v1 **Street Design Principles**

SIDE|WALK|LABS

About the Principles.

These Sidewalk Labs Street Design Principles reflect our belief that cities can leverage new and emerging mobility technologies, such as connected and autonomous vehicles, to make their streets safer, more comfortable, and more efficient — for all modes.

Sidewalk Labs' mission is to radically improve quality of life in cities. The ability to confidently and comfortably ride a bike or meander down the street is critical to that mission. So is the ability to get where you need to go as efficiently as possible, which often involves traveling in a vehicle. These two needs can often be at odds with each other, but while the vehicle usually wins today, the balance is starting to shift.

Many cities, like Boston and Toronto, have published Complete Streets Guidelines to promote design standards for pedestrians, bicycles, transit, and public space. In 2017, NACTO released its Blueprint for Autonomous Urbanism to "proactively guide the [self-driving vehicle] technology to prioritize people-first design." Sidewalk Labs aims to build on these ideas by asking: "Instead of teaching new mobility services to operate on today's streets, can we take advantage of new technologies to fundamentally redesign the street?"

This living document proposes design principles that strive to harness these advances to create safer and more flexible streets. These principles will be updated periodically based on collaboration with city planners, engineers, mobility providers, and technology companies — and by Sidewalk Labs itself, as we test designs in prototype and pilot environments.
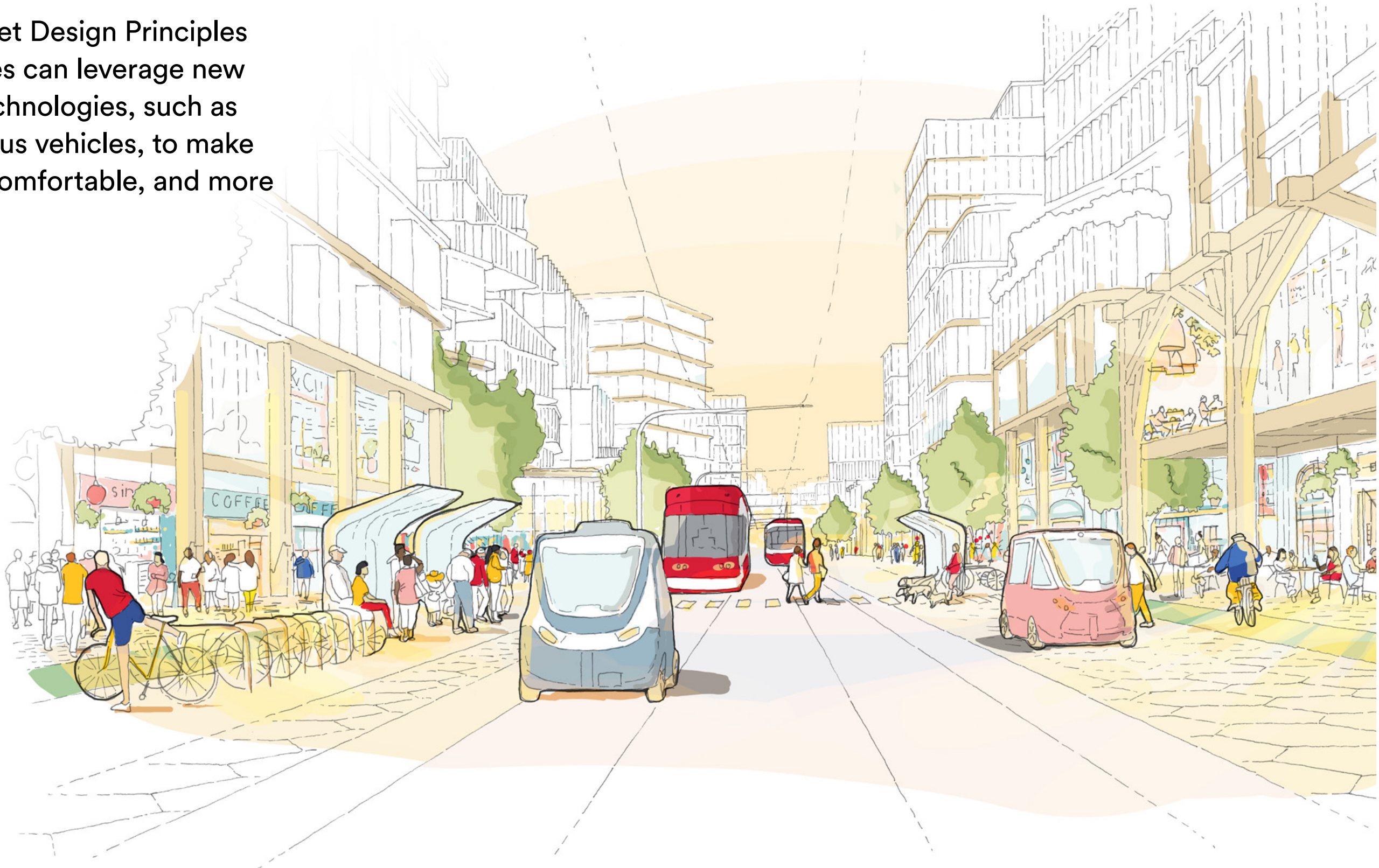
Streets Today.

