
TÓRY
ALUGA-SE SALAS

3

Design for the Autonomous Age

Photo: NACTO (São Paulo)


Photo: NACTO (Memphis)

3.1 Streets for Safety

3.1

Streets for Safety

In 2017, car crashes killed 37,133 people in the US. This fatality number has been rising steadily over the past decade, as Americans drive more and drive faster, in increasingly large vehicles. The US has the dubious honor of having the worst per capita fatality rate in the industrialized world; double to quadruple the rate of our Canadian or European counterparts.[78]

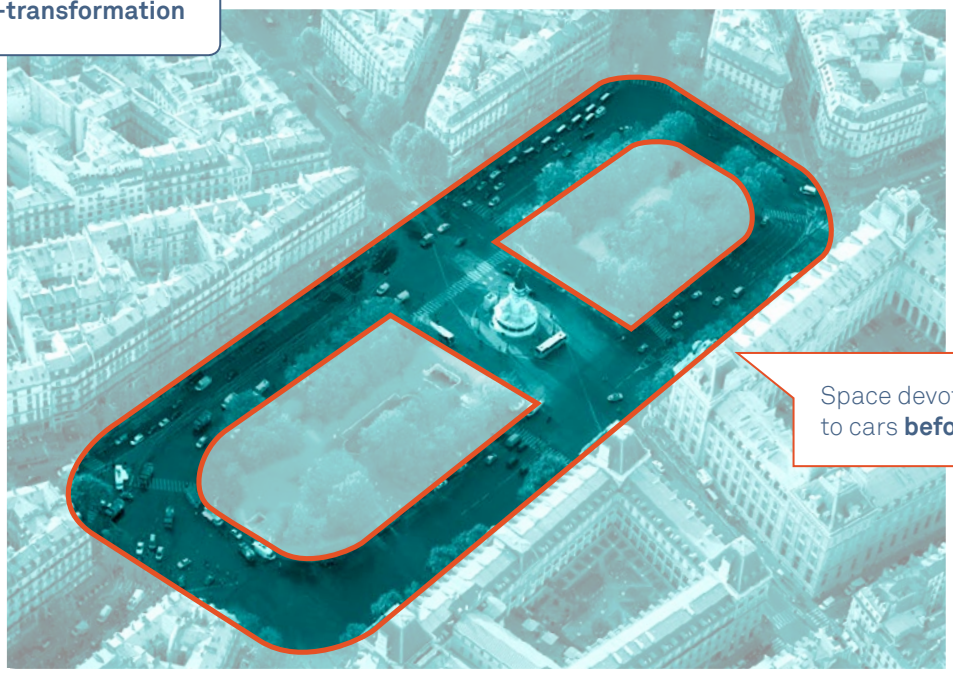
The design and management of streets is one of the most powerful tools that cities can exercise to achieve their safety goals, improve transit service, and reduce carbon emissions. In their initial development and deployment, automated vehicles are being programmed to follow a complex set of traffic rules, abiding by the geometries that cities plan, engineer, and construct. This power over street geometry gives cities unique opportunities to shape technology policy.

Cities must seize their chance now to shape new technologies, rather than wait for technologies to shape them. We have made that mistake before. During the early twentieth century, cities embarked on large-scale modernization projects to accommodate cars, reshaping their streets and public spaces. The landscape created by car dependence led to increased racial and economic segregation, abysmally high traffic fatalities, increasingly long commutes, and rising global temperatures and emissions. Today, 30 percent of all US carbon emissions come from transportation.[79]

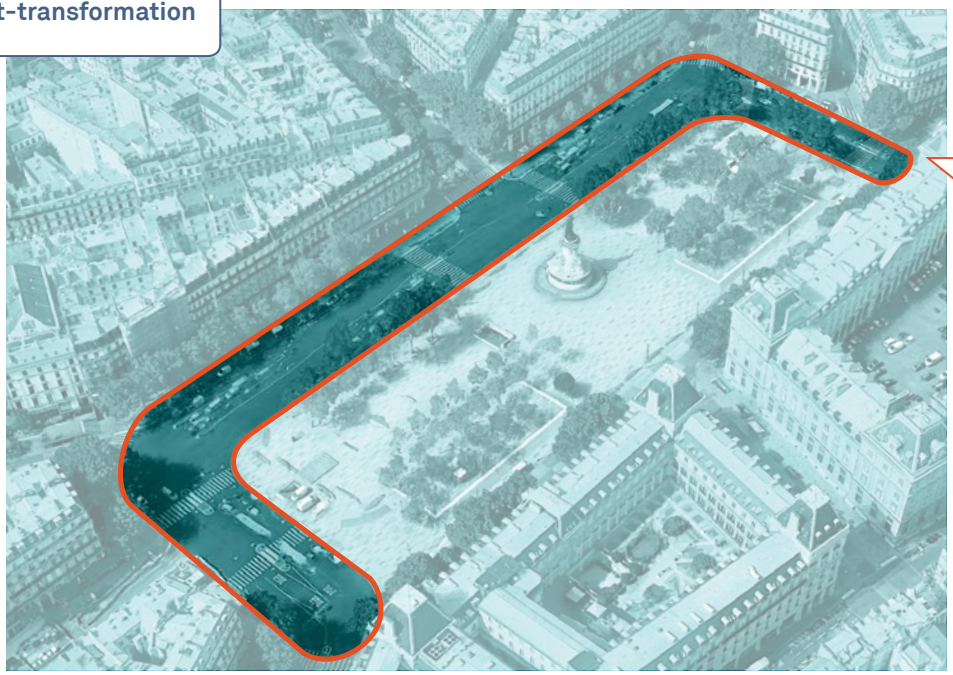
To ensure safety in an autonomous age, cities should prioritize high-capacity transit and active transportation. These modes are the foundation of a more urban-oriented vision for the future of transportation. City and state DOTs must reassess long held engineering and planning "rules of thumb" such as level-of-service, 85th percentile, and assumptions about what transit riders want. Using a combination of digital tools that analyze user data and automatically enforce regulations, combined with street design strategies that manage the speed, flow, and directions of travel, cities can regulate their streets according to a sustainable hierarchy of street users and design transportation systems around the needs of people.

Place de la Republique, Paris

Pre-transformation



Post-transformation



Managing the Future Street

Policies for **Safety and Comfort**

Pedestrians Detected, Not Connected
People walking and biking should not be required to carry sensors or signals to stay safe. Cities should require AVs to detect and yield to pedestrians in all conditions, and to retain full responsibility for not injuring people using the street.

Low, Steady Speeds
To ensure a safe environment for active transportation modes, cities must actively manage speeds. Speeds should be limited to 25 mph citywide and lower (typically 15 to 20 mph) in city centers, residential areas, and near schools and other sensitive locations.

Places to Rest
Plazas, parklets, and pocket parks provide places for people of all ages and abilities to stop, congregate, and spend time.

Children Are the Design User
Cities should design streets to meet the safety and mobility needs of a small child. By reducing vehicle speed, shifting people away from car trips, and increasing the visibility of the people most vulnerable to traffic violence, cities can make streets safer for all.

Policies for **Efficiency and Growth**

Transit First
Cities should allocate street space to prioritize transit and other high-efficiency modes. High-frequency, reliable routes, made possible by bus-only lanes, transit signal priority, and AV technologies can ensure that in the future, success is measured by moving people, not vehicles.

Real-Time Street Data Collection
Cities should collect data from AV and other vehicles operating on their streets to manage streets in real-time. This information can pinpoint hazardous locations and direct resources towards redesigning streets for safer and more efficient operations.

Curbside Demand Management
Cities should adopt policies to allow the curb to serve different functions over the course of the day. Curbside inventories and demand-based pricing will allow curb access to be managed and prioritized in real-time.

Congestion Pricing
Pricing will play a key role in the autonomous future. Cities and states should implement pricing policies to reduce driving and mitigate the safety, health, environmental, and economic burdens of single-occupancy car use.

Places for Commerce
Increased street efficiency will lead to improved economic outcomes for individuals, neighborhoods, cities, and regions. With flex zones, curbside pricing policies, and increased space for pedestrians and vendors, cities can create opportunities for businesses of all sizes.

Tools for **Safety and Comfort**

Narrow Lanes
Narrow lanes reduce speeds. Lane widths should be 10' or less in most urban contexts. Lanes on streets without large transit vehicles can often be narrower.

Smaller Municipal Vehicles
Emergency and municipal vehicle needs often dictate street design decisions. Using smaller street sweepers, plows, and emergency vehicles creates opportunity for safer street design.

Tight Corner Radii
Small corner radii at intersections increase safety. Smaller radii can be achieved by selecting the smallest possible design vehicle, accommodating trucks and buses on separate routes, and restricting right turns on red.

Frequent Pedestrian Islands & Stopping Points
Pedestrian islands increase safety. They should be installed wherever people must cross three or more lanes of traffic.

Diverters and Mini-Roundabouts
Diverters and mini-roundabouts slow vehicles and help prioritize key modes such as transit and bikes.

Tools for **Both**

Sensors and Street Technology
Sensors and other data collection devices gather real-time information that can inform pricing and street space allocation decisions.

Protected Bike Networks
Robust, connected, and citywide bikeway networks make cycling an option for all ages and abilities.

Pedestrian Plazas
Plazas in street space reclaimed from vehicles provide places for people to walk, rest, shop, and socialize.

Tools for **Efficiency and Growth**

Bus-Priority/Bus-Only Lanes
Reallocating travel lanes to transit use improves bus operations and reduces travel times.

Better Bus Stops
Boarding bulbs and islands improve transit operations by allowing buses to stop in-lane. Shelters, lighting, and real-time information displays improve rider safety and comfort.

