles

Automated vehicles can control some or all aspects of driving. Building on the systems incorporated in connected vehicles, automated vehicles are able to sense and respond to their environment. The National Highway Traffic Safety Administration (NHTSA) defines six Levels of Automation, Figure 3. These levels detail a vehicle's progression from an automobile that is fully controlled by a person to an automobile that is capable of performing all driving functions under all conditions.

Figure 3: Levels of Vehicle Automation

0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

As older vehicles age out of the existing vehicle fleet and newer vehicles are introduced, vehicle automation will become more common place. The adoption of automated vehicles will impact jurisdictions in different ways. Benefits to adopting automated vehicles include enhanced safety, increased efficiency and convenience, expanded mobility, and positive economic impact. Each of these benefits are expanded upon in the next section.

Enhanced Safety

Automated vehicles will help to enhance safety by removing one of the primary causes of crashes, human error. The NHTSA estimates that 94% of serious crashes are due to human error. By providing a rapid response to hazardous situations, automated vehicles will help to increase safety for drivers, passengers, pedestrians, and bicyclists. This will be an essential element to accomplishing Vision Zero.

Increased Efficiency and Convenience

The introduction of automated vehicles will also increase the efficiency of roadways and convenience of travel. According to a study by the Texas A&M Transportation Institute, the average American spends 54 extra hours a year in traffic delays. Without factoring in technology advancements such as autonomous vehicles, traffic delay is projected to increase to 62 hours a year by 2025. A fully automated vehicle fleet will be able to support more efficient travel times, ultimately reducing this projected delay. Additionally, automated vehicles will integrate the capability to communicate with connected infrastructure and vehicles. This will allow for the automatic adjustment of travel speeds as vehicles approach intersections and facilitate efficient merging of vehicles on roadways, which will alleviate major sources of travel delay. As driver responsibility for monitoring roadway conditions decreases, they will be able to use their travel time for other activities. Drivers can use the time spent during their daily commute for better uses, such as increased work productivity, additional hours spent sleeping, or quality time with commuting partners.

Expanded Mobility

Automated vehicles also have the potential benefit of expanding the mobility of seniors and persons with disabilities. Fully autonomous vehicles that can operate without human interaction can transport people that currently are not able to drive a vehicle. This would provide expanded mobility to the 50.9 million Americans that are over the age of 65 and 61 million adults that have some form of disability.

Projected Economic Impact

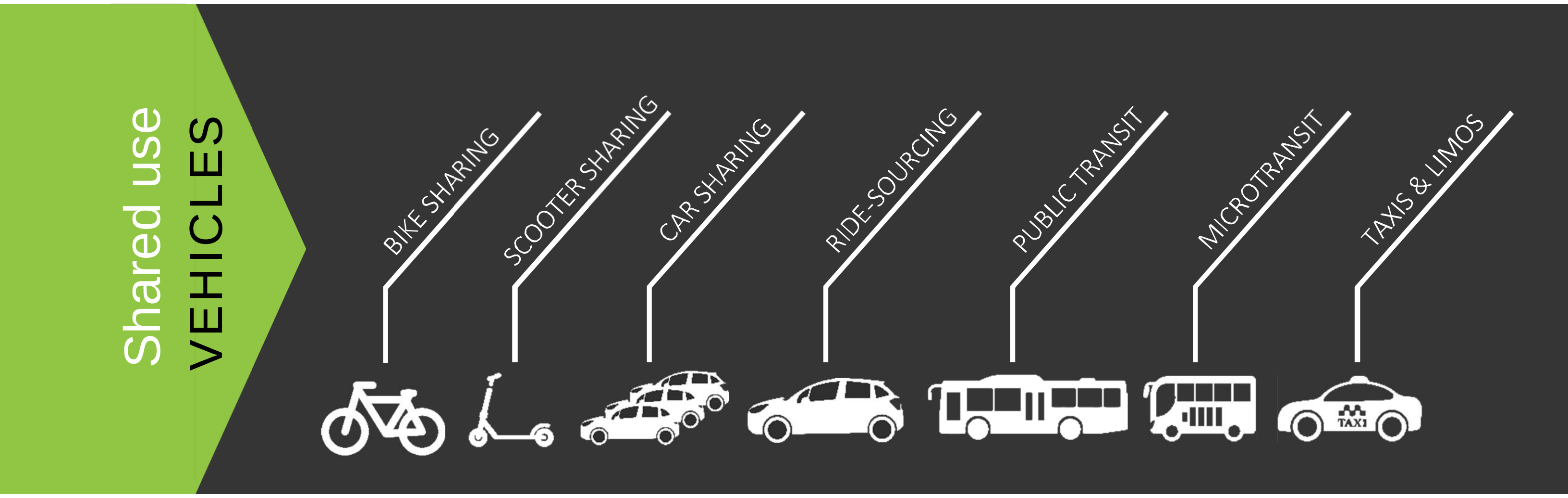
Automated vehicles are projected to have various economic impacts. As roadway safety improves and there is a corresponding decrease in motor vehicle crashes, the cost associated with crashes is expected to decrease. According to NHTSA, vehicle crashes cost $242 billion in economic activity and $594 billion due to loss of life and decreased quality of life due to injuries. By enhancing vehicle safety, automated vehicles will significantly reduce the physical and financial toll of vehicle crashes.