Cities often have the worst of both worlds when it comes to street design: top speeds that create safety risks but average speeds that frustrate everyone. The common solution is often to add lanes and buffers, but that approach can do more harm than good.

Cities often design streets to be safe by making them wide, but wide streets cause speeding.

Streets today are designed to allow vehicles to move quickly. But this decision requires streets to be designed defensively as well — because speed kills. As a result, engineers design wider lanes to account for drivers who drift or veer, and they design buffer spaces like shoulders, medians, and street-parking areas to try to improve pedestrian and cyclist safety. But they are not safe; more than 6,700 pedestrians and cyclists died on streets in the United States in 2017 due to automobile crashes.[1] Neither pavement markings nor bollards are enough to protect vulnerable bicycles and pedestrians — and certainly not enough to make them feel comfortable.

This approach doesn't help move people, either.

Despite being engineered for speed, today's streets are often congested — and frustratingly slow. Congestion caused by double-parking and uneven distribution of traffic volume across the day leads to lower average speeds overall. In 2018, nearly every major U.S. city recorded a downtown last-mile travel speed below 20 mph.[2] In downtown Toronto, the speed limit is 40 km/h (~25 mph), but most vehicles travel at an average speed of 24 km/h (~15 mph) — and some much, much slower than that.[3] As a result,

drivers and passengers are still frustrated with long, stop-and-go commutes.

One common solution is to add even more lanes, but this leads to streets that can feel empty, because they've been designed for the worst-case traffic scenario.

In an effort to accommodate more vehicles, engineers have defaulted to calculating the space needed to handle peak, rush-hour demand. The result is acres of pavement that are empty most of the time and are neither pleasant to walk around nor conducive to the types of welcoming urban spaces that encourage street life. Part of the reason engineers feel the need to plan for worst-case traffic scenarios is because curbs and pavement markings are set rigidly into place and unable to adapt to changing needs.

[1]   "2017 Fatal Motor Vehicle Crashes: Overview," US Department of Transportation National Highway Traffic Safety Administration, October 2018, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812603.

[2]   INRIX defines inner city last-mile speed as "the speed at which a driver can expect to travel one mile into the central business district during peak hours." "INRIX 2018 Global Traffic Scorecard," INRIX, February 2019, http://inrix.com/scorecard/.

[3]   "Congestion Trends in the City of Toronto (2011-2014)," McMaster Institute for Transportation Logistics, September 15, 2015, https://www.toronto.ca/wp-content/uploads/2017/11/91f0-city_congestion_trends_09-15-2015.pdf.

Photo: "Rockaway Blvd," by Tdorante10

The Opportunity.

Technology is not a cure-all solution to mobility challenges. But it offers the chance to fundamentally redesign our street system with narrower, safer streets that still get people where they need to go.

Connected and autonomous vehicles (CAVs) can be required to follow speed limits and can operate in narrow streets where lanes may appear, disappear, or change direction.

Connected vehicles are vehicles driven by people that receive warnings on speed limits, potential conflicts, hazardous conditions, and other detailed information to improve safety. Autonomous or self-driving vehicles are able to ingest this information and have the vehicle itself respond, without a person driving.

Together, CAVs can be expected to follow speed limits, stay out of areas that are restricted, and obey rules of interaction with cyclists and pedestrians. These advances also apply to e-bikes and e-scooters that could be programmed to remain in vehicle or bike lanes. Similarly, CAVs could safely travel on narrower streets that are prioritized for transit, bicycles, and pedestrians, including pedestrians using wheelchairs or other assistive devices.

Dynamic (LED-embedded) pavement and moveable street furniture can help adapt the number of lanes, the width of the sidewalk, and even the direction of the street, meaning that a narrower street can serve multiple uses based on demand.

The operation and character of a street can change daily when raised concrete curbs can be removed in favor of dynamic pavement and moveable street furniture. Several companies have started to experiment with dynamic pavement, which embeds LEDs into the surface to change the color and shapes of markings. These design features can be used to create travel lanes, bike lanes, transit lanes, or pick-up/drop-off zones. They can also be used to change a lane's travel direction, providing more flexibility than a fixed, grade-separated curb ever could.

Such a dynamic allocation of space allows for a potential reduction of vehicle space, creating safer crossing distances for pedestrians; providing a more pleasant walking and cycling environment; improving the travel experience for pedestrians using strollers, wheelchairs, or other types of wheels; and naturally slowing down vehicles that are used to wide lanes.

Sensors, digital signage, and integrated navigation apps and fleets can communicate real-time information on speed limits and lane closures.