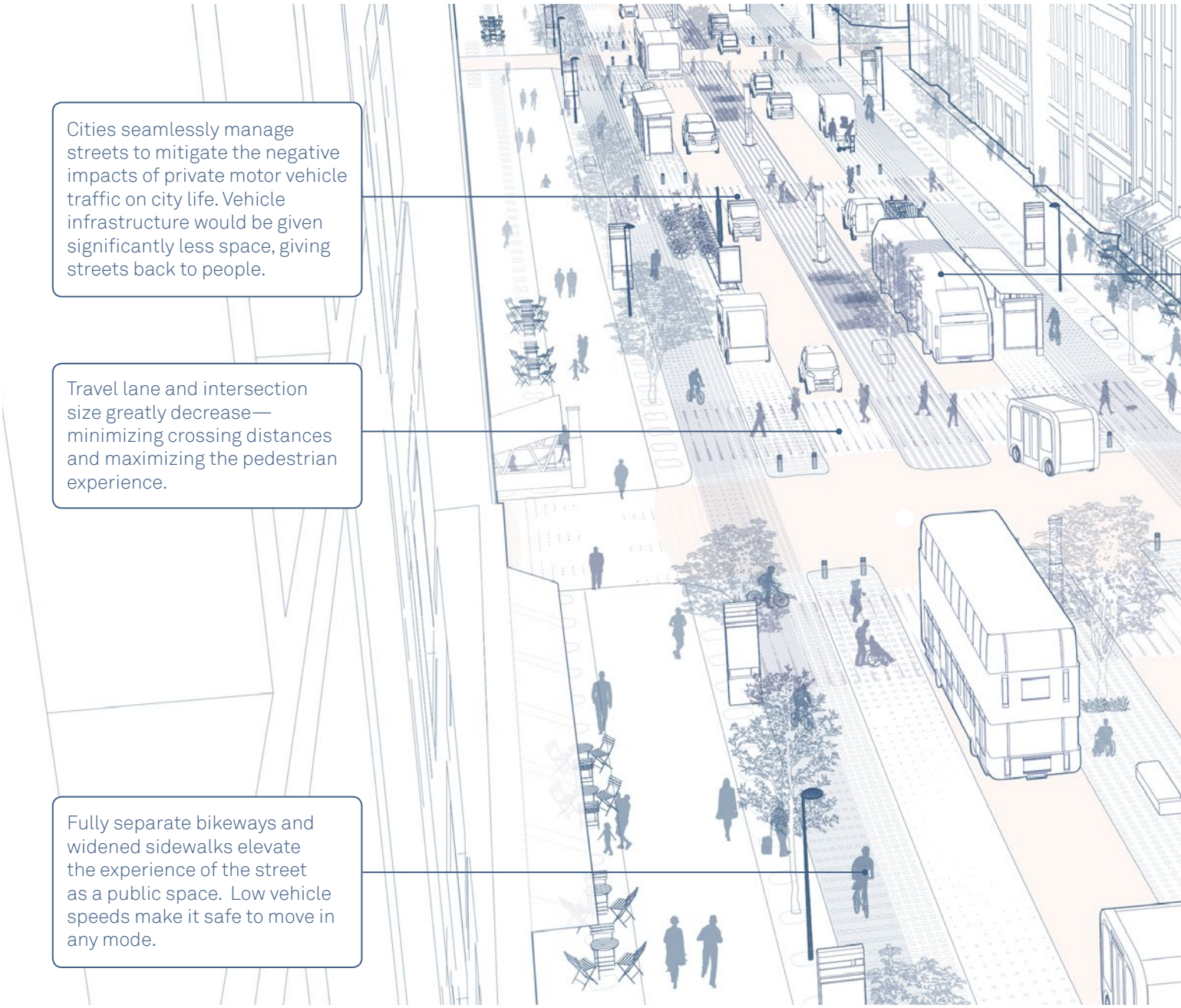
Time of Day Management
Demand-based tools allow streets to serve different purposes at different times of day. High pedestrian activity may trigger closures for vehicles, speed reductions, or re-routing.

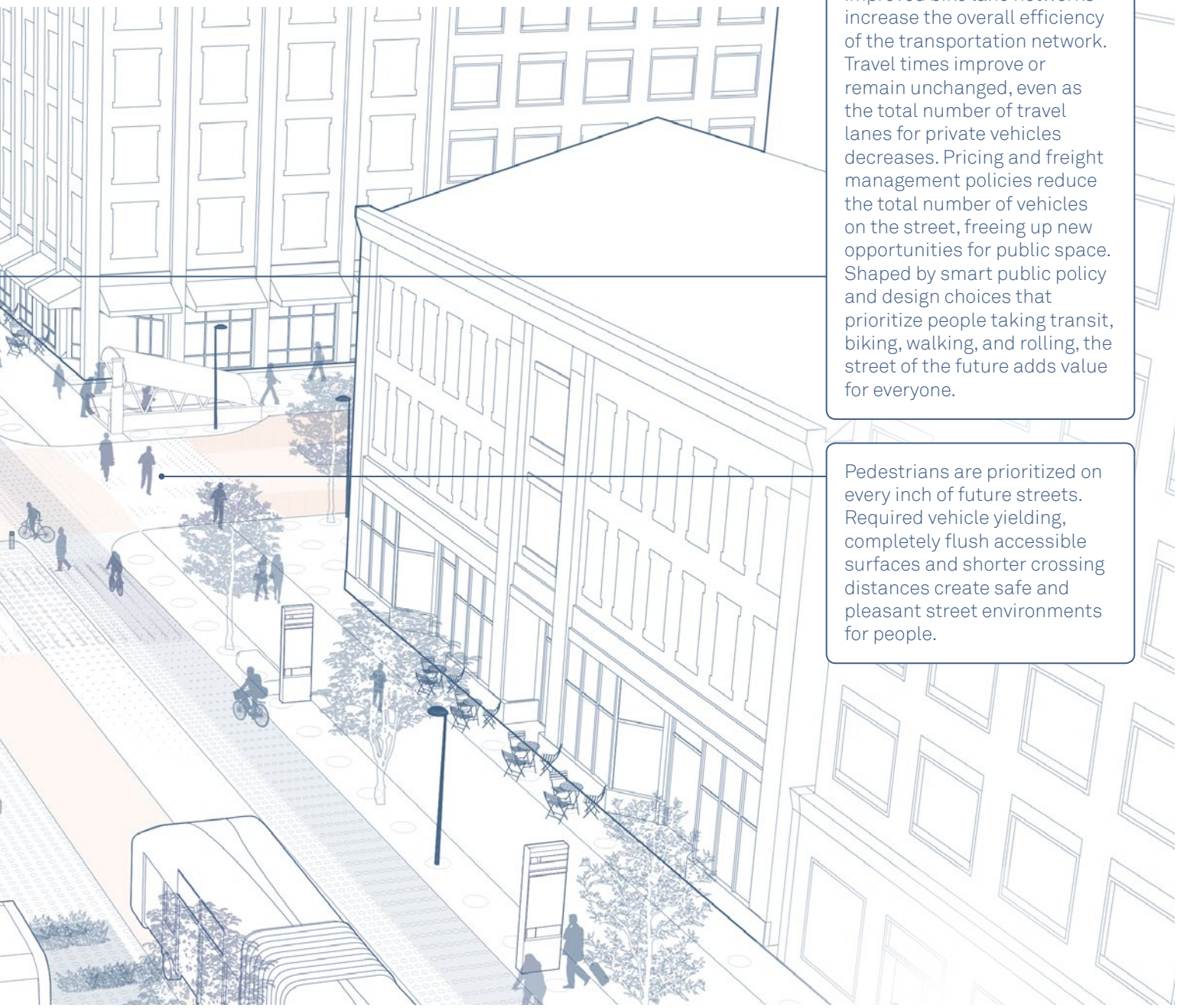
Green Infrastructure
Bioretention planters, swales, and permeable paving materials manage stormwater in the street, improve water and air quality, cool urban surface temperatures, and improve the public realm while supporting calmer streets.

Mobility Hubs
Mobility hubs link multiple transportation options at key locations, providing opportunities for transfers and increasing efficiency across the transportation network as a whole.

Dynamics of the Future Street

In the autonomous age, streets must 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, the backbone of the urban mobility system, has priority operation in dedicated lanes. Flexible curbsides allow for a myriad of public and private uses—from loading zones to parklets. Street design and AV programming restricts speeds to safe levels of 25 mph citywide and typically lower (15 to 20 mph) in downtown cores, residential areas, and near schools and other sensitive areas.





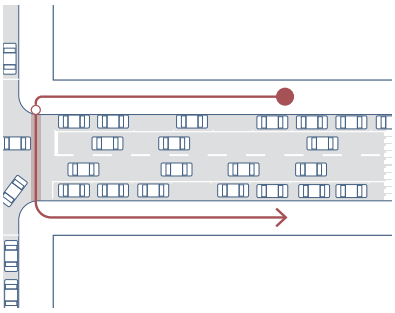
Dedicated transit lanes and improved bike lane networks increase the overall efficiency of the transportation network. Travel times improve or remain unchanged, even as the total number of travel lanes for private vehicles decreases. Pricing and freight management policies reduce the total number of vehicles on the street, freeing up new opportunities for public space. Shaped by smart public policy and design choices that prioritize people taking transit, biking, walking, and rolling, the street of the future adds value for everyone.

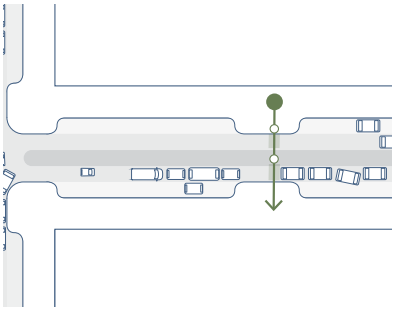
Pedestrians are prioritized on every inch of future streets. Required vehicle yielding, completely flush accessible surfaces and shorter crossing distances create safe and pleasant street environments for people.

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.

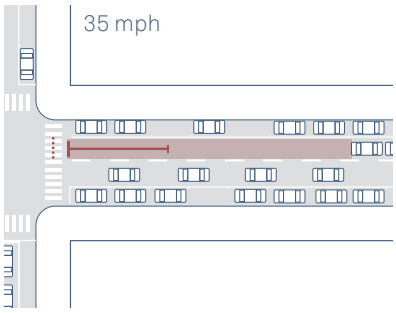
More Frequent Crossings

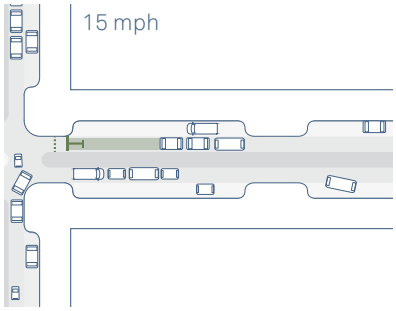




Present-day traffic operations focus primarily on conflict points at or near intersections. In the era of automation, the intuitive act of crossing directly to one's destination—known technically as mid-block crossing—could become normal once again. Frequent, formal midblock crossing points (every 50–100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

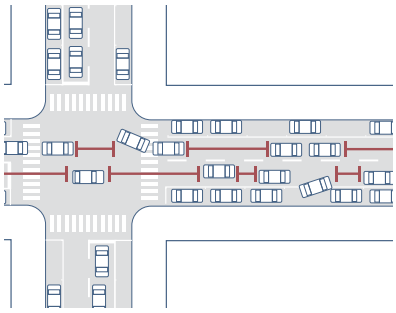
Stopping Distances

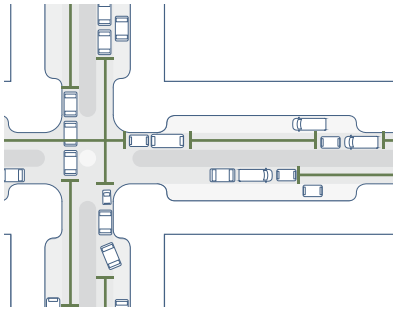




To ensure a safe street environment for all street users, speeds can be actively programmed, managed, and limited to 25 mph citywide and 20 mph or less in city centers, especially where bicycling or transit are not fully separated from other motor vehicles. Vehicle coordination, decreased traffic volumes, and lack of signal delay would provide consistent, reliable movement.

