BLUEPRINT FOR AUTONOMOUS URBANISM

Module 1 | Fall 2017
Designing Cities Edition

NACTO

National Association of City Transportation Officials
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ABOUT NACTO

NACTO's mission is to build cities as places for people, with safe, sustainable, accessible and equitable transportation choices that support a strong economy and vibrant quality of life.

The National Association of City Transportation Officials is a 501(c)(3) nonprofit association that represents large cities on transportation issues of local, regional, and national significance. The organization facilitates the exchange of transportation ideas, insights, and best practices among large cities, while fostering a cooperative approach to key issues facing cities and metropolitan areas. As a coalition of city transportation departments, NACTO is committed to raising the state of practice for street design and transportation by building a common vision, sharing data, peer-to-peer exchange in workshops and conferences, and regular communication among member cities.

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Foreword

The autonomous revolution will be humanized.

One century ago, as the automotive age swept across the nation, cities responded not by adapting cars and trucks to the varied uses of the street, but with a relentless clearcutting of urban roads, removing all obstacles from curb to curb—including pedestrians—and all but eliminating street life. Subsequent generations of urban planners built upon this, hollowing out downtown urban cores with congestion and traffic danger, replacing housing with parking lots, and eviscerating urban economies.

Today, in the second decade of the 21st century, and as we anticipate the arrival of self-driving vehicles on city streets, we have a historic opportunity to reclaim the street and to correct the mistakes of a century of urban planning. This adaptation starts with a plan.

The Blueprint for Autonomous Urbanism is based on the principle of people, showing how to adapt new mobility technologies to our cities, and not the other way around. If we redesign streets to meet the needs of people, they begin to look very different. Curbsides become places for commerce and shared mobility, not parking. Vehicle travel lanes occupy only as much road space as they need to move people efficiently, and are not saturated with thousands of single-occupancy vehicles. And space is dedicated to the kinds of mobility that really make our cities move: public transit, walking, biking and shared rides.

The Blueprint looks to the autonomous future as a chance to revolutionize the street for the people, and not just a revolution in the technology running on it.

Janette Sadik-Khan

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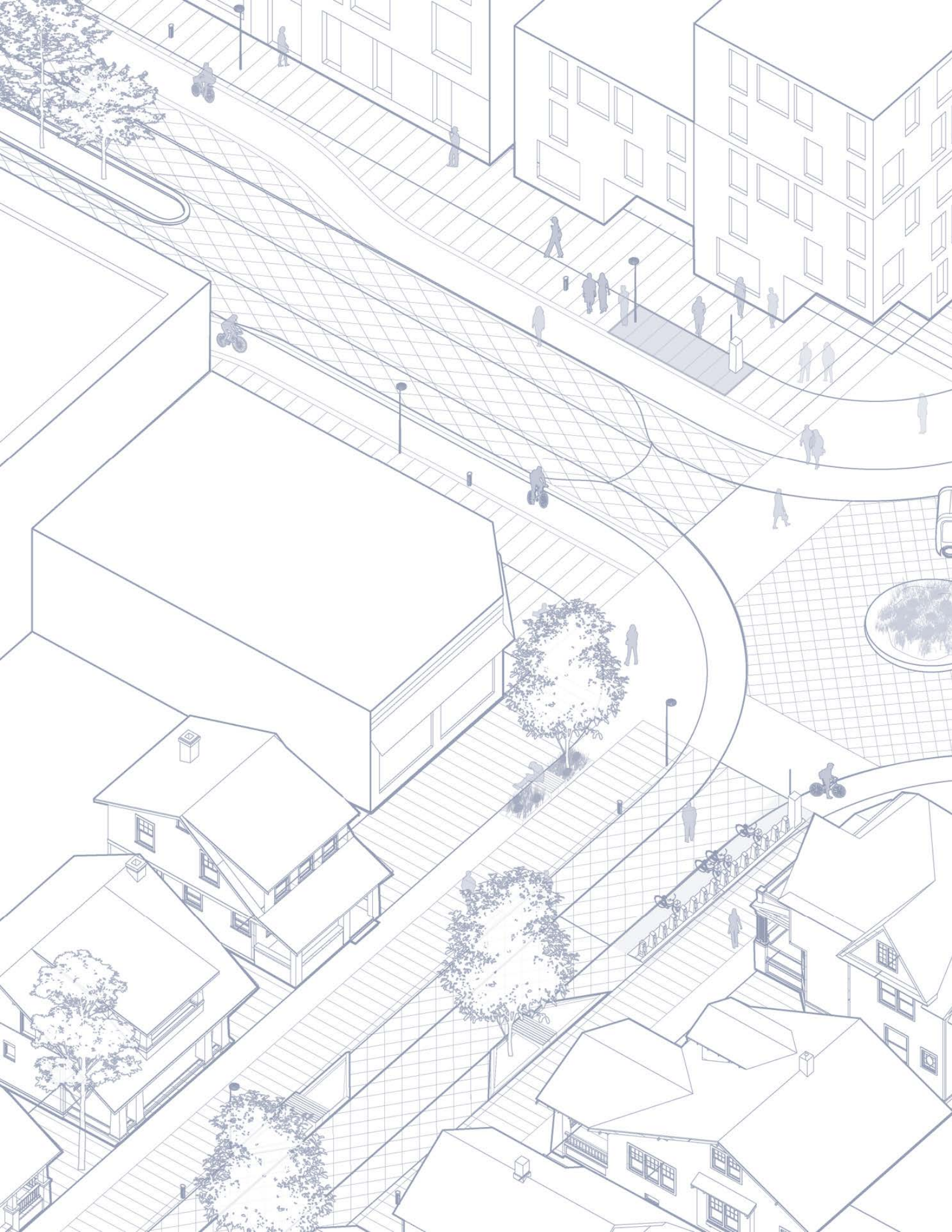


Blueprint for Autonomous Urbanism

Drastic advances in automated and connected vehicle technology will upend the way people move around cities, presenting sweeping opportunities as well as serious risks. This Blueprint envisions a future where cities and transit agencies leverage new technology as a tool to enhance the public realm and improve the lives of all urban residents. This is a future shaped by proactive urban policy, in which the footprint of vehicular travel is reduced, every transit vehicle supports high occupancy trips, and safe spaces for walking and cycling are abundant. With the right policies, automation can enable newfound dynamism in mobility and make it easier than ever to access quick, affordable, equitable and sustainable transportation options throughout cities.

Introduction

Transportation decisions have dramatically changed the face of cities over the last 100 years. From streetcars to traffic signals to highways and parking lots, transportation infrastructure has reshaped how humans engage with their surroundings. While many transportation innovations were optimistically intended to benefit society, the changes were not always for the better; from sprawling land uses, to highways that divide neighborhoods, to the public health burden of traffic crashes, to the sheer amount of space dedicated to parking cars, a century of automobile-oriented transportation policy has left an entrenched legacy in urban design.

Today, the advent of autonomous vehicles poses a similar risk—and presents an opportunity to learn from the mistakes of the past and ensure that cities and transportation systems become more efficient, sustainable, and equitable.

The prospect of a widespread shift to automated transportation comes on the heels of a decade of unprecedented progress in sustainable transportation. City leaders and practitioners have not only embraced biking, walking, and transit as essential to their city's attractiveness, but have experimented successfully with new, more nimble forms of project delivery and implementation. Automated vehicles must not negate this progress.

This Blueprint outlines a vision for cities in a future where automated transportation is both accepted and widespread as part of the built environment. It is a human-centered vision for the potential of city streets, intersections, and networks—one in which automation is harnessed to serve the goals of safety, equity, public health, and sustainability. As a vision, it sets out to inspire policymakers and practitioners to challenge basic assumptions of design, traffic operations, and engineering and to project a vision that builds on present progress, yet takes advantage of technological possibilities.

A Critical Turning Point

As with other visions of the not-too-distant future, the Blueprint charts a course amidst many open questions. Despite the recent enthusiasm for automated vehicles, much remains to be seen about how they will ultimately perform on streets and highways, how people will (or will not) integrate them into their lives, and how their evolution may impact the many people who rely on transportation services for their livelihood across the globe.

Speculating on these unknowns is not the purpose of this document. Nonetheless, waiting to see how events unfold is not a viable option. The onset of automated vehicles marks a critical and consequential turning point in the history of mobility—as important as the early 20th century rise of motordom. The policies contained here are a step towards building a policy agenda and aspirational framework for the deployment of automated vehicles. In the absence of such policies, transportation network companies and technology companies will shape urban transportation policy by default. Cities must restate and reiterate their goals and priorities now in order to proactively create cities that best serve the long-term needs of their residents—and other levels of government must heed their call.

For those working in cities and public officials, the Blueprint is intended to serve as a foundational and aspirational human-oriented vision for the city—a statement and visualization of core principles in an uncertain future shaped by technology.

For the private sector, the Blueprint is intended to communicate the urban vision that cities are working toward and the importance of partnership to achieve this vision.

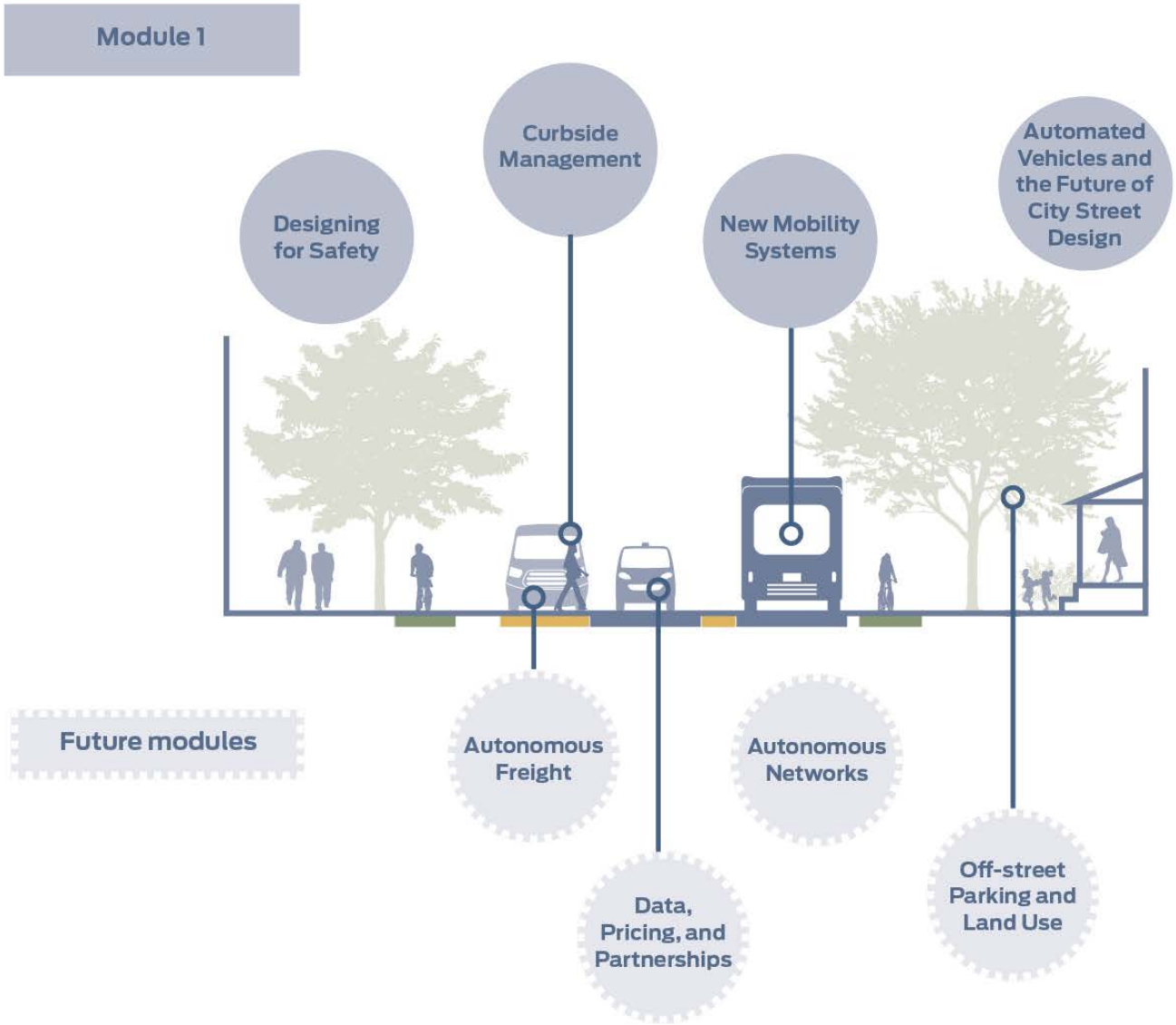
This Blueprint outlines a vision for cities in a future where automated transportation is both accepted and widespread as part of the built environment. It is a human-oriented vision for the potential of city streets, intersections, and networks—one in which automation can serve the goals of safety, equity, public health, and sustainability.

Structure of the Document

Unlike the NACTO Design Guides, the Blueprint does not focus on specific markings or measurements. It endeavors first and foremost to illustrate policy goals using renderings and diagrams, and to present an alternative vision of the future oriented around city streets as public spaces.

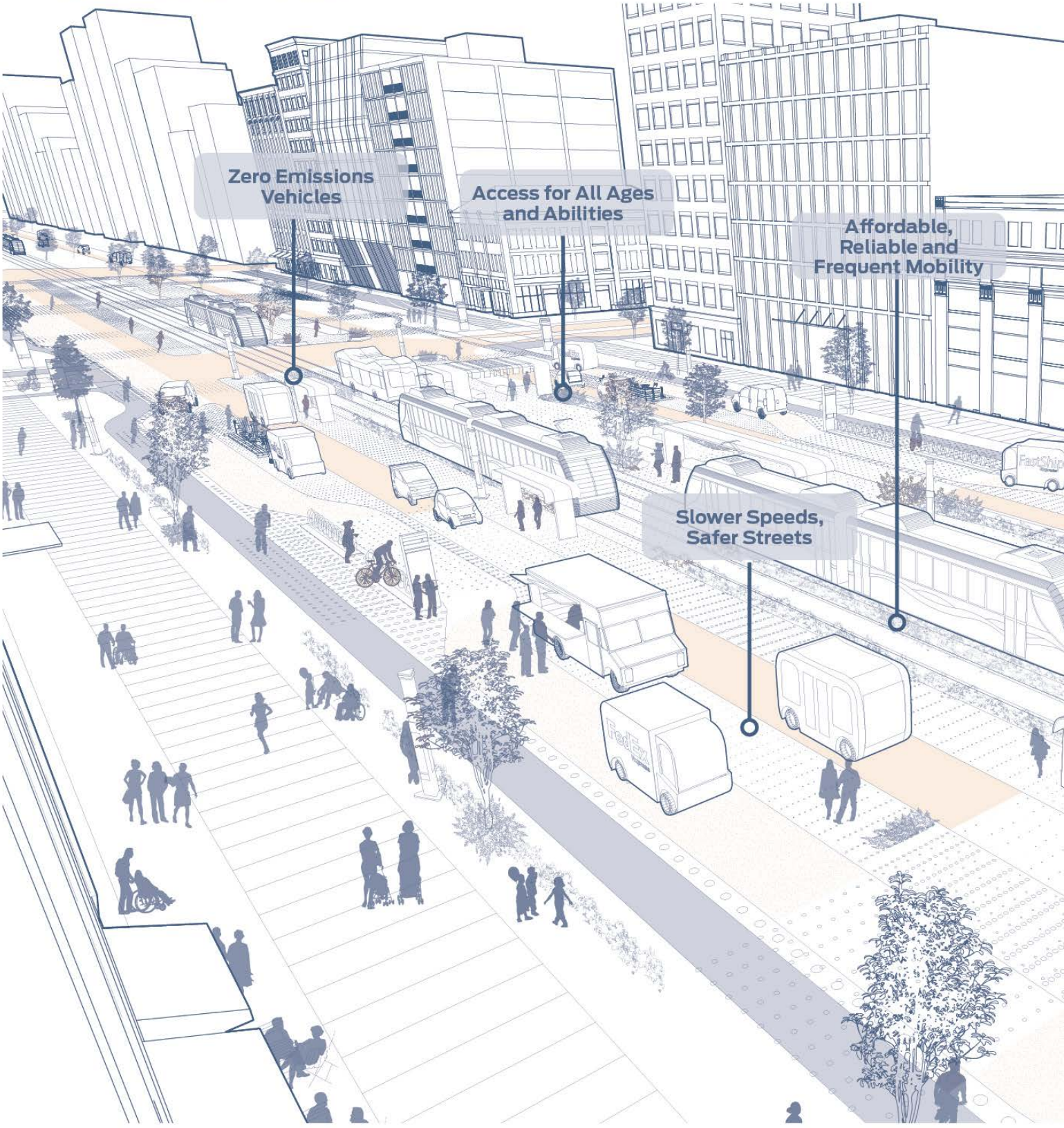
This is not a design guide. The Blueprint lays the groundwork and sets a vision for city streets in the automated future that are designed for people. It is rooted in our cities' goals for building safe, accessible and equitable communities with strong economies and vibrant communities. The ideas and vision presented in the Blueprint adapt NACTO's foundational principles to the rapidly changing technology and transportation realm.

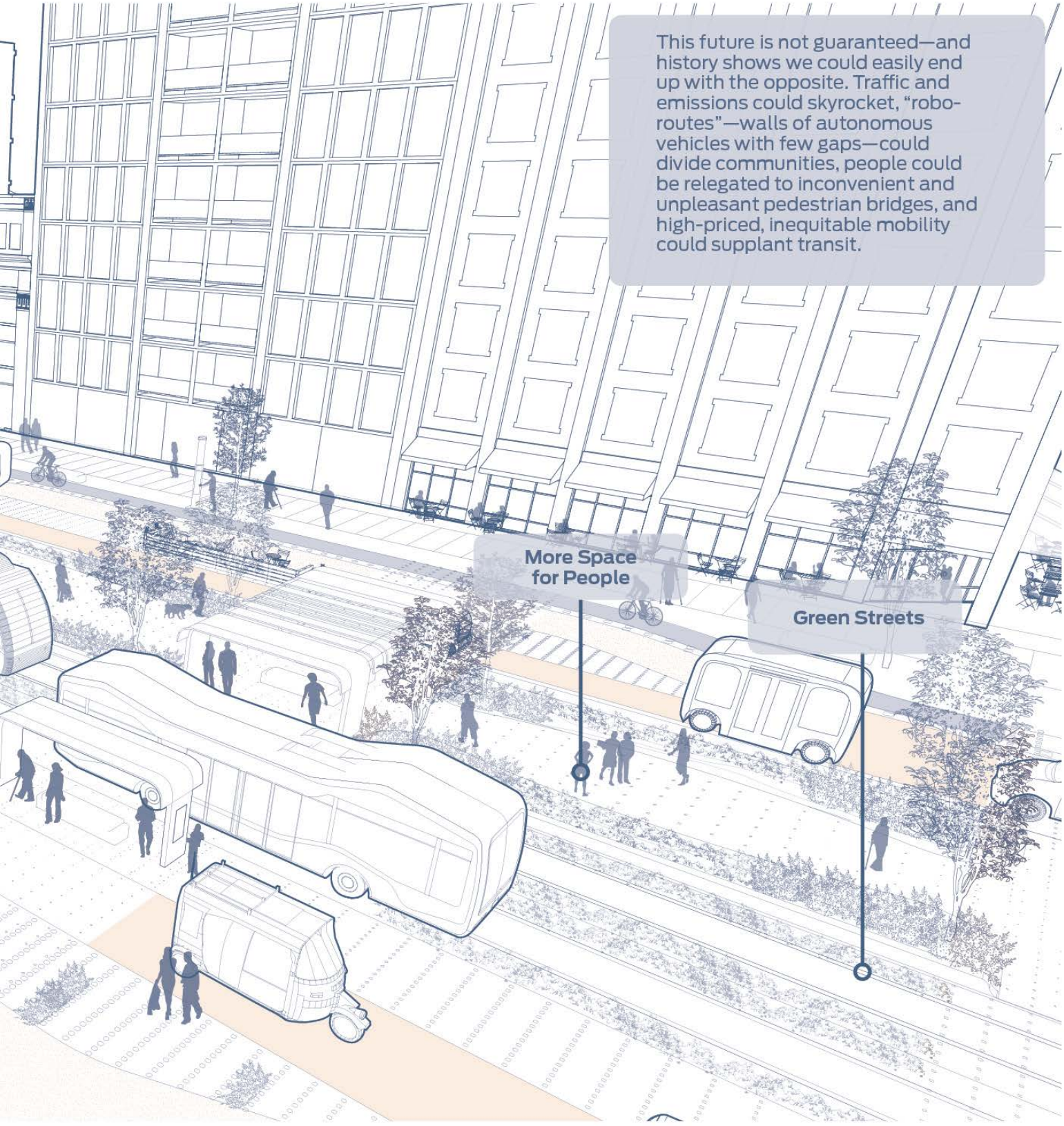
This module of the Blueprint addresses some of the most pressing issues city transportation agencies face today but acknowledges those issues will vary by city and over time. The modular approach is an attempt to lay the groundwork in a field that moves rapidly. We will be build on this vision as technology advances.