Spatial occupancy sensors can give cities a better understanding of street conditions by generating real-time feedback like curb space availability or congestion on a given road. That information can be communicated directly to travelers through digital signage or via integration with vehicles and navigation apps.

It can also identify patterns that emerge over time, information that is critical to urban planners and traffic engineers. For example, BriskLUMINA sensor applications have helped planners in Atlanta and Pittsburgh identify intersections with higher than normal risk of pedestrian injury. Other cities have used sensors to help optimize traffic light timing.

Traffic management tools can recommend changes to lanes, speed limits, and pricing to maintain person-throughput or meet policy goals, such as Vision Zero.

Traffic management tools can make the most of roadway space and increase "person throughput," or the total amount of people traveling through an intersection, across all modes (not just vehicles). These tools include low-cost sensors, edge computing capabilities, machine-learning simulation models, and adaptive traffic signals that can adjust green times to optimize flow or prioritize certain modes. Together, these tools can form a mobility management system that can adapt to real-time street conditions by reallocating lanes and adjusting signal timings to keep all modes moving — and safe.

One promising management advance is the bicycle "green wave," which works with adaptive traffic signals to give cyclists a premium experience. LED indicators embedded at the edge of a bicycle lane can light up in front of cyclists to form a moving green segment. The segment sets the ideal travel speed for cyclists, so they arrive at intersections when the traffic signal is green. Information on speed and green times can be communicated by fleets and navigation apps.

The Principles.

With these new capabilities in mind, Sidewalk Labs developed an overlapping network of streets, each designed to prioritize certain modes, that can improve safety and the public realm without restricting movement.

We used four principles to design four different types of streets. These principles and street types are introduced briefly here and described in greater detail on the pages that follow.

Principle 1. Tailor streets for different modes.

New capabilities make it possible to design streets that prioritize certain modes, instead of aiming to accommodate all uses at all times of day. Laneways prioritize pedestrians while Accessways prioritize cyclists. Transitways give priority to public transit through dedicated lanes and signal priority. Boulevards are intended for all modes but primarily for vehicles.

Principle 2. Separate streets by speed.

CAVs and digital navigation tools enable faster street types to focus on moving people with vehicles and public transit, and slower street types to provide a safe and active environment for cycling and walking. Laneways operate at fast walking speed of 4 mph (8 km/h) while Accessways operate at 14 mph (22 km/h) - a brisk speed for most urban cyclists. Boulevards and Transitways have a speed limit of 25 mph (40 km/h), which evidence shows is the maximum speed consistent with pedestrian safety.

Principle 3. Incorporate flexibility into street space.

Adaptable infrastructure and real-time traffic insight make it easy for lanes to become "dynamic," serving different purposes across the day. Sidewalk Labs is exploring a concept we call the "dynamic curb" which could be reserved for vehicles or converted into public space, depending on priorities. Optimizing this space requires a management system to understand demand and congestion patterns at various times and can vary depending on local policy objectives.

Principle 4. Recapture street space for the public realm, transit, bikes, and pedestrians.

CAVs, adaptable infrastructure like dynamic pavement, and moveable street furniture enable cities to recapture space once devoted to parking and vehicles. This space can be reallocated to the public realm and high person-throughput modes, such as transit, while still enabling all travelers to get where they need to go.

These principles come together in the design of four different street types.
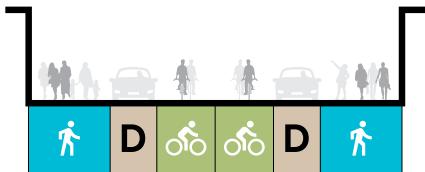
Laneway
TAILORED TO PEDESTRIANS
4 MPH / 8 KM/H

P	Parking
↑	Vehicle Lane
🚋	Transit ROW
🚴	Bike Lane
🚶	Pedestrian Only
D	Dynamic Curb *

Dynamic curb description on pages 5 and 8

Accessway
TAILORED TO BICYCLES
14 MPH / 22 KM/H

Transitway
TAILORED TO TRANSIT
25 MPH / 40 KM/H

Boulevard
TAILORED TO ALL MODES
25 MPH / 40 KM/H

Principle 1.

Tailor streets for different modes.

Because each transportation mode is different in size, top speed, and the vulnerability of the person traveling, we designed four types of streets that each prioritize one particular mode. Streets are narrower overall and tailored to the size and speed of the priority mode that they serve, with the goal of improving safety and comfort. This principle is consistent with "complete streets" principles, as space is provided on each street for every mode except for traditional vehicles driven by people, which are restricted to streets specifically designed for their movement.

For instance, streets designed for pedestrians and cyclists allow them to travel naturally, without being hemmed into "safe zones" — instead, the majority of space on that street is dedicated for their use. Street furniture and landscaping can create changes in width and travel paths that can slow vehicles. In addition, pavement texture, color, and patterns can be used to send tactile, auditory, visual, and other accessibility cues to pedestrians. However, for this approach to reach its full potential, it is critical to ensure that vehicles follow the designated speed limits for a given street — which would require restricting access by vehicles or requiring CAVs, ebikes, and other new mobility modes to limit their speed and behavior based on rules.