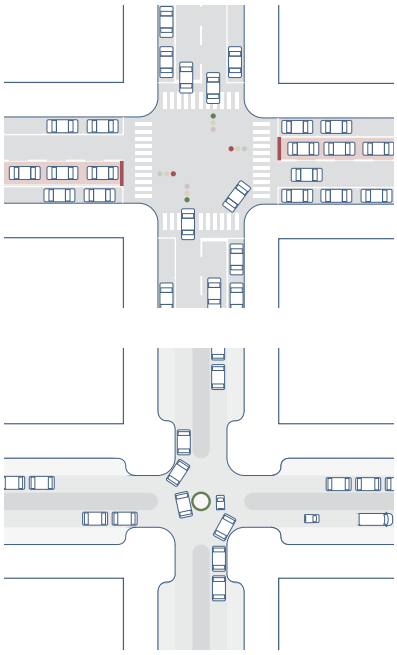
Vehicle Spacing





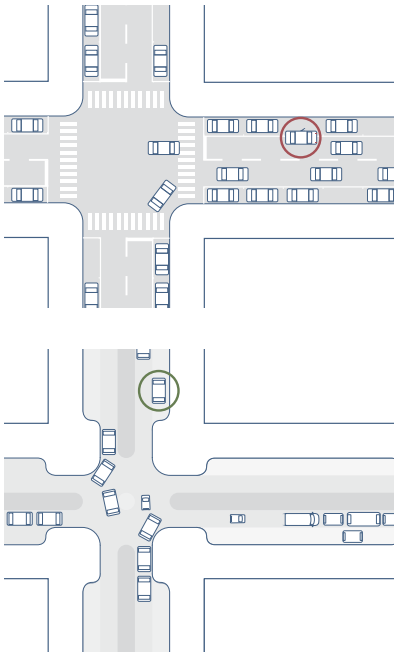
Cities must avoid creating impassable, highway-like arterials with endless platoons of traffic. With more passenger consolidation into multi-use vehicles, pedestrians could have safer, more frequent crossing opportunities than traditional signalization can provide, achieving both safety and operational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

Roundabouts and Diverters



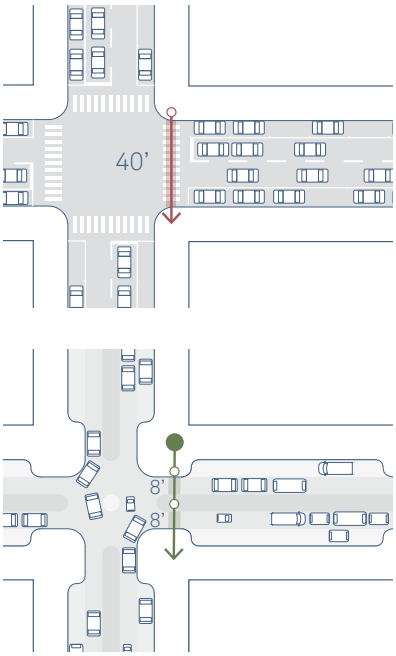
In a connected and automated vehicle environment, intersections accommodate more fluid streams of traffic. Certain types of intersections, especially at minor crossings, behave more like roundabouts with consistent, slow traffic as opposed to persistent stop-and-go movement. Cities must use street design tools to allow certain modes while discouraging others.

Pick-up and Drop-off



To drop off passengers, vehicles on major streets will first turn right. Turning off of the main street to stop reduces congestion on main corridors and allows 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.

Safe, Frequent Crossings

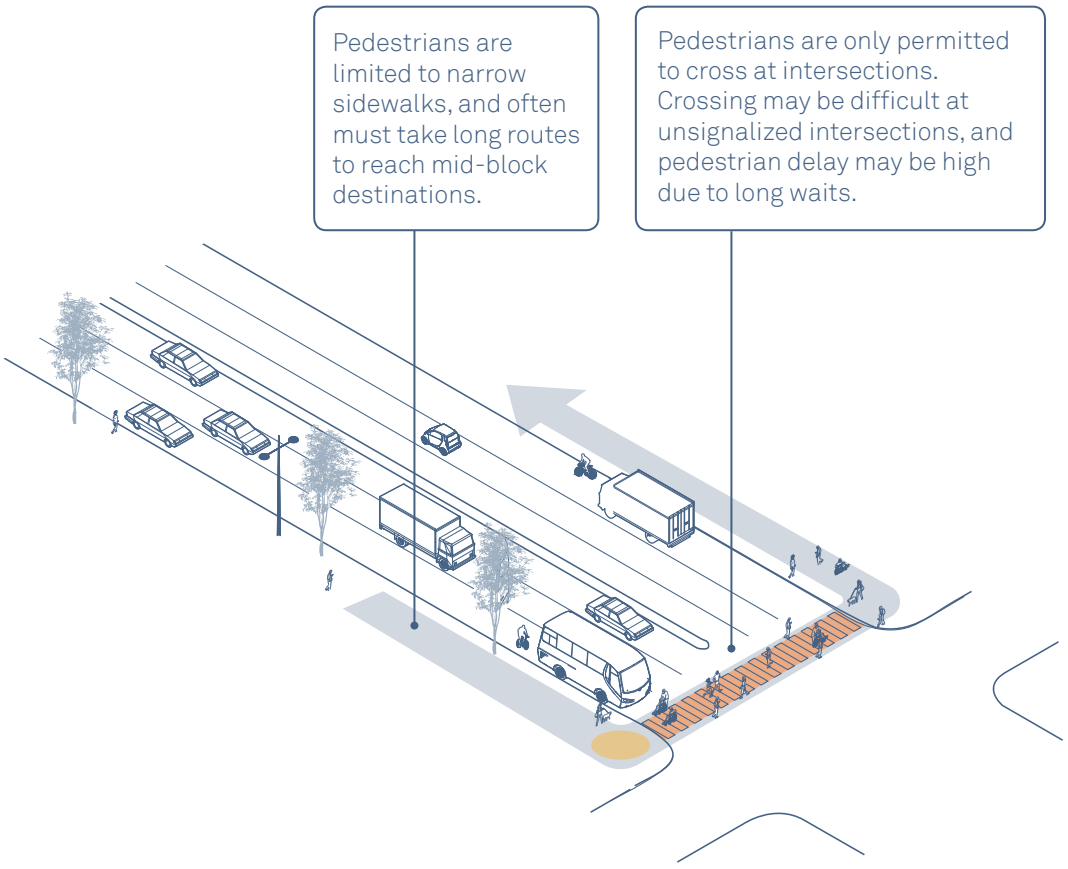
Today

People incur significant delays while walking 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 prioritize pedestrians through software and infrastructure.

Legend

- Safe Zone
- Wait Zone
- Exposure Zone



Distance to cross

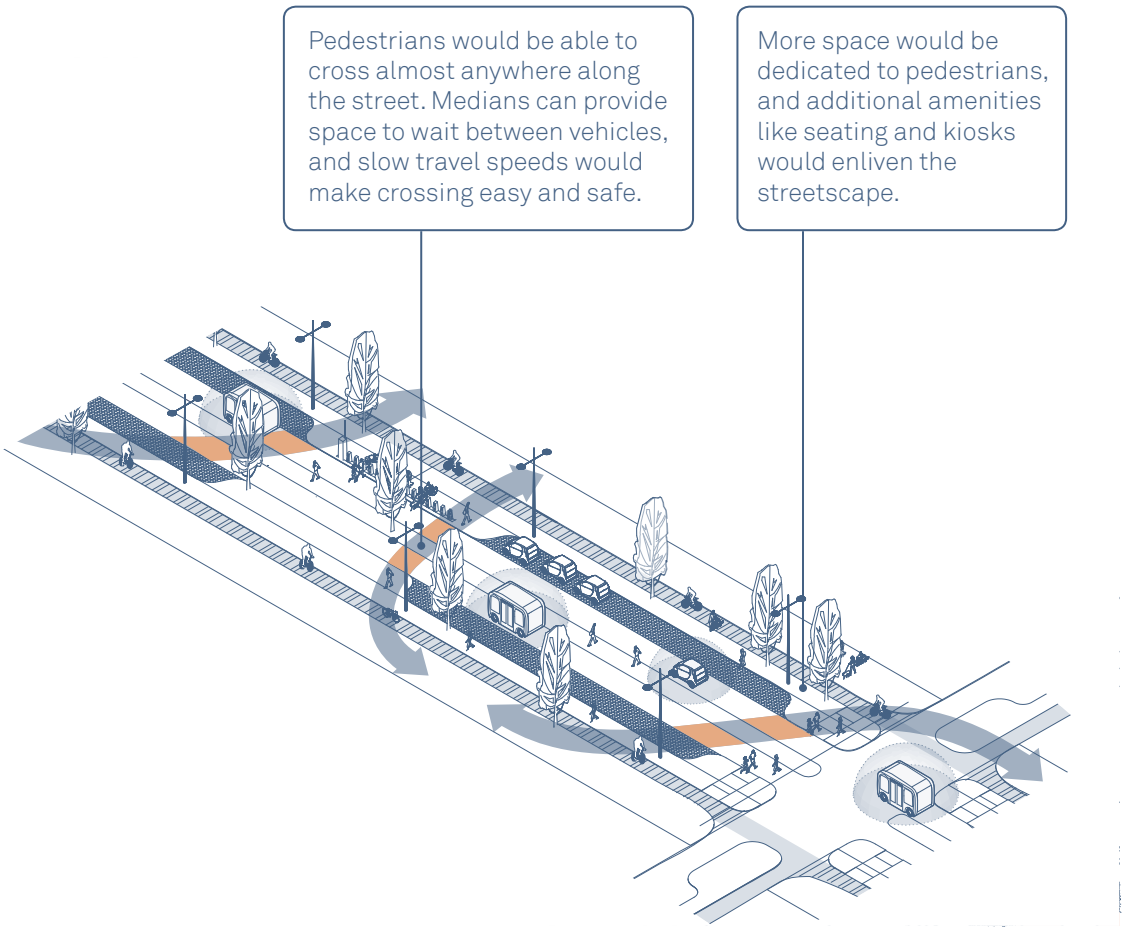
260 feet

Time to cross

100 seconds

Tomorrow

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 convenient 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."

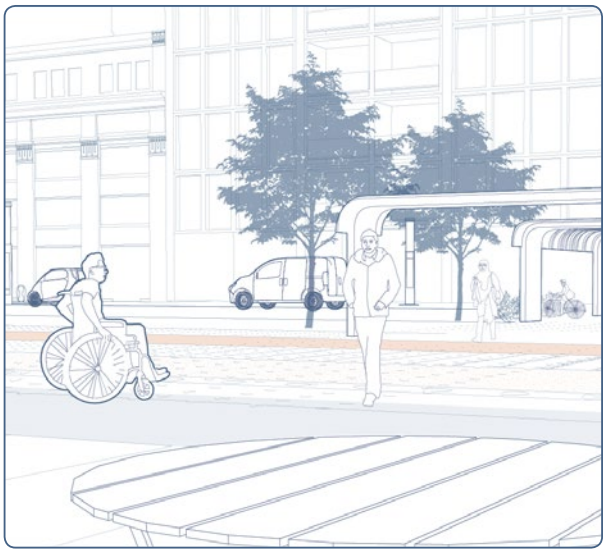


Distance to cross
80 feet

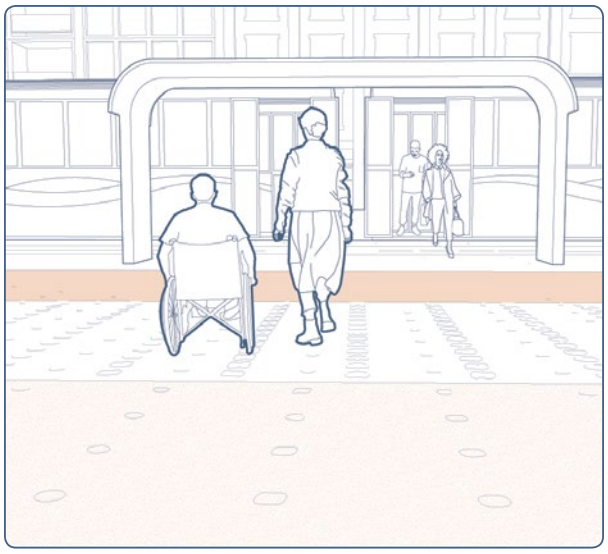
Time to cross
23 seconds

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.