The Promises and Perils of Automation

Automated vehicle technology holds many promises for cities, but the potential benefits of automation are not guaranteed. City policies must proactively guide the technology to prioritize people-centric design.



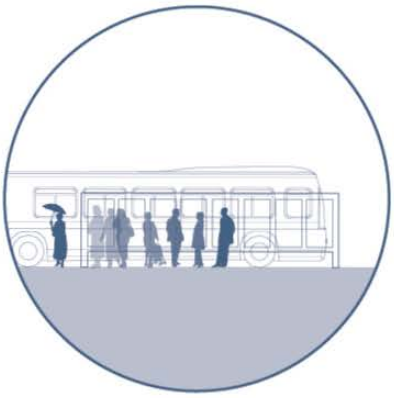


This future is not guaranteed—and history shows we could easily end up with the opposite. Traffic and emissions could skyrocket, "robo-routes"—walls of autonomous vehicles with few gaps—could divide communities, people could be relegated to inconvenient and unpleasant pedestrian bridges, and high-priced, inequitable mobility could supplant transit.

Principles for Autonomous Urbanism

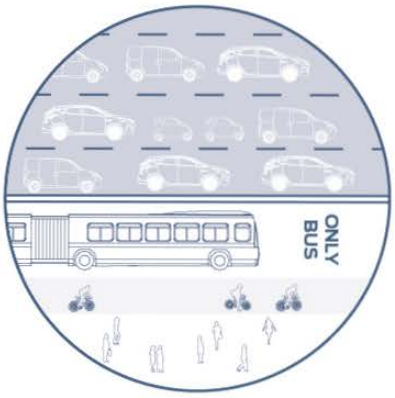
Safety is the Top Priority

Streets should be designed for the safety of all users, with special attention necessary for pedestrians and cyclists. Cities should require that highly automated vehicles be programmed for safe, slow speeds on city streets, with mandatory yielding to people outside of vehicles. Maximum vehicle operating speeds in city street environments should not exceed 20 mph, or 25 mph in very limited circumstances, with lower speeds in downtown and neighborhood zones.



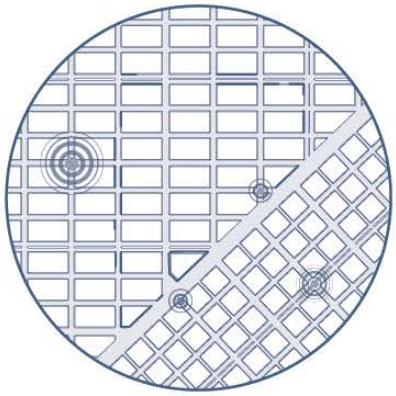
Provide Mobility for the Whole City

The benefits of autonomous urbanism can only be realized if mobility is made more accessible, convenient, and affordable for the entire city. Cities and their partners should offer flexible and affordable mobility options tailored to the needs of different communities, from walking and biking to fixed transit and ridesharing.



Rebalance the Right-of-Way

With the right policies, autonomous vehicles can move more people in fewer vehicles on less congested streets. That means that cities can use space more wisely. Instead of planning for roadway expansion, reallocate street space to active, sustainable modes and use technology to manage the public realm dynamically.



Manage Streets in Real Time

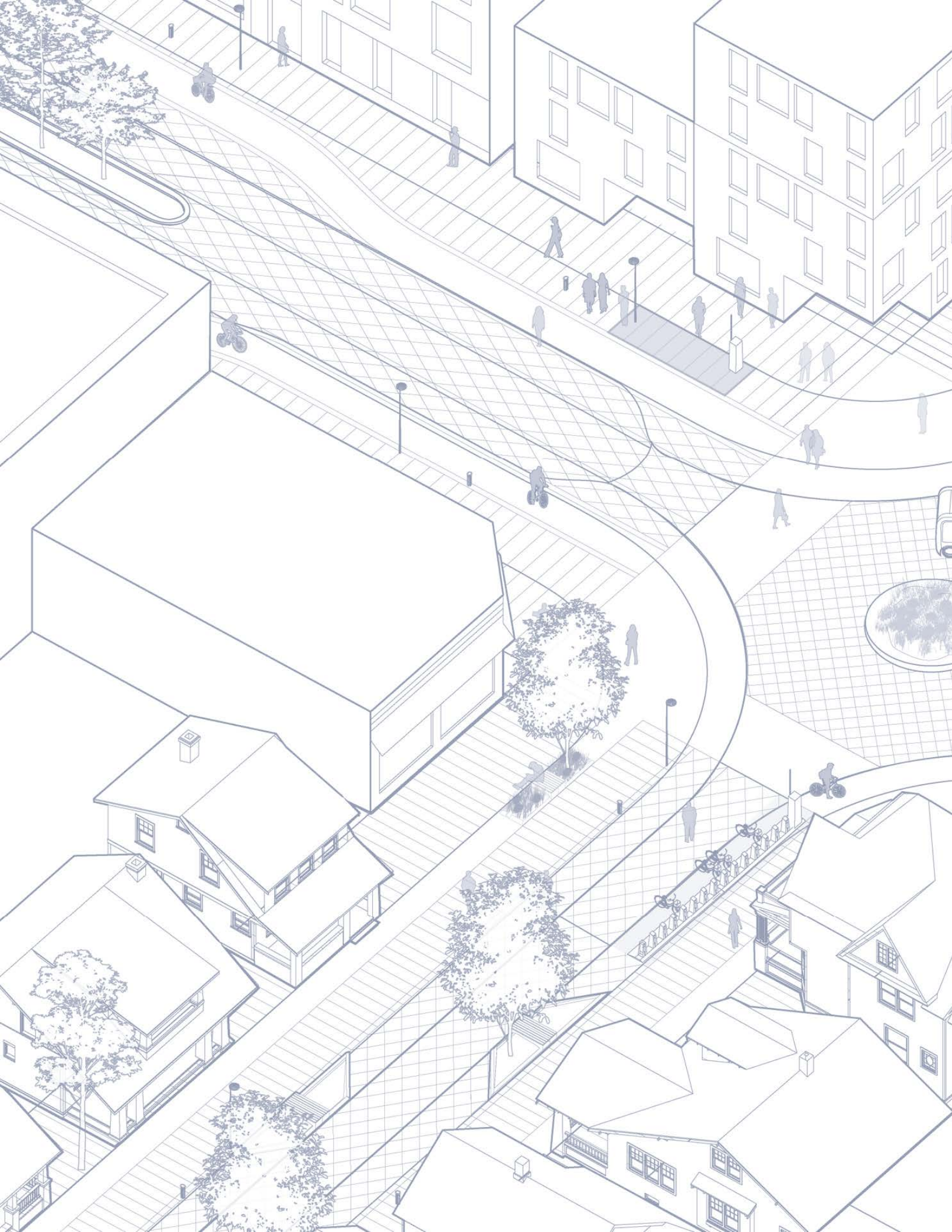
New technology makes real-time, proactive street management feasible. Cities must leverage this opportunity to revolutionize the services they provide and the ways they capture revenue. Real-time right-of-way management and vehicle occupancy pricing mechanisms will allow cities to incentivize shared and active modes over private automobile trips, while reapportioning vehicle space as public space.

Move More with Fewer Vehicles

As technology is embedded in urban transportation, vehicles can assume maximum rider occupancy, creating an interconnected network of mobility supply and demand whether for freight or passengers. Transit agencies will need to adapt to new consumer expectations and reshape their services to ensure seamless connections with other modes.

Public Benefit Guides Private Action

Autonomous urbanism should foster balanced collaboration with the private sector that maximizes public benefit. Smart governance ensures that these partnerships are neither unconditional endorsements nor punitive prohibitions, but are instead guided by set criteria and clear, measurable and adaptive policy goals.



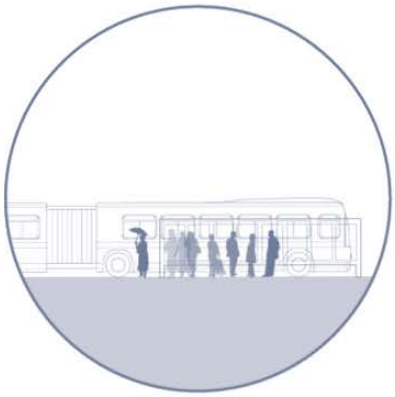
2 Policy Ideals and Actions

Cities need strong policies to guide the future of automation and to help communities shape powerful technologies around their goals, rather than the other way around. Clearly articulated policy goals represent a good first step for cities. Achieving these goals will require creative public-private partnerships, adaptive decision-making, and critical data-sharing agreements.

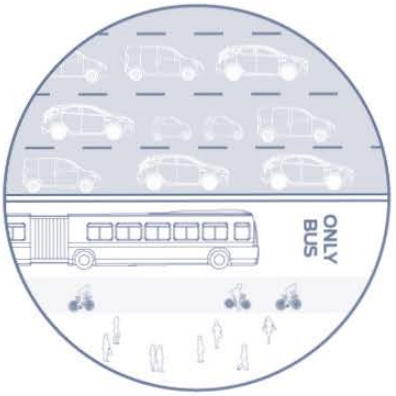
Setting up for Success

The right policies today will position cities for success in the autonomous era of tomorrow. The autonomous revolution can support cities as they work toward streets that prioritize pedestrians, dedicate more space to better bicycle infrastructure, and allow for reliable transit service-but only with smart, thoughtful, intentional policies. The following are critical steps that NACTO cities have already adopted and are implementing to prepare for the autonomous future.

Safety is the Top Priority



Mobility for the Whole City



Rebalance the Right-of-Way

20 is Plenty

Set speed limits for automated and human-driven vehicles that are safe for people walking, cycling and taking transit.

Create a Citywide AV Working Group

For automated vehicles to work for the whole city, all city departments must be involved in planning for the autonomous future.

Stop Expanding Roads

Update existing traffic models to reflect the reduced need for roadway due to future efficiencies through automation.

Collect Better Data for Safety

Use a third-party platform to anonymize and aggregate data from vehicles operating in the city to pinpoint hazardous locations and redesign streets for safer operation.

Invest in Active Modes

Build streets that prioritize sustainable and active modes like transit, walking and biking.

Take a Lane for Transit

Dedicate travel lanes for high-volume transit services to boost person-throughput in critical corridors.

Set Operating Principles that Prioritize People

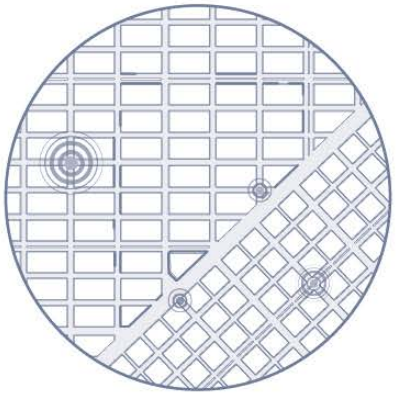
Establish principles for operation and geometry on city streets that ensure safe operation of both human-driven and automated vehicles.

Collaborate Regionally to Promote Interoperability

Support multiple modes to provide complete coverage to all areas of the city, integrating them all in a single platform to allow for easy customer use.

Pavement for the People

Repurpose underutilized travel lanes to ensure safety and comfort for people walking along the curbside, and create valuable public spaces in neighborhoods and downtowns alike.



Manage Streets in Real Time

Street Management with Data

Use third party data platforms to exchange data about the street securely and seamlessly, supporting street management in real time.

Price the Curb

Create delivery and pick-up and drop-off management plans that maximize customer experience while minimizing the fight for the curb that endangers people across modes.

Code the Curb to Optimize Access

Maintain a dynamic, digitally-visible curbside inventory to democratize curbside access while guarding safe function of the roadway.

Move More with Fewer Vehicles

Prepare for a Future without Parking

Reduce parking minimums in zoning codes to reflect lower overall parking needs. Develop prototypes for adaptable parking garages and infrastructure that could be retrofitted in the future.

Incentivize Electrification

Support shared, electric vehicle use by allocating space for charging stations and employing occupancy-based congestion pricing.

Invest Strategically in Transit

Modernize and strengthen public transit and its partners on high volume routes.

Public Benefit Guides Private Action

Clear Hurdles for Public-Private Partnerships

Create replicable requests for qualifications with 'piggy-backing clauses' so that companies can clear hurdles once to work across US cities, supporting local goals.

Engage the Public

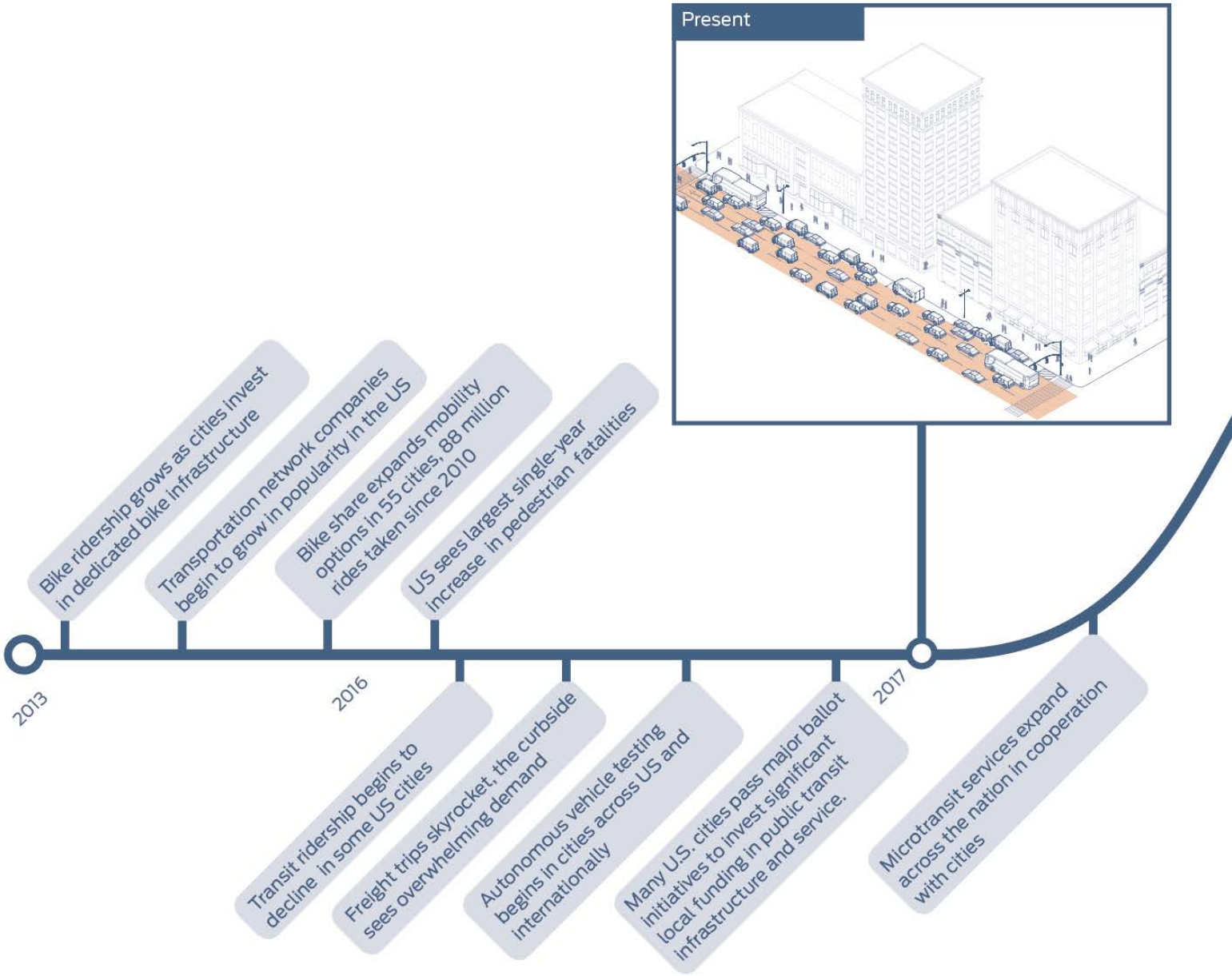
Make technology development and pilot projects transparent so that the public can engage in an informed discussion about how new technology can make their lives and communities better and stronger.

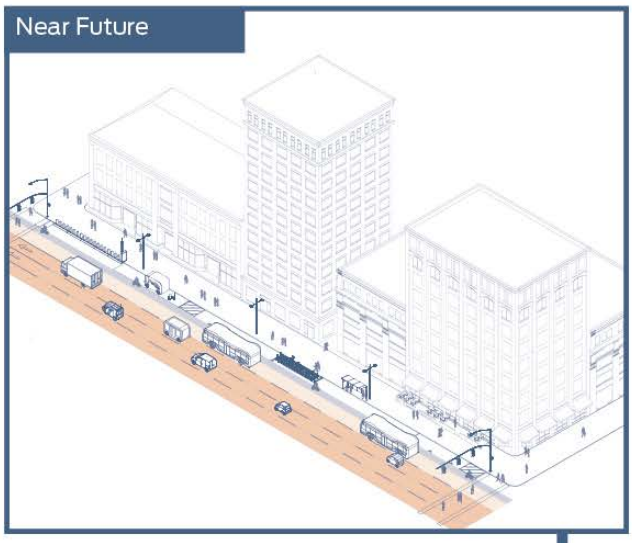
Cities are Integral to Autonomous Operations

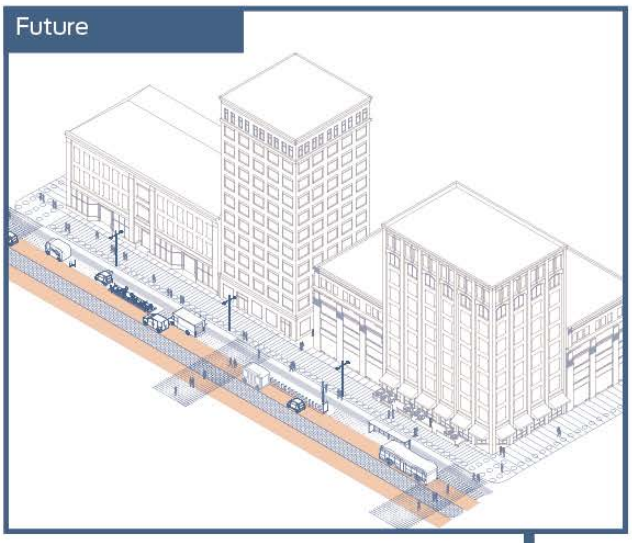
Cities already support and manage traffic. They must be integral partners in discussions about future technology operations.

Managing the Transition

Automated vehicles are on the horizon and cities are preparing for their arrival today. Though the pace of technological change is rapid, changes to urban infrastructure tend to be incremental. While much experimentation will take place on the vehicle side of automation, city streets and sidewalks can also serve as an important venue for testing new policies, technologies, materials, and street types.