All streets are designed to accommodate emergency vehicles and disabled access, as necessary.

Traditional Vehicles	Transit	Bicycles	Pedestrians	Connected & Autonomous Vehicles
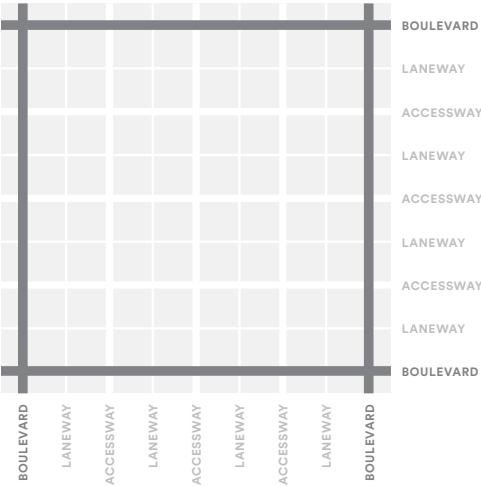
Boulevards

Boulevards are the only street type designed to accommodate **traditional vehicles**, which require buffer space between other modes for safety. However, Boulevards will be designed to safely accommodate transit vehicles, cyclists, and pedestrians as well.
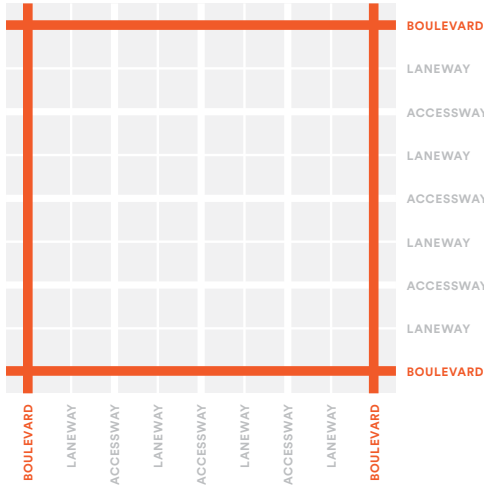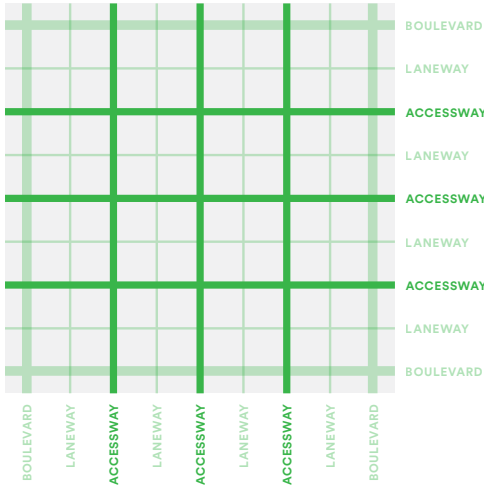
Transitways & Boulevards

On Transitways, priority is given to **transit vehicles** — through designated lanes and signal priority — to travel at their desired speed. Bike-share and scooter-share stations are co-located with transit stops to enable convenient transfers to other modes. Transit can also travel on Boulevards, but may not be given the highest priority.
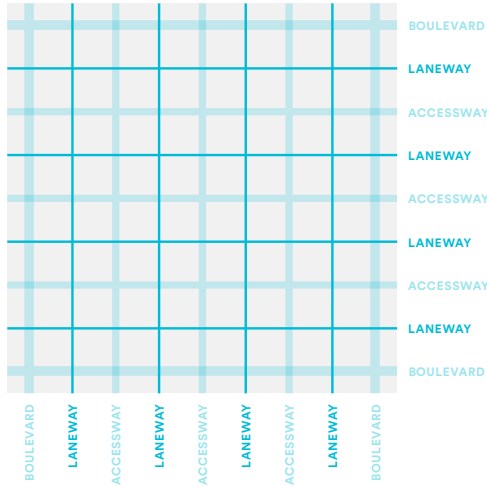
All Streets
priority on Accessways

On Accessways, center-running bike lanes with green waves will allow comfortable **cycling**.
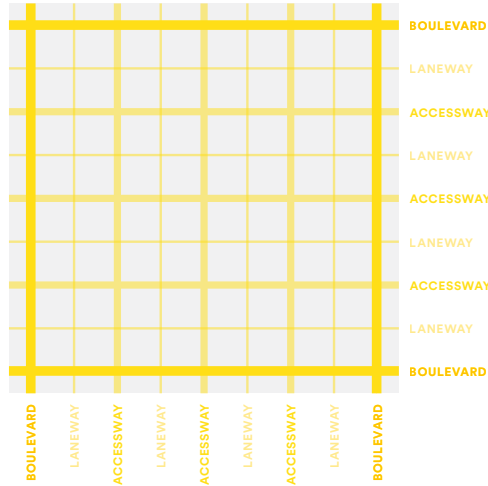
All Streets
priority on Laneways

On Laneways, street furniture and greenery will create safe yet lively paths for **pedestrians** whether they are trying to get somewhere quickly or just want to stroll through the city.