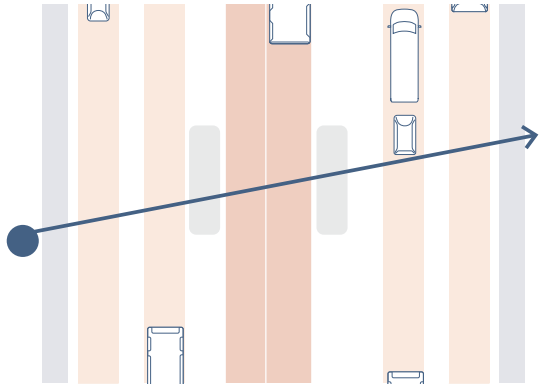


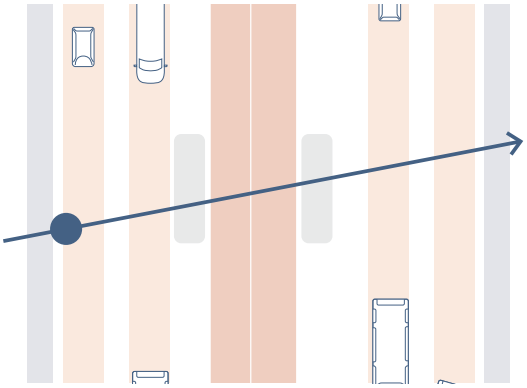
A person who uses a wheelchair is leaving a café table in the middle of the block, and wants to cross the street to meet a friend.

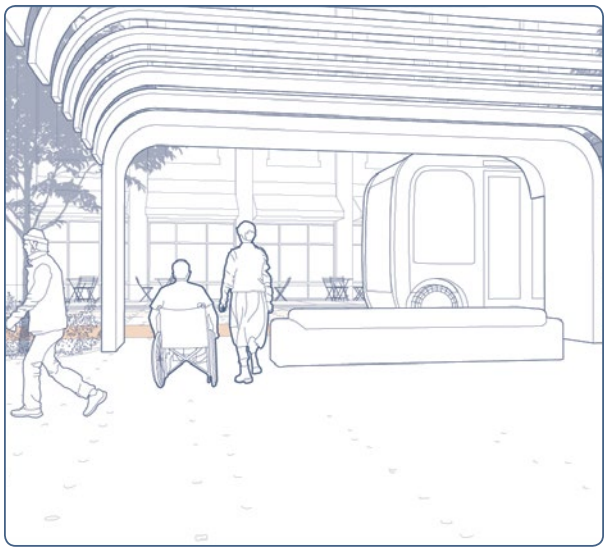


He looks left and crosses the bikeway, which is level with the sidewalk, feeling a slight rumble over the textured edge between the two.

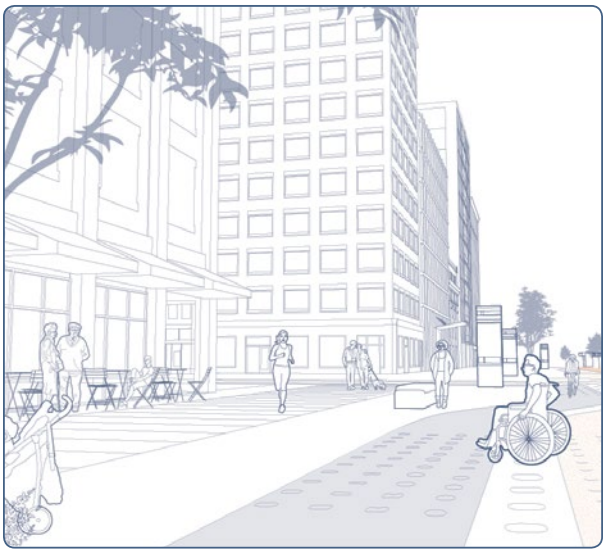
He waits briefly before crossing the low-speed flex zone lane, while a vehicle carrying freight pulls away slowly from nearby. The truck has detected that people are moving toward the lane, and has slowed to 10 mph to stop quickly if needed.



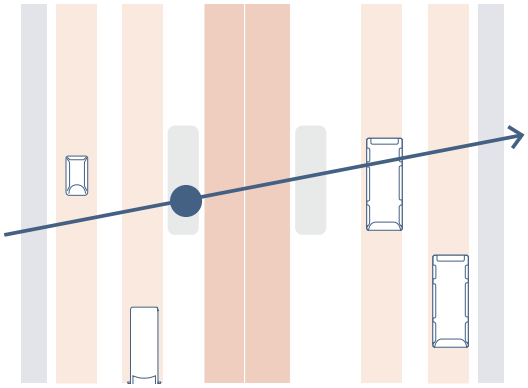


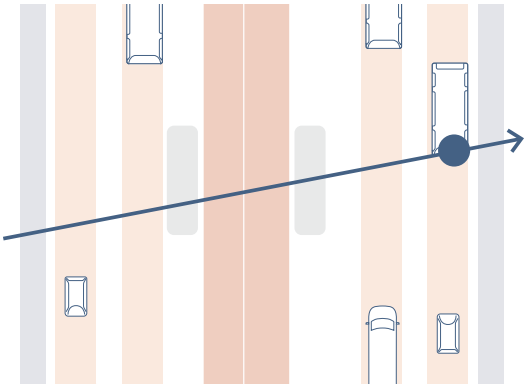


He crosses the flex zone and proceeds to cross the main vehicle lane. Seeing that approaching vehicles are still relatively far away, he begins crossing, but his wheels hit a piece of litter and he slows down. A vehicle approaching senses that he might still be in the lane if it continued at its current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



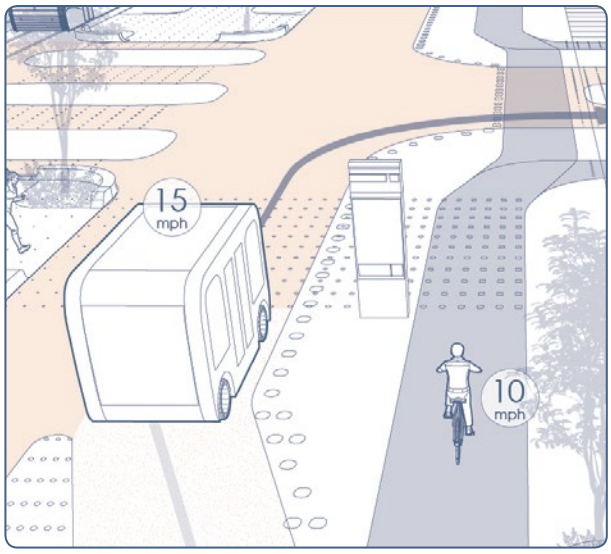
He proceeds through the transit lanes after waiting for the bus to pull away. He sees that there is a gap in the main vehicle lane and that all vehicles are stopped in the flex zone lane. He crosses the rest of the way at a normal speed, reaching the other side of the street to meet his friend.





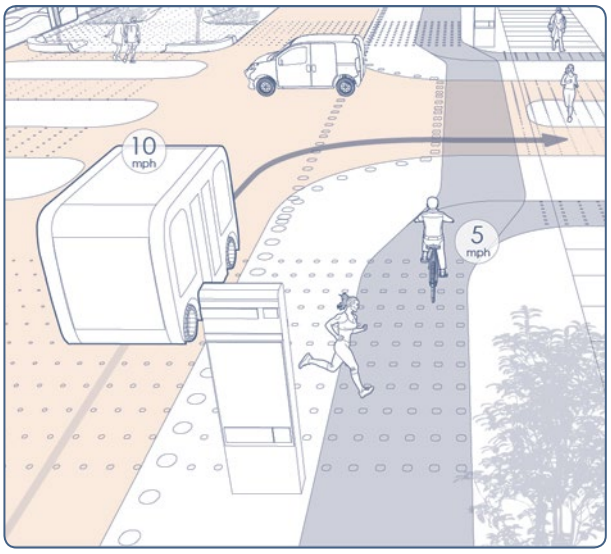
Cycling through Intersections

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. AVs must sense and prepare to yield to cyclists before the vehicle enters the intersection.

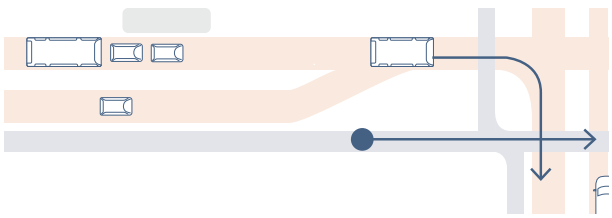


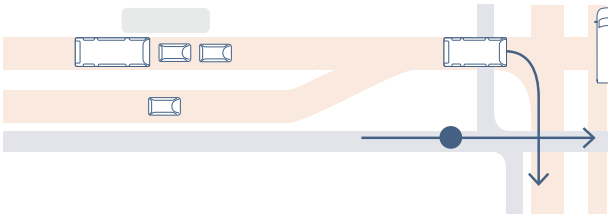
As the cyclist approaches the intersection, she is passed gradually by an automated shuttle that intends to turn right. The shuttle detects and tracks her movement, and slows as it approaches the intersection.

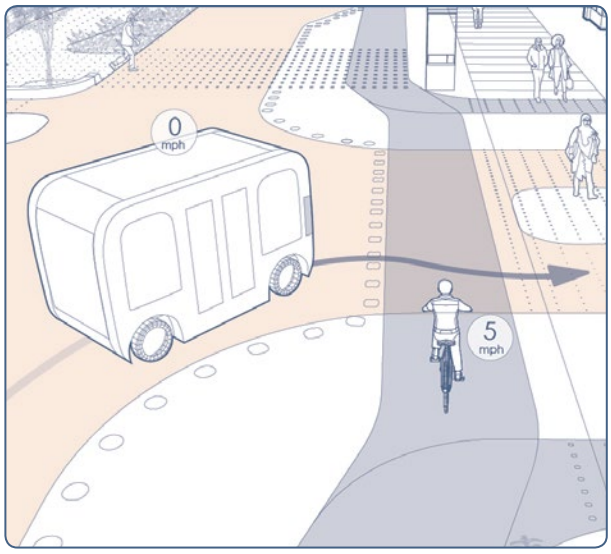
An audible signal is flashing yellow, giving the shuttle permission to continue with caution, which the bicyclist can see and hear. During this phase, vehicles are permitted but must yield to one another and to people. These intersection controls also have a pedestrian-and-bike-only phase. The shuttle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



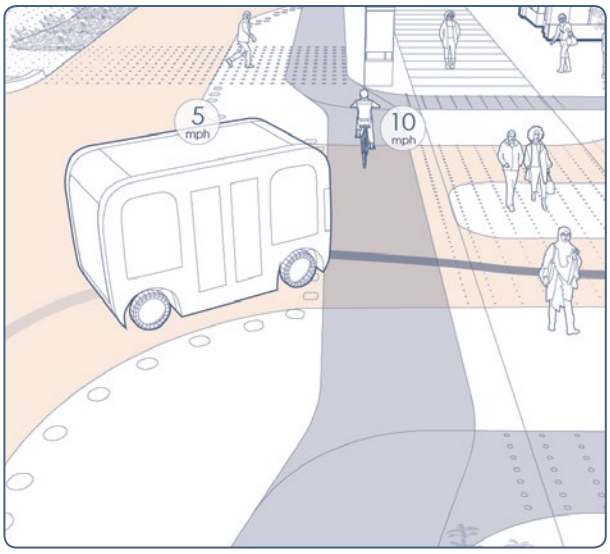
The bikeway curves to the right, creating space for a vehicle to wait as indicated by a yield line in the pavement. As the bicyclist gets close to the intersection, the shuttle slows to a crawl to be ready for an instant stop as it approaches the crosswalk—since the bicyclist might turn left, too. It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



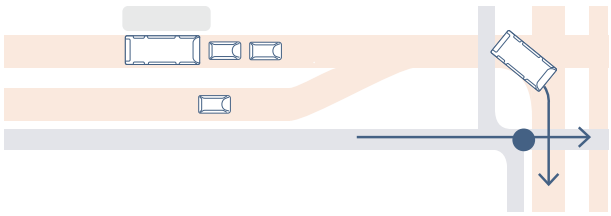


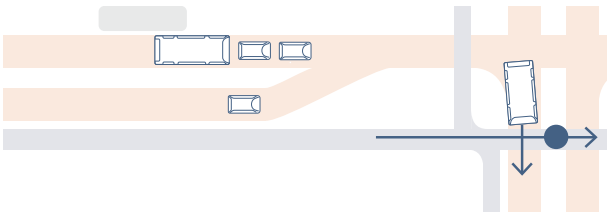


Seeing that there is no other cross-traffic, the bicyclist goes straight and the shuttle waits for her and the pedestrians in the crosswalk. The shuttle's routing algorithm anticipated that it will usually need to pause here.