Partial Automation

Full Automation

Cities invest strategically to simultaneously prepare for connected, autonomous technology and to make every street safe and welcoming for cycling and walking

Speed limits reduced to 20 mph, curbside lanes are dynamically priced and reclaimed for people

Mobility pricing enacted in the first US city, emissions and congestion reductions seen

Walking, cycling and core transit use surge, all vehicles in cities are shared

More cities begin to price VMT to reduce congestion as AVs proliferate

Fleet vehicles are fully automated, VMT decreases, cities densify

Data Foundations

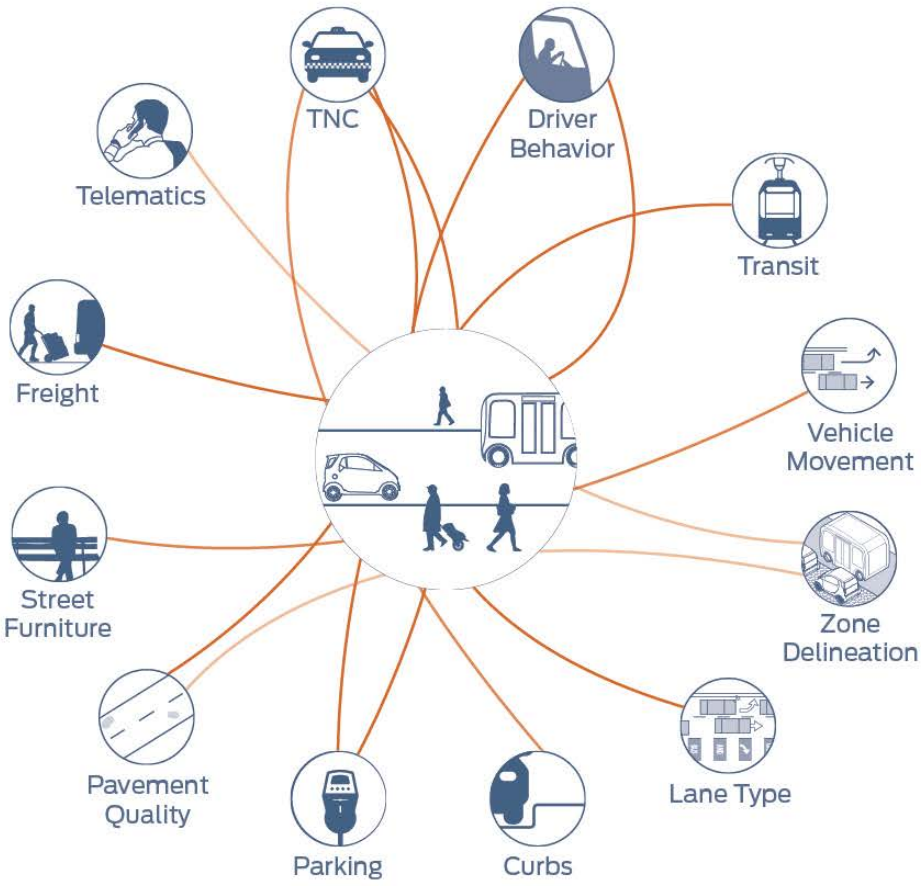
Data is replacing concrete, asphalt and steel as the foundation of 21st-century urban transportation planning and management. New technologies have the potential to radically improve the efficiency, cost, and inclusiveness of our transport system.

The World Wide Street

Billions of detailed, street-level data points are collected in real time daily on everything from traffic speeds and volumes to travel patterns and transit use. This data is vital to the operations and management of streets, regardless of the entity generating them. Cities need to establish partnerships that align private technologies with the public interest.

Street-level data points can be aggregated from a variety of different sources. The graphic at right depicts a selection of the diverse data streams that cities can use to better manage and inform transportation networks.

However, intricate information on people movement is laden with personally identifiable information that neither government nor private companies should have access to. Cities need access to this information in an anonymized and aggregated format so that they can effectively track trends and plan for the future.



Keeping Data Safe

In order to protect user data, an independant third-party company can sort and anonymize data collected before it is used for analysis, ensuring individual users are not identified. Once analyzed, this data can be used to direct city policy and prioritize projects.

Data Generation

Vast amounts of data are generated by users and vehicles of streets. This data is immensely useful for cities seeking to make data-driven policies based on real-time information, but it is frequently too big, includes sensitive information, or is not appropriate for the necessary analysis.

Curbside User Data

Transit Data

Vehicle & Driver Behavior

Third Party Data Platform

Third party data platforms aggregate and anonymize sensitive data in order to make information available to cities in a format they can use quickly and easily. For example, NACTO's partner, the Open Transport Partnership, collects, aggregates, anonymizes and provides analytical tools based on this data.

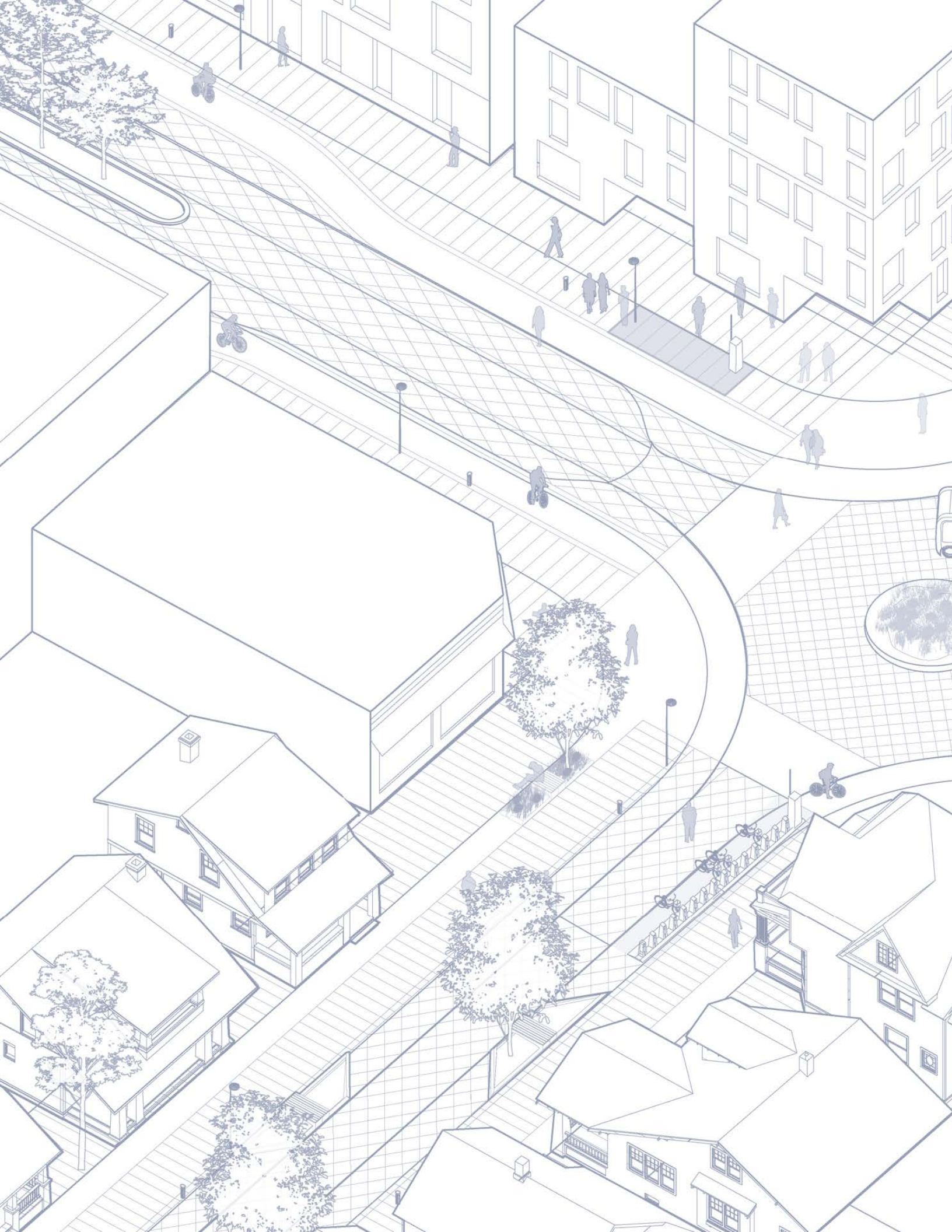
Data Driven Policies

Data platforms can show data in formats that are applicable for complex transportation issues. Cities can then use this accessible information to make the best decisions for their rights-of-way.

Curb Pricing

Lane Allocation

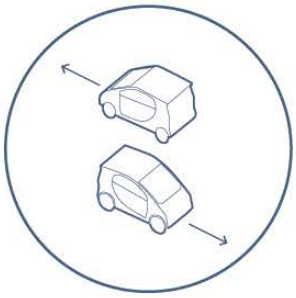
Safety Projects



3 Automated Vehicles and the Future of City Streets

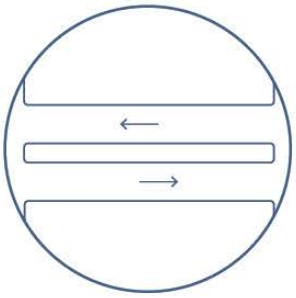
The vision for the future is one in which streets of all sizes are designed for people, not vehicles. Autonomous vehicles will require less space than traditional vehicles, affording cities the opportunity to dedicate more space to public amenities. These streets could move traffic more efficiently and safely for all users. From major urban streets that allow seamless transit access, to residential streets that become a place for neighbors to meet and children to play, the future street is a place for people.

Dynamics of the Future Street



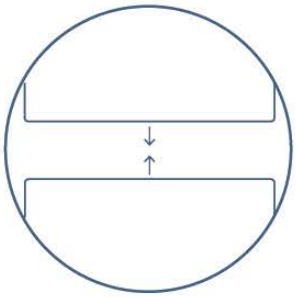
Two-way Operation

In a connected vehicle environment, streets can operate two-way, enhancing the overall flexibility of the network when properly managed. However, two-way operation should never be implemented at the cost of pedestrian movements, and medians or transit platforms would be needed to facilitate shorter crossings on major streets. In residential areas, limits on VMT and through-traffic can minimize conflicts.



One Lane Each Way

Outside of highways, streets could be limited to a single lane of vehicle traffic in each direction, excluding dedicated transit lanes. Residential streets can be designed as "yield" streets to limit through traffic. Major streets should provide high-capacity bus or rail service. AV-only lanes should be discouraged.

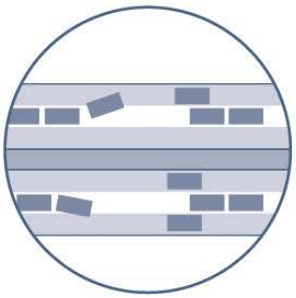


Lane Width

Lane widths can be kept to a minimum. In most urban environments, lanes of 10' or less suffice with controlled lane guidance, and streets without large transit vehicles can be even smaller if adjacent flexible space is available. In the long term, lanes should not be demarcated by markings, but instead be relatively flush with the sidewalk and median, with elements like bollards, accessible textured pavers, or other cues to demarcate uses.

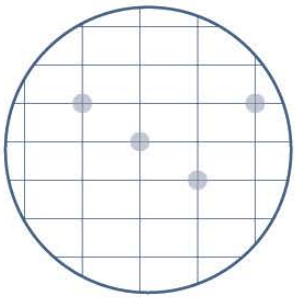
Integrate freight & deliveries

Vehicle design in the future could make use of constrained street space to accommodate both passengers and freight operations. Where possible, freight and electric charging infrastructure could be paired with peripheral dispatch points or be integrated into the street to minimize freight congestion.



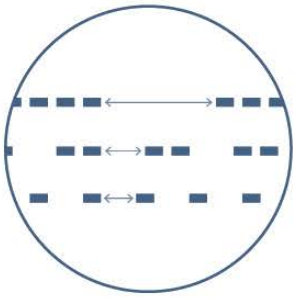
Manage Curbside Demand

Cities could dynamically manage curbside environments more easily in the future, allowing for curbs to serve a variety of different functions over the course of the day, ranging from public space to bike share stations, mobility hubs, information kiosks, and vendors. Detailed curbside inventories and management strategies will allow for the curb to be managed and priced in real-time.



Flexible Mobility Hubs

Passenger pick-ups and drop-offs can happen at designated hubs, encouraging both vehicles and people to coordinate trips. Curb space and flexible medians may provide this infrastructure, or sign posts may suffice to indicate key hubs. Both permanent infrastructure and flexible kiosks for pick-up points could exist in both transitional and future states.

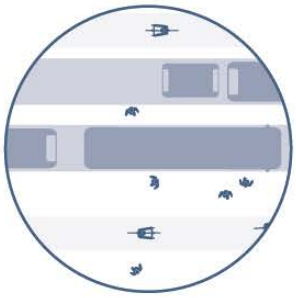


Manage Traffic Gaps

Cities should avoid creating robo-route arterials with endless platoons of traffic. With more passenger consolidation into multi-use vehicles and sufficient spacing between vehicles and platoons, pedestrians could have safer, more frequent crossing opportunities than traditional signalization can provide, achieving both safety and operational goals.

Street Tech

Wherever possible, sensor and other real-time mobility management technology should be embedded within the vehicle. For infrastructure that cannot be embedded, consolidation of on-street sensor technologies is critical for streetscape quality. In the transition period, inexpensive design elements could be considered as a retrofit for the ubiquitous 'unconnected' hardware of the street environment, such as regulatory signs and warning devices.

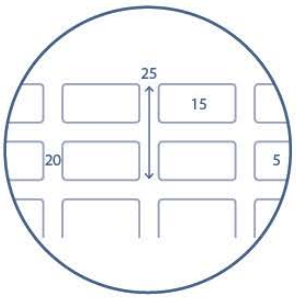


Manage Streets by Mode

Shared spaces, rather than separation, could define street operations in the future, especially on lower capacity streets. Motor vehicle traffic would be allowed at low speeds on many streets, diminishing some of the challenges of preserving freight access while dramatically expanding public space. As with truck routes today, some vehicle types could be forbidden from certain streets. An alignment between vehicle type and roadway role may be desirable.

Time of Day Management

Streets could be managed actively according to different demand during different times of day. Certain thresholds of pedestrian activity may trigger closures, temporary 10 mph operation, or ensure re-routing to other parts of the network.



Low, Steady Speeds

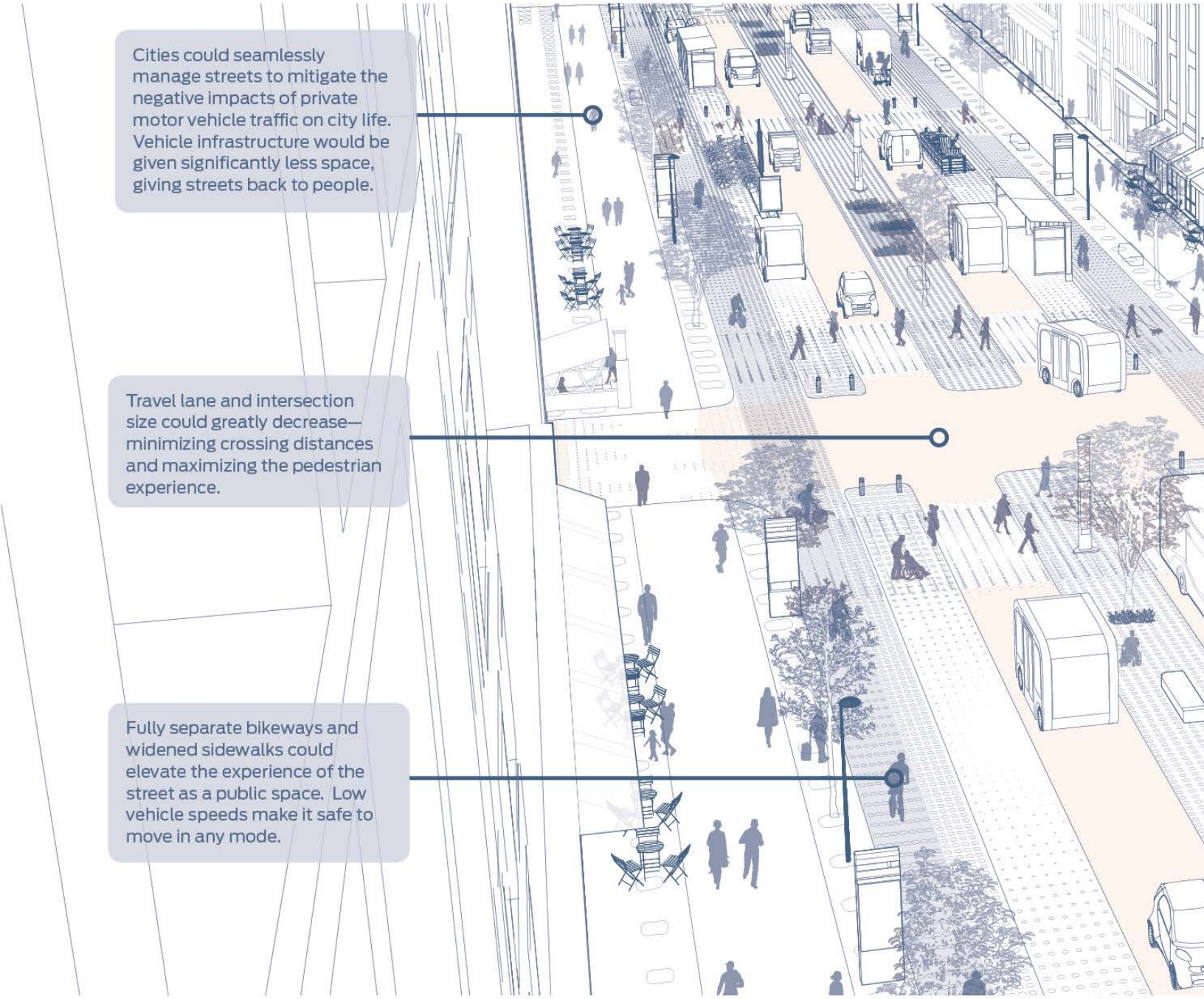
To ensure a safe environment for active transportation modes, speeds could be actively managed and programmed, and limited to 20 mph or less in city centers, especially where bicycling or transit are not fully separated from other motor vehicles. Lack of signal delay, vehicle coordination, and decreased traffic volumes would provide consistent, reliable movement—taking less time to go from place to place than in the existing hurry-up-and-wait system.

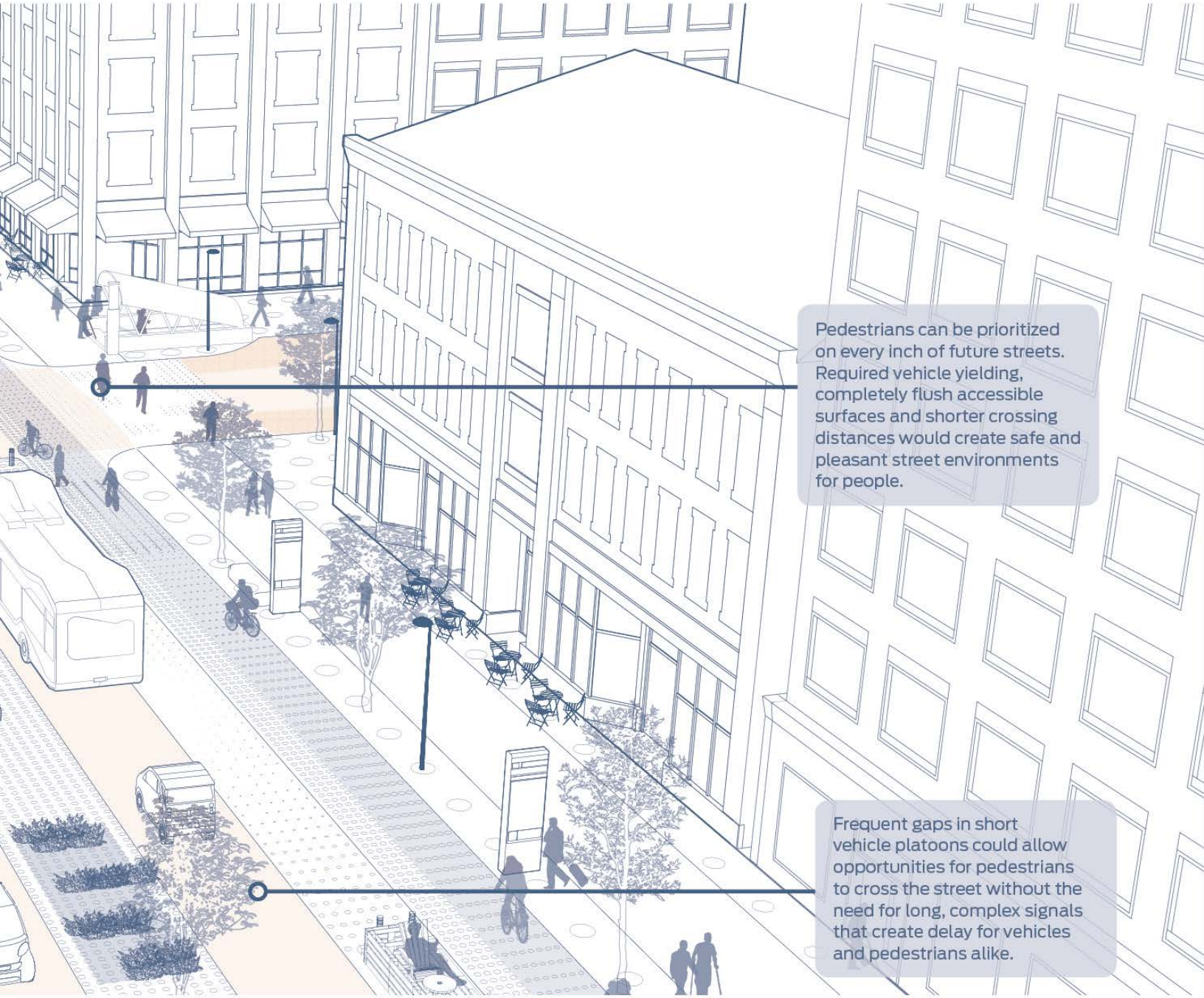
Pedestrians Detected, Not Connected

People walking and biking should not be required to carry sensors or signals to stay safe. Connected or individual vehicles should be able to detect and yield to pedestrians in all conditions, and retain full responsibility for not injuring people using the street.