All Streets
CAVs defer to transit, cyclists, and peds

When they have proven an ability to follow speed limits and yield to other users, **CAVs** will be able to use every type of street, maintaining building accessibility for those who need it.

Principle 2.

Separate streets by speed.

Each street type is designed for the preferential speed of its priority mode. For example, the speed limit for every mode on Accessways is the average speed of a bicycle, about 14 mph (22 km/h). Streets become characterized by their speed and overall width for safety and comfort.

This design principle should translate into much greater safety, especially for cyclists and pedestrians. Research has found that collisions at 14 mph (22 km/h) may cause injury but are less likely to be fatal than ones over 30 mph (48 km/h), and a vehicle traveling at 4 mph (6 km/h) doesn't create discomfort or a safety risk for nearby pedestrians and cyclists.[4]

We designed Boulevards with barriers and buffer spaces so traditional vehicles can travel at 25 mph (40 km/h) and keep other modes safe, but we restrict all other streets to connected and autonomous vehicles that can adhere to the speed limit and yield to bikes and pedestrians.

Speed limits on each type of street will lead CAVs to naturally select the faster, wider streets for the most efficient trip — as a result, the only vehicles on Laneways and Accessways are likely to be those on the final leg of a door-to-door trip.

Boulevard route	**Boulevard route**	6 min travel time
	longest distance / fastest speed	
Laneway route	**Laneway route**	52 min travel time
	shortest distance / slowest speed	
Accessway route	**Accessway route**	20 min travel time
	medium distanct / medium speed	

4   "Road Safety Web Publication: No. 16: Relationship between Speed and Risk of Fatal Injury: Pedestrians and Car Occupants," DC Richard, Transport Research Library, Department of Transport, London, September 2010.

Principle 3.

Incorporate flexibility into street space.

Management tools can help traditional vehicles, CAVs, transit, and bikes flow at consistent travel speeds by reallocating flexible lanes to meet demand throughout the day. This process of optimizing streets requires several capabilities:

1. a real-time and historical understanding of travel demand and supply of road and curb space,

2. analytics to identify allocation of space alongside any pricing or regulation changes, and

3. physical or digital infrastructure to communicate those changes to travelers.

Sidewalk Labs plans to test this ability to manage flexible lanes in real time through its dynamic curb concept, which envisions a curbside lane that

can change uses throughout the day, becoming a passenger loading zone at peak times or public space at off-peak times. The hope is to build technical capabilities through the dynamic curb that can ultimately be applied to travel lanes as well.

The dynamic curb integrates several technologies to actively manage passenger pick-up and drop-off space, including availability sensors, digital signs, dynamic pavement indicators, dynamic pricing, vehicle dispatching, and reservations to create quick turnover of spaces when needed.

6   ENFORCEMENT CAMERA

A government-run enforcement system that is separate from the other elements mentioned here could provide tools for the mobility management authority to enforce regulations.

5   PARKING APP

An active pick-up/drop-off zone with available spaces will broadcast information to an API. Third-party apps can display this information inside vehicles or use data to schedule deliveries in advance.

4   DIGITAL SIGNAGE

A mobility manager can view the system and issue directions to navigation apps or change curbside rates.

3   DYNAMIC COLORED PAVEMENT

Dynamic pavement illuminates a divider between the pedestrian zone and the vehicle zone. When the curb lane is used for pick-up/drop-off, markings create spaces. When used as a sidewalk, markings are straight.

2   MOUNTED SENSOR

Mounted sensors can provide reliable information on which curbside spaces are available, as a back-up to in-pavement sensors.

1   IN-PAVEMENT SENSORS

Low-cost, easy to install, in-pavement sensors can detect when a vehicle is present. When the curb lane is used for pick-up/drop-off, the sensors are activated. When the curb lane is used as a sidewalk, they are not activated.
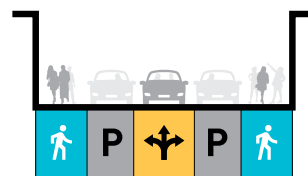
Principle 4.

Recapture street space for the public realm, transit, bikes, and pedestrians.

The improved performance of streets based on the first three principles should allow less space overall to be devoted to mobility, especially if cities and planners focus on "person throughput" rather than vehicle throughput as their guiding metric. The safety of vehicles that are self-regulating in terms of sp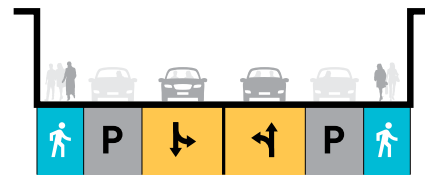eed allows every address to be reached by vehicles without undermining the focus of a given street on pedestrians, cyclists, or transit. The potential to do away with on-street vehicle storage and instead use dynamically-managed drop-off spaces offers width for other uses. As a result, streets can have a much greater amount of space devoted to human uses.