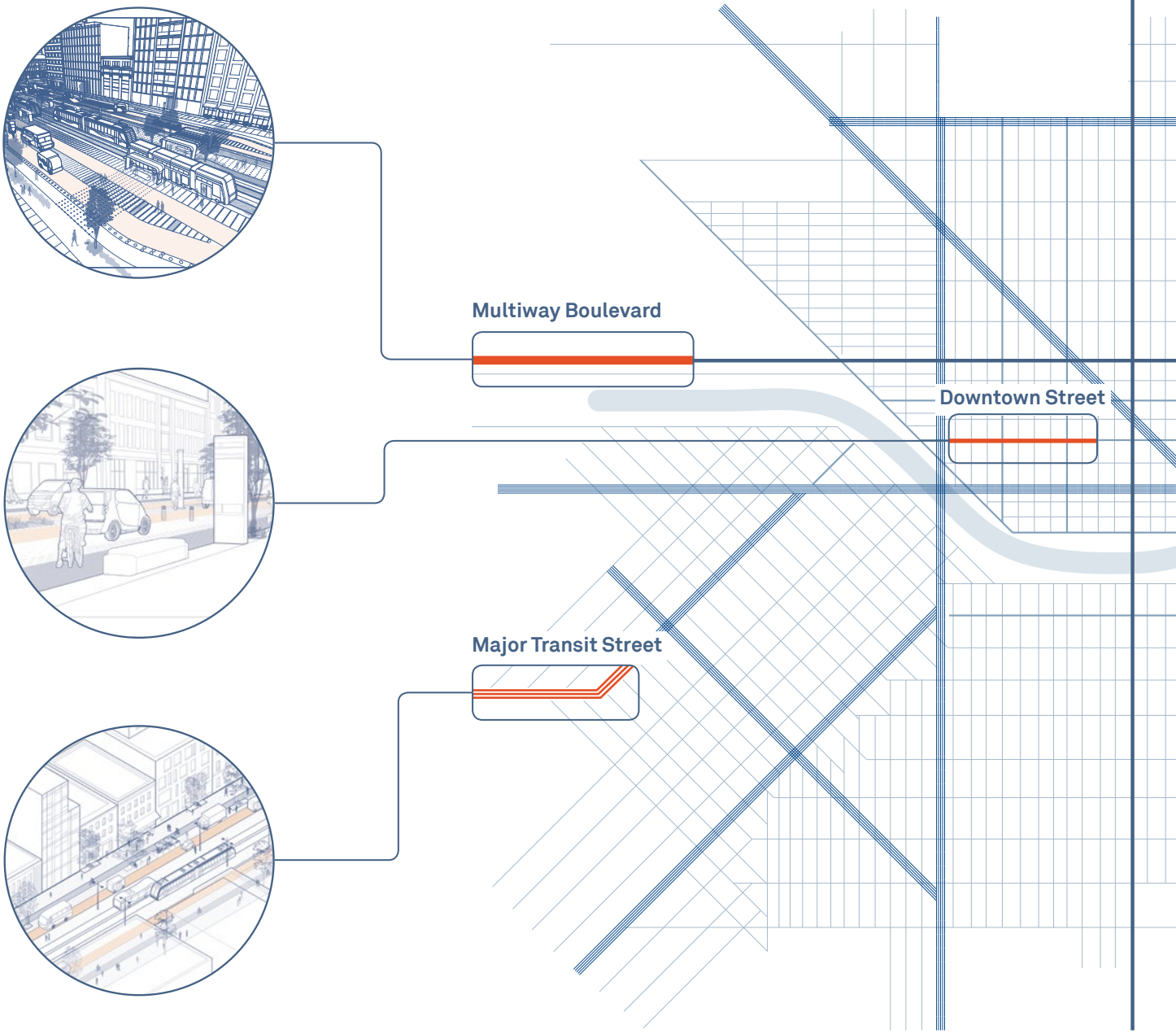
The bicyclist proceeds, seeing as she crosses the median that vehicles coming from her right also slowed. The group of people in the crosswalk finish crossing the street, and the shuttle proceeds.

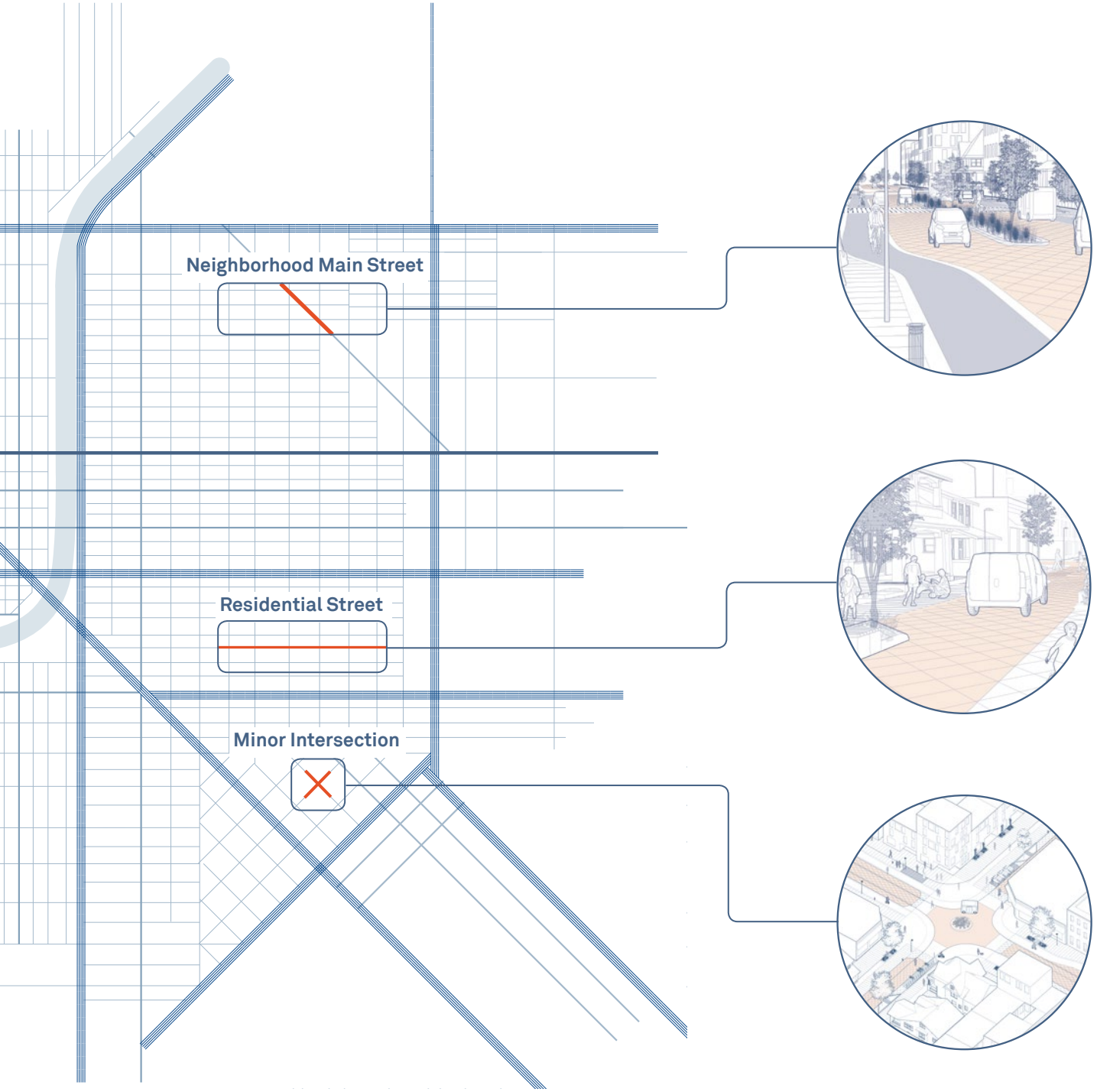




Street Types

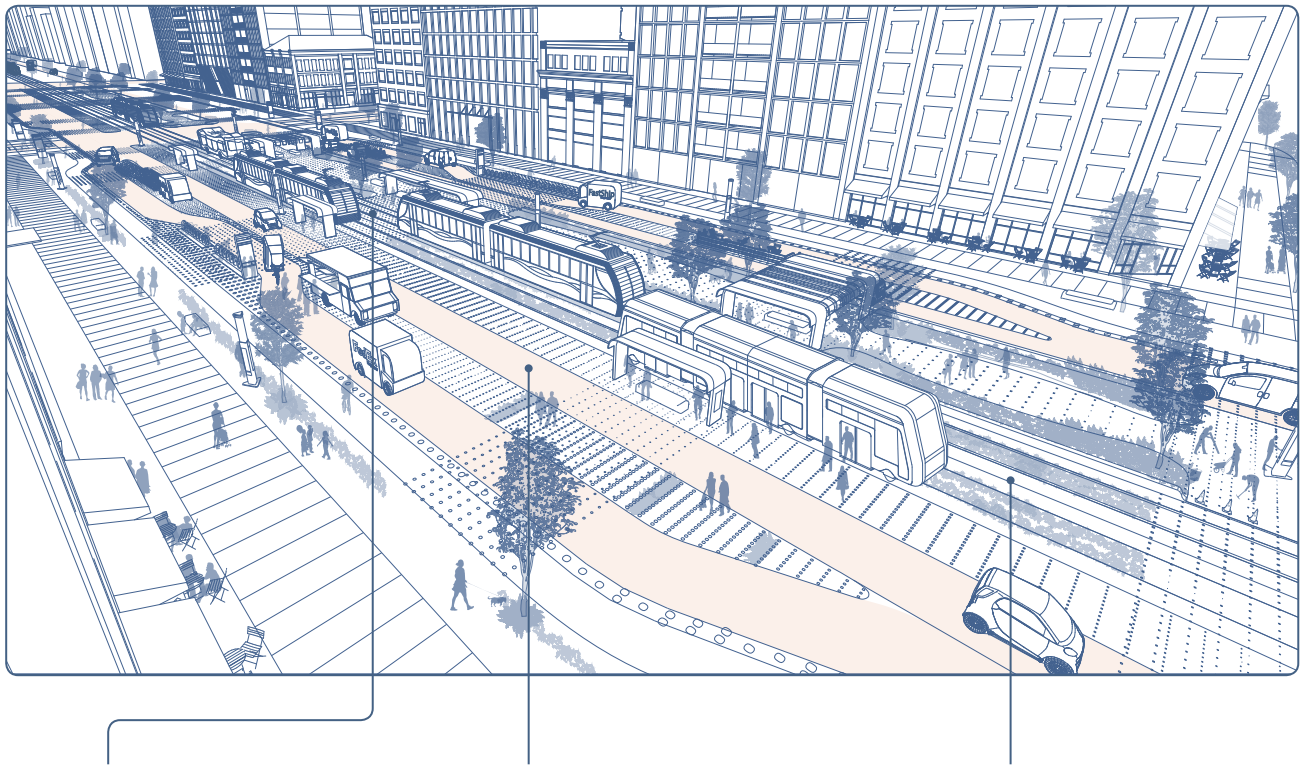
Streets and highways today reflect a century of investment in auto-oriented infrastructure that has failed to provide reliable or safe urban mobility. Much more efficient, humane streets are possible. Technological changes present a chance to remake our streets as cities adapt to, and shape, the new 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.