Dynamics of the Future Street

Streets in the autonomous age should give ultimate priority to pedestrians, bicyclists and transit riders. Smaller and fewer lanes can minimize conflicts and crossing distances for pedestrians and allow space for robust bicycle infrastructure on all streets. Transit should have priority operation in dedicated lanes and be the backbone of the urban mobility system. Curbsides could be flexible and allow for a myriad of public and private uses—from loading zones to parklets. Speeds can be restricted to 20 mph and overall travel lanes for private vehicles can be drastically reduced. Travel times could remain unchanged due to the greater capacity of active travel, dedicated transit lanes and shared vehicles, as well as smoother intersection movement at low speeds. This street of the future would add value for everyone using it through sound design and smart policies.



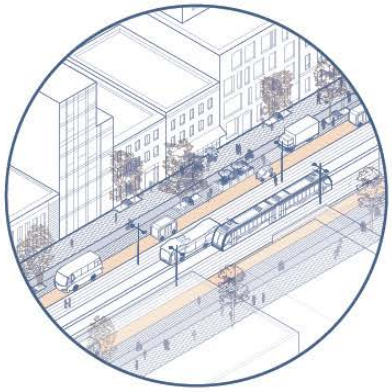

Pedestrians can be prioritized on every inch of future streets. Required vehicle yielding, completely flush accessible surfaces and shorter crossing distances would create safe and pleasant street environments for people.
Frequent gaps in short vehicle platoons could allow opportunities for pedestrians to cross the street without the need for long, complex signals that create delay for vehicles and pedestrians alike.

Street Types

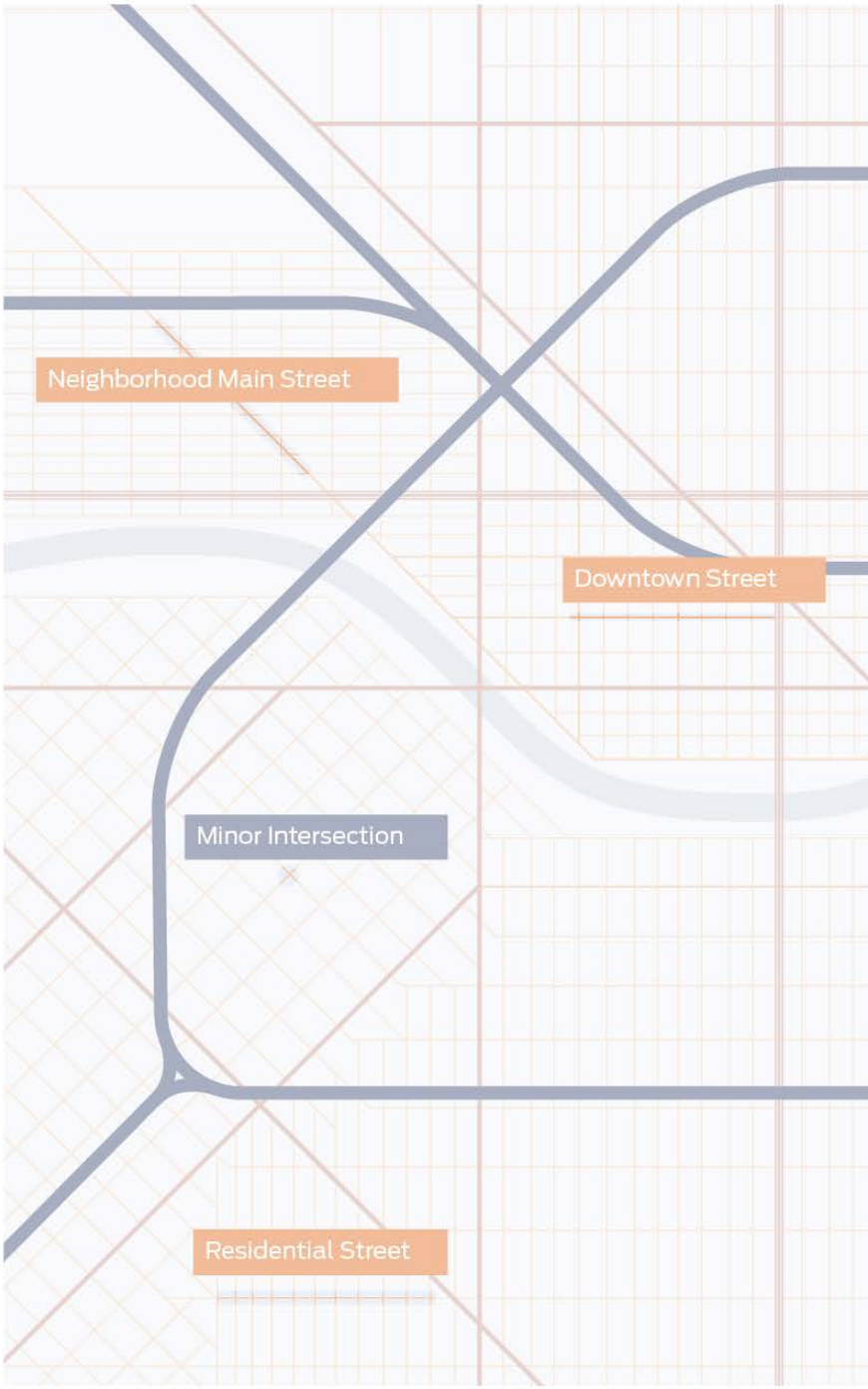
Streets and highways today reflect a century of investment in auto-oriented infrastructure that has failed to provide reliable or safe urban mobility. Much more efficient, humane streets are possible. Technological changes present a chance to remake our streets as cities adapt to, and shape, the new mobility system. The changes shown in the following pages are not dependent on vehicle automation. They complement and build upon the new dynamics of mobility, operational safety, and efficient use of space.

Multiway Boulevard

Major Transit Street



Downtown Street



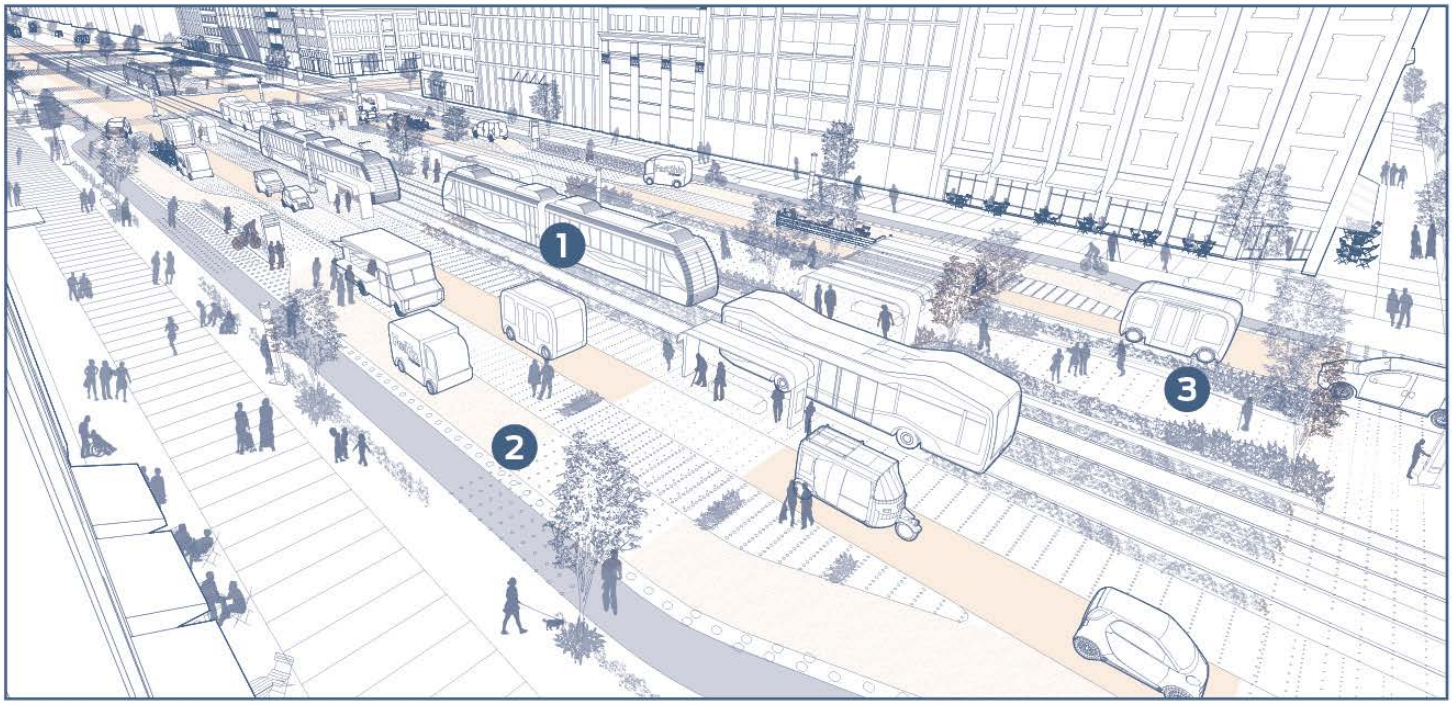
Neighborhood Main Street

Residential Street

Minor Intersection

Multiway Boulevard

Multiway boulevards represent an opportunity to reconnect neighborhoods and provide reliable transit. With only one lane for through traffic in each direction, these boulevards could recover a large amount of space for functional green infrastructure such as rain gardens. Managed curbsides can allow for seamless transit access, while dynamic pricing would discourage vehicles from blocking through traffic. By dividing the street into manageable parts and creating more opportunities for people to cross the street, boulevards can link, rather than sever neighborhoods.



Center Transitway

A transitway in the center lanes would afford a priority space for transit unimpeded by other vehicles.

Access Lanes

Access lanes would provide space for pick-ups, drop-offs, and deliveries. As pedestrian-priority space, the lanes would be fully traversable and could have restricted access at certain times of day.

Green Infrastructure

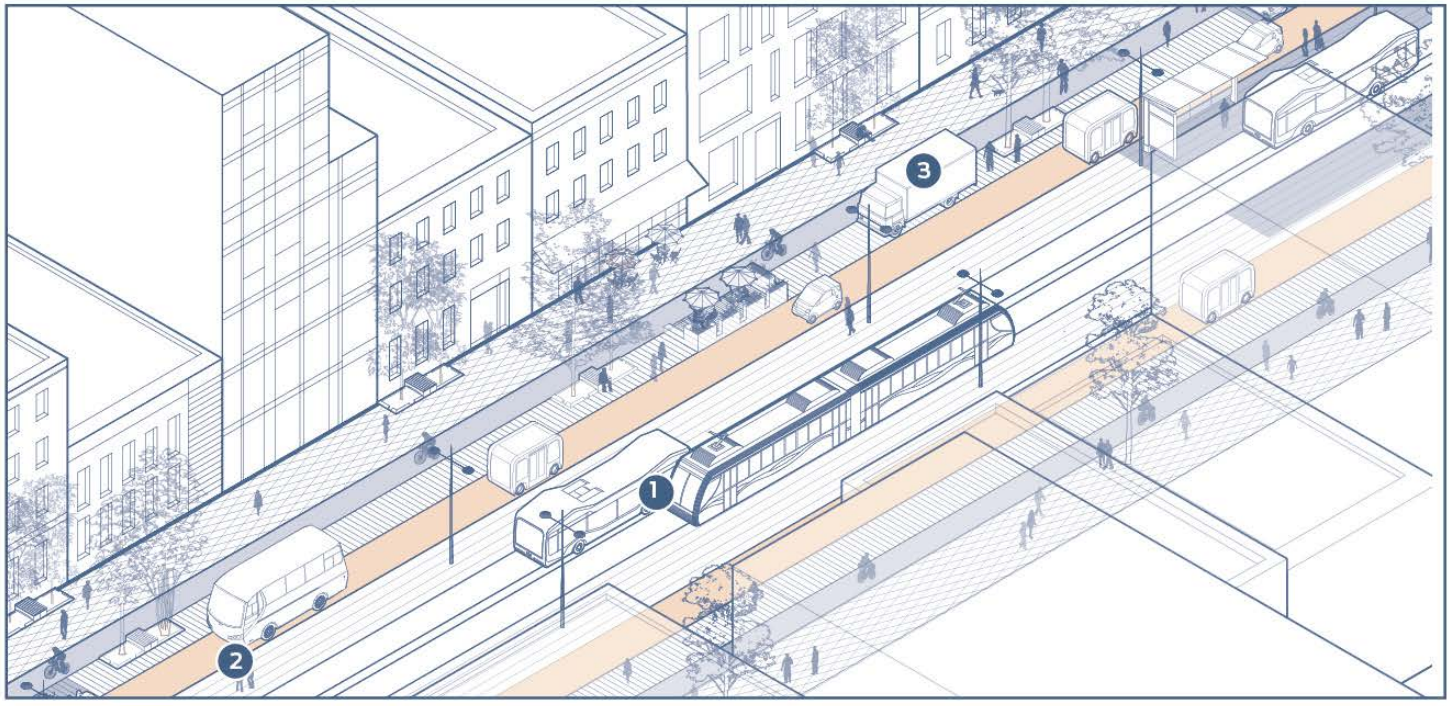
Green infrastructure helps absorb stormwater and keep the city cool, in addition to providing green space for people to enjoy.


Today


Tomorrow

Major Transit Street

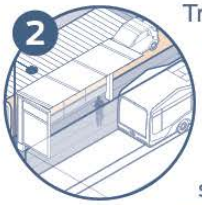
Major transit streets serve as critical aggregators in the transportation network, funneling people and activity onto central corridors. To prevent these corridors from turning into impassable robo-routes, public and private actors will have to closely monitor, actively manage, and ingrain modal hierarchies through design. With strong design and management, streets that are overburdened by car traffic today can become welcoming, high-performing public spaces in the future.



Dedicated Transit Lanes

Dedicated, central lanes could serve light rail, bus, and microtransit, while smaller vehicles could be permitted in narrow access lanes. System-wide reliability and capacity should be the touchstones of tomorrow's transit agencies and street operations.

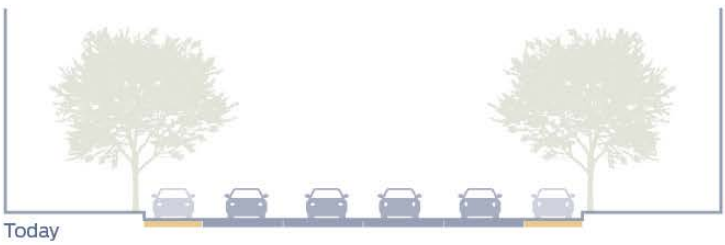
Mobility Hubs



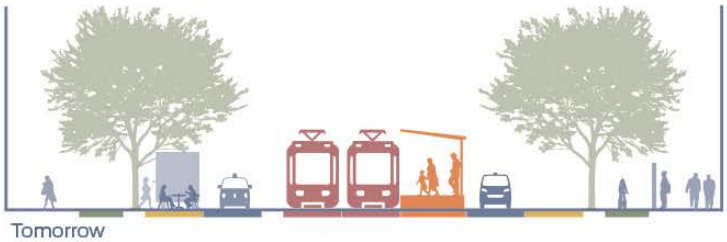
Trunkline transit could integrate seamlessly with point-to-point options. Cities' proactive policies on data sharing would allow for integrated transit options, no matter the provider.

The Flex Zone

Freight and small vehicles are could be accommodated at low speeds. The former curbside could become a flex zone alternating between public spaces and loading without delaying or endangering transit users.



Today



Tomorrow

Downtown Street

Downtown streets, perennially in high demand by many modes and as gathering spaces, are vital to the future of the city. Every element of the street, from sidewalks to loading zones, should allow a seamless walking experience for people, and high-capacity transit should be given the space it needs to operate reliably. Downtown streets should prioritize transit and freight access by disincentivizing low-occupancy vehicles.

Safe & Short Crossings

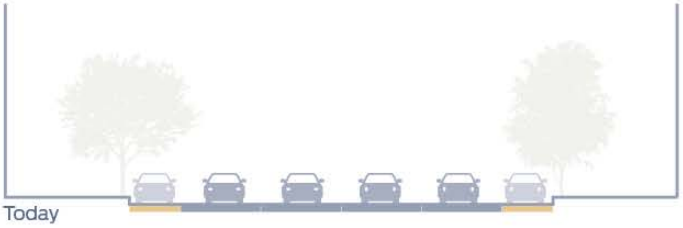
Crossing the street should no longer be a difficult or time consuming task. Traffic streams of few cars with frequent breaks and smaller lanes would allow safer crossing environments.

Parking to Public Spaces

The rebalanced right-of-way could allow for lively public spaces, leaving enough room for sidewalk cafes and expansive sidewalk areas. No vehicles would need to be stored on downtown streets.

Protected Bike Lanes

With motor vehicles still present, people bicycling will need protection from traffic in the form of fully separate infrastructure buffered from flex zones.



Today

Tomorrow

Neighborhood Main Street

Neighborhood main streets are active, lively places that attract people from across the area. They are also where residents pick up mobility services such as transit and bikeshare. Accessible mobility hubs can facilitate better corner-to-corner transit services, and dedicated bicycle infrastructure would prioritize non-auto modes.

Surfaces Over Striping

With vehicle speeds at a bicycle pace, bicyclists and vehicles could interact seamlessly by using separated but flush lanes. Street surfaces can indicate the rules of the road in place of striping.

Functional Medians

Permeable medians would manage stormwater and beautify neighborhoods while also providing a refuge for pedestrians crossing the street.

Freight and Loading

Freight and loading vehicles could be accommodated in a curb lane so as to not disrupt passing vehicles and bicyclists.


Today


Tomorrow

Residential Street

Residential streets are the heart of the city. The decreased need for vehicle storage means that streets can be an extension of the front yard. Flush curbs could create environments that are fully accessible and green infrastructure further beautifies the streets. These streets could become central meeting hubs for the community and encourage transit travel through bike share and nearby mobility hubs for corner-to-corner transportation options.

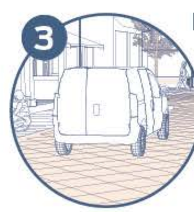
Play Streets

Residential streets should primarily be spaces for residents to enjoy—for people to recreate or meet neighbors.

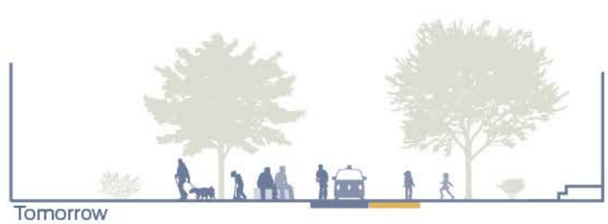
Green Infrastructure

Trees, bioswales, and planters would reduce stormwater runoff, while providing shade and evaporative cooling effect for the neighborhood.

Vehicle Access

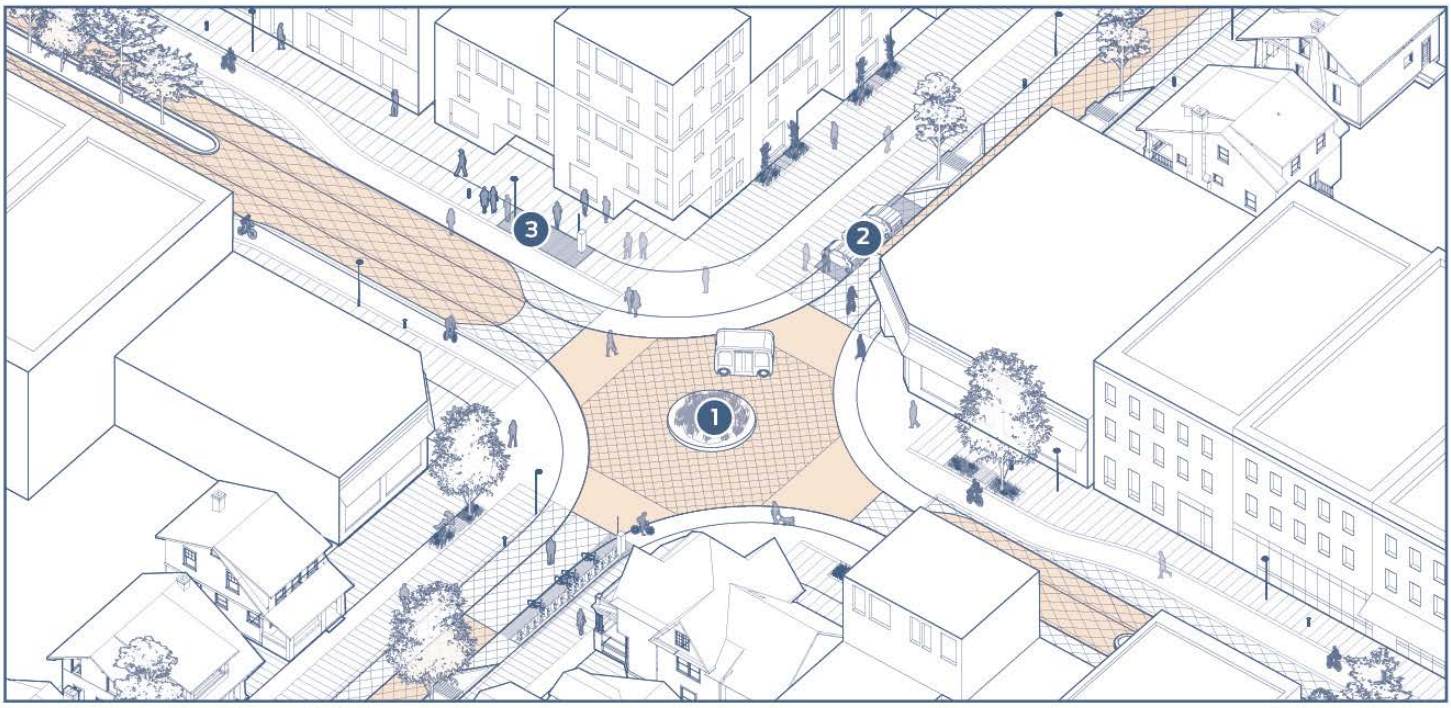


Most vehicles whould be restricted, permitting only local traffic and delivieres, and speeds limited to 10 mph.