	Local	Collector	Minor Arterial	Major Arterial

Traditional Street Designs
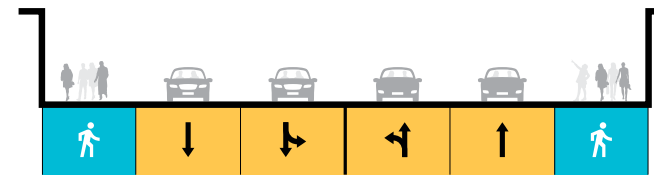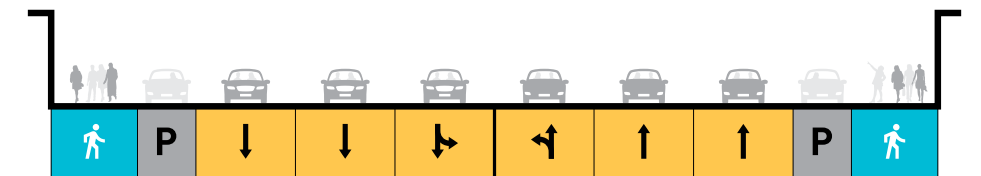
Sidewalk Labs Street Designs

Laneway PEDESTRIANS

Accessway BICYCLES
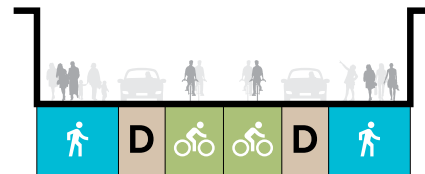
Transitway TRANSIT

Boulevard ALL MODES

Legend:
- Pedestrian Only
- P Parking
- Vehicle Lane
- Bike Lane
- Transit ROW
- D Dynamic Curb *

* Dynamic curb description on pages 5 and 8

Bringing It Together:

A New Street Network.

Collectively, these principles enable the design of a new street network that can accommodate the same throughput as today's streets while drastically improving safety and creating a robust public realm.

Retractable bollards at the ends of the Laneway can allow only bikes or small CAVs to enter. Bollards can be lowered by emergency vehicles or those who require larger vehicles for accessibility.

Laneways help people get places, but also are places unto themselves, filled with pop-up shops, street fairs, and other types of community gatherings.

Person-throughput capacity estimates*	Laneways with CAVs	Locals in a typical downtown
Speed limit	4 mph / 8 km/h	25-30 mph / 40-50 km/h
Typical average speed	4 mph / 8 km/h	15 mph / 24 km/h
In vehicles	~120 persons/hour	~200 persons/hour
On transit	n/a	n/a
On bikes	~400 persons/hour	~700 persons/hour
On foot	~2,250 persons/hour	~600 persons/hour
Total person-throughput	~2,770 persons/hour	~1,500 persons/hour

* Initial estimates based on Highway Capacity Manual 2010 and New York City City Environmental Quality Review Manual. Estimates will be updated based on meso/micro-simulation when available.

Laneways can be closed entirely for a summer block party

Laneways can still provide easy access for emergency and accessibility vehicles

To ensure accessibility without compromising comfort, Laneways permit self-driving vehicles as long as they travel at walking speeds. CAV usage and pick-up/drop-off is infrequent due to the pedestrian speed limit.

Laneways.

35 FEET / 11 METERS WIDE

Laneways are primarily pedestrian pathways where walking or strolling is pleasant. Cycling or slow vehicle travel is permitted at the designated speed limits to ensure pedestrian priority and discourage Laneway use for long-distance travel.

To ensure accessibility without compromising comfort for pedestrians and cyclists, Accessways permit self-driving vehicles as long as they travel at cycling speeds.

Moveable street furniture helps to create a barrier between travel lanes and pedestrian zones.

Person-throughput capacity estimates*	Accessways with CAVs	Collectors in a typical downtown
Speed limit	14 mph / 22 km/h	25-30 mph / 40-50 km/h
Typical average speed	14 mph / 22 km/h	15 mph / 24 km/h
In vehicles	~850 persons/hour	~430 persons/hour
On transit	n/a	n/a
On bikes	~2,600 persons/hour	~700 persons/hour
On foot	~380 persons/hour	~200 persons/hour
Total person-throughput	~3,830 persons/hour	~1,330 persons/hour

* Initial estimates based on Highway Capacity Manual 2010 and New York City City Environmental Quality Review Manual. Estimates will be updated based on meso/micro-simulation when available.

Accessways are prioritized for public realm on Saturday afternoons in summer

Accessways move people through bikes and CAVs during rush hour in winter

Accessways.