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

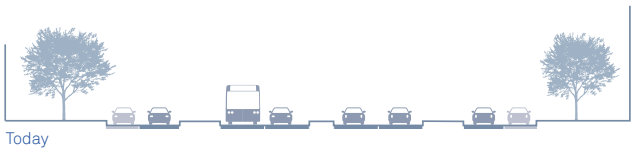
A transitway in the center lanes afford a priority space for transit unimpeded by other vehicles.

Access Lanes

Access lanes provide space for pick-ups, drop-offs, and deliveries. As pedestrian-priority space, the lanes are 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.

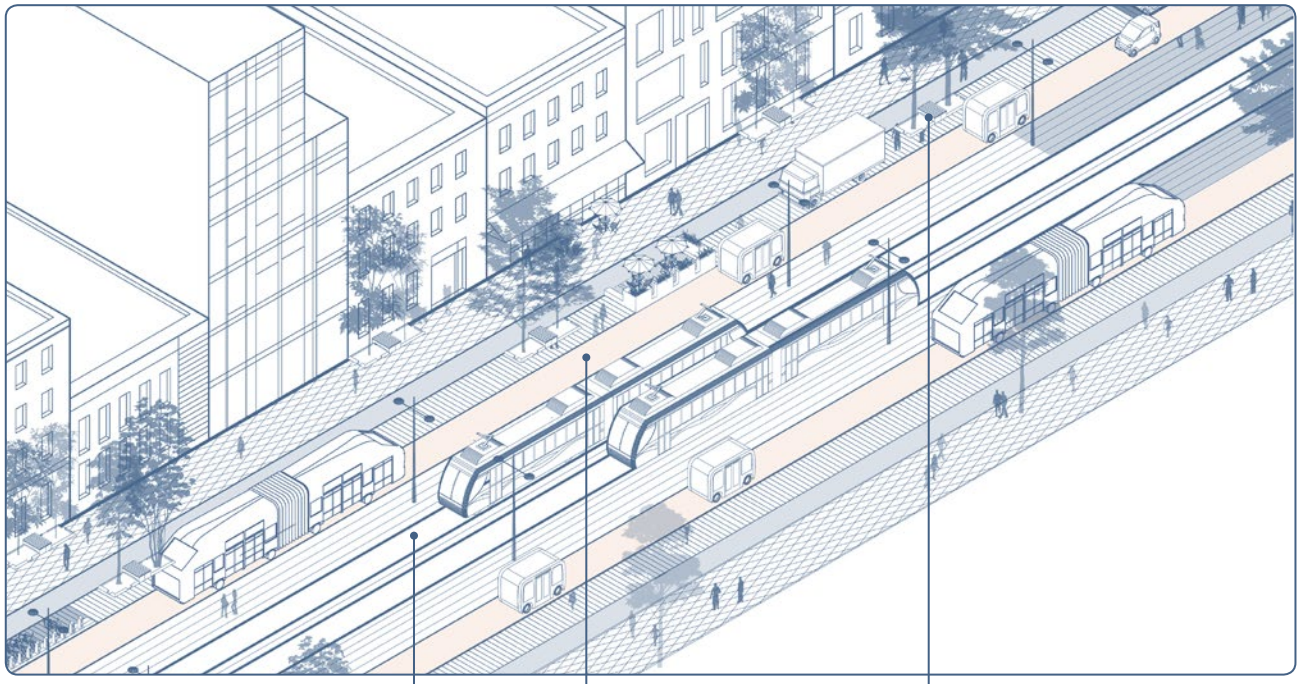


Today

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, cities must use street design to prioritize transit, walking, and biking. 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 serve bus and light rail while smaller vehicles could be permitted in narrow access lanes.

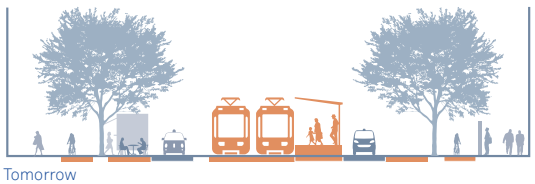
Mobility Hubs

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

The Flex Zone

Freight and small vehicles access the flex zone at low speeds. Dynamic pricing and management allows the former curbside to alternate between public space, loading/unloading, and pick-up/drop-off.

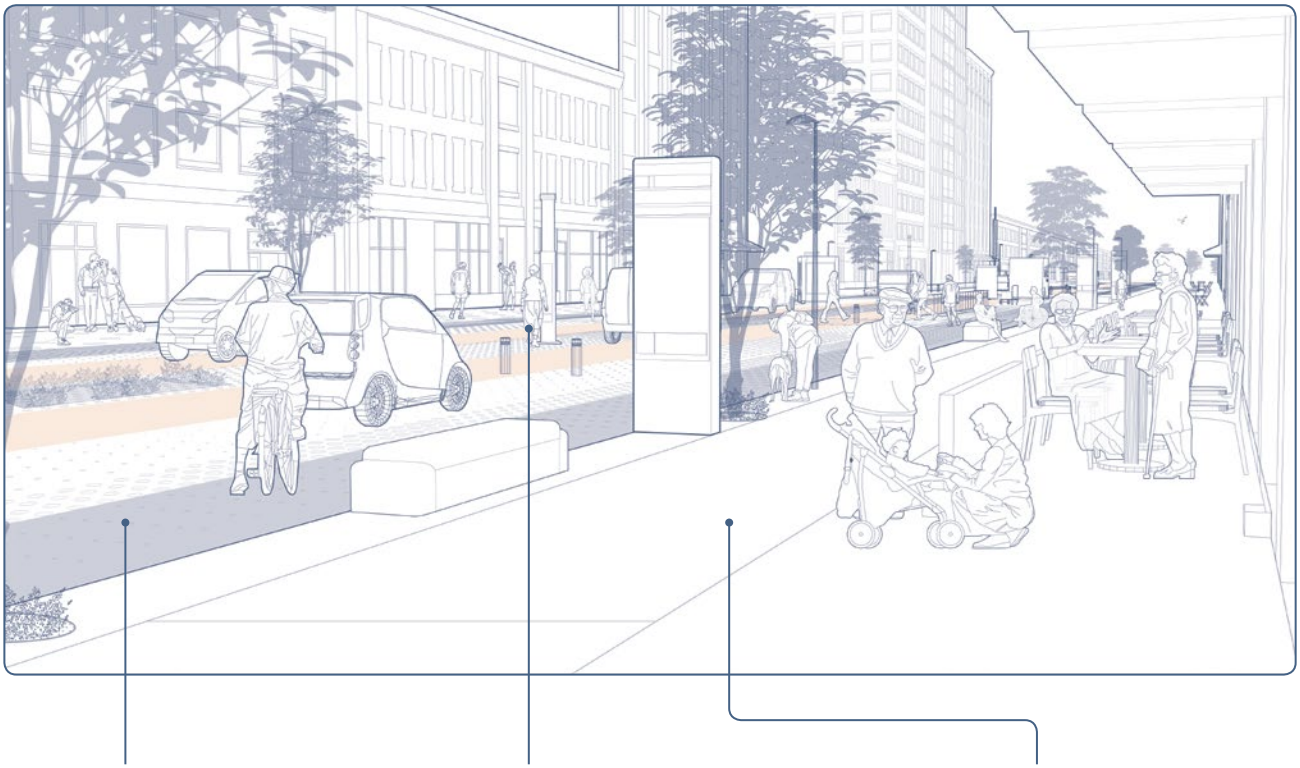
Today



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. Cities should prioritize transit and freight access by enacting pricing policies that disincentivize single/low-occupancy vehicles.



Protected Bike Lanes

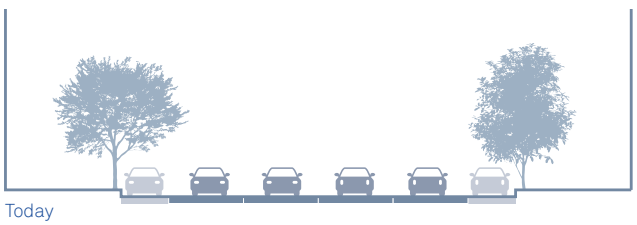
With motor vehicles still present, people bicycling will need protection from traffic in the form of fully separate infrastructure buffered from flex zones.

Safe & Short Crossings

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

Parking to Public Spaces

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



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.

Freight and Loading

Small freight vehicles use the curb lane. Their small size allows them to load/unload quickly and efficiently without endangering pedestrians or cyclists.

Surfaces Over Striping

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

Functional Medians

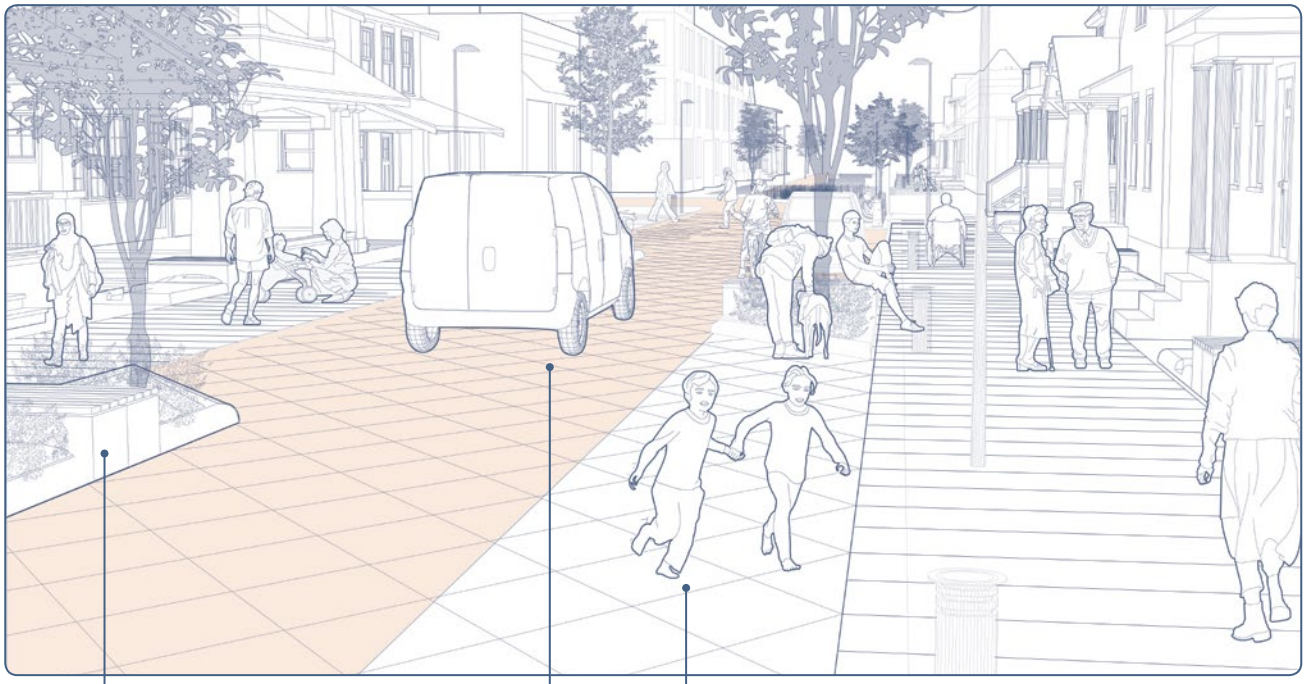
Permeable medians manage stormwater and beautify neighborhoods while also providing a refuge for pedestrians crossing the street.