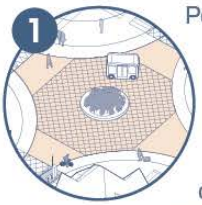


Minor Intersection

Minor Intersections could serve as the core of residential neighborhoods, with dynamic mobility hubs, bike share, car share and other mobility services. Mini-roundabouts and flush curbs can communicate the residential, shared nature of the street, while active volume and speed management would ensure that these areas are protected from an onslaught of through traffic.

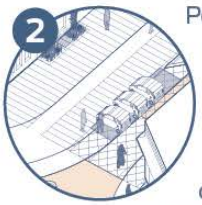


Mini-Roundabouts



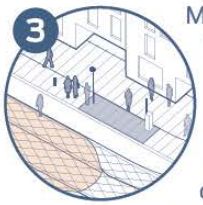
Pedestrian delay could be significantly decreased due to short platoons and shorter crossing distances. Mini-roundabouts would allow vehicles to travel at consistent, slow speeds.

Last Mile Connections

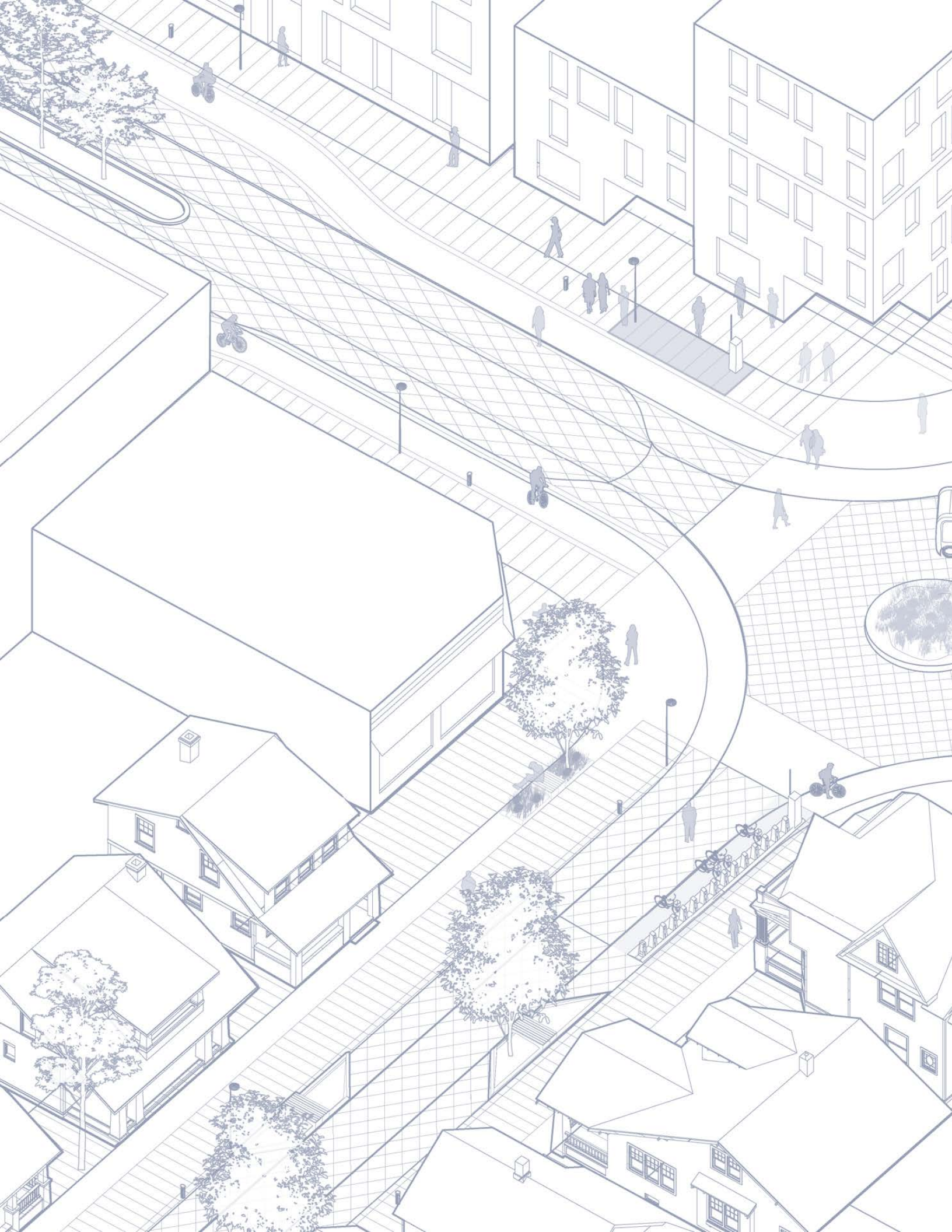


Point-to-point transit options could be abundant in residential neighborhoods, allowing multiple options to connect to core transit close by.

Mobility Hubs



Mobility hubs would provide clearly marked zones for pick-up and drop-off, necessary for the corner-to-corner transportation services in the new mobility network.



4 Design for Safety

The safest places in cities are those with the most walking, biking and transit. The evidence is clear that no investment or new technology can make it safe to mix high-speed traffic with people walking or cycling. Without a line of code or byte of data, livable street design and the growth of active modes have been proven to make cities safer.

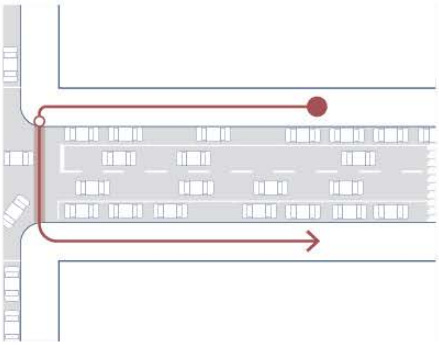
There is a growing recognition that eliminating motor vehicle-related deaths can only be achieved by decreasing vehicle speeds, using design and regulation to create a system in which it is safe to be human.

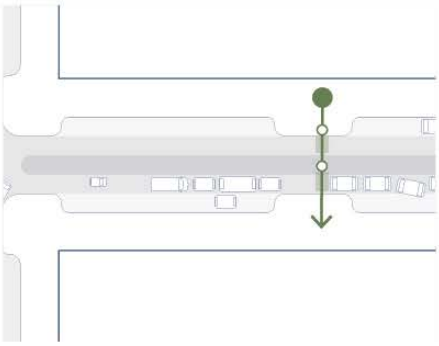
Setting safe speed limits is one critical part of the equation. Sensors have the potential to improve conflict-detection and reaction time over that of trained human drivers, but even the best detector cannot avoid a crash if vehicle speeds are too high to stop after an unexpected event. Lower speeds are the way out of the ethical dilemmas of driving: physical limits will still make the difference between life and death.

New Rules of the Road

A shift in transportation technology presents an opportunity to rethink long-held assumptions about how streets operate and how cities manage their traffic flows. Traffic signals, curbs and striping were products of the last revolution in mobility. They became widespread and standardized only after a period of flux and uncertainty. The advent of automated vehicles presents a chance to question the modern rules of the road and to consider new possibilities for street operations, infrastructure and design.

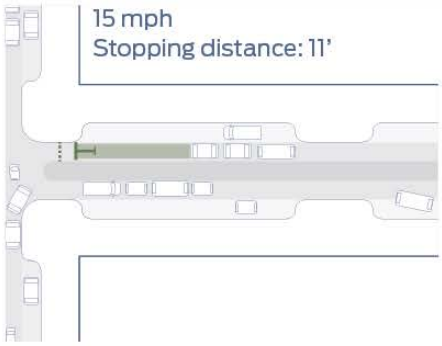
More Frequent Crossings





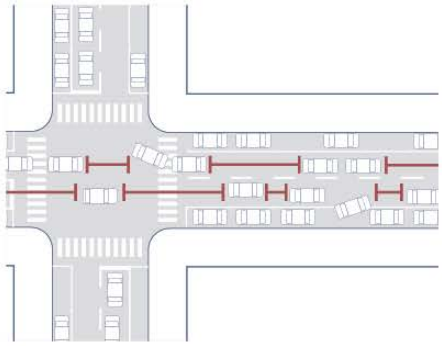
Present-day traffic operations focus primarily on conflict points at or near intersections. In the era of automation, the intuitive act of crossing directly to one's destination—known technically as mid-block crossing—could become normal once again. Frequent, formal midblock crossing points (every 50–100 feet), coupled with sufficient gaps in AV traffic, would relieve bottlenecks at intersections, while accommodating pedestrian desire lines more seamlessly.

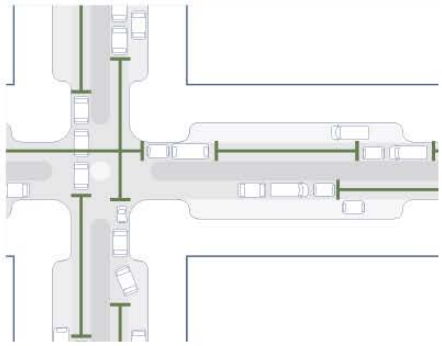
Stopping Distances



To ensure a safe street environment for all street users, speeds can be actively programmed, managed, and limited to 20 mph or less in city centers, especially where bicycling or transit are not fully separated from other motor vehicles. Vehicle coordination, decreased traffic volumes, and lack of signal delay would provide consistent, reliable movement.

Vehicle Spacing



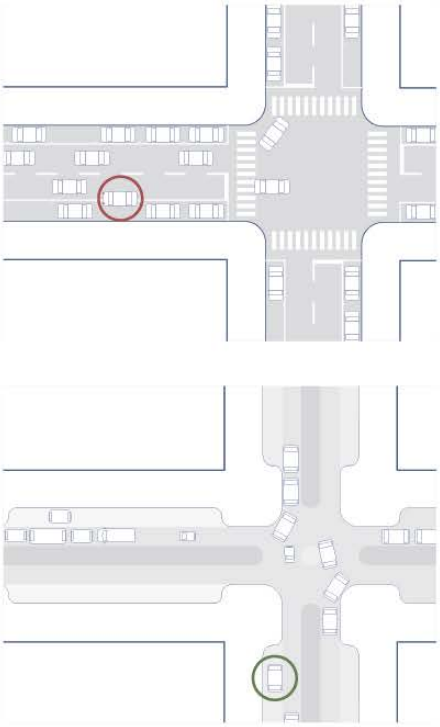


Cities can avoid creating impassable, highway-like arterials with endless platoons of traffic. With more passenger consolidation into multi-use vehicles and sufficient spacing between vehicles and platoons, pedestrians could have safer, more frequent crossing opportunities than traditional signalization can provide, achieving both safety and operational goals.

Intersections to Roundabouts

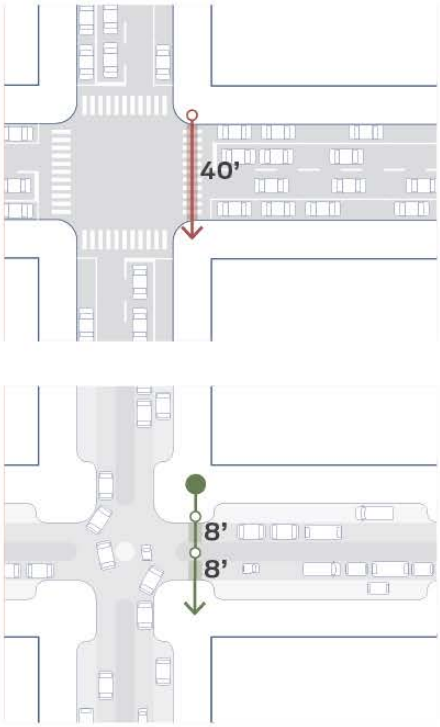
In a connected and automated vehicle environment, intersections could accommodate more fluid streams of traffic. Certain types of intersections, especially at minor crossings, could behave more like roundabouts with consistent, slow traffic as opposed to persistent stop-and-go movement.

Pick-up and Drop-off



To drop off passengers, vehicles on major streets should first turn right. Turning off of the main street stopping would reduce congestion on main corridors and allow more space along the curb to be dedicated to other uses. Where bicycle traffic is heaviest, right turn pick-ups and drop-offs may be less ideal.

Shorter Crossing Distances

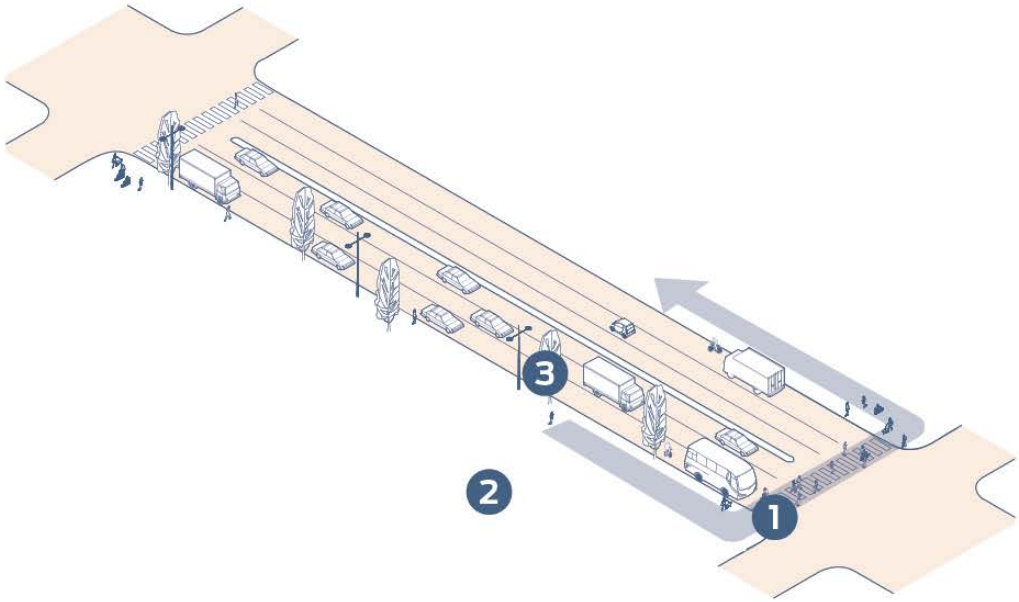


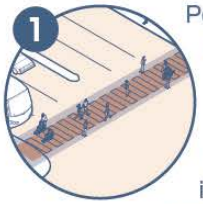
Streets with narrow lanes and medians allow for shorter crossing distances and frequent refuge. When paired with short platoons with gaps adequate for pedestrian crossing, pedestrian and vehicle delay is minimized.

Safe, Frequent Crossings

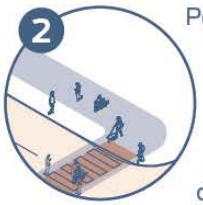
Today, pedestrians incur significant delay when traveling to their destinations. Long signal lengths and infrequent or poorly spaced crosswalks increase both the time and distance to cross the street, making walking undesirable in some places. In the future, streets could proritize pedestrians through software and infrastructure.

Today

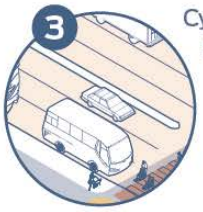




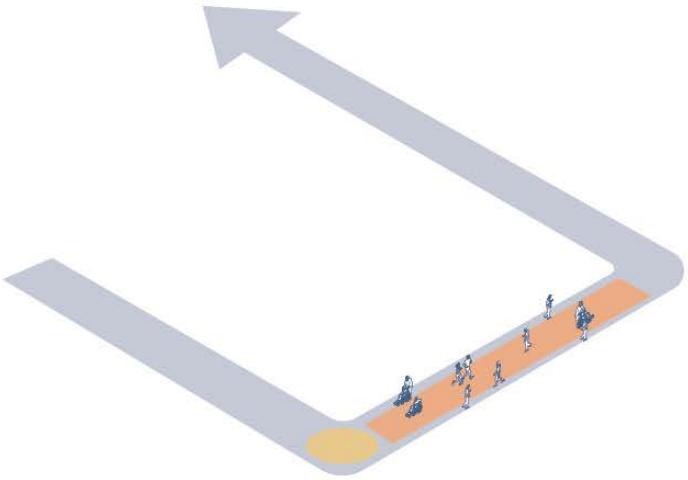
Pedestrians are only permitted to cross at intersections. Crossing may be difficult at unsignalized intersections, and pedestrian delay may be high due to long waits.



Pedestrians are limited to narrow sidewalks, and often must take long routes to reach mid-block destinations.



Cyclists often must share a lane with vehicles, resulting in stressful conditions and discouraging new cyclists.



Distance to cross

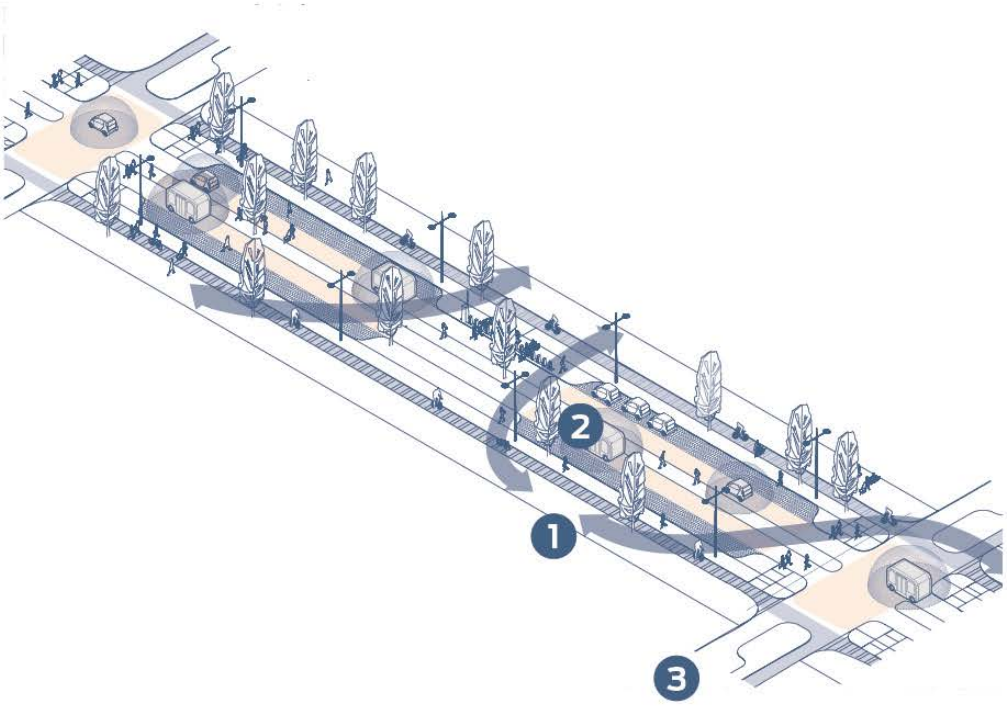
260 feet

Time to cross

100 seconds

On the streets of tomorrow, people rule the road. Vehicles should be optimized to travel at consistently slow speeds, allowing for pedestrians to safely cross streets at close intervals. Fewer lanes and crossing distances would make it more convienient and quicker to get to destinations on the other side of the street. The instinctive human act of walking straight to one's destination, pejoratively known as "jaywalking," becomes simply "walking."