Additionally, automated vehicles can significantly reduce transportation costs associated with the shipment of goods. Fully autonomous trucks will be able to ship goods at faster speeds and shorter timeframes due to reduced stop times. Fully autonomous trucks will require fewer skilled operators, if operators are needed at all. This will reduce the cost associated with shipping while introducing a shift in staffing needs from vehicle operators to larger roles in dispatching or other types of fleet oversight. Taxi and rideshare drivers may face a similar threat of job loss or job shifts due to fleet automation.

Shared Use Vehicles

Shared use vehicles are transportation services and resources that can be shared among users. This includes cars, shuttles, bikes, and micromobility devices. At the heart of shared vehicles lies that objective of increasing transportation efficiency by sharing resources in a sustainable manner. Shared use vehicles can be placed into six primary categories: bike sharing, scooter sharing, car sharing, ride-sourcing, public transit, microtransit/flexible shuttle service, and taxis and limos, Figure 4.

Figure 4: Typology of Shared Use Vehicles



Shared Mobility Definitions

The Federal Transportation Administration defines shared use mobility modes as follows:

- Bike Sharing: short-term bike rental, usually for individual periods of an hour or less over the course of a membership (periods which can range from a single ride, to several days, to an annual membership).
- Scooter Sharing: a service in which electric motorized scooters (also referred to as e-scooters) are made available to use for short-term rentals.
- Car Sharing: a service that provides members with access to an automobile for short-term intervals of less than a day.
- Ride-Sourcing: Use of online platforms to connect passengers with drivers and automated reservations, payments, and customer feedback. Riders can choose from a variety of service classes, including drivers who use personal, non-commercial, vehicles; traditional taxicabs dispatched via the providers' apps, and premium services with professional uniformed drivers and vehicles.
- Public Transit: publicly owned fleets of buses, trains, ferries, facilities, and rights of way, with fixed route local and express service.
- Microtransit/Flexible Shuttle Service: IT-enabled private multi-passenger transportation services, such as Bridj, Chariot, Split, and Via, that serve passengers using dynamically generated routes, and may expect passengers to make their way to and from common pick-up or drop-off points.
- Taxis and Limos: regulated for-hire vehicles that pick-up passengers via street hails or pre-arrangements. Payment for taxis are typically meter-based.

Benefits of Shared Use Mobility

One major benefit of shared use vehicles is their ability to help first/last mile connectivity. Shared use vehicles such as bike sharing, scooter sharing, and ride-sourcing help to close the gap between fixed public transit stations and a person's final destination. Shared use vehicles also provide for increased roadway efficiency. By using a vehicle to serve multiple uses, shared mobility vehicles help to reduce vehicle miles traveled, emissions, car ownership rates, and household transportation costs. Additionally, shared use vehicles increase mobility options for people who do not own a private automobile. This is particularly important for vulnerable populations such as children, elderly, persons with disabilities, and persons of lower socioeconomic status.

Challenges of Shared Use Mobility

Shared use vehicles, particularly newer modes such as ride-sourcing and scooter sharing, can present a significant challenge to jurisdictions. Infrastructure for ride-sourcing, such as passenger pick-up/drop-off zones, requires the reallocation of curb space that has been traditionally allocated for parking. Scooter sharing presents challenges to the pedestrian environment by creating sidewalk clutter, introducing fast moving vehicles to the pedestrian walkways, and creating potential conflicts with vehicular traffic. Lastly, shared use modes such as public transit and microtransit can come with significant capital and operational costs to jurisdictions.

Electric Vehicles

Electric vehicles derive all or part of their power from electricity supplied by the electric grid. There are two types of electric vehicles: All Electric Vehicles (AEVs) and Plug-in hybrid electric vehicles (PHEVs).

- All electric vehicles are powered by one or more electric motors that receive electricity from the power grid and store it in batteries. AEVs do not use gasoline or other fuel as an energy source.
- Plug-in hybrid electric vehicles use a combination of power from electric motors and a petroleum-based or alternative fuel power source. PHEVs can also plug in to the electric grid to charge.

As an alternative to conventional internal combustion engines, electric vehicles help to reduce emissions and reduces the United States' reliance on petroleum-based fuel sources. In addition to electric vehicles obtaining their power from fuel sources such as coal, nuclear, and natural gas, EVs can use renewable sources such as solar or wind energy. Using renewable fuel sources offers the opportunity to decrease vehicle emissions as well as emissions associated with fuel production.

Electric Vehicle Infrastructure

The future of electric vehicles is dependent on the expansion of supporting infrastructure. Incorporating EV charging stations into land development codes and providing charging stations at parking facilities will be critical to the success of this emerging technology. Jurisdictions have begun to require the installation of charging stations for commercial, residential, and office land uses. These requirements provide essential infrastructure needed to support the adoption of electric vehicles.

Other Emerging Transportation Technology

Freight

A major contributor to the future of transportation will be roadway and curb lane demand associated with the movement of goods. In 2019, U.S. online retail sales of physical goods amounted to approximately $343 billion. Retail e-commerce sales are projected to increase to approximately $477 billion by 2024. This will increase the number of freight vehicles that are needed to move and deliver goods. As the number of freight vehicles increases, the infrastructure needed to support these vehicles will become vital to the operation of cities. Traditionally, truck loading zones have been used to provide infrastructure needed for freight vehicles, however using new technology and curb lane management principles, truck loading zones are being converted to flex zones. Flex zones allow for truck loading zones to be converted to different uses throughout the day. Additionally, flex zones can be equipped with sensor technology to provide real-time occupancy information. This data can help to create smart loading zones that allow logistics companies to coordinate delivery times for high demand areas.

Future of Freight Vehicles

As a part of the increased demand associated with the growth of e-commerce, freight companies are looking for ways to diversify their fleet type. The United Parcel Service (UPS) has introduced cargo-bikes into their fleet mix. UPS cargo-bikes are bicycles equipped with a battery-powered electric motor that allows the bikes to be powered by pedaling or battery. This enables cargo-bikes to travel longer distances, carry up to 400 pounds of cargo, and navigate in an urban environment where traditional delivery trucks have limited access. To facilitate the distribution of goods, cargo-bikes are paired with a larger delivery vehicle that serves as a centralized hub for packages. Multiple cargo-bikes can be deployed from a centralized delivery hub to decrease the time it takes to distribute packages. This system has the added benefits of reducing the number of large trucks and vans needed to deliver packages, decreasing the congestion by reducing vehicle dwell times and preventing double parking by delivery vehicles.

Throughout the United States, freight is primarily moved through the use of trains. Trains provide a cost-effective method of moving large quantities of freight at both the regional and national level. This is particularly true for areas of the country that have limited access to waterways. Similar to roadway vehicles, the future of railways will include increased automation and connected technology. Automated and connected trains will increase the efficiency of transporting freight, allowing cargo to be shipped over longer distances with less stoppage time for crew transfers.

As railway freight increases in automation, coordination between freight operators and jurisdictions will be critical. Roadway intersections along freight routes will need to be upgraded to a fully connected intelligent transportation system that ensures the safety of pedestrians, vehicles, and trains.

Connected Curb Lanes

In addition to intersections equipped with intelligent transportation systems, jurisdictions should prepare curb lanes to interact with CASE vehicles. In recent years, curb lanes have transitioned from their traditional role as areas for vehicles to park to areas that provide access for multiple user groups. Curb lanes interact with CASE vehicles in various ways.

- Connected Vehicles – Curbs equipped with smart meter technology, mobile payment options, or real-time occupancy sensors can communicate with connected vehicles to allow for parking payment or help connected vehicles identify available parking spaces.
- Automated Vehicles – Automated vehicles interact with the curb by using parking assist technology that parks a vehicle without guidance from the driver. Automated vehicles may also use the curb lane as nesting areas or pick-up/drop-off locations.
- Shared Vehicles – Shared vehicles can interact with the curb through the use of rideshare pick-up/drop-off areas, which can be geo-fenced to ensure drivers and passengers use designated areas. Shared use modes such as bike and scooter sharing use the curb to house bike share stations and micromobility hubs, respectively. The connected curb can also be used to provide real-time arrival information for public transit services.

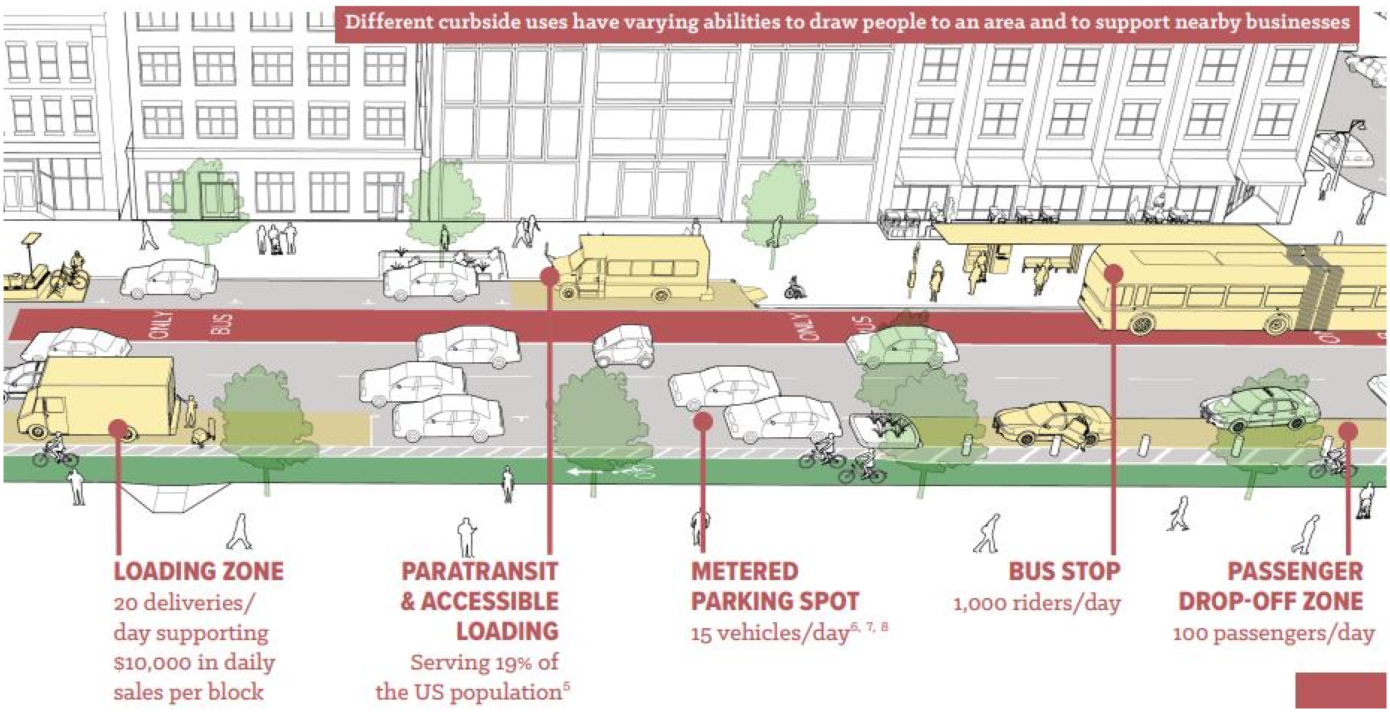
- Electric Vehicles – Connected curbs can be equipped with EV charging stations that allow vehicles to be charged during a parking session. On-street parking spaces equipped with EV charging stations help to expand the network of charging facilities, which increases the feasibility of owning and operating electric vehicles.