Today

Tomorrow

Residential Street

Residential streets are the heart of the city. As improved transit and shared AV and micromobility services decrease the need for vehicle storage, streets can become new public spaces and front yards. Flush curbs create environments that are fully accessible and green infrastructure further beautifies the streets. Shared residential streets become central meeting hubs for the community and encourage transit travel through bike share and nearby mobility hubs for corner-to-corner transportation options.



Green Infrastructure

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

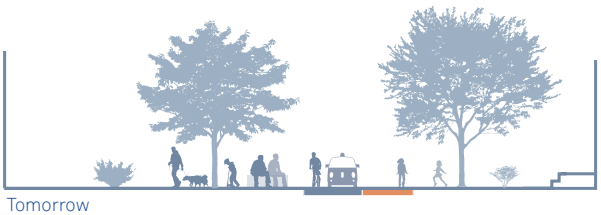
Vehicle Access

Most vehicles are restricted, permitting only local traffic and deliveries. Speeds are limited to 10 mph.

Play Streets

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

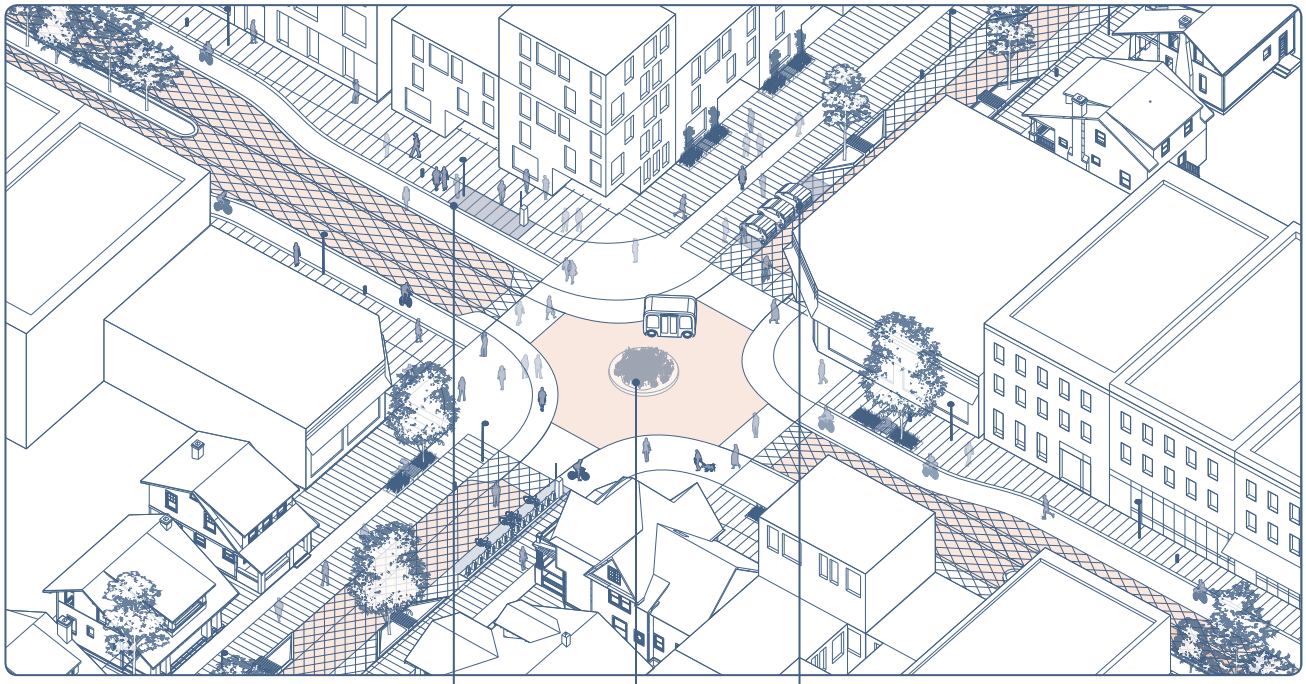
Today



Tomorrow

Minor Intersection

Minor Intersections serve as the core of residential neighborhoods, with dynamic mobility hubs, shared micromobility, car share and other mobility services. Mini-roundabouts, diverters, 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 through traffic.



Mobility Hubs

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

Mini-Roundabouts

Pedestrian delay is significantly decreased thanks to shorter crossing distances. Mini-roundabouts allow vehicles to travel at consistent, slow speeds.

Last Mile Connections

Local transit and shared micromobility options are abundant in residential neighborhoods, allowing multiple options to connect to core transit close by.

Photo: Seattle DOT (Seattle)

3.2 Curbs for Access

3.2

Curbs for Access

Historically, most cities have managed their curbsides based on adjacent land use and historic precedent. In practice, this often means that the most desirable curbsides, for example along a main shopping street, are priced the same as all other curbs, even when behavioral science and economics shows that they should be priced at the highest rates and in the shortest increments to encourage turnover and allow for as many shoppers as possible. Compounding this challenge, in most cities, curbside regulations are static, based on time limits, uses, or residency, which leaves cities unable to adjust prices by time of day or in response to demand.

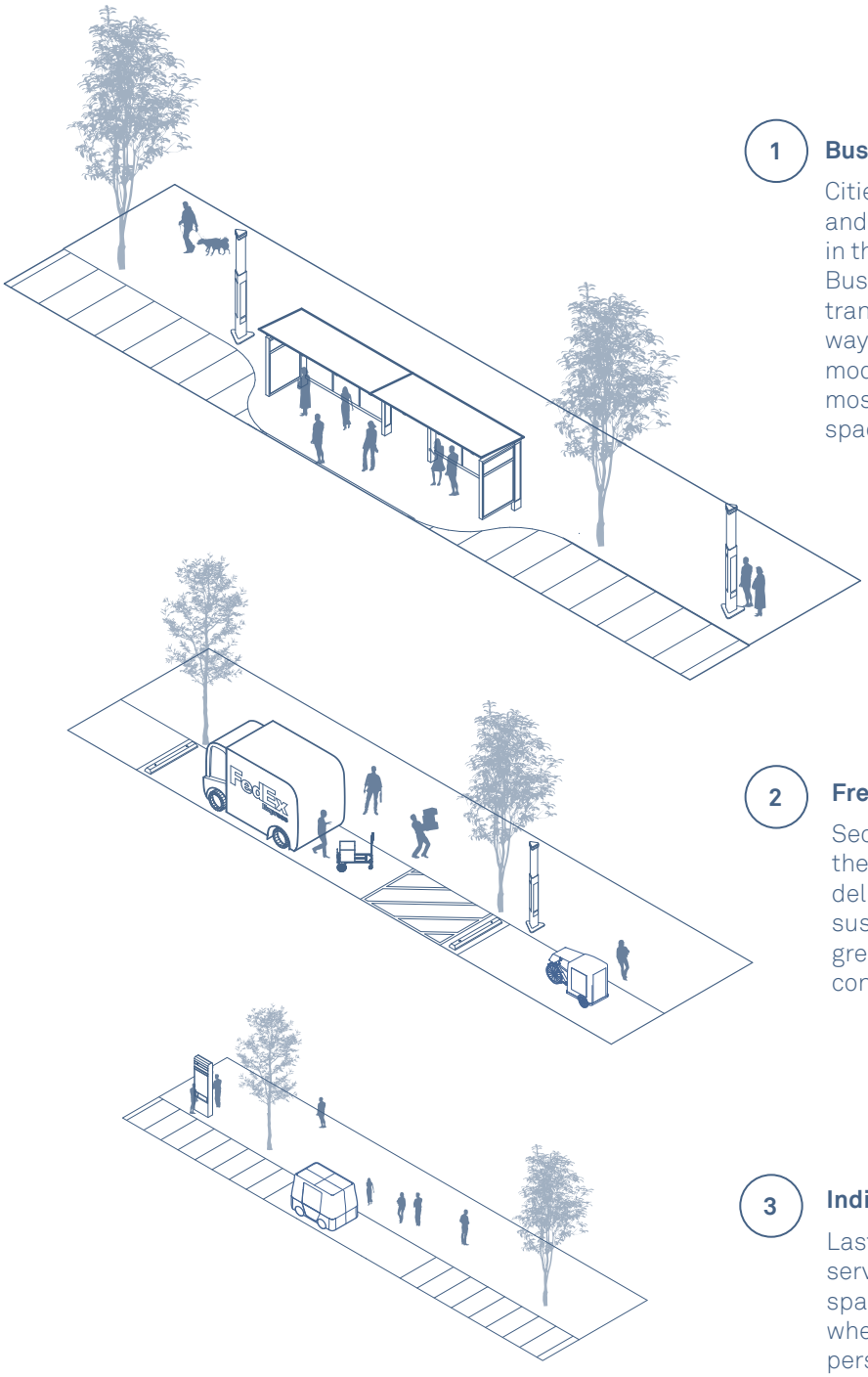
But already, the curb is changing. In many cities, today's curb is activated by a diversity of new uses, including bike share, car share, freight loading, food trucks, bioswales, pedestrian safety bulb-outs, ride-hail, delivery trucks, and other competing uses. If people switch to transit and shared services in large numbers, residential and commercial parking pressures could diminish. A flexible, adaptable program of amenities, ranging from permanent public spaces like parklets to temporary programs like food trucks or small vendors, could be programmed in the freed up curb space.

Today and in the future, managing the curb will be essential. Emerging technologies can help cities dynamically shape and manage curbs as flexible, or "flex," zones serve different uses and users at different times. Enhanced with sensors, the price and allowed use for the most in-demand curb space could fluctuate according to the time of day or shifting public priorities. Real-time curbside management systems could allow vehicles to automatically reserve time slots a few minutes in advance of arrival at a site. Armed with sufficient data, cities could actively manage curbsides, setting rates in real-time, changing uses with demand, and automating enforcement to ensure turnover.

Cities don't need to wait for fully autonomous vehicles in order to take advantage of new and emerging technologies. Technological advances are driving down the cost and size of sensor technologies. Cities are repurposing static parking meters to enable dynamic pricing tools. Cities should expand on these investments by inventorying curbside uses and regulations, building smart partnerships with the private sector, and using new technologies like LIDAR to collect data.

Who Gets Curbside Priority?

As curbside demand intensifies, cities must develop curbside prioritization and management frameworks that spell out how to make decisions about user priority, including decisions that balance expected revenues with public benefits.



1 **Buses, Transit, & Bikes**

Cities should prioritize curbside uses and modes that serve the most people in the most sustainable fashion. Buses, para-transit, and other surface transit, which are the most efficient way to move people, come first. Active modes which feed transit and are the most sustainable and require minimal space, are also high priority.

2 **Freight & Delivery**

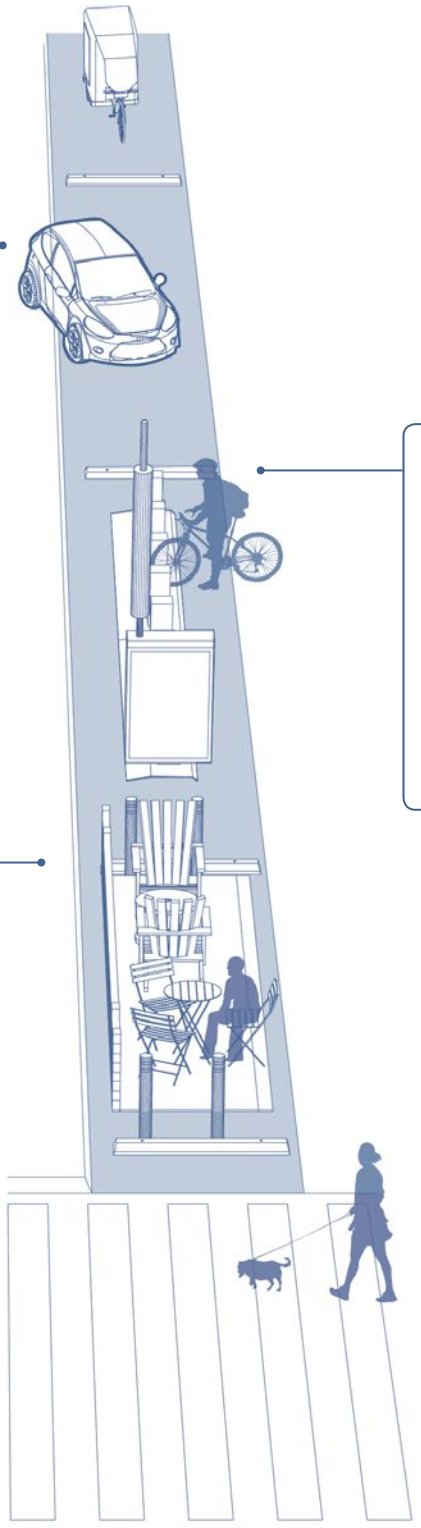
Second, cities should focus on the curbside needs for freight and delivery, which are necessary to sustain local economies, and on green spaces for people to relax, congregate, and shop.

3 **Individual Trip Vehicles**

Lastly, only after other needs are served, cities should allocate space to individual trip vehicles, whether shared, fleet, or personal, and ride-hail services.

Zones of the Future Street

The Flex Zone



Pick-up/Drop-off

Curbside access is in heavy demand by transit, freight, and ride-hail. Cities should develop modal hierarchies to optimize curb use and minimize the impact of private cars.

Active Transportation

Active transportation needs, including bike racks, bike share stations, shared micromobility corrals, and other capital investments deliver tremendous public benefits. Curbside priorities must account for social goods as much as they find ways to manage dynamic payment.

Public Amenities

The conversion of curbside space into public space should continue as a major priority for cities. The economic and social benefits of parklets, bioswales, curb extensions, and other amenities should not be overlooked, even as new uses crowd the curb.

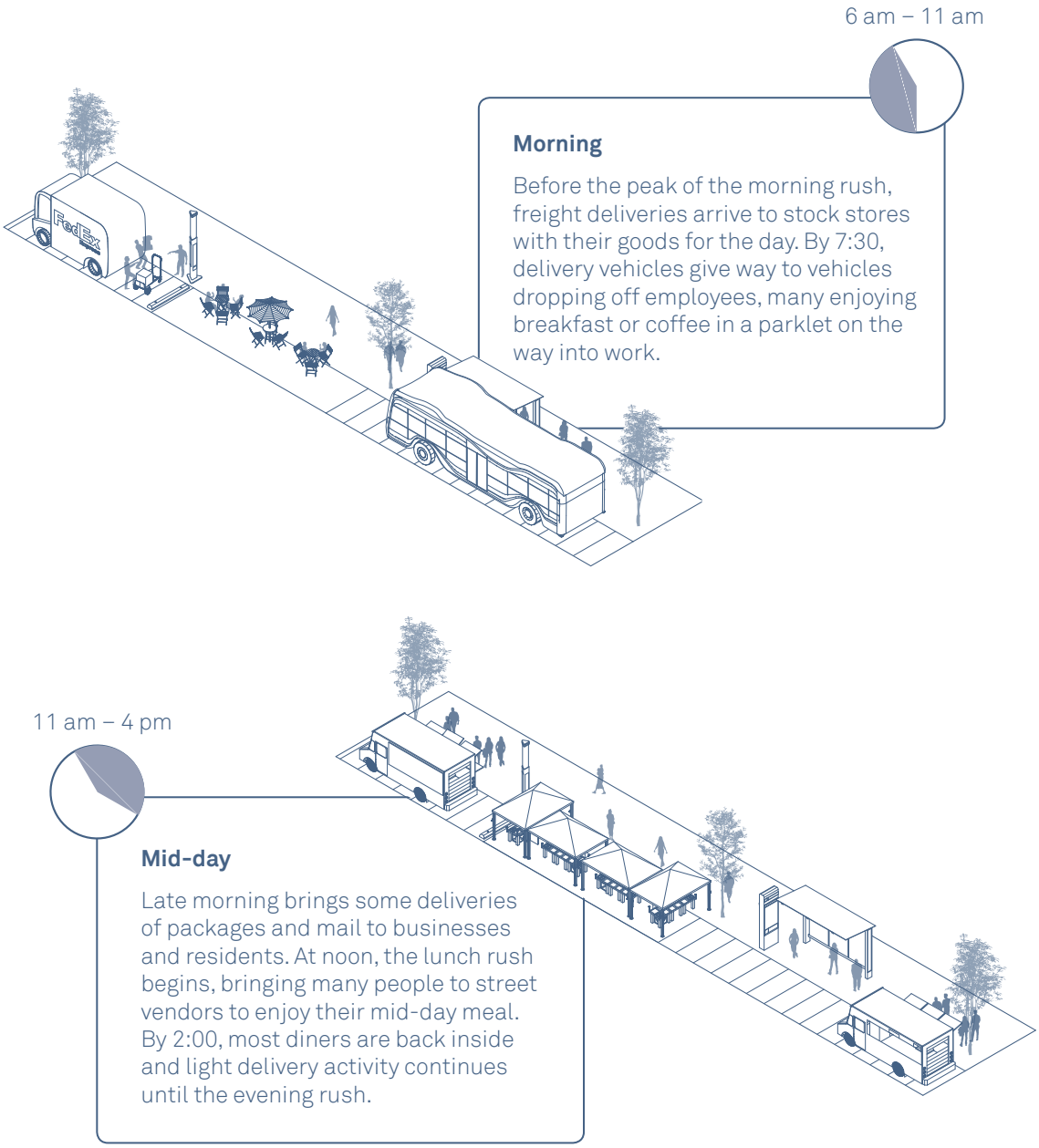
Safety Features

Intersection design treatments, like crosswalks and bulbouts, also represent curbside uses and need to be accounted for when devising prioritization frameworks for the curb.

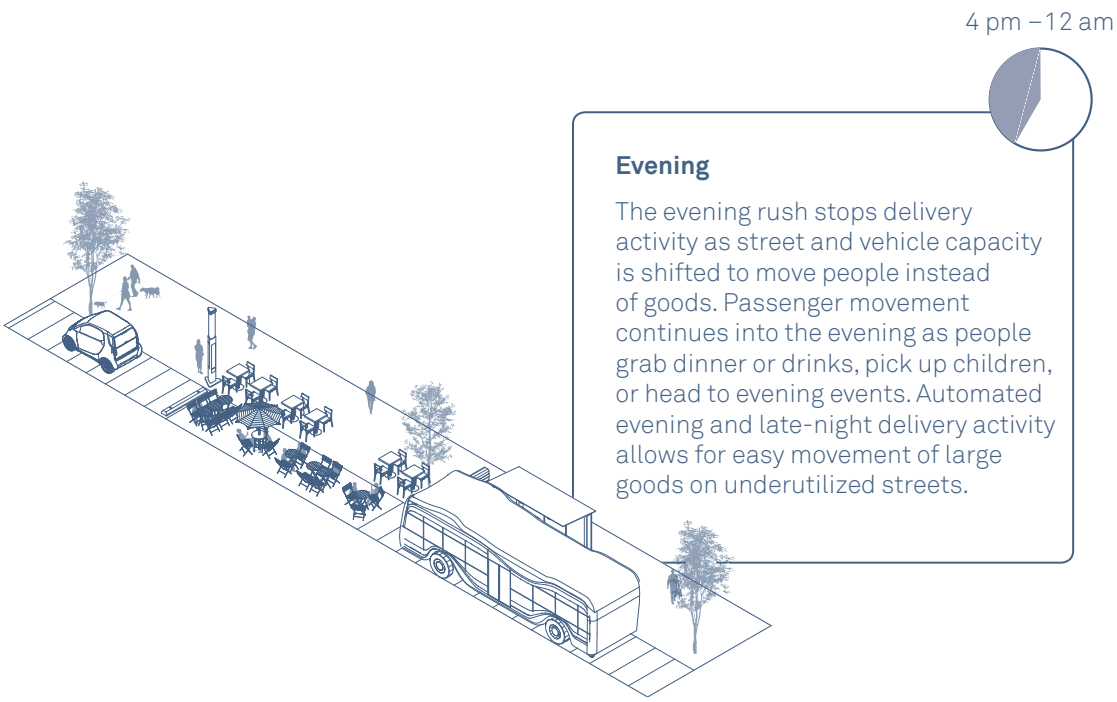
Coding the Curb

As cities update curbside regulations and shift to demand-based management systems, they must ensure that this information is coded in formats that are standardized, open, and available to street users. In particular, a strategic flow of data about how curbside assets are used can help cities understand demand throughout the day and prioritize modes and uses accordingly. Already, new data sharing pilots are focusing on curbside management pilots as a testbed for public-private collaborations.

Cities should begin by inventorying curbside uses and regulations, and using new technologies like LIDAR to collect and automate data. Owning and managing curbside asset data is the number one way that cities can assume control over the future of the curb, especially as private sector actors begin to catalog curbside data for their own traffic management.



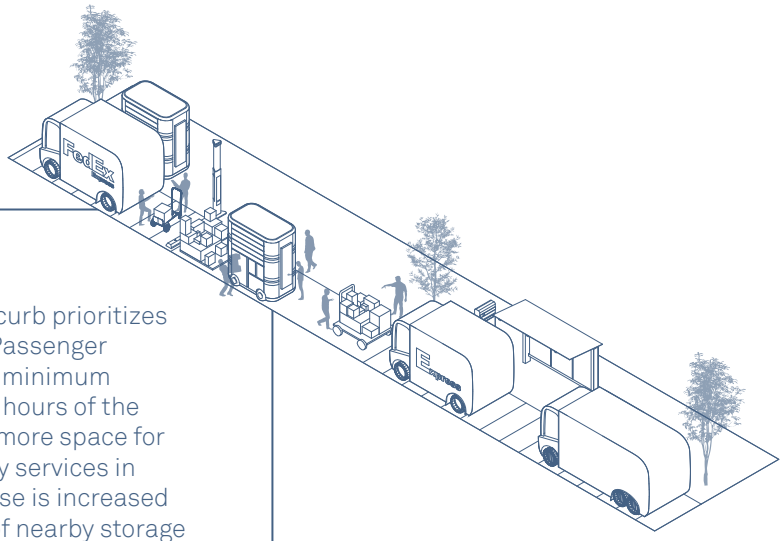
4 pm – 12 am



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.

12 am – 6 am



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.