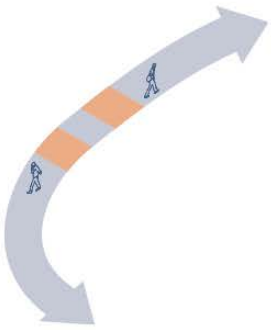
Tomorrow



Pedestrians would be able to cross almost anywhere along the street. Medians can provide space to wait between vehicles, and slow travel speeds would make crossing easy and safe.

More space could be dedicated to pedestrians, and additional amenities like seating and kiosks would enliven the streetscape.

Safe, protected bike lanes would make active transportation easy for many more people.

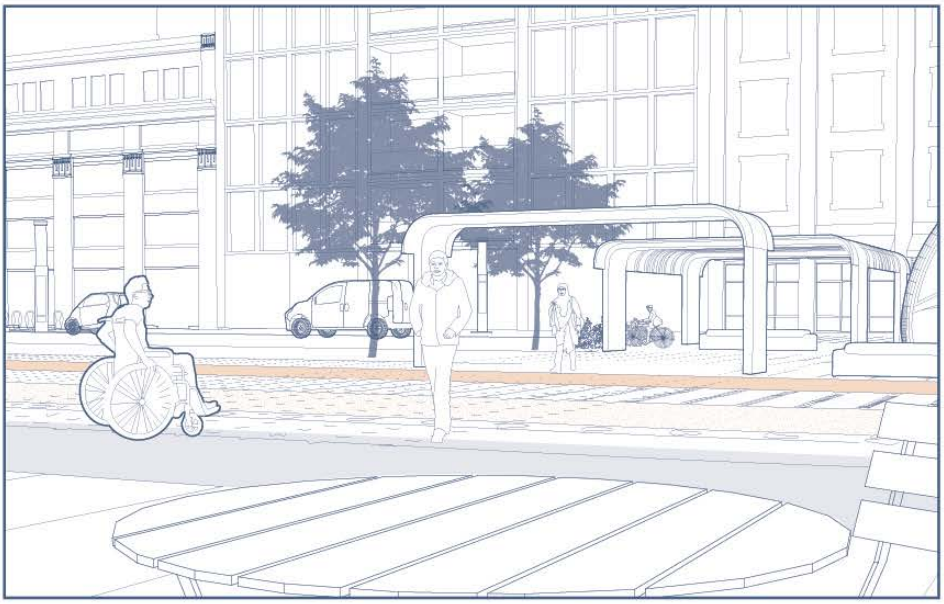


Distance to cross
80 feet

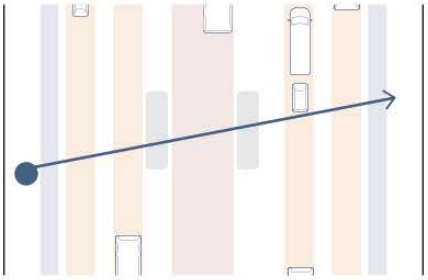
Time to cross
23 seconds

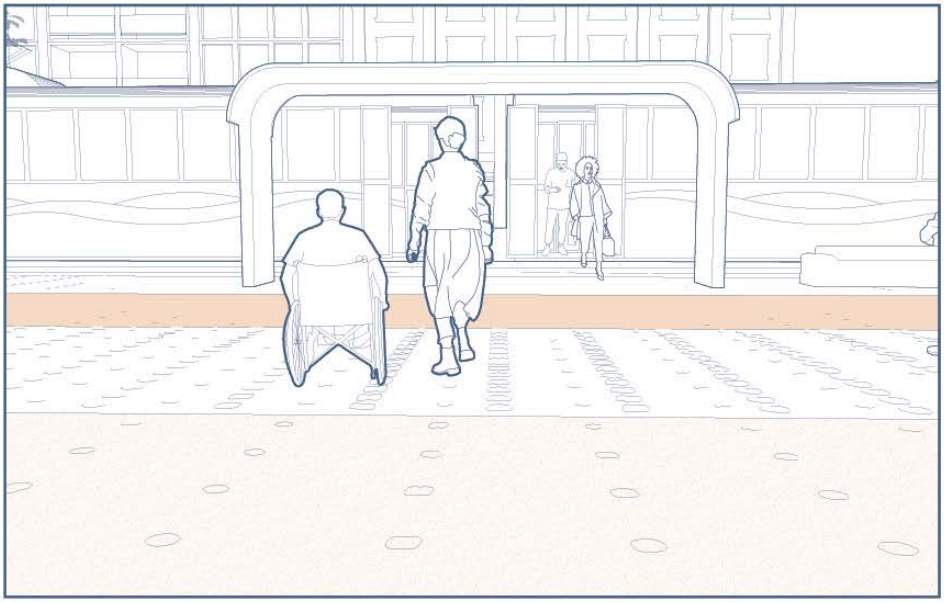
Crossing the Street

Today's streets are characterized by missing sidewalks or curb ramps and uneven surfaces, rendering many parts of the city completely inaccessible. By providing flush surfaces, regular gaps in platooning vehicles, and medians for refuge, future streets can be accessible for all street users.



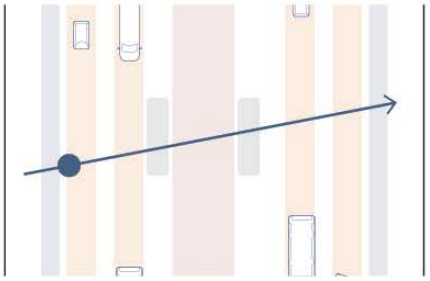
A person who uses a wheelchair is leaving a café table in the middle of the block, and wants to cross the street to meet a friend.

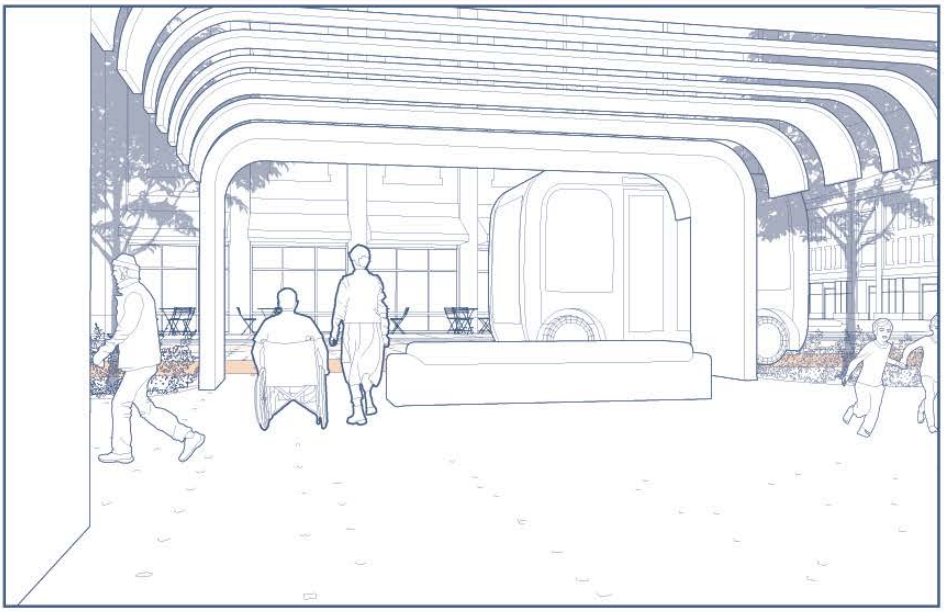




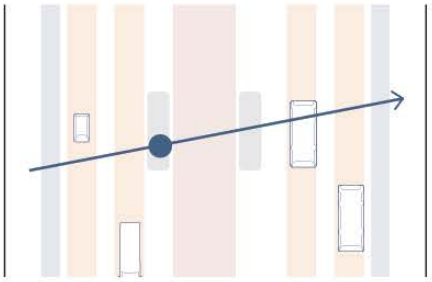
He looks left and crosses the bikeway, which is level with the sidewalk, feeling a slight rumble over the textured edge between the two.

He waits briefly before crossing the low-speed flex zone lane, while a vehicle carrying freight pulls away slowly from nearby. The truck has detected that people are moving toward the lane, and has slowed to 10 mph to stop quickly if needed.

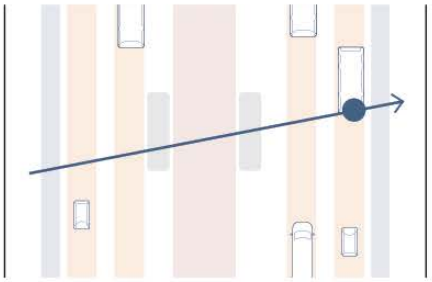




He crosses the flex zone and proceeds to cross the main vehicle lane. Seeing that approaching vehicles are still relatively far away, he begins crossing, but his wheels hit a piece of litter and he slows down. A vehicle approaching senses that he might still be in the lane if it continued at its current speed, and slows slightly from 15 to 10 mph to keep a longer distance between them.

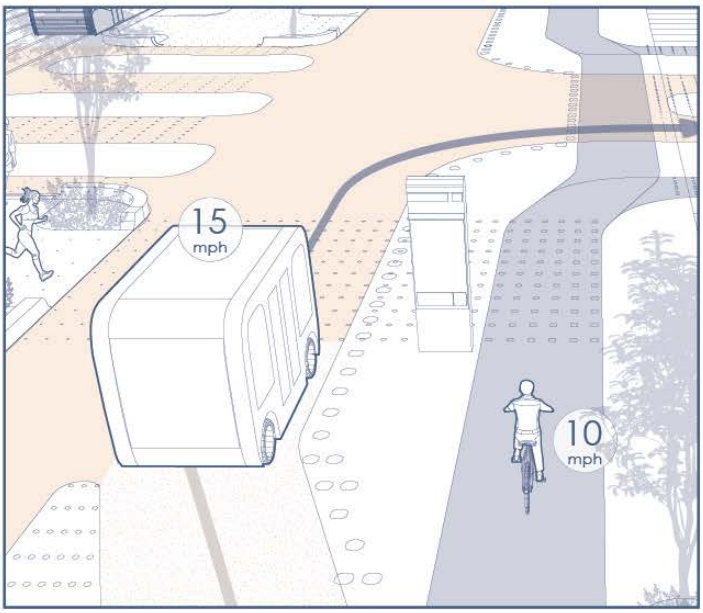


He proceeds through the transit lanes after waiting for the bus to pull away. He sees that there is a gap in the main vehicle lane and that all vehicles are stopped in the flex zone lane. He crosses the rest of the way at a normal speed, reaching the other side of the street to meet his friend.



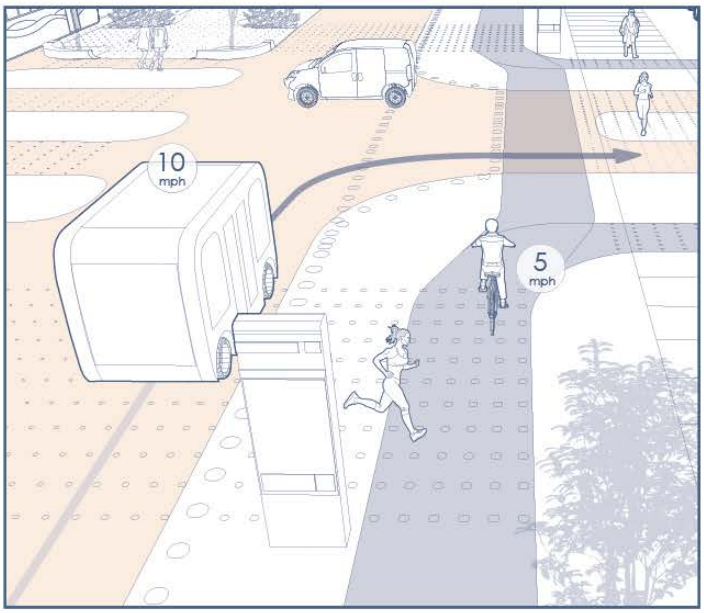
Cycling through Intersections

In the future, bicyclists and autonomous vehicles could interact seamlessly. Today, right hook collisions, when a right-turning vehicle hits a bicyclist continuing straight, are frequent and deadly. Automated vehicles would need to sense bicycles before the vehicle enters the intersection. To ensure safety for all, vehicles should be programmed to give bicyclists and pedestrians priority.

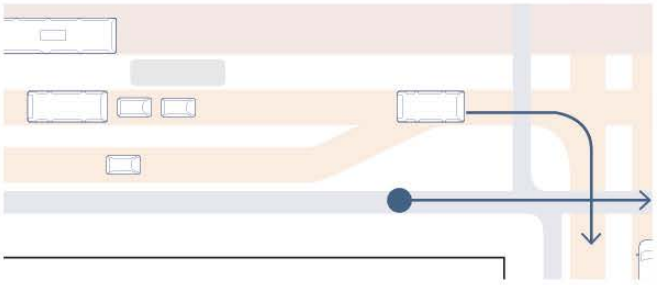


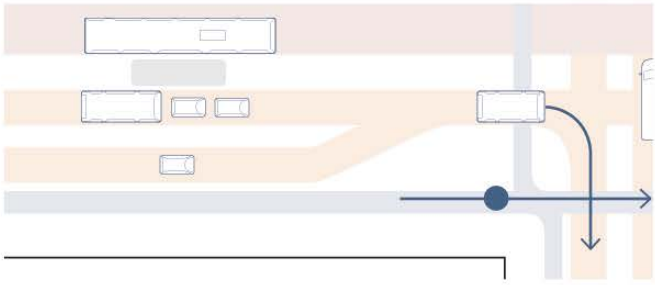
As the cyclist approaches the intersection, she is passed gradually by an automated shuttle that intends to turn right. The shuttle detects and tracks her movement, and slows as it approaches the intersection.

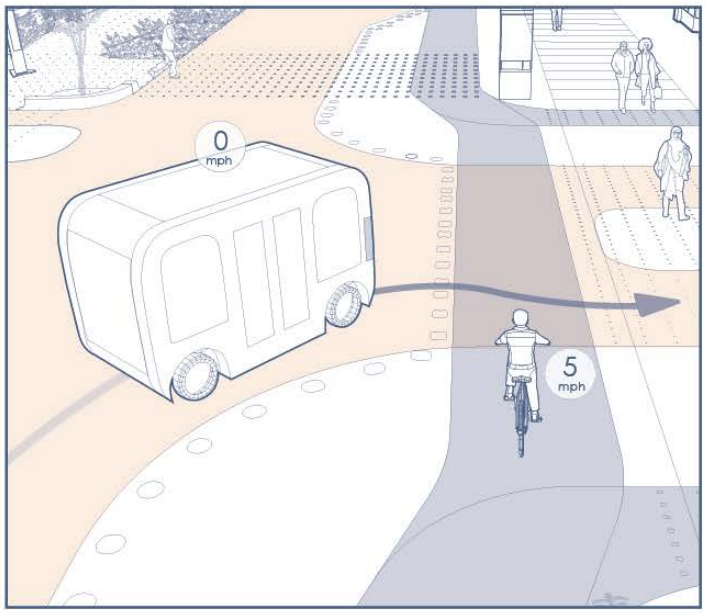
An audible signal is flashing yellow, giving the shuttle permission to continue with caution, which the bicyclist can see and hear. During this phase, vehicles are permitted but must yield to one another and to people. These intersection controls also have a pedestrian-and-bike-only phase.
The shuttle has been tracking a jogger on the left, but has calculated that she'll just be arriving at the crosswalk when the shuttle passes.



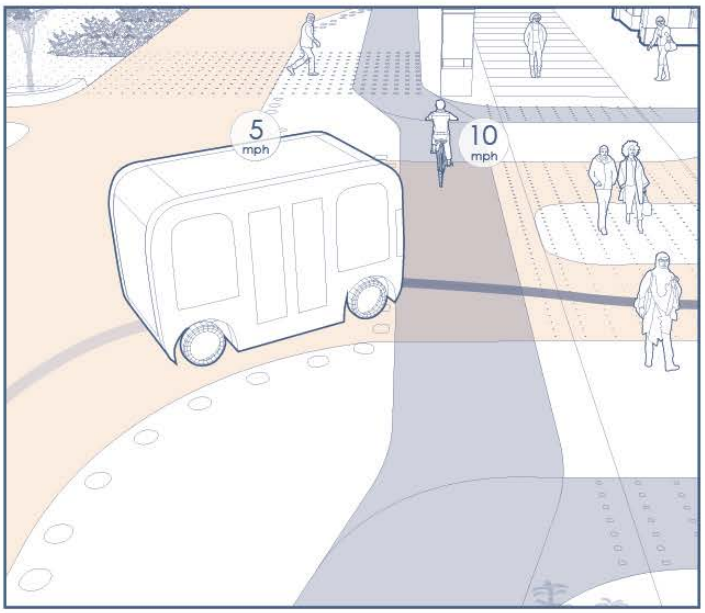
The bikeway curves to the right, creating space for a vehicle to wait as indicated by a yield line in the pavement. As the bicyclist gets close to the intersection, the shuttle slows to a crawl to be ready for an instant stop as it approaches the crosswalk—since the bicyclist might turn left, too. It anticipates that she will probably go straight, and sets its speed so it can stop within three feet (usually 7 mph).



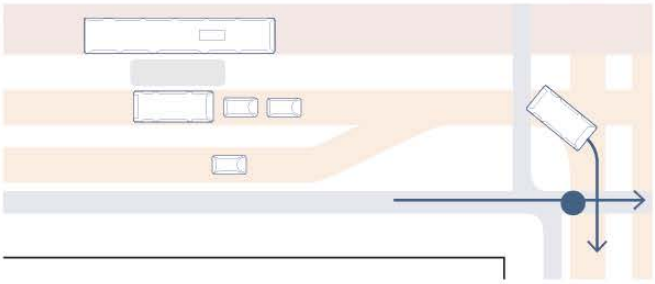


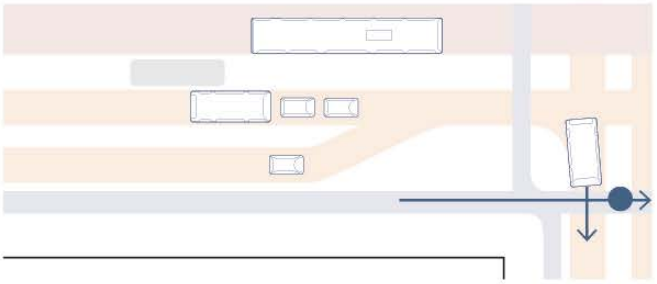


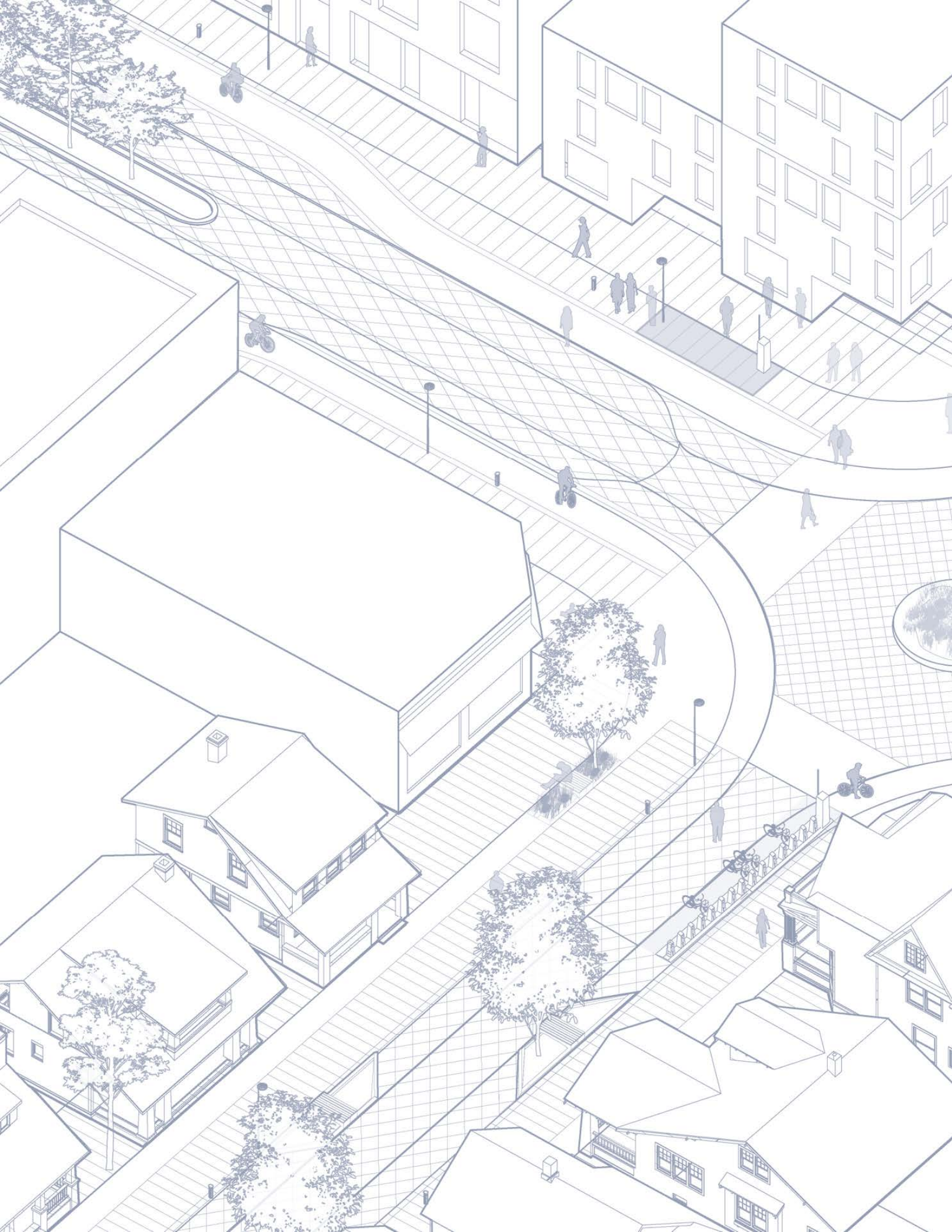
Seeing that there is no other cross-traffic, the bicyclist goes straight and the shuttle waits for her and the pedestrians in the crosswalk. The shuttle's routing algorithm anticipated that it will usually need to pause here.



The bicyclist proceeds, seeing as she crosses the median that vehicles coming from her right also slowed. The group of people in the crosswalk finish crossing the street, and the shuttle proceeds.







5 New Mobility Systems

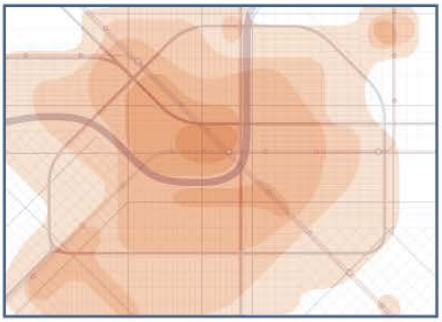
New mobility systems can offer a seamless passenger experience that integrates microtransit and shared on-demand service with traditional bus and rail lines.

Automated vehicles could make personal car ownership an ever more expensive proposition. Increasing numbers of vehicles could become part of shared networks of fleets and many routine trips served today by cars or ride-hail could evolve into more transit-like services. Transit, in turn, could deliver more reliable, frequent service as demand grows on main routes. New transit partnerships could match vehicles to travel demand in real time and be capable of managing and deploying services for both fixed routes as well as flexible, last-mile options. Cities can take a lead role in creating the policy basis and incentives for this system to work—as well as managing streets as a public right-of-way. People of every income level could benefit, with smart policy, from a greater diversity of mobility options, and a more integrated, seamless payment and information system.

Principles for New Mobility Systems

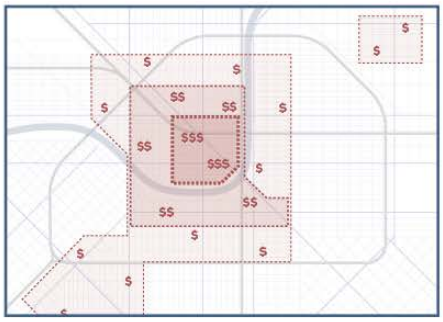
In the future, the city's role will include active management of street capacity as well as providing the regulatory structure for mobility service providers—transit companies and new service providers alike. New mobility systems must be designed to meet critical city goals: ease of use, efficient use of space, equitable mobility and reliable performance.

Build a network to match demand



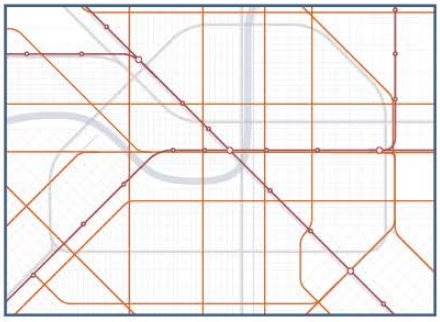
Even today, transit is best able to serve cities' densest and most vibrant areas, where driving and parking is impractical and takes up too much space that could be used for more productive activities. In the future, transit will function best if cities map demand between various neighborhoods, and connect the busiest and densest areas together with high-capacity transit.

Pricing creates a reliable network



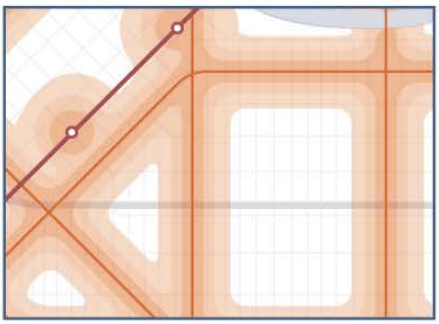
Pricing supports transit and for-hire providers by making travel times reliable across the day for each link in the network—no matter how high demand rises. Equitable allocation of the public right-of-way depends on the city's ability to incentivize aggregated trips to dense areas and prioritize critical travel, such as ambulances, police and other emergency services.

Create an interconnected grid network



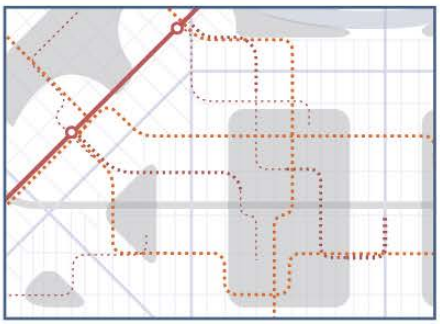
Service could be configured into a grid network to make the best use of transfers, allowing easier connections between neighborhoods, businesses, and activity centers, and helping transit capture the largest share of total trip-miles citywide. An all-purpose network can be relied on at all times of day and for all trips, a necessity for supporting car-free households.

Upgrade the transit backbone



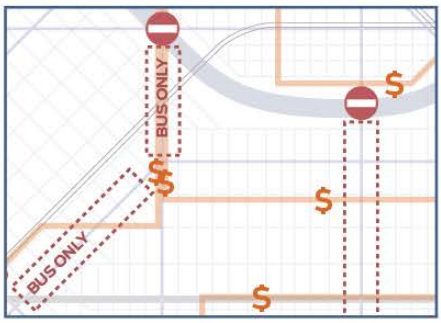
Busy bus routes can be upgraded into rapid lines with on-street priority provided by technology available today. These lines could be enhanced with active traffic management and AVs feeding more riders into the system. City experience shows that taking early action to insulate transit from changing vehicle traffic patterns can yield large benefits in ridership.

Fill in gaps in the network with flexible services



Dense demand in core neighborhoods supports a strong transit system, but after decades of car-based development, travel demand is spread thinly across city-regions. Cities should convene mobility providers to create a level playing field that provides reliable, affordable mobility for everyone. With regular routes and curbside management, private companies could thrive while consumers could have access to convenient mobility services.

Create conditions for reliable, affordable mobility



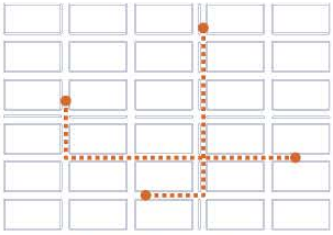
With multiple mobility providers, cities will likely need to use regulations to create viable service conditions: regular routes, curbside management, or even a passenger trip assignment system. Otherwise, competitors will send as many vehicles as possible onto the street to capture riders first—a self-defeating situation familiar in informal transport systems, and which might otherwise be exacerbated by the presence of zero-occupant vehicles.

Integrating Flexible Services

Automated, shared vehicle fleets can help fill last-mile gaps in the fixed transportation network, aggregating multiple trips and consolidating them along major corridors. Technology could allow vehicles to group trips and use streets more efficiently, reducing the amount of space used—and time wasted in congestion—while moving more people.

Flexible

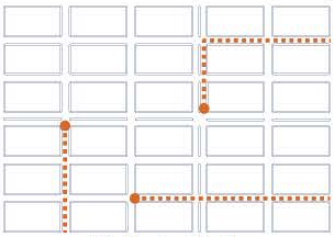
Personal Bike | Walking | For-Hire Vehicle | Point-to-Point Car Share



Door-to-Door

Walking is part of every door-to-door trip, and biking is fast, cheap and space-efficient. Expensive, higher impact motorized services, such as taxi-like vehicles and point-to-point car share, serve an important role for freight and some passenger trips, but left unregulated could overwhelm the rest of the street system. With price or occupancy incentives to use road space efficiently, cities can make sure the right size of vehicle is used for each trip.

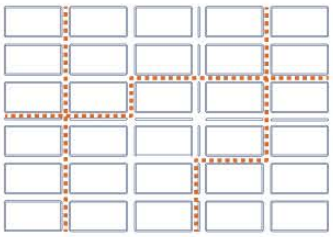
Bike Share | Microcar Share Scooter Share



Hub-to-Hub

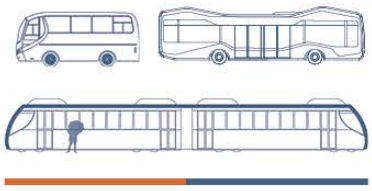
Mobility hubs are already emerging in cities. Bike share and car share allow users to check out and return vehicles at stations or spots spaced closely within a given service area so that they are only a short walk away. These services are already successful and can cover larger areas as bicycling infrastructure expands.

Micro-transit and Delivery

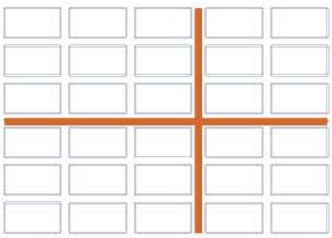


Flex Route

Dynamic and flexible services can maximize vehicle occupancy and route efficiency when there are not enough passengers to justify a full-scale fixed transit route. These services could connect customers with fixed route transit or serve as node-to-node transportation. The same vehicle can serve a "semi-on-demand" flex route in a low density area, and then act like a fixed route vehicle in a denser area.



Local Bus | Rapid Bus Metro or Subway | Light Rail | Regional Rail



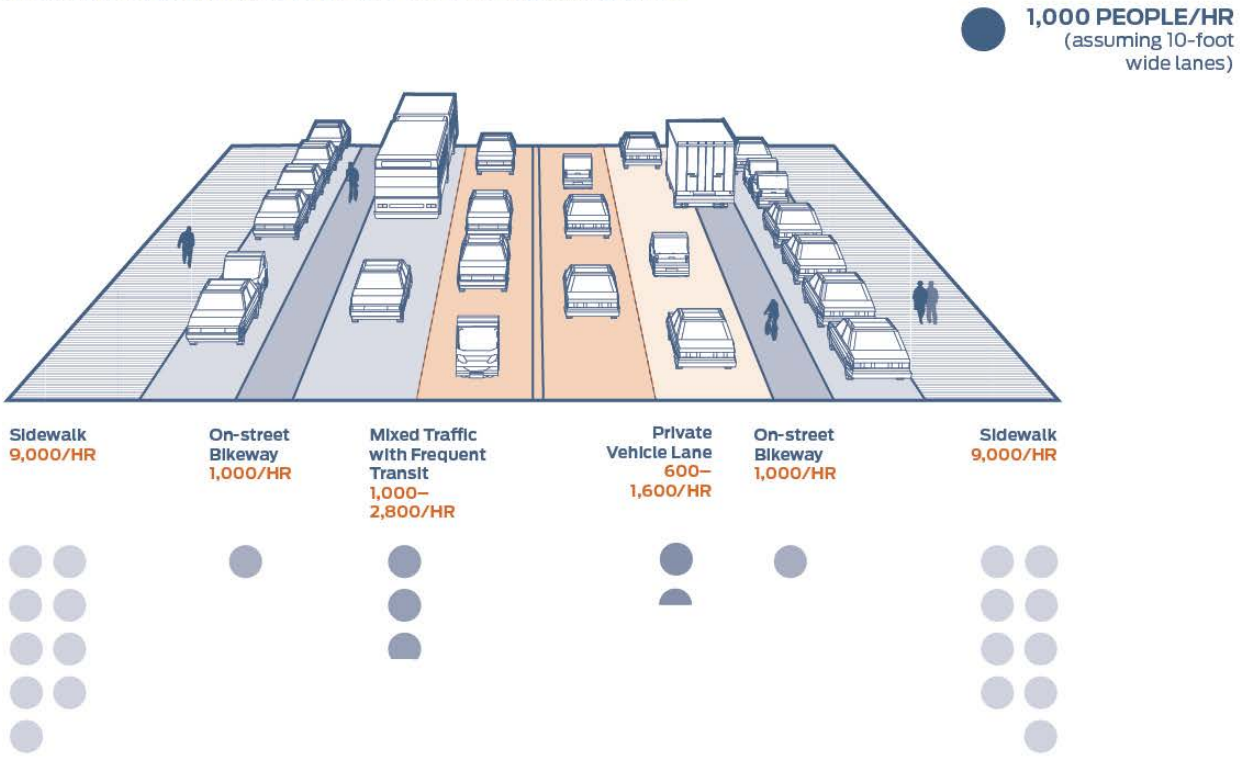
Fixed Route

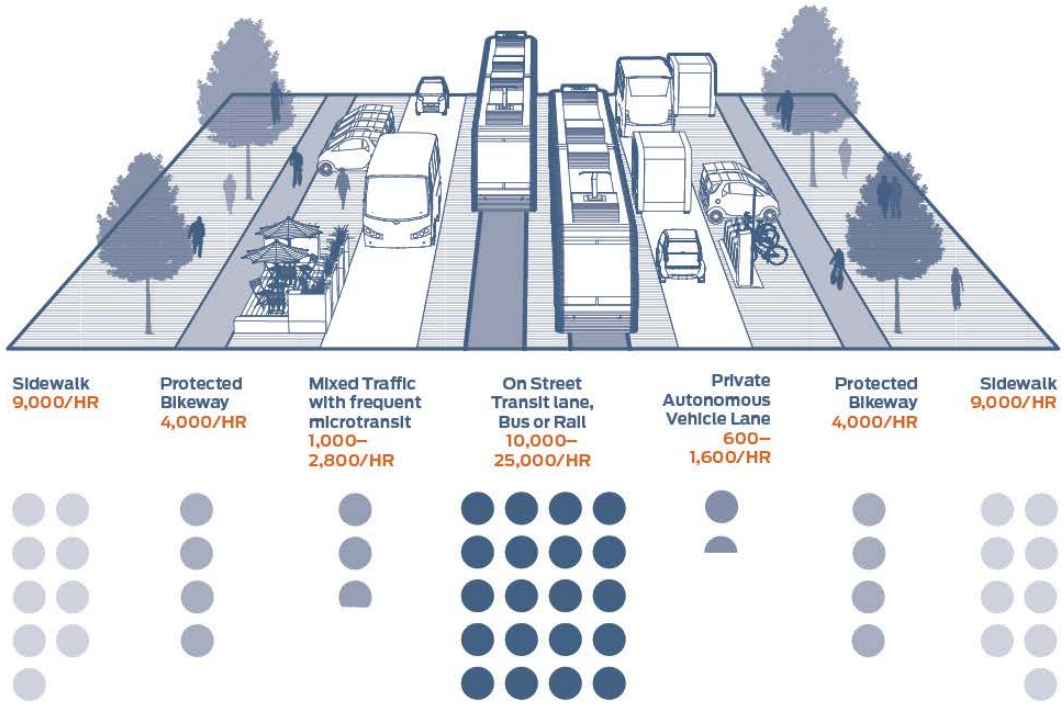
Fixed route service today ypically involves large vehicles that travel a set route with predetermined stops. These transit routes could expand as the backbone of the urban mobility system, accented by microtransit AVs, to serve more of the city. Vehicles could shrink on low-demand routes in order to maintain frequency, or even improve it. Transit agencies should focus on expanding service time span and frequency to grow ridership on core routes while cities should provide priority space for transit to increase reliability.

Fixed

Move More People With Fewer Vehicles

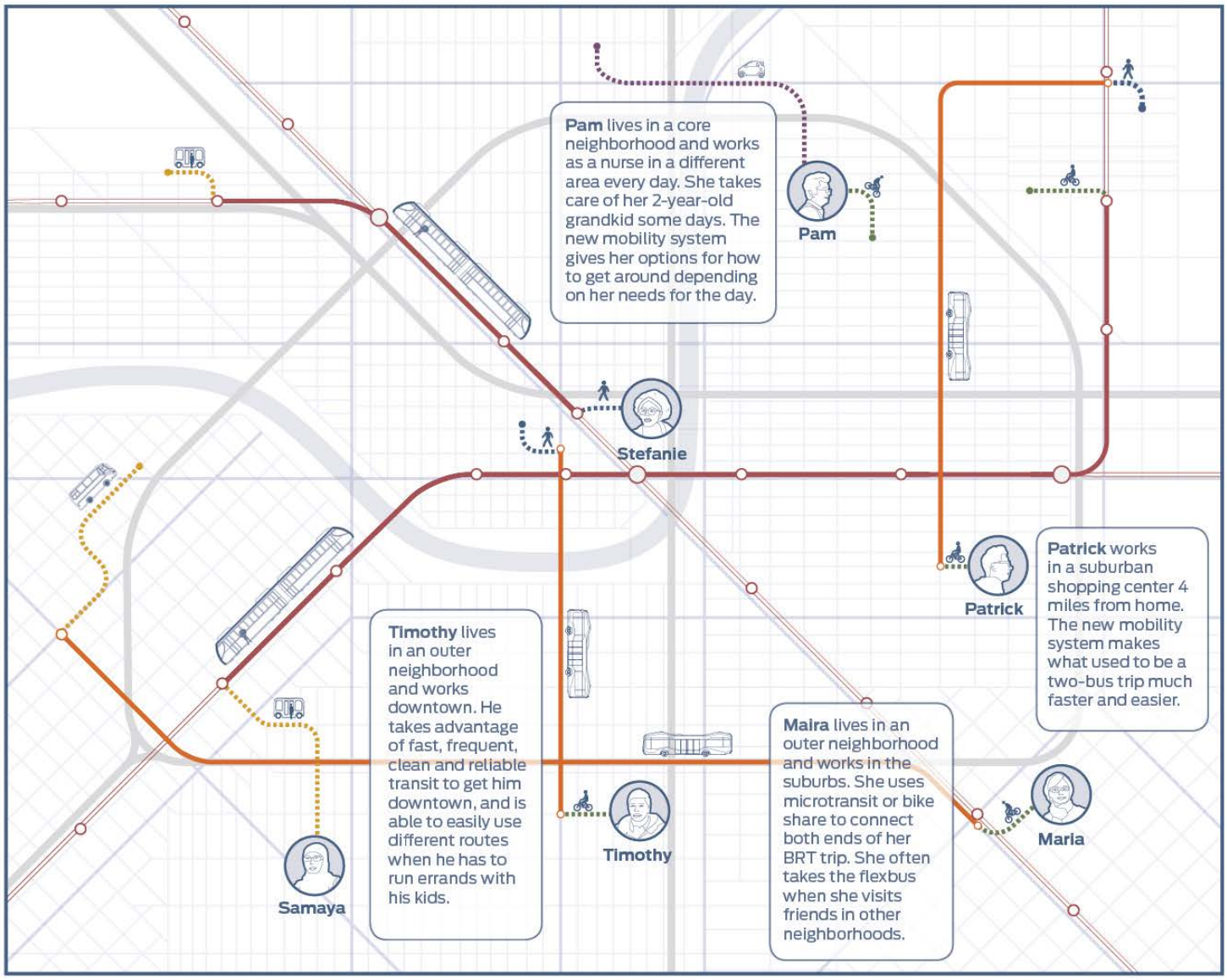
Cities can use technology to drastically increase the capacity of a travel lane, allowing more people to be moved in less space. However, the greatest capacity gains cannot be achieved if single occupancy vehicles predominate. Biking and high-capacity transit must remain a key component of streets, with dedicated space, in order to move the large numbers of people who live in growing cities.





The New Mobility Network

Mass transit should serve as the backbone of the transportation network, while autonomous vehicles, biking and walking complement the core parts of the network and provide service where mass transit is not as efficient. Public agencies and private companies could work in tandem to actively manage the network, with volume, mode and speed thresholds controlled through real-time pricing and curbside demand management.

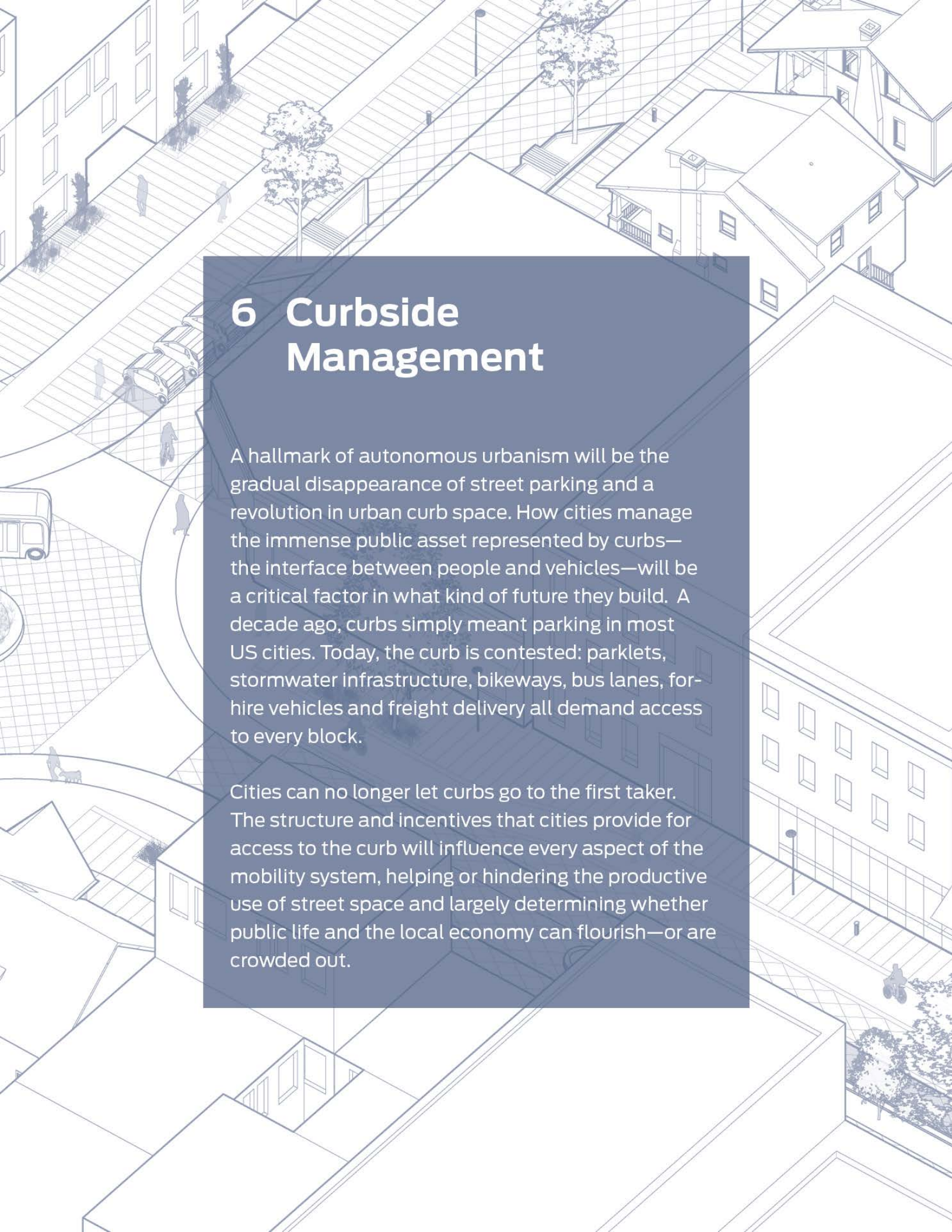


A Reassuring Rider Experience

The success of integrated transit systems around the world shows that consistent branding and easy-to-understand routing that can give riders confidence that they will arrive at their destination is much more important than who or what is driving each transit vehicle.

Changing Trip Types

Cities today are decentralized, making hub-and-spoke transit systems inconvenient for many types of trips. Along with realigning bus routes into a grid network, providing a larger range of services and travel options can help people get around conveniently and affordably.



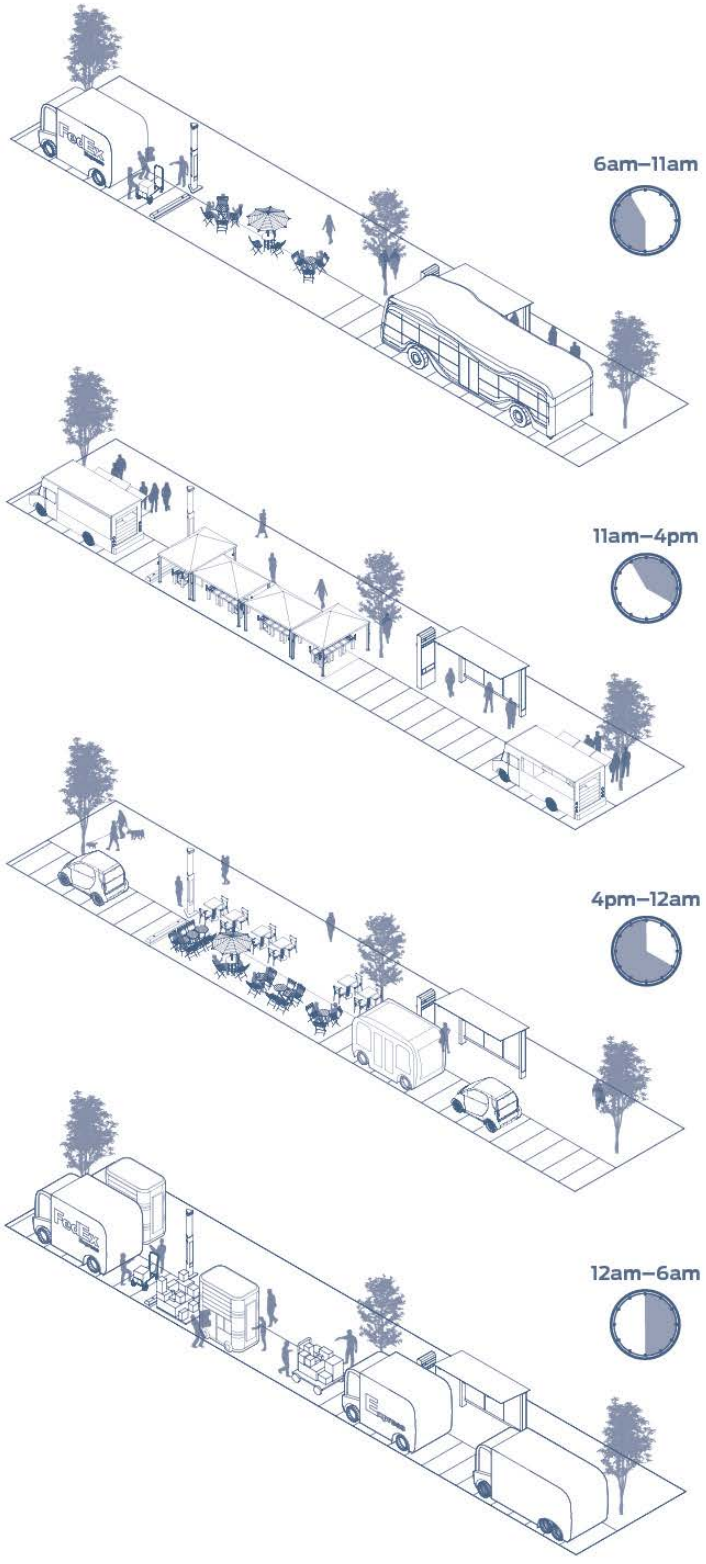
6 Curbside Management

A hallmark of autonomous urbanism will be the gradual disappearance of street parking and a revolution in urban curb space. How cities manage the immense public asset represented by curbs—the interface between people and vehicles—will be a critical factor in what kind of future they build. A decade ago, curbs simply meant parking in most US cities. Today, the curb is contested: parklets, stormwater infrastructure, bikeways, bus lanes, for-hire vehicles and freight delivery all demand access to every block.

Cities can no longer let curbs go to the first taker. The structure and incentives that cities provide for access to the curb will influence every aspect of the mobility system, helping or hindering the productive use of street space and largely determining whether public life and the local economy can flourish—or are crowded out.

Time of Day Management

Curbside flex zones can play many roles, from public space to loading zones. They could change use over the course of the year, week, or even the day.



Morning

Before the peak of the morning rush, freight deliveries arrive to stock stores with their goods for the day.

By 7:30, delivery vehicles give way to vehicles dropping off employees, many enjoying breakfast or coffee in a parklet on the way into work.

Mid-day

Late morning brings some deliveries of packages and mail to businesses and residents. At noon, the lunch rush begins bringing many people to street vendors to enjoy their mid-day meal.

By 2:00, most diners are back inside and light delivery activity continues until the evening rush.

Evening

The evening rush stops delivery activity as street and vehicle capacity is shifted to move people instead of goods. Passenger movement continues into the evening as people grab dinner or drinks, pick up children, or head to evening events.

Automated evening and late-night delivery activity allows for easy movement of large goods on underutilized streets.

Late night

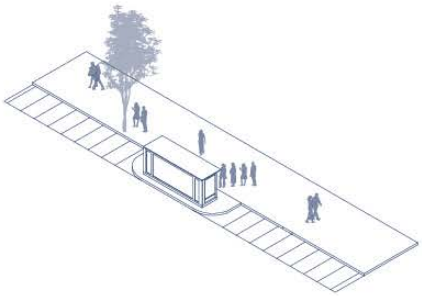
Late at night the curb prioritizes freight vehicles. Passenger movement is at a minimum through the early hours of the morning, leaving more space for increased delivery services in cities. Delivery ease is increased through the use of nearby storage lockers.

In the morning, freight makes way for transit vehicles.

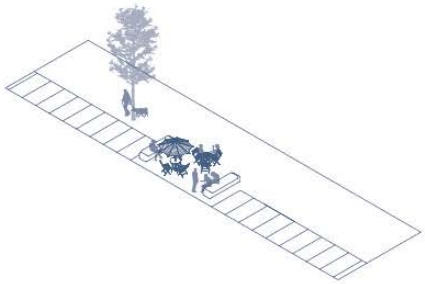
Flexible Curbside Uses

Curbsides have the potential to host a variety of different programs and activities— some permanent and others variable throughout the day or time of year. Cities can actively manage curbsides through pricing and make curbs feel more like an extension of the sidewalk than the edge of the roadway.

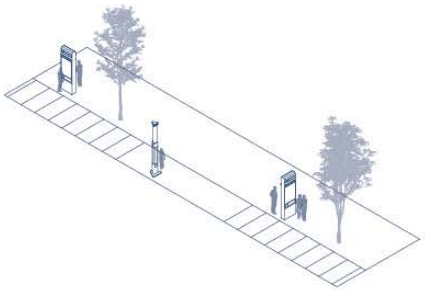
Vendors



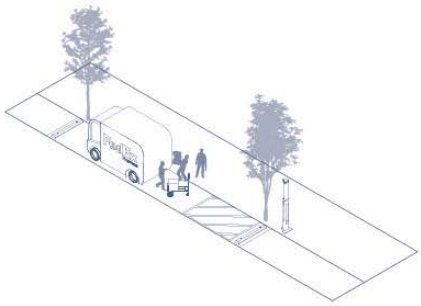
Public Seating



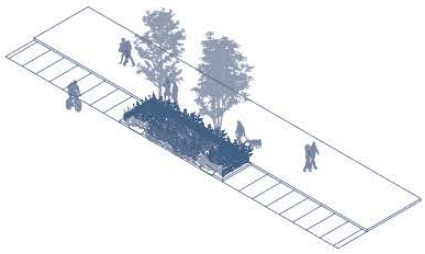
Digital Infrastructure



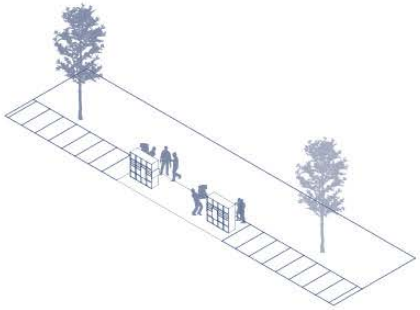
Freight Loading



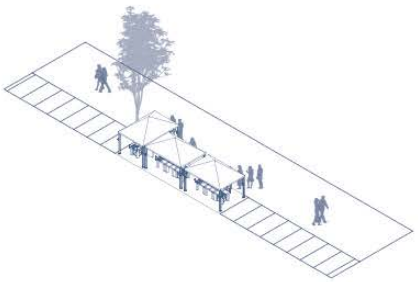
Green Infrastructure



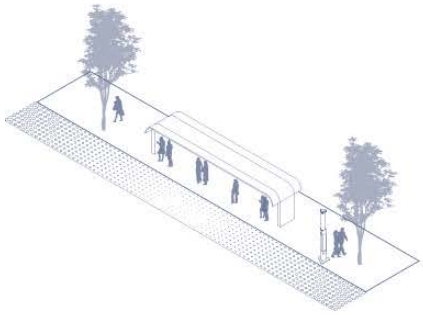
Delivery Lockers



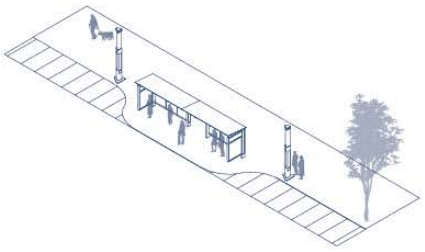
Market



Pick-up/Drop-off Zone



Transit Stop



Coding the Curb

Today

Cities today have to dedicate curb space either for loading or parking or transit or public space, but can only change use according to pre-set times. Conventional practice is to allocate spaces on the curb based on the adjacent land use, using only meters and time limits to create turnover in business areas, rather than to match curb demand to supply.

The city's typical role is to update curb regulations periodically based on changes to land use or in response to specific requests, such as for loading zones at supermarkets or bike corrals and parklets at small retailers. Usage data for planning purposes is in short supply, and real-time curb availability data is absent. Little attention is paid to curbs on residentially-oriented and industrial streets.

The Near Future

Cities are already updating curb uses based on demand and values. A portion of parking on high-demand curbs may be allocated to high-capacity transit and active modes, but these changes are flashpoints because on-street parking is under-regulated and over-used. With a combination of curbside inventories, pricing and permits for residential parking, and transparent, demand-based charging for the curb on highly used streets, cities could better manage the curbside.

With systematic implementation of existing technology, cities could charge for the amount of time a vehicle uses the curb, and account for and broadcast the availability of curbside spaces. These changes would quickly lead to better use and availability of curb space.

Today

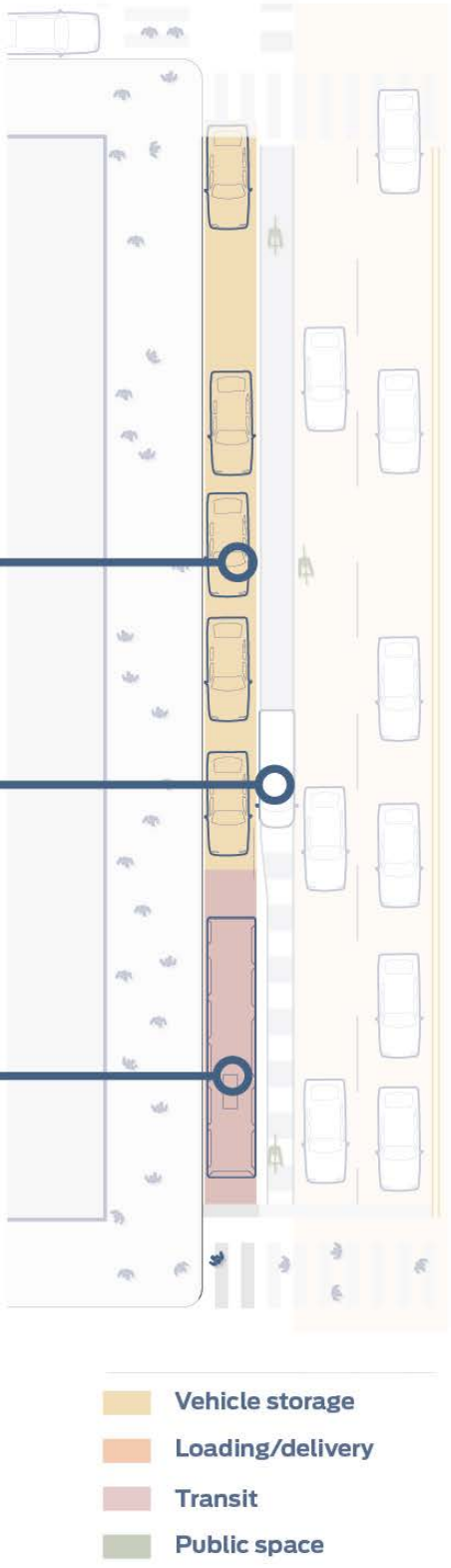
(Under)Pricing the Curb

The curbside today sees overflowing demand that varies by mode and time of day. However, in most cities, prices for curb use remain stagnant and curbs are inflexible to new short-term uses.

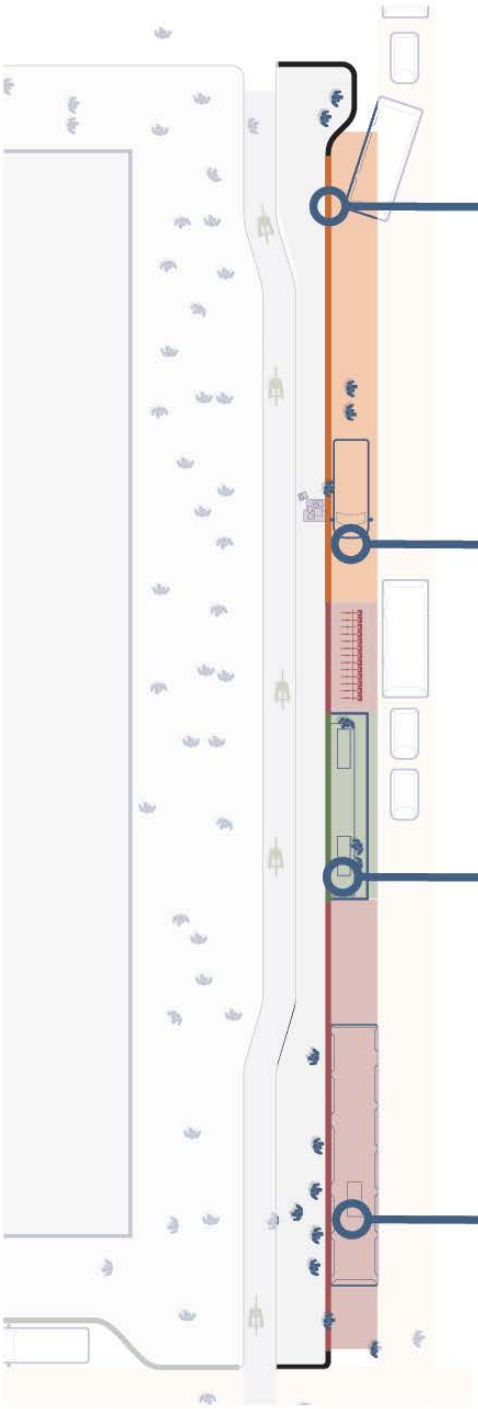
Vehicle storage occupies the majority of curb space today. Vehicles circle the block looking for unoccupied spaces and cities rely on parking enforcement and ticketing for a significant amount of revenue.

Bicycle lanes blocked by freight or vehicles loading passengers are a common occurence. These instances dangerously force cyclists into adjacent vehicle travel lanes or the 'door zone'.

Transit stops are heavily used during peak periods, but may be blocked by non-transit vehicles, especially during off-peak periods when bus frequency is lower. At other times this space may simply stand empty.



Tomorrow



Passenger loading space is available on busy urban streets during peak periods for high prices in comparison with side streets. As vehicles are charged by time, increased occupancy decreases costs per user. Drop-off space for smaller fleet vehicles is available on each block, but is priced according to demand.

Freight is a high-value use but consumes a large amount of time and square footage; pricing will guide companies to consolidate orders and improve efficiency, using high value right of way for the time necessary.

Public space is allocated on most major streets to provide people walking or lingering a place to interact. These spaces create more liveable and welcoming streetscapes.

A rapid bus stop, every third of a mile, is primarily used by buses, but microtransit is permitted to use it when it is not occupied by a full-sized bus.

The Fully Autonomous Future

A real-time curbside management system could work on an instant reservation basis, where specific vehicles can automatically reserve timeslots a few minutes in advance of arrival at a site, with the free market determining what they pay for the amount of flex zone time they use.

Creating a more dynamic and nimble system gives private companies as well as public agencies more tools to get the best use out of the curbside space. For example, high-value uses, such as drop-offs for disabled passengers or grocery deliveries, can be prioritized in both time and space.

Pricing the Curb

Cities should price curb space dynamically, prioritizing uses that align with their values, possibly through real-time bidding. Prices for low occupancy modes on major urban streets will be higher than those on side streets.

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