50 FEET / 16 METERS WIDE

Accessways are narrower streets that prioritize micromobility modes like bikes and scooters — when connected, Accessways form a bicycle network that rivals the travel time and convenience of transit and vehicles.
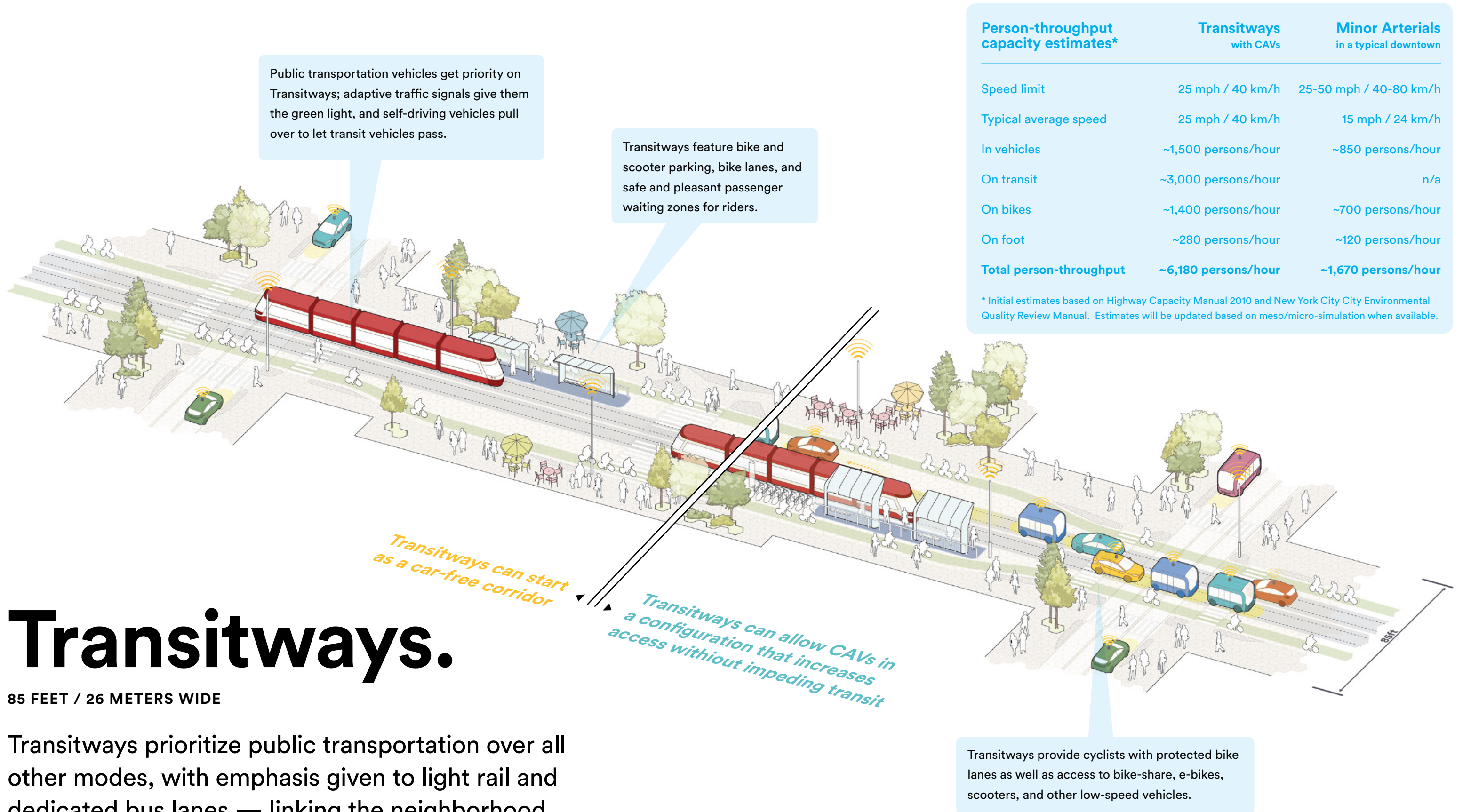
Center-running bike lanes use LED green waves, which help cyclists maintain an optimum speed to avoid being stopped at intersections.

Transitways.

85 FEET / 26 METERS WIDE

Transitways prioritize public transportation over all other modes, with emphasis given to light rail and dedicated bus lanes — linking the neighborhood to the city's greater transit system.

Public transportation vehicles get priority on Transitways; adaptive traffic signals give them the green light, and self-driving vehicles pull over to let transit vehicles pass.

Transitways feature bike and scooter parking, bike lanes, and safe and pleasant passenger waiting zones for riders.

Transitways can start as a car-free corridor

Transitways can allow CAVs in a configuration that increases access withiout impeding transit

Transitways provide cyclists with protected bike lanes as well as access to bike-share, e-bikes, scooters, and other low-speed vehicles.