Connected curb lanes can also be equipped with sensor technology that enhances a jurisdiction's understanding of how curb lane usage varies throughout the day. Sensor technology, such as pole-mounted cameras, curb mounted sensors, or in-ground sensors, can be used to provide real-time occupancy information. Jurisdictions can use information collected through sensors to develop a curb lane management plan that allocates curb space to different user groups throughout the day. The National Association of City Transportation Officials (NACTO) provides guidance on how the curb lane can be allocated to serve multiple user groups, Figure 5. NACTO's recommended curbside prioritization reflects the principle of curb productivity, in which the number of people using the curb is assessed over a specific period of time for a given curb length. Curb productivity increases as the number of people that can use a portion of the curb increases.

NACTO Recommended Curbside Prioritization:

1. Transit stops
2. Transit lanes
3. Quality bikeways
4. Bike share stations
5. Commercial loading
6. Accessible passenger loading
7. Parklets
8. Stormwater infrastructure
9. Pick-up and drop-off areas for rideshare and private vehicles
10. Managed parking: short-term, one-hour, multi-hour, and longer-term car storage

Figure 5: NACTO Curb Lane Uses by Number of Users Served



Right Sizing Emerging Transportation Technologies

There is not a one-size-fits-all approach to preparing for emerging transportation technology. Embracing emerging transportation technology requires an understanding of each jurisdiction's current capabilities and the level of supporting infrastructure and processes in place. Jurisdictions should perform a self-evaluation of their preparedness to adopt new technology using the Capability Maturity Model (CMM) Framework. The CMM Framework uses three tenets:

- Process matters: projects fail or do not achieve desired functionality for a variety of reasons unrelated to the technology;
- Prioritizing the right actions is important: is an agency ready, how do they know, and what should they do next?
- Focus on the weakest link: what is holding the agency back in becoming a leader in a particular area?

Based on the CMM Framework, agencies should evaluate their ability to advance infrastructure and processes by conducting the following steps.

- Step 1: Self-Assessment. Work with your stakeholders to assess the agency or regional maturity level relative to defined assessment dimensions.
- Step 2: Identify dimensions that receive a lower maturity level thereby require a higher focus to increase the maturity.
- Step 3: Identify actions that can be taken to move from the current maturity level to the next.

Table 1 presents three dimensions that an agency or region should assess to define the current maturity level. These dimensions are Preparedness, existing Infrastructure, and formalized Policy/Practices. This assessment is geared towards evaluating the agency's maturity level for each category of the CASE framework. The self assessment process is outlined below.

- Step 1: Select the relevant CASE category you are intending to assess.
- Step 2: For the CASE category selected, identify strengths and challenges in the agency's preparedness to adopt or support the category and the related emerging transportation technologies.
- Step 3: Review each dimension (Preparedness, Infrastructure, and Policy/Practice) and the related Maturity Level descriptions. *
- Step 4: Score the agency's current Maturity Level.
- Step 5: After the agency has identified Strengths and Challenges and scored their Maturity Level, the agency should develop context-sensitive action items that build on their identified strengths and help to overcome their cited challenges.
- Step 6: As a part of developing action items, the agency should refer to Table 2as a starting point to identify foundational activities.

Building on the CMM Framework, action items were developed to assist the jurisdiction's response to emerging transportation technology, Table 2. These action items reflect Level 1 to Level 2, Level 2 to Level 3, and Level 3 to Level 4 advancement strategies. Additionally, these action items reflect strategic approaches to connected, automated, shared, and electric vehicles. As CASE vehicles become prevalent, they will play an ever-increasing role in reshaping cities.

*Additional templates for the CMM Framework have been provided for use by agencies. These include a page for action item pages for each dimension.