Person-throughput capacity estimates*	Transitways with CAVs	Minor Arterials in a typical downtown
Speed limit	25 mph / 40 km/h	25-50 mph / 40-80 km/h
Typical average speed	25 mph / 40 km/h	15 mph / 24 km/h
In vehicles	~1,500 persons/hour	~850 persons/hour
On transit	~3,000 persons/hour	n/a
On bikes	~1,400 persons/hour	~700 persons/hour
On foot	~280 persons/hour	~120 persons/hour
Total person-throughput	**~6,180 persons/hour**	**~1,670 persons/hour**

* Initial estimates based on Highway Capacity Manual 2010 and New York City City Environmental Quality Review Manual. Estimates will be updated based on meso/micro-simulation when available.

Though meant for faster traffic, Boulevards still improve safety for all street users by featuring separated bikeways for cyclists and traditional (though curbless) sidewalks for pedestrians.

Boulevards include dynamic curb space that can be used as ride-hail or taxi pick-up/drop-off zones during heavy travel periods.

Person-throughput capacity estimates*	Boulevards with CAVs	Major Arterials in a typical downtown
Speed limit	25 mph / 40 km/h	25-50 mph / 40-80 km/h
Typical average speed	25 mph / 40 km/h	15 mph / 24 km/h
In vehicles	~2,000 persons/hour	~1,300 persons/hour
On transit	~3,000 persons/hour	n/a
On bikes	~1,400 persons/hour	~700 persons/hour
On foot	~250 persons/hour	~120 persons/hour
Total person-throughput	~6,650 persons/hour (~3,650 w/o transit)	~2,120 persons/hour

* Initial estimates based on Highway Capacity Manual 2010 and New York City City Environmental Quality Review Manual. Estimates will be updated based on meso/micro-simulation when available.

Boulevards can be optimized for through movement

Boulevards can be optimized for expanded public realm

Boulevards.

100 FEET / 31 METERS WIDE

Boulevards accommodate all modes but are geared towards moving people efficiently without sacrificing safety.

These streets are designed to carry the highest vehicle volumes but also to make up a minority of the street network. They are ideally spaced far enough apart to create significant zones of pedestrian and bicycle-only streets. On Boulevards, modes are separated from each other by barriers and buffers, and speeds are restricted to 25 mph (40 km/h).

The Boulevard is the only street type designed to accommodate traditional (person-driven) vehicles. Parking facilities for traditional vehicles are accessible via Boulevards.

Streets for an Integrated Mobility System.

The Street Design Principles should be considered just one part of an overall mobility strategy. Even the best-designed street network can only realize its full potential as part of an integrated transportation system with many trip options.

Much of Sidewalk Labs' thinking on streets has been developed in the context of our Sidewalk Toronto project in Toronto, Ontario, which also shows how we believe these street design principles should be applied in the context of overall mobility planning.

At Sidewalk Toronto, our planning is anchored by the extension of a high-capacity light rail transit network — knowing that public transit is by far the most efficient way to connect people and jobs across dense urban areas. It continues with expanded walking and cycling infrastructure to encourage the use of active transportation modes, with bike-share, scooter-share, and other low-speed vehicle options playing an increasing role.

Finally, new mobility options — such as carshare, taxi, and ride-hail services — can help reduce the need for residents or workers to own a car while still facilitating vehicle trips.

Successful mobility management most likely requires that one entity be empowered to manage the mobility tools in concert. In addition to allocating space dynamically, this manager should be empowered to use tools like regulation changes, pricing, and adaptive traffic signal management to achieve the policy goals and performance targets that are set.

The Street Design Principles are the foundation for this integrated mobility system, providing the infrastructure and framework for cities to balance the need to move people with the re-emergence of streets as vital community space.

Next Steps.

In the coming year, we'll test our principles — and the designs and technologies that enable them — through real-life prototypes, always seeking feedback from experts and communities.

The goal of these prototypes will be to gauge how drivers, pedestrians, and cyclists react to these designs and, in particular, the dynamic elements.

Over the course of 2018, Sidewalk Labs hosted a series of co-design sessions, events, and workshops in order to engage with the accessibility community and co-create our accessibility principles with them. We remain committed to these principles, which will evolve as we receive more feedback, and we will continue to work with the accessibility community to ensure our street designs work for all people with lived experience of disability.

We'll have a better understanding of how dynamic pavement, bicycle LEDs, and sensor hardware work — and begin to test operational, maintenance, and life-cycle costs.

We'll bring these elements together in order to test for safety, operability, and throughput.

Most importantly, we'd like to hear from you — the mobility engineers, planners, advocates, providers, disrupters, and enthusiasts. Let us know what you think, and help us drive towards the next version of these designs.

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Prototype of Kinaptic LightPavers installed at Sidewalk Toronto's 307 campus.

Acknowledgements.

This set of street design principles was developed by:

The authors would like to acknowledge the important contributions of: