Rethinking Streets: Urban Life with Autonomous Vehicles

by

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Rethinking Streets: Urban Life with Autonomous Vehicles

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ABSTRACT:

Historically, streets have served a range of functions, primarily those associated with traffic circulation and social interaction. However, in the 20th century, the street design became centered on traffic movement and maximum space for automobiles, while public lives were marginalized to narrow sidewalks. Contemporary urban planners and designers have acknowledged that both livability and efficiency are indispensable components to a city's sustainable development. However, to achieve them both is a difficult task with the conventional dominance of automobiles.

This thesis explores the mutual influence of urban design and transport technology, and offers a solution to rethink streets as urban surfaces, which integrate traffic infrastructure and the public realm with the application of shared autonomous vehicles. The thesis presents a new design paradigm based on a three-prong approach: 1) design of shared surfaces for pedestrians, cyclists and vehicles as a continuous public living room; and (2) inclusion of efficient surfaces that provide dedicated space for shared vehicles and cyclists to collect and distribute people at a faster speed; and (3) inclusion of the transition zone between shared surfaces and efficient surfaces. Another feature of this thesis is a new approach to the design of these autonomous vehicles that combines the self-driving technology of autonomous vehicles with new robotic features that tell vehicles when to reduce speed to share surfaces with pedestrians, and when to resume speed on dedicated surfaces.

Using South Boston Waterfront as a case study, the thesis shows that cities do not have to remain under the dominance of vehicles; and that urban life can gain new spatial integrity that serves the needs of people and, at the same time, responds to the realities of urban mobility.

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RETHINKING STREETS:
Urban Life with Autonomous Vehicles

SMArchS Urbanism Thesis, May, 2018

Daya Zhang

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Before coming to the graduate school, I know I have an interest in transportation, but I am not sure what exact areas I could contribute as an architect and urban designer. Fortunately, I had the chance to meet so many talented and generous people who have guided me in the right direction to find an interesting thesis topic. Exciting ideas and interdisciplinary collaborations not only occur in classes, discussions, and lectures, but also take place over a coffee, at the dining table, or even on the way home along Mass Ave. Here, I want to express my gratitude to all people who have helped and challenged me in the past two years.

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- Marshall Berman

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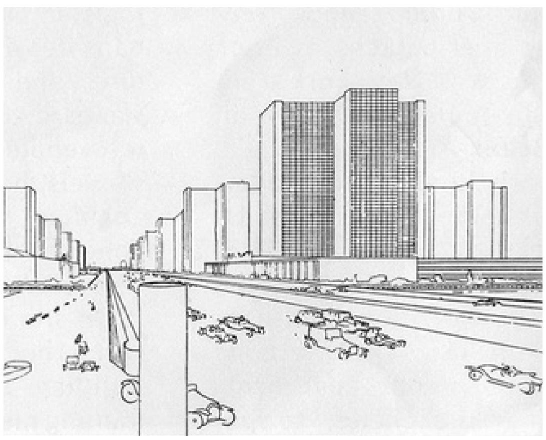
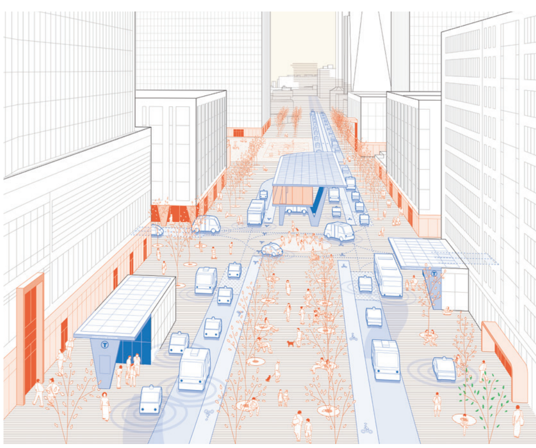


20th Century
Highway

"The hallmark of 20th century urbanism has been the highway, a means for putting them asunder." - Marshall Berman

Figure 0.2: A Contemporary City, 1929, illustration from *The City of Tomorrow and its Planning* by Le Corbusier



21st Century
Urban Surface

As proposed by this thesis, the identity of 21st century will be a new type of urban surface embracing social mixing without compromise of traffic efficiency.

Introduction

Historically, streets have served several functions, primarily those associated with traffic movement and social interaction. Like the 19th century Boulevard, streets belonged to the people. The Boulevard culture encouraged people from all backgrounds to see and be seen in the street. However, since the mass application of automobiles in the 20th century, streets have become a machine for traffic where automobiles dominate. The car-dependent culture perusing personal freedom has a big appetite for space and has marginalized public lives to narrow sidewalks, or even stripped people off from the streets. According to Victoria Transport Policy Institute, a single occupant automobile moving at 20mph requires space 75 times bigger than a pedestrian does. No wonder that, today in a motorized city, 30-60 % of the urban land is devoted to roads and parking, compared to the 10% mainly for pedestrians in the pre-automobile era (Rodrigue, 2017).

If it is true as Marshall Berman once remarked in his book, *All That Is Solid Melts into Air*, “the distinctive sign of 19th century urbanism was the boulevard, a medium for bringing explosive material and human forces together; the hallmark of 20th-century urbanism has been the highway, a means for putting them asunder.” Then my question is that, what is the identity of 21st-century urbanism? Contemporary urban planners and designers have acknowledged that both livability and efficiency are indispensable components to a city’s sustainable development. However, to achieve them both is a difficult task with the conventional dominance of automobiles. Since the application of transport technology can cultivate lifestyle and shape streetscape, this thesis sees the transition from conventional automobiles to shared autonomous vehicles as an opportunity to create a new paradigm for people-centric urban design.

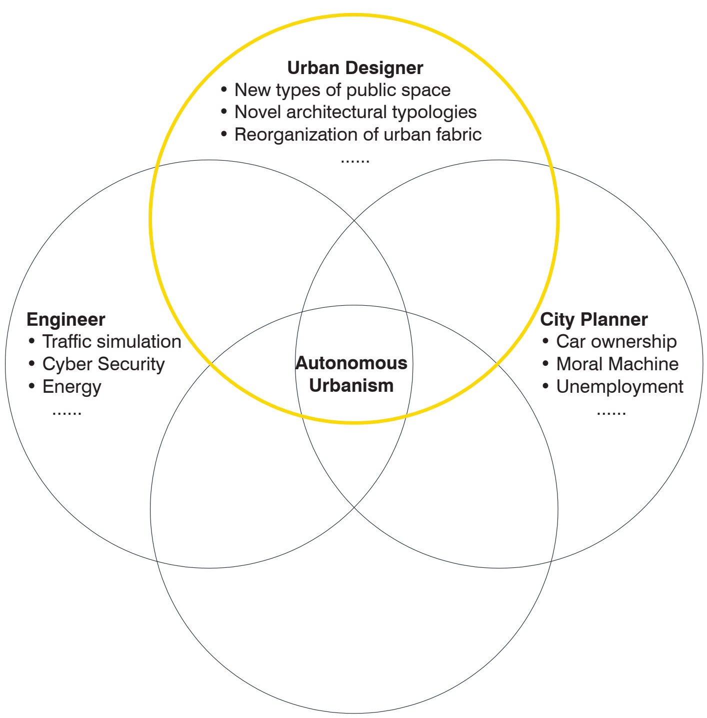
Thanks to advances in technologies, including GPS, high-definition digital maps, sensors and artificial intelligence, autonomous vehicles could improve our lives by offering increased safety, optimized efficiency and freeing-up space from cars for pedestrians. More importantly, the new technologies provide an opportunity to create new forms of pedestrian experience and new ways of inhabiting cities where efficiency and livability are both addressed. This is a challenging undertaking requiring interdisciplinary collaboration between technologists, who are working to improve the automated driving systems and hardware, scientists, who are running simulations to ensure efficiency, and planners, who are revising policies to regulate the use of the new technology. To complement the studies mentioned above, this thesis calls for reorganization of urban fabrics, new forms of public space and novel architectural typologies.

The thesis has four chapters, covering history, technology, strategy, and design. Chapter 1 goes back in time to trace the shifting priorities- traffic or people in street design. The 19th-century Boulevard and the 20th-century Highway are analyzed to demonstrate the mutual influence of urban design and transport technology. In addition, contemporary attempts, such as the Shared Space, are studied to learn the potentials and constraints to re-balance the relationship between traffic and people under today's dominance of automobiles.

To establish premises for the new paradigms, Chapter 2 reviews common features and working mechanism of autonomous vehicles. Moreover, to better realize the people-centered urban design, this chapter recommends combining the self-driving technology of autonomous vehicles with new robotic features that tell vehicles when to reduce speed to share street and communicate with pedestrians, and when to resume speed on dedicated areas. Total percentage of space freed up by taking advantages of the new technologies are calculated base on a typical streets with four traveling lanes.

By employing a new fleet of shared, electric, autonomous vehicles, Chapter 3 presents a new design paradigm by rethinking streets as urban surfaces based on a three-prong approach: 1) design of shared surfaces for pedestrians, cyclists and vehicles as a continuous public living room; and (2) inclusion of efficient surfaces that provide dedicated space for shared vehicles and cyclists to collect and distribute people at a faster speed; and (3) inclusion of the transition zone between shared surfaces and efficient surfaces.

Chapter 4 uses South Boston Waterfront as a case study because the peninsular study area is one of the piloting sites permitting AVs to move on city streets. More importantly, as the site is developing into a world-class innovative district to attract more people to live, work and play, it faces challenges of increasing traffic pressure and lack of public space. Therefore, it is essential to update the streetscape with the new design methodology to improve the traffic efficiency and the public realm. The design proposal for the full-autonomous era shows cities do not have to remain under the dominance of vehicles; and that urban life can gain new spatial integrity that serves the needs of people and, at the same time, responds to the realities of urban mobility.



1 HISTORY | TIMELINE

Urban Design & Transport Technology
19th Century | Boulevard
20th Century | Highway
Where We Are Now

Urban Design & Transport Technology

Looking back to the history, regardless of transportation development, walking has remained the one continual mode of travel for human beings. To satisfy our desires to go further and faster, various mechanized transportation technologies by sea, by land or by air, have been invented (Lay, 2015), usually with one replaced the other. Ideally, those technologies are used to improve our lives, but sometimes our lives are adjusted to fit the vehicles and infrastructure.

Admittedly, cities are complex and shaped by many forces, while the application of transport technology is one of the dominant forces that has led to changes in urban form (Newman, 1999). Since people started using something other than their own feet to travel, boats, horses, omnibuses, elevators, subways, and cars have all influenced spatial layout and land allocation in the city. Although the process might be slow, the accumulated effects could be significant. For example, before the arrival of the automobile, pedestrians occupied most of the street space, which took less than ten percent of the urban land (Figure 1.1). By comparison, in any typical motorized city today, about half of the city land is designated for roads and off-street parking. Within this right-of-way, pedestrian areas use only ten to twenty percent (Figure 1.2). Although vehicular traffic dominates the landscape, on average, cars are in use less than five percent of the time; the rest of the time, they are idling on the precious land, which could have been utilized for other purposes (Rodrigue, 2017).

Reversely, urban form shape our lifestyle and preference over modes of travel. The following analysis of the 19th-century boulevard culture and 20th-century car-dependent lifestyle gave two examples of how we succeeded or failed to remake the world to fit our life by applying new technologies.

Figure 1.1: A Street in Jerusalem shows a typical street primarily for pedestrians in the pre-automobile era. Photo from the Internet.

Figure 1.2: Massachusetts Ave, Cambridge, a typical thoroughfare with four traveling lanes and street parking.

19th Century | Boulevard

Historically, streets have served several functions, primarily those associated with traffic movement and social interaction. Like 19th century Boulevard, streets belong to the people. The “boulevard culture” encouraged people from all backgrounds to stroll, window-shop, see and be seen on the promenades and in the cafés along the city’s wide streets (Orum, 2010). Although not directly related to transportation, new technologies during that period – the introduction of pavement and sidewalks, gas and electric illumination- were all utilized to enable the realization of the new type of street and enhance public lives (Orum, 2010).

The boulevards were first implemented in Paris by Georges-Eugene Haussmann from 1852 and later were introduced as the basis for public space development in America under the name of the City Beautiful Movement. Examples include Daniel Burnham’s 1909 plan of Chicago, which intended to promote formal and informal interactions through diagonal Broadways across the city. As Marshall Berman said, “the street (the 19th-century boulevard) belonged to the people, while in contrast, the highway implemented next century brought up the antithesis: No Streets, No People, but a Machine for traffic (Le Corbusier, 1927).

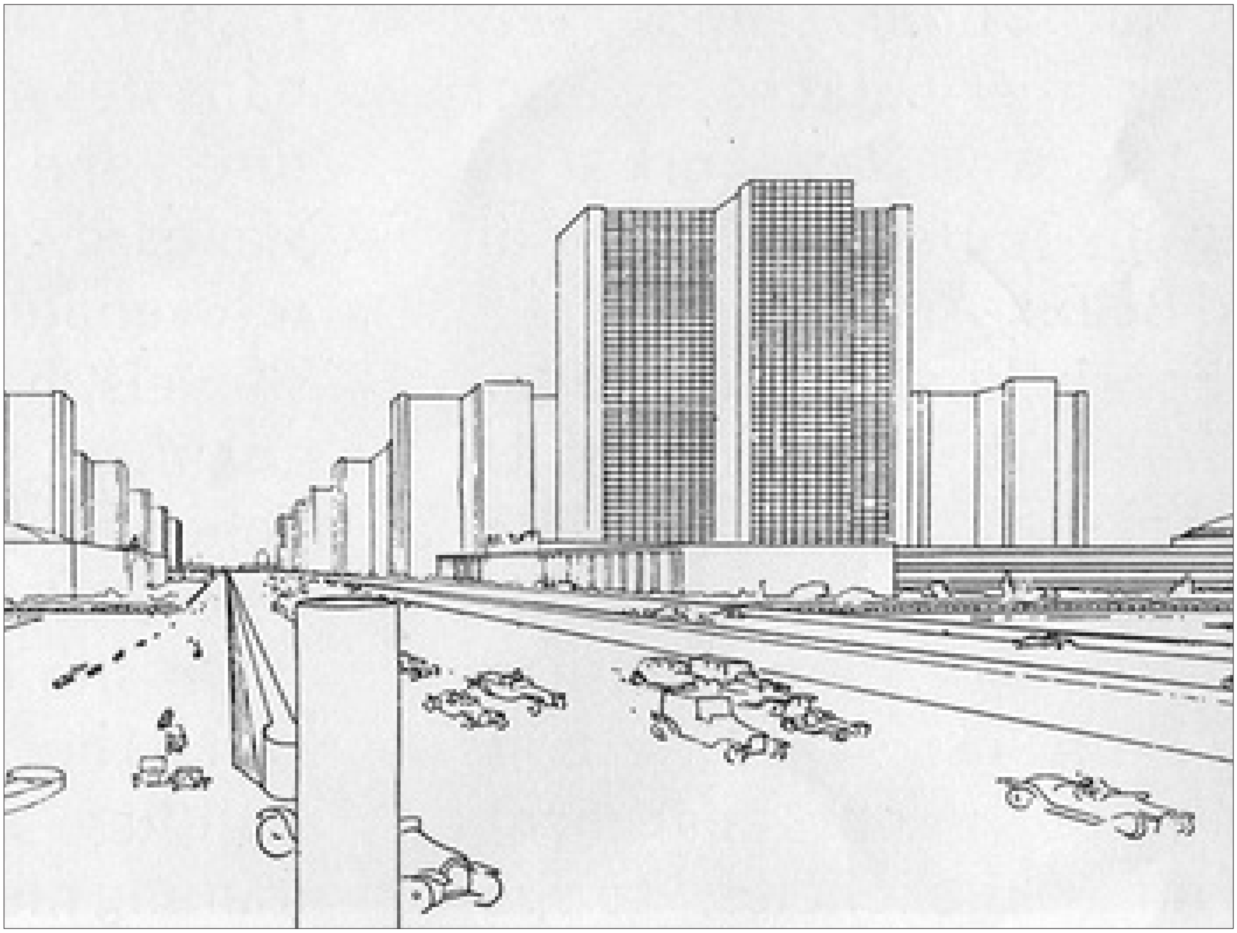
Figure 1.3: The Street Belongs to the People. *Le Boulevard Des Capucines,* 1873, oil painting by Claude Monet

Figure 1.4: The “Boulevard Culture” encouraged people from all backgrounds to stroll, windowshop, see and be seen in the street. *La Parfumerie Violet* ,1880, oil painting by Giuseppe De Nittis

20the Century | Highway

From CIAM's dominate concept of the Functional City in the 1920s, through Le Corbusier's City of Tomorrow, to the "Buchanan Report" of 1961 addressing the traffic efficiency, the principle of segregation of traffic from pedestrians developed as the foundation for urban backbones. The familiar elements of signals, signs, marks, curbs, barriers, underpass and overpass all stem from this principle. The mass application of automobiles in the 20th century restructured streets to be a machine for traffic where cars dominate. People were marginalized to the narrow sidewalk or even stripped off from the street.

The problem is not with the transport technology itself but is associated with the way we use it and the cultivated lifestyle coming along. In this case, the car-dependent lifestyle perusing personal freedom has a big appetite for space. For example, a single occupant automobile moving at 20mph requires space 75 times bigger than a pedestrian does. No wonder, today in a motorized city, 30-60 % of the urban land is devoted to roads and parking, compared to the 10% mainly for pedestrians in the pre-automobile era.



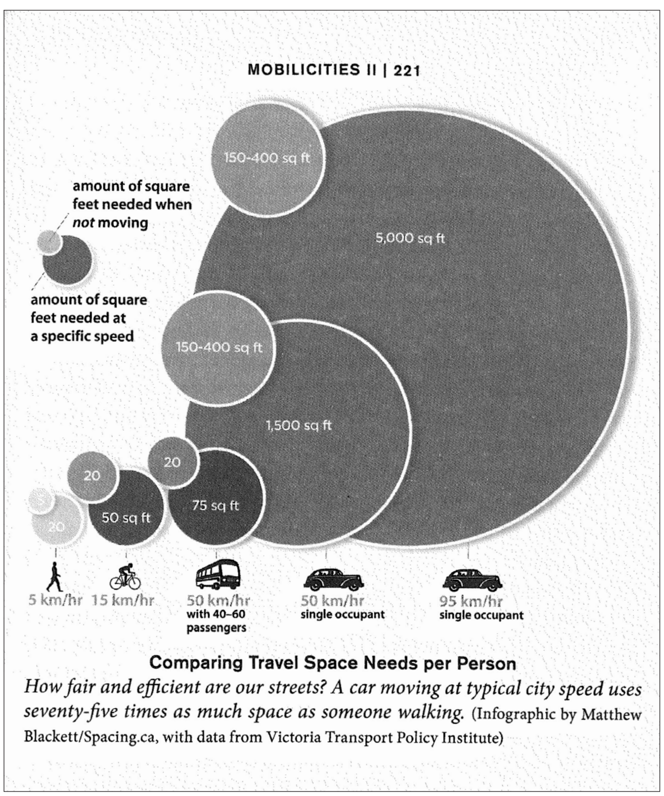


Figure 1.5: "No Street, No People......A Machine for Traffic." A Contemporary City, 1929, illustration from *The City of Tomorrow and its Planning* by Le Corbusier

Figure 1.6: Car-dependent lifestyle perusing individual freedom has a big appetite for space, including those associated with traveling and parking. Infographic by Matthew Blackeett/Spacing.ca

21st Century Challenge

Rejecting to apply highway thinking to urban streets and let them dominated by cars, urban planners and designers have advocated to bring back human factor on the street. Those advocates include Jane Jacob and Jan Gehl active in the 20th century, as well as Janette Sadik-Khan and Jeff Speck who are active in today's practice. On the other extreme, many cities, such as Oslo, Madrid and Mexico City, are considering banning cars in the city center to give space back to the pedestrians (Garfield, 2018). I am not advocating to ban cars but agree with Alex Wall that the challenge of the 21st century is "the reworking of movement corridor as new vessels of collective life". Vehicles should not be banned but be restrained as an equal participant on the street.

Experiment: Shared Space

To achieve this goal, different experiments have been done across the world. One of them is the Shared Space, which intends to integrate traffic infrastructure and the public realm by minimizing the segregation between modes of travel to let pedestrians, cyclists, cars use street more efficiently at different times. All street users negotiate right-of-way through courtesy and interactions, such as eye contact and gesture. Examples such as Exhibition Road in London have demonstrated positive effects on road safety, traffic volume and economic vitality. The shared space originated in the Netherland during the 1960s. It is also known as "Woonerf" or "Home Zone" in different countries.

The most notable pioneer of Shared Space concept is Hans Monderman, a traffic engineer and former Head of Road Safety for the northern provinces of the Netherlands. Through his practice and observation, Monderman believed that traditional traffic safety infrastructure endangers pedestrians and cyclists rather than protects them, because

"In Popular Culture, the instruments and spaces of mobility - especially the automobile and the freeway- have provided new sites of collective life. A real challenge to urban design is to accept that infrastructure is as import-ant to the vitality and experience of the contemporary metropolis as the town hall or square once was...... to create a new and public type of urban corridor, collecting, distributing a, and connecting a great range of users and functions. ***As we move into the 21st century, one of the primary roles of urban design will be the reworking of movement corridors as new vessels of collective life****."*

- Alex Wall*, Programming the Urban Surface , 1999*

Figure 1.7: Portrait of Alex Wall from http://www.alexwall.com/

all those signs ensure cars of their exclusive use of the road space, and there is no need to pay attention to the surroundings. Therefore, Monderman proposed to remove all traffic safety infrastructure and let street users negotiate right-of-way through courtesy and interactions, such as eye contact and gestures (Hamilton- Bailliem, 2011).

In his lifetime, Monderman developed more than 100 Shared Space projects in Netherland. Those projects demonstrated that urban streets become safer and more lively when they are stripped of street safety infrastructure so that drivers must take cues from observing people and environmental contexts, rather than signs. Later the Shared Space was adopted by cities in other European countries and in often car- dominated U.S. cities, with benefits such as less congestion, lower speed, reduced accidents, increased traffic, and more vibrant and attractive streets. For example, Winthrop Street at Harvard Square was transformed into the Shared Space in 2007. The conversion led to more efficient use of space, accommodating pedestrians, cyclists, outdoor diners, and cars simultaneously or at different times(NACTO). The concept of Shared Space addresses both livability and efficiency as indispensable factors for a city's sustainable development. Cars are not excluded but restrained as equal participants on the road.

Laweiplein, Drachten, Netherland | 1990s

Among many of Monderman’s successful projects is the Laweiplein intersection in the town center of Drachten. It was once an unattractive, signal- controlled intersection (Figure 1.8 (left)). After years of discussion, the junction was remodeled into a “square-about” which is made up of a roundabout and a square (Figure 1.8 (right)). Around the roundabout, the lack of demarcation on the street surface made it unclear where the car zone ends, and the pedestrian zone begins. Under this circumstance, drivers are required to be more mindful of the surroundings when passing through the junction. At the square, the fountain on the roadside becomes a popular destination for residents’ meeting and children’s playing, which helps to slow down traffic further (Hamilton-Bailliem, 2011).

After a few years of operation, vehicular accident rates dropped from twenty-three to two. Despite the increasing vehicle volume, the time taken to pass the intersection has fallen by 20 seconds. In general, the remodeling of the intersection has succeeded in creating a space that has not only increased safety and efficiency but also created a high-quality public space for the whole town (Hamilton- Bailliem, 2011).

Figure 1.8: Before and after Laweiplein intersection was converted to a “Squareabout”. Photos from *Towards shared space*, 2008, by Ben Hamilton-Baillie

Exhibition Road, London, UK | 2011

Another successful example is the Exhibition Road, a historic thoroughfare connecting university buildings, museum districts, commercial and residential neighborhoods in London. Since the 1960s, the road had been divided into two vehicular traffic lanes, three parking lanes, and two narrow sidewalks. It was difficult for pedestrians to cross the street due to the dominance of cars in the street. In general, the appearance of the Exhibition Road was unattractive and not appropriate for the prestigious institutions along the street (Figure 1.9 (left)).

In response to the government's request for proposal, the architect, Dixon Jones proposed a shared surface by removing all existing signs, marks, curbs, and barriers. The continuous pavement consists of a broad diamond pattern of pale granite on dark, promoting more convenient diagonal crossing. A row of tall lamps in the center of the street units the buildings of various characters along the street (Figure 1.9 (right)).

The remodeled Exhibition Road won several awards, including a RIBA reward, for its successful combination of traffic movement and public space. The project was one of the very first experiments of Shared Space in London, and was used as the example for future implementation of the concept in the area. In fact, UK has made the most significant progress in transforming segregated roads into Shared Space in recent years (Hamilton-Billie, 2010).

Unfortunately, a recent accident injuring 9 pedestrians on the Exhibition Road (Figure 10) raised doubts on safety issues of the Shared Space (Mairs, 2017). In fact, it was not the first time the concept was brought into question. In 2015, a report published by Lord Holmes accused Shared Space as "architectural conceit" which exposes the public to risk (Clark, 2015).

<u>Critics on the Concept of Shared Space</u>

After a thorough reading of Lord Holms' report, most complaints can be traced back to driver's faults, including rule violation, distraction, lack of courtesy, and miscommunication between multiple users on the road.

Pedestrians complained that, in many areas, drivers violated the speed law and failed to slow down to allow people to cross. One person commented, "Motor traffic often failed to give way at "informal crossings," and lack of pedestrian priority crossings meant you had to take your chances or wait a long time to cross the road." (Clark, 2015)

A cyclist on London's roads said: "sharing is never on equal terms- as a confident but anxious cyclist, I usually win the sharing transactions, but if a particular driver doesn't want to yield, they won't." The Shared Space turned out to a battlefield for other modes of traffic to compete with cars (Clark, 2015).

Drivers, as the document claimed, were equally as concerned about their right on the streets. One driver who responded to the survey said, "If as a driver you stop to let pedestrians across you are often abused by other drivers. I stop, but the cars coming the other way don't, so pedestrians don't know whether to cross or not or they cross and then have to run." This type of miscommunication between drivers, and between drivers and other modes of travel harm the overall experience of the Shared Space (Clark, 2015).

Figure 1.9: Before and after Exhibition Road was converted to a Shared Space Street.
Photos from http://www.publicspace.org/en/works/g069-exhibition-road

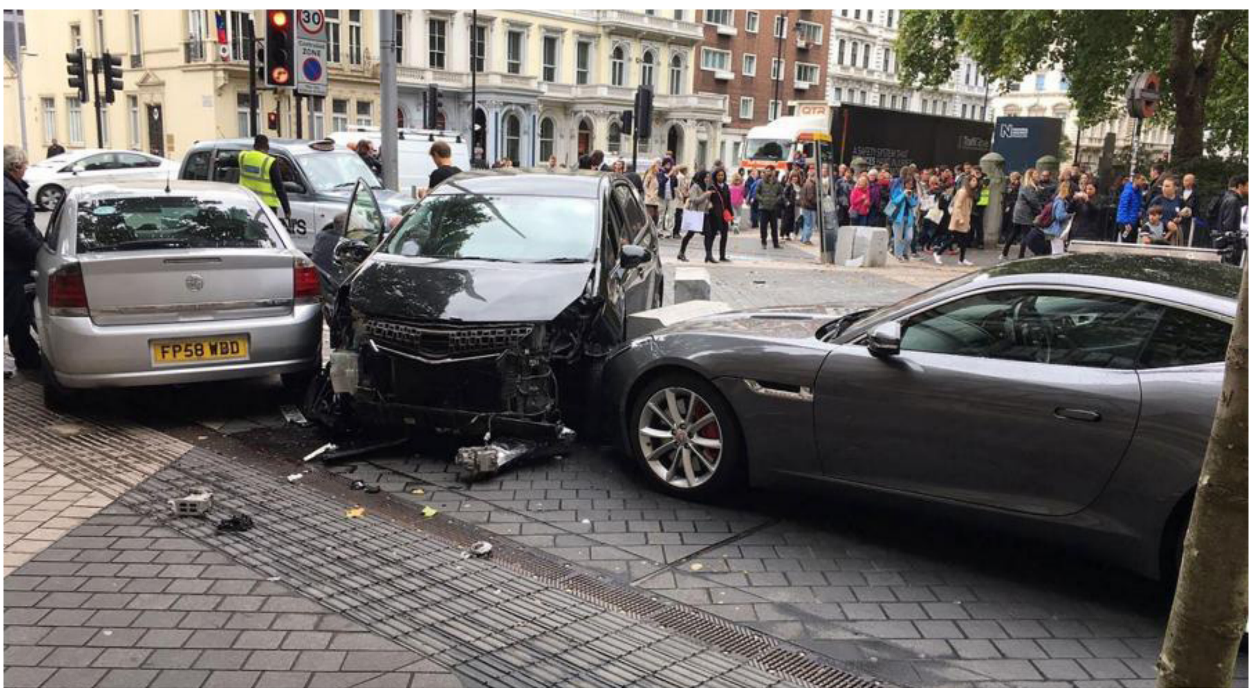


Figure 1.10: The concept of Shared space was called into question after an accident on Exhibition Road (London) in 2017. Complaints go to driver's error, inattention and miscommunication between different street users. Photo from https://www.standard.co.uk/news/london/natural-history-museum-crash-police-appeal-for-witnesses-after-11-injured-in-crash-in-south-a3653131.html

In short, due to drivers' error, inattention and miscommunication between street users, shared space cannot be implemented in larger scale. Although we have acknowledged both livability and efficiency are indispensable components for cities' sustainable development. However, to achieve both of them is a difficult task with conventional dominance of automobiles and drivers. Since transport technology and its application can cultivate lifestyle and shape streetscape, this thesis sees the transition from conventional automobiles to shared autonomous vehicles as an opportunity to rework on the relationship between traffic and people.

2 TECHNOLOGY | OPPORTUNITY

Global Atlas of Autonomous Vehicles
Features of Autonomous Vehicles
Fleets & Flexible Service
Opportunities

Global Atlas of Autonomous Vehicles

Due to advances in digital maps, sensor technology, and artificial intelligence, autonomous vehicles (AVs) could improve our lives by offering increased safety, optimized efficiency and freeing-up space from cars for pedestrians. Although in an early stage, global cities are initiating AV piloting programs in hope to take advantages of what the new technology claims to achieve. According to the Global Atlas of Autonomous Vehicles in Cities released by the Bloomberg Philanthropies, as of December 2017, 50 global cities, such as Boston, have been hosting AV tests in the designated area, or have committed to doing so shortly. Another 23 cities are developing proactive policies and plan to prepare the coming of AVs (Figure 2.1).

Those city governments have seen various potentials of AVs, from transit to freight, and the most popular anticipation is to firstly integrate AVs into the public transit system for the last-mile delivery. Regardless cities' emphasis on a shared system that could allow general accessibility, except Paris, which has explicitly expressed its plan to forbid privately owned AVs, other cities are expecting a reduction in private car ownership but not ruling out the option of private AVs (Fairs, 2017).

Meanwhile, Indian cities may ban AVs in afraid that the technology will take away jobs and exacerbate the country's long-term problem of unemployment. In fact, many cities have recognized the issue as part of a greater technological disruption brought by the automation. In contrast to India, Singapore believes AVs can provide greater rewards than risks to urban life. Researchers at Singapore's Center for Livable Cities suggest there are ways to prepare the workforce going through the transition. In the short term, there will be more jobs to maintain the vehicles. In the long term, those workers whose jobs depend on driving could be re-skilled to fit the new job market (Wortham, 2017).

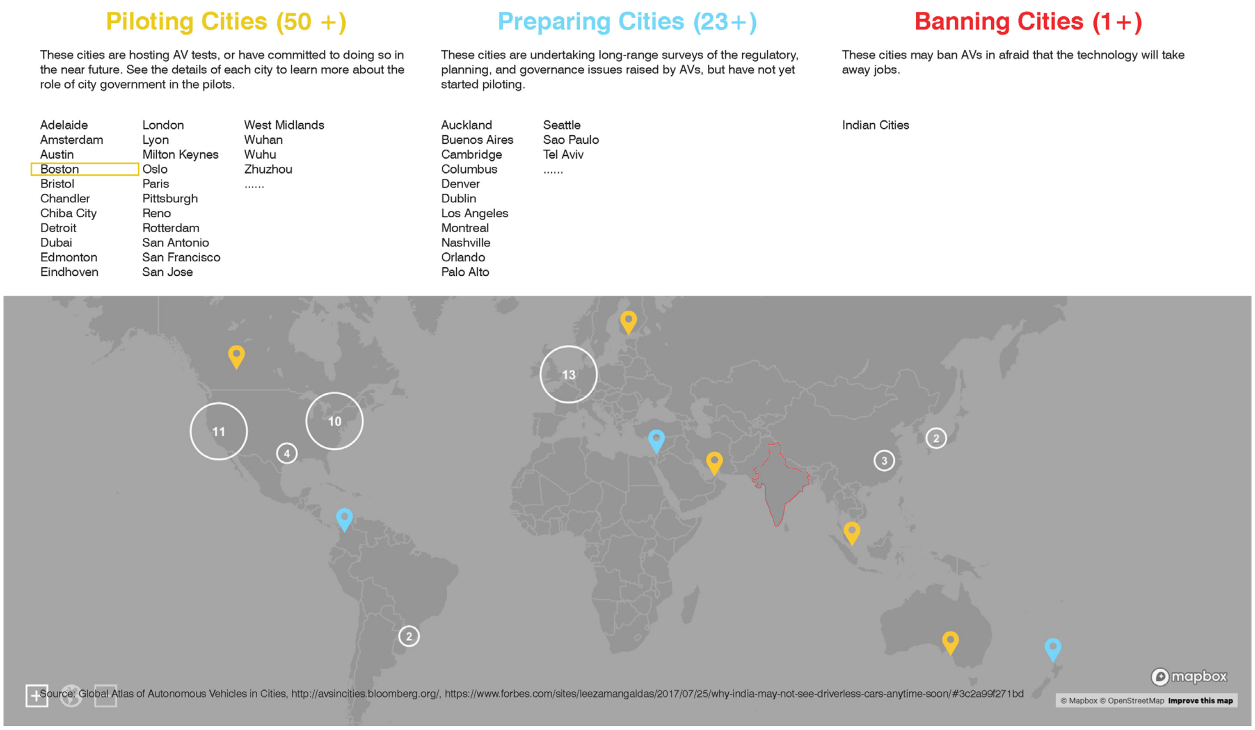


Figure 2.1: Many countries are thinking of ways to introduce autonomous vehicles to urban streets. Map from *Global Atlas of Autonomous Vehicles (AVs) in Cities*, by the Bloomberg Philanthropies, https://avsin-cities.bloomberg.org/global-atlas, retrieved in December 2017.

Figure 2.2: Both traditional automakers and rising tech companies are designing autonomous vehicles and operating systems. Vehicle types vary from taxi to minivan to bus. Photos from the Internet.

Common Features of Autonomous Vehicles

Both traditional automakers and rising tech companies are designing autonomous vehicles and operating systems. Vehicle types vary from taxi to minivan to bus (Figure 2.2). However, no matter how different they look like from each other, the common feature shared by all fully autonomous vehicles is that there will be no drivers but only passengers.

To achieve that feature, AVs use GPS and high definition digital map to locate themselves and use multiple onboard sensors to detect the distance and speed of surrounding objects. The in-taking data is processed by the built-in software with feedbacks in responding to various road conditions (Figure 2.3)(Lipson, 2016). While in my opinion, this type of one-way communication will either sacrifice efficiency or lead to worse communication between people and AI driver. Some companies, such as drive.ai and Semcon, are incorporating screens to enhance vehicle-pedestrian communication (Figure 2.4 & 2.5). To enhancing safety and efiicienty furhter, I would recommend a new robotic feature as following.

Recommend a New Feature: Changing Characteristics of AVs

A new approach to the design of these autonomous vehicles that combines the self-driving technology of autonomous vehicles with new robotic features that tell vehicles when to reduce speed to share street with pedestrians, and when to resume speed on dedicated areas. In another word, when AVs are on the dedicated areas, they are regarded as a machine moving at a consistently dominant speed. When AVs are in the shared space with pedestrians and cyclists, they are regarded as robots moving at the walking pace of human (Figure 2.6). People inside the vehicles (passengers) and outside (pedestrians & cyclists) share equal right-of-ways. When share street at low speed,

“Fully driverless cars will take you places without anyone in the driver’s seat. Just hop in the back and let Waymo drive you.”

- Waymo (Formerly, the Google self-driving car Project)

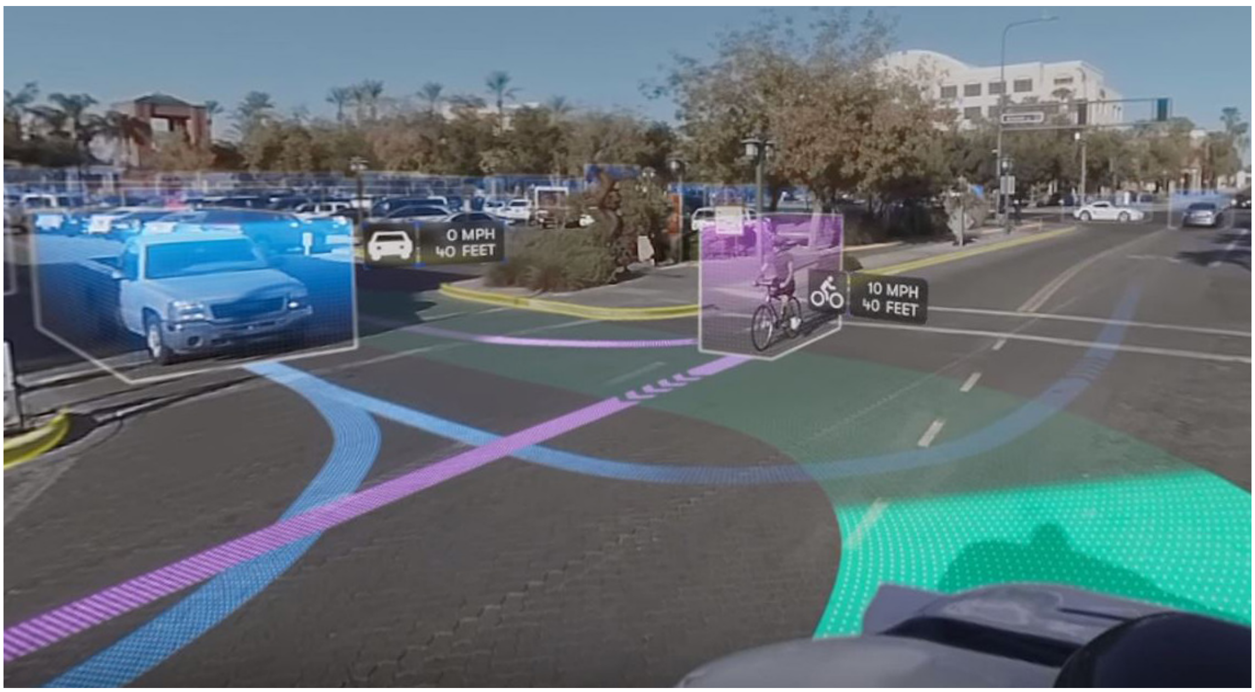


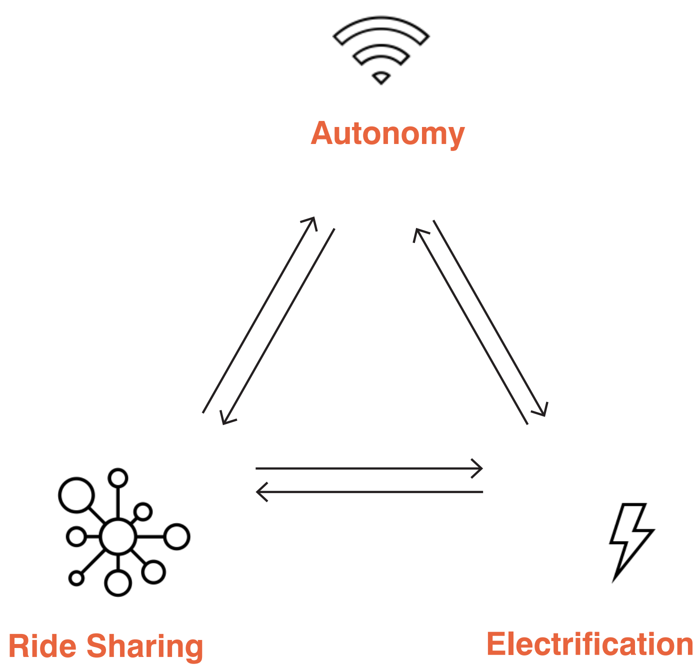
Figure 2.3: AV’s view of world. Image from video by Waymo,
https://www.youtube.com/watch?v=B8R148hFxPw

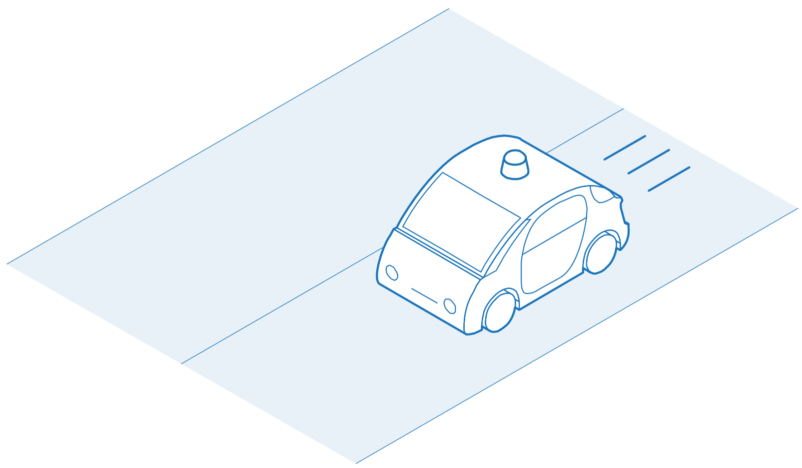
Figure 2.4 & 2.5: current devices used by drive.ai (left) and Semcon (right) for vehicle-pedestrian communication. Left image from www.drive.ai. Right image from https://semcon.com/.

AVs can negotiate right-of-ways through screens or speakers, which talk, not honk.

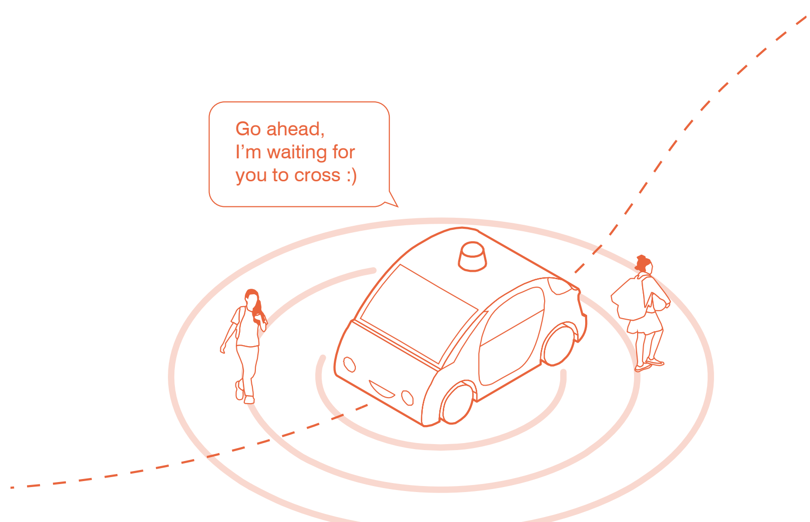
Fleets & Flexible Service

Regarding ownership, energy, and automation, this thesis takes the shared, electric, autonomous vehicle as the ideal way to respond to the environmental crisis, guarantee generalized accessibility, and drastically reduce the production of green house gas. In the full autonomous era, all vehicles on the streets are connected in the format of taxi, shuttle or bus. Together with walking and cycling, the future mobility can provide a flexible service to satisfy various needs (Figure 2.7).





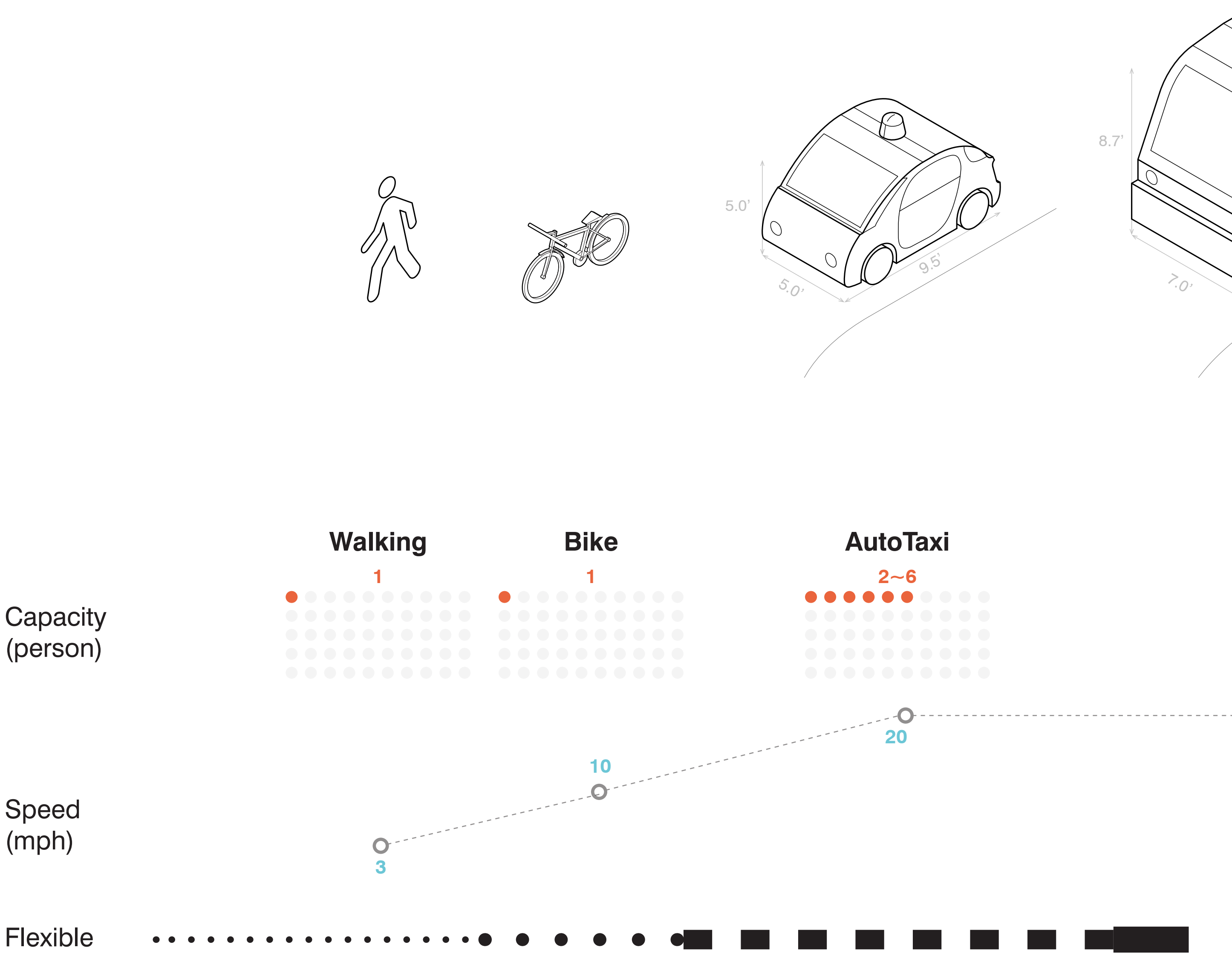
Machine Moving at a Consistently Dominant Speed (>20mph)

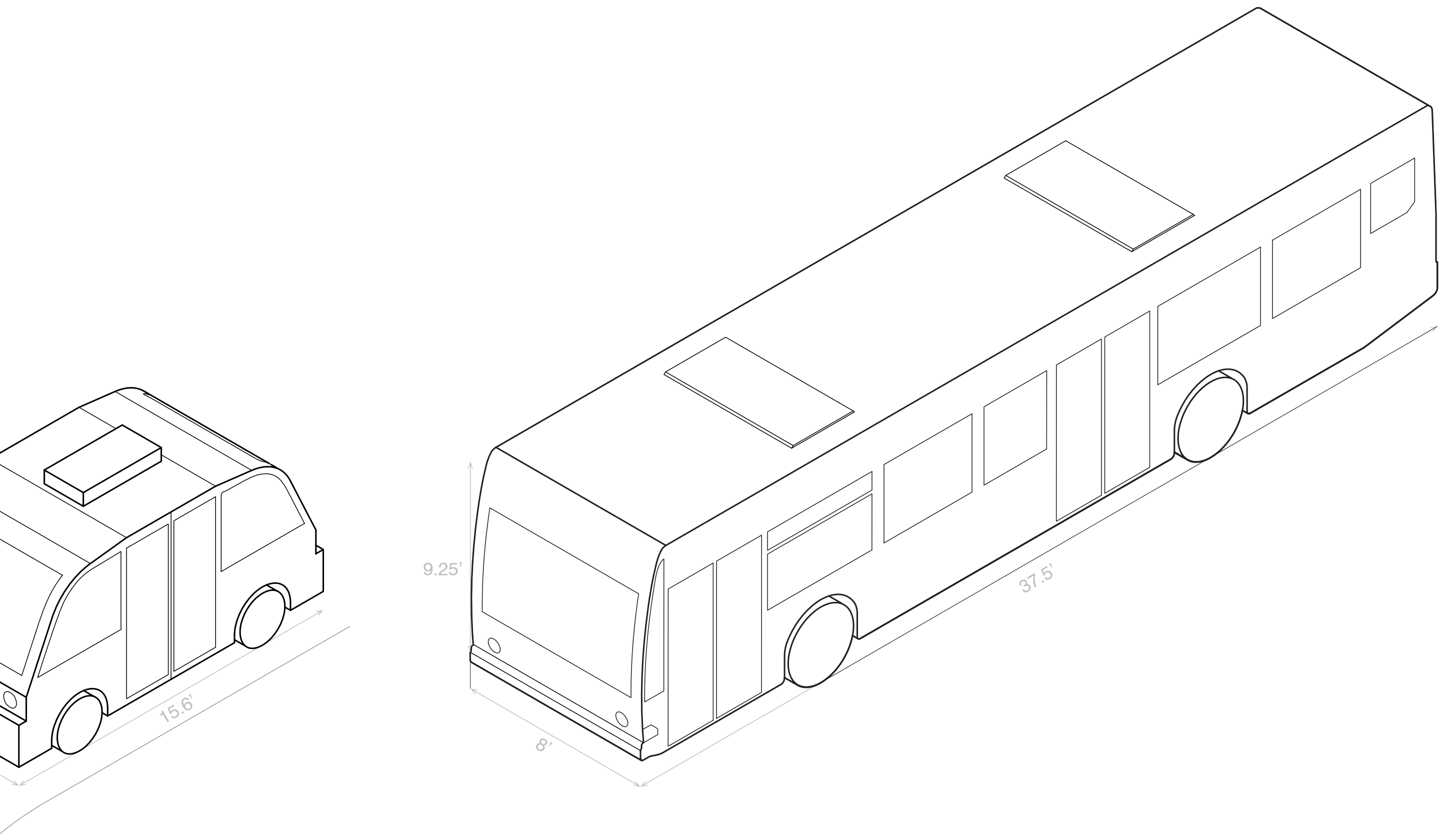


Robot Moving at the Walking Pace of Human (3mph)

Figure 2.6: changing characteristics of autonomous vehicles

Figure 2.7: Fleets & Flexible Service





AutoShuttle

15

AutoBus

>50

20

20

Fixed

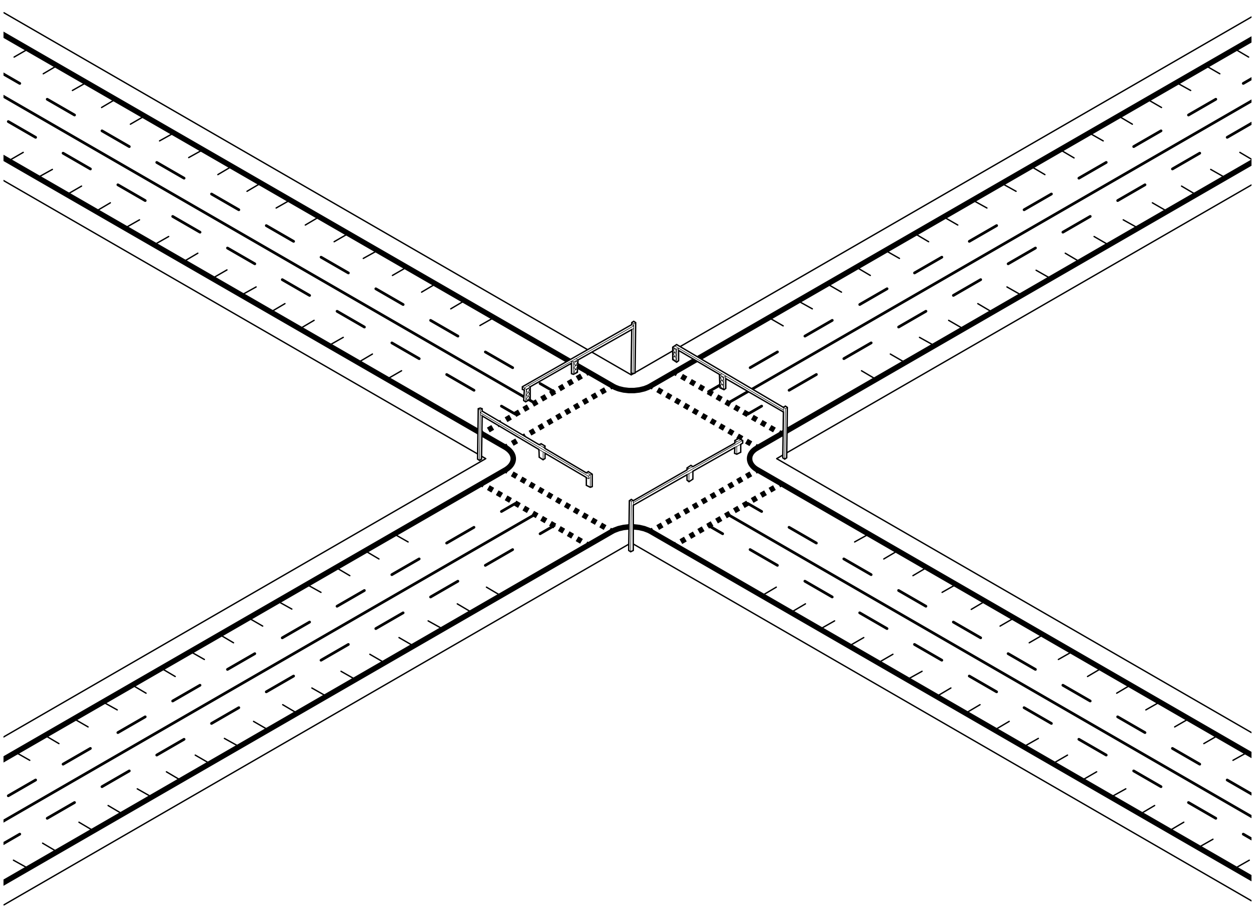
Opportunities

You may often hear reports or quotes saying that AVs will reclaim space from cars for people without sacrificing efficiency. But how an how much? Here I did a rough calculation based on a street with four traveling lanes, two rows of street parking and two

> *"... Re-claim parking space..."*
> - Anantha Kancherla, Director of Engineering, Lyft Level5 Engineering Center

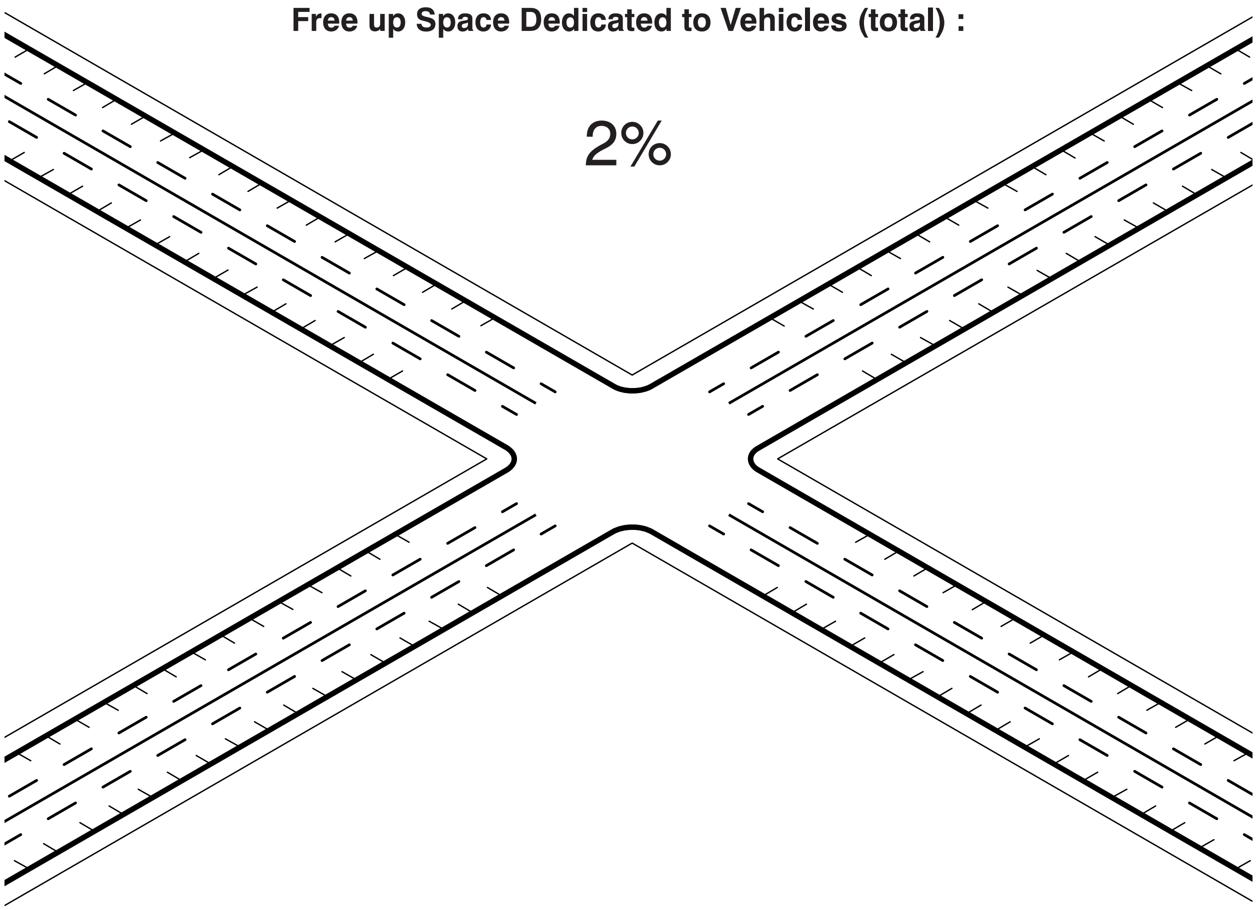
> *"The revolutionary (full autonomous) scenario produced almost 50% more space from parking needs."*
> - BCG, Global Management Consulting

> *"Giving Streets Back To People — Roadways will be reclaimed for people in the form of pedestrian zones, bike lanes, community spaces, outdoor cafes, and parklets."*
> - Andy Cohen, CO-CEO, Gensler



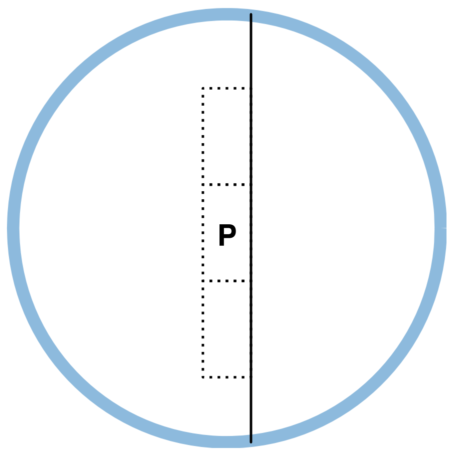
Signage

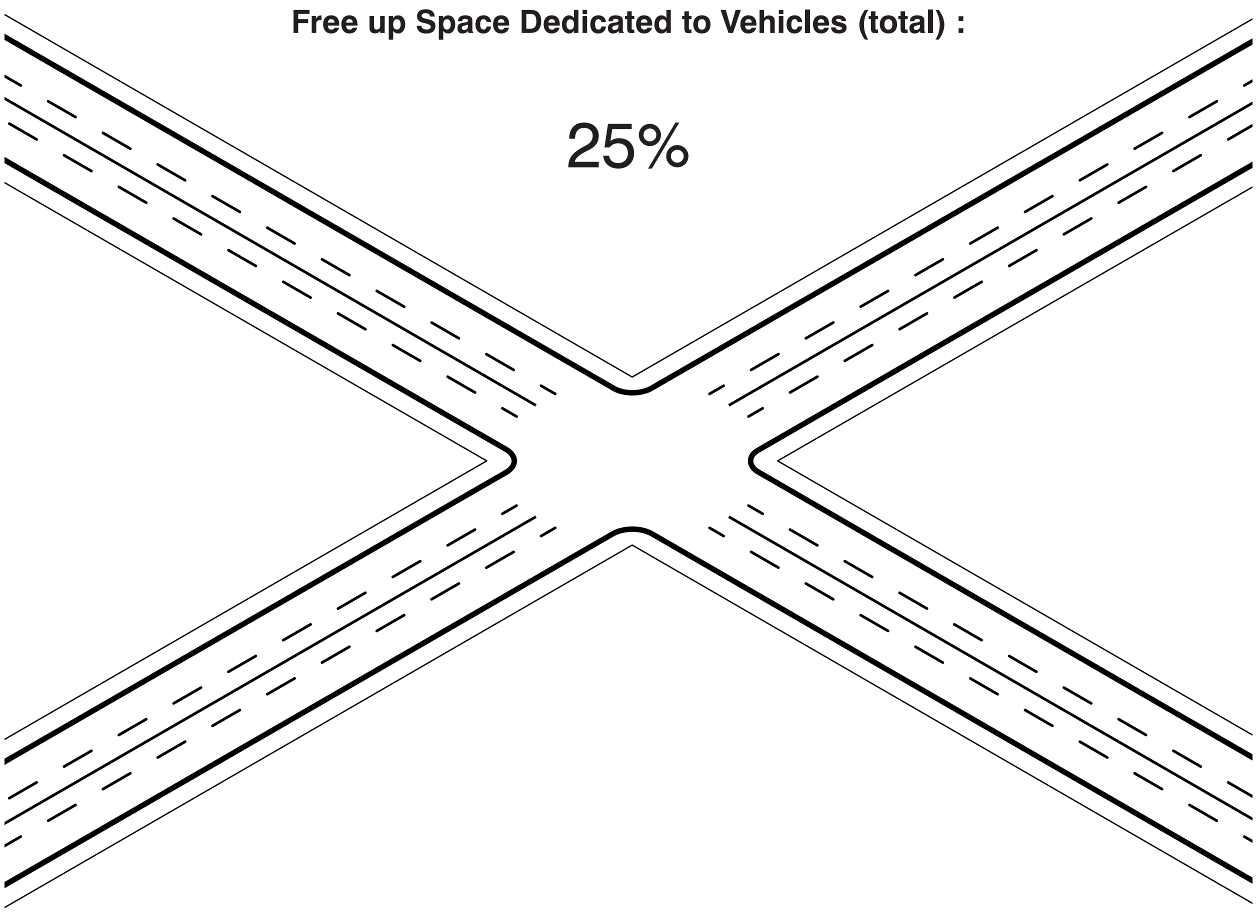
First, signage, such as traffic lights, can be removed due to direct communications between vehicle and vehicle, and between people and vehicles (Lipson, 2016).



Parking

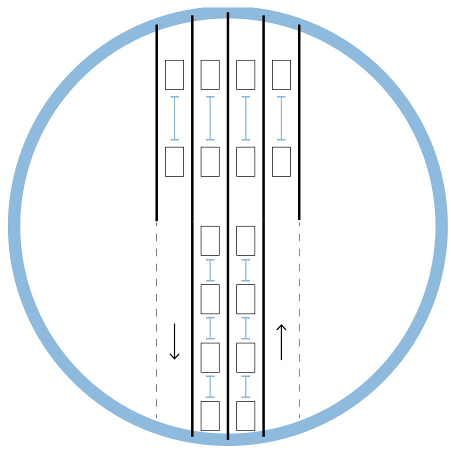
Then, street parking can be removed because AVs are shared, and can park themselves anywhere when in idle. With reduced off-street parking, more space can be freed up for alternative uses (Lipson, 2016).

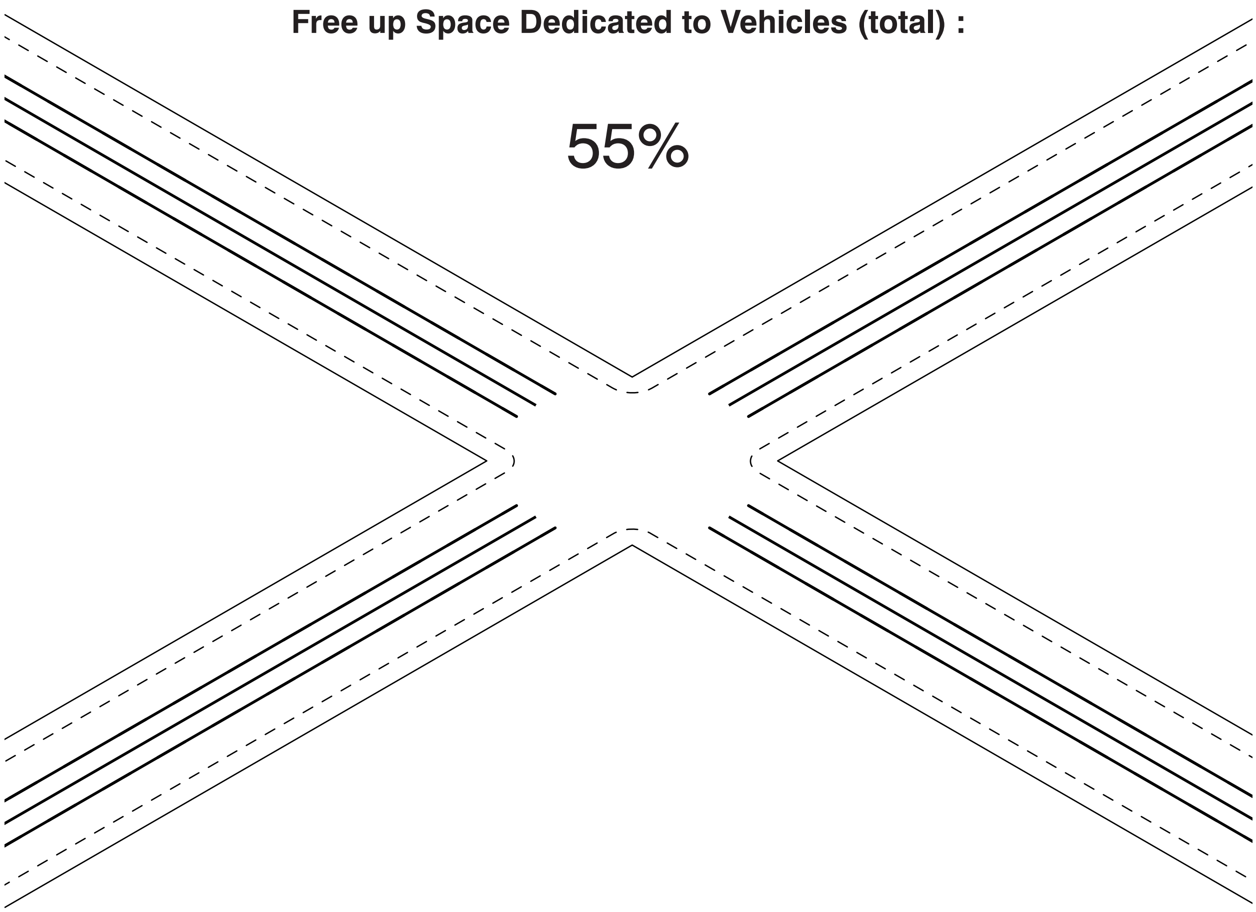




Lanes

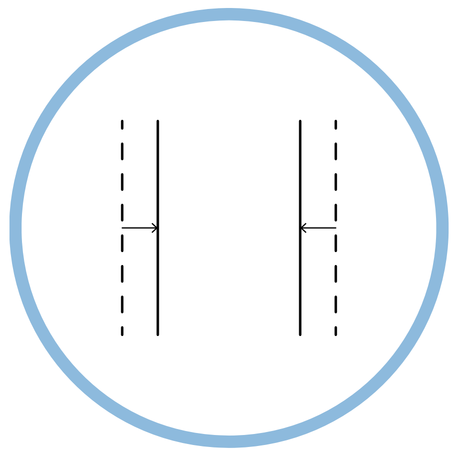
Number of lanes could be reduced in half but keep the same traffic volume because of the shorter vehicle spacing (Lipson, 2016).

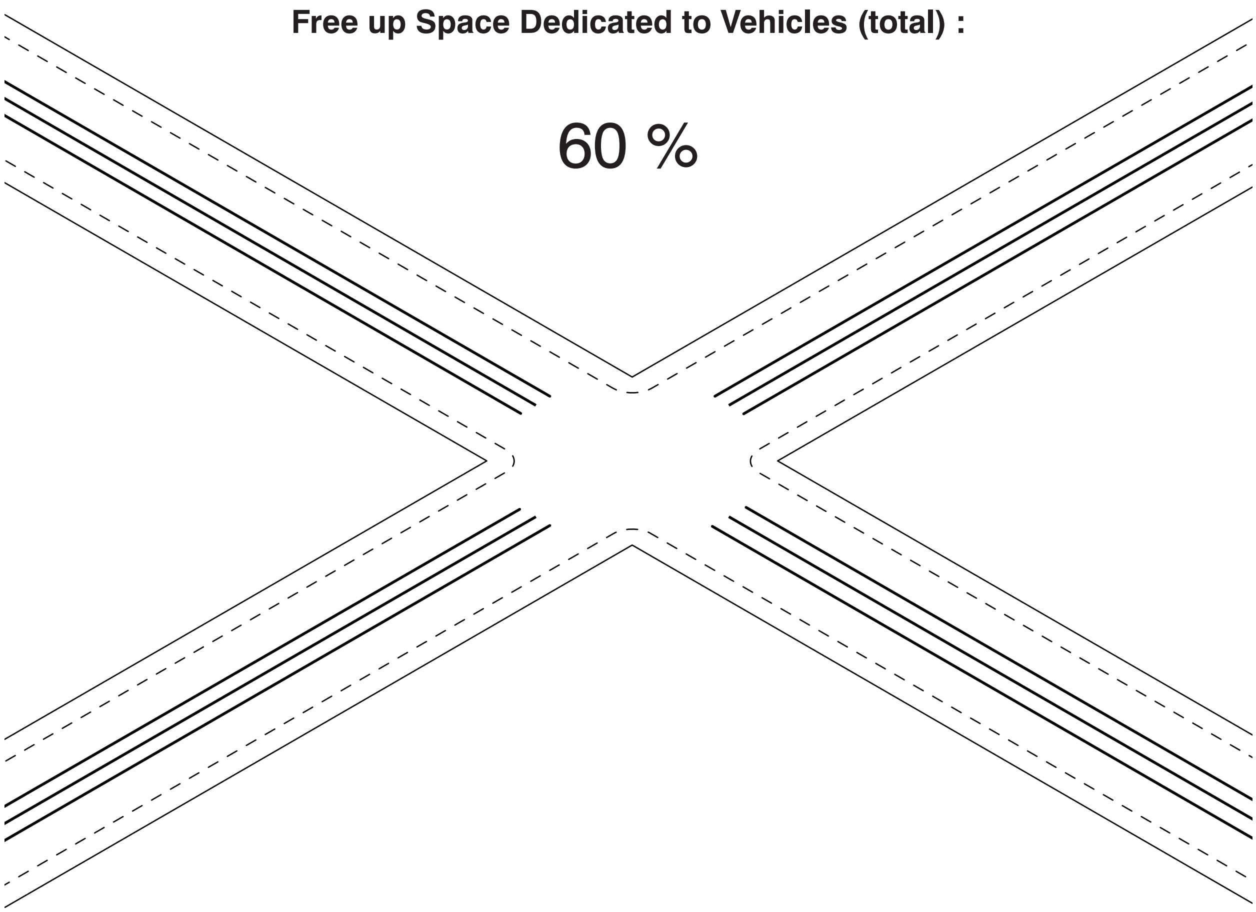




Lane Width

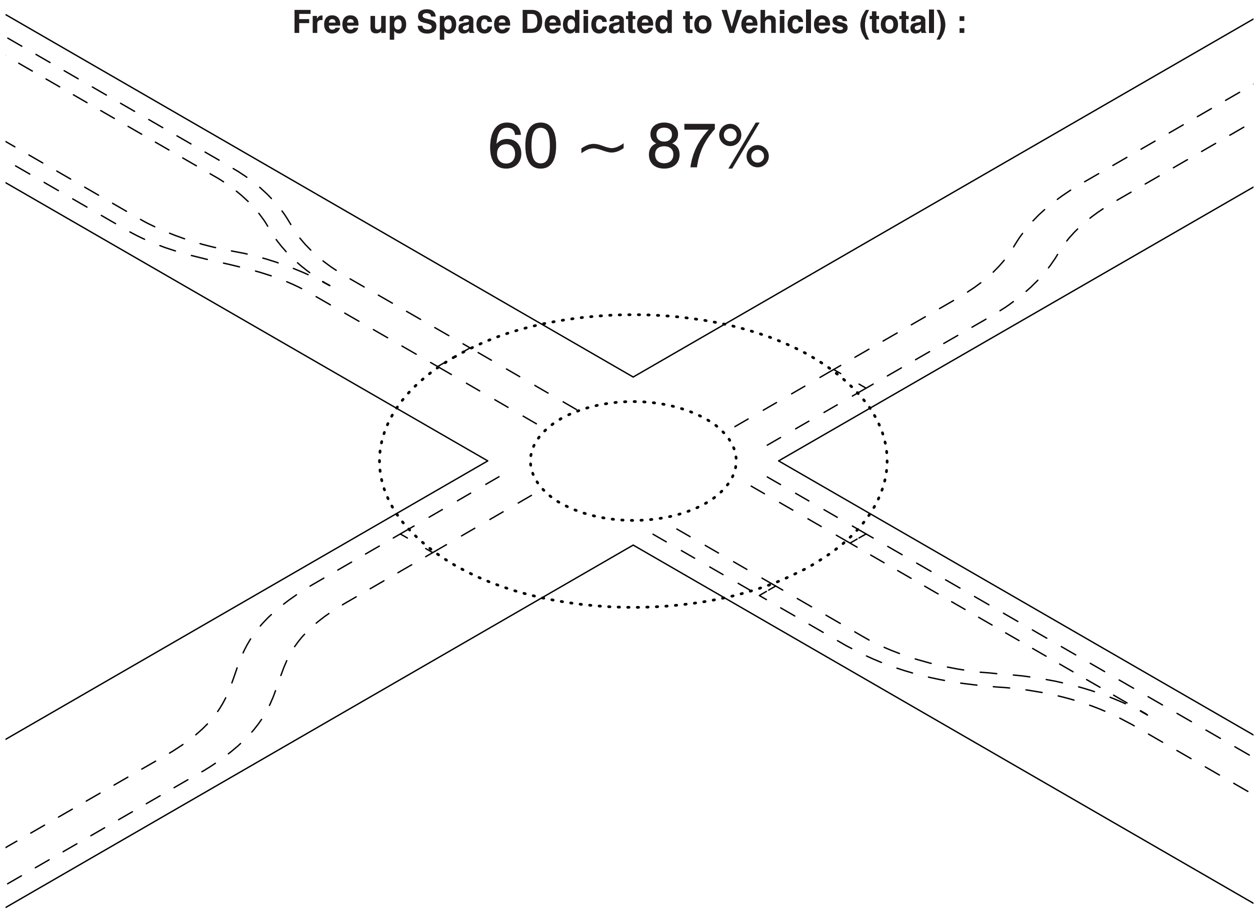
Lane width can be kept to minimum, 10’ or less, because of the increased precision in driving, and smaller vehicle size after removing the engine (Lipson, 2016).



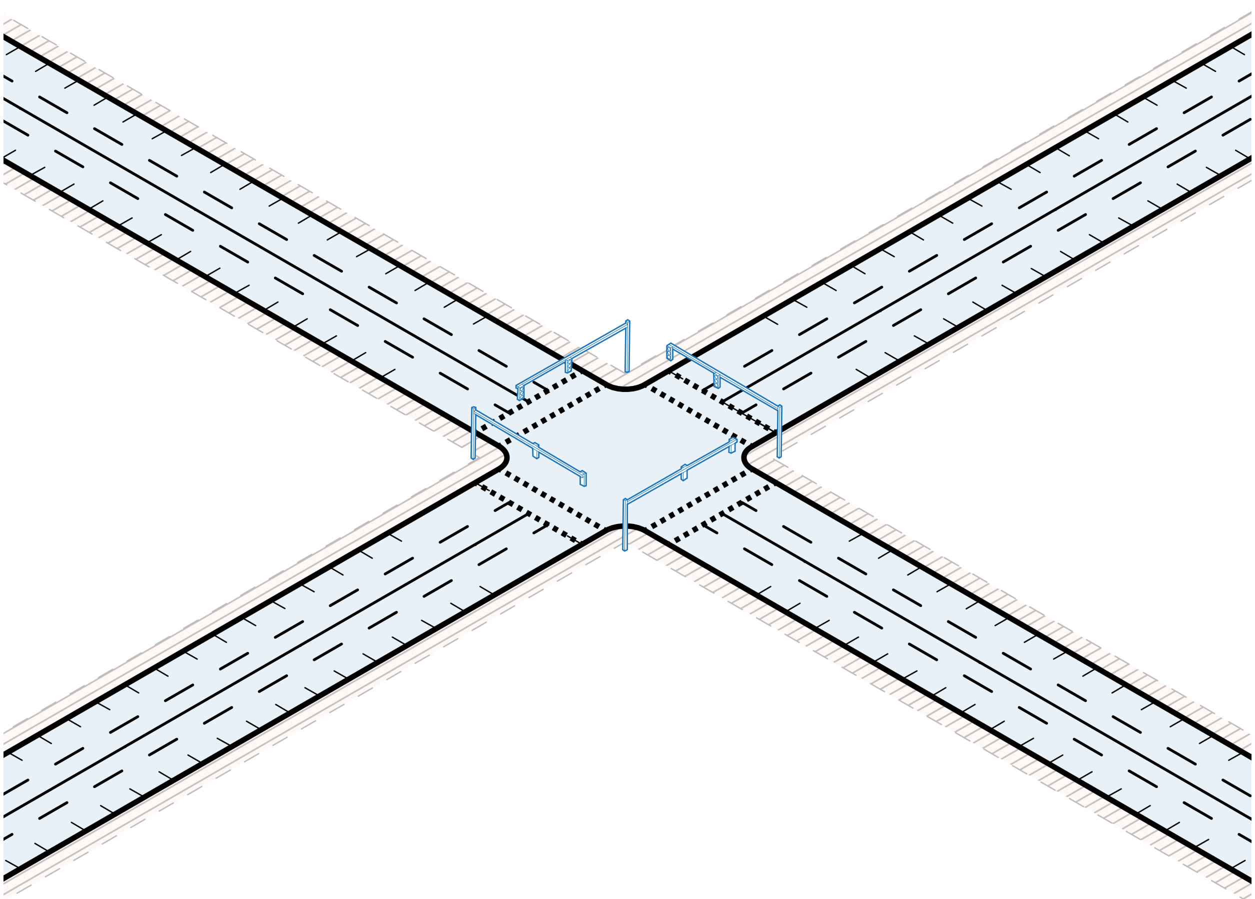


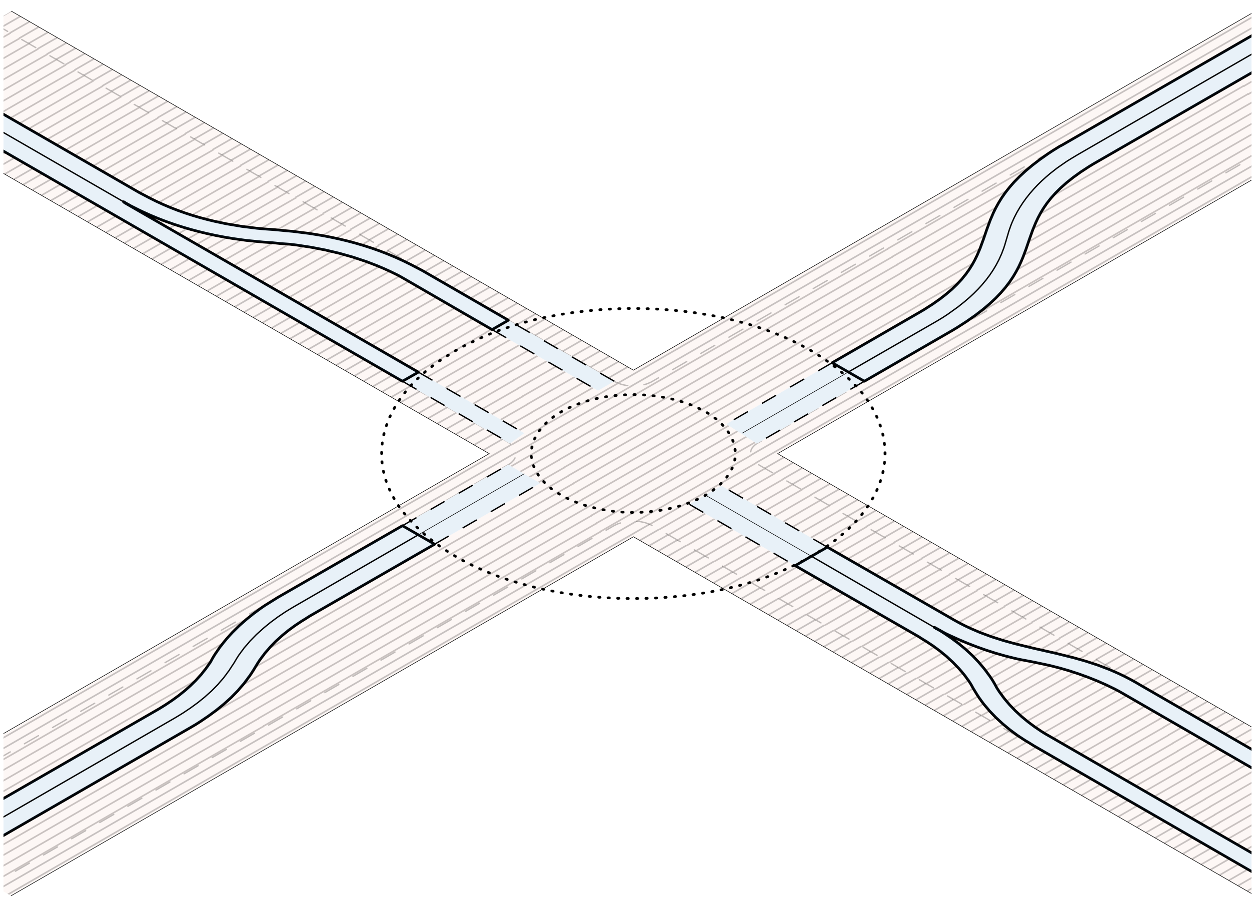
Flexible/Invisible Lane

Furthermore, lanes are not necessary to be centered, or even marked because computer vision is one of the many technologies AVs utilize to find their way through. Those features together would lead to almost the whole space between buildings to be re-imagined.



To sum up this chapter, on the one hand, we have the power and rights to shape the development of technologies to better serve our lives; on the other hand, those technologies together would provide us an opportunity not just to-re-claim parking space, but to re-imagine public space, as well as its relationship with traffic infrastructure. In the following chapter, I will introduce my strategy to rethink street as urban surfaces, which integrate traffic infrastructure and collective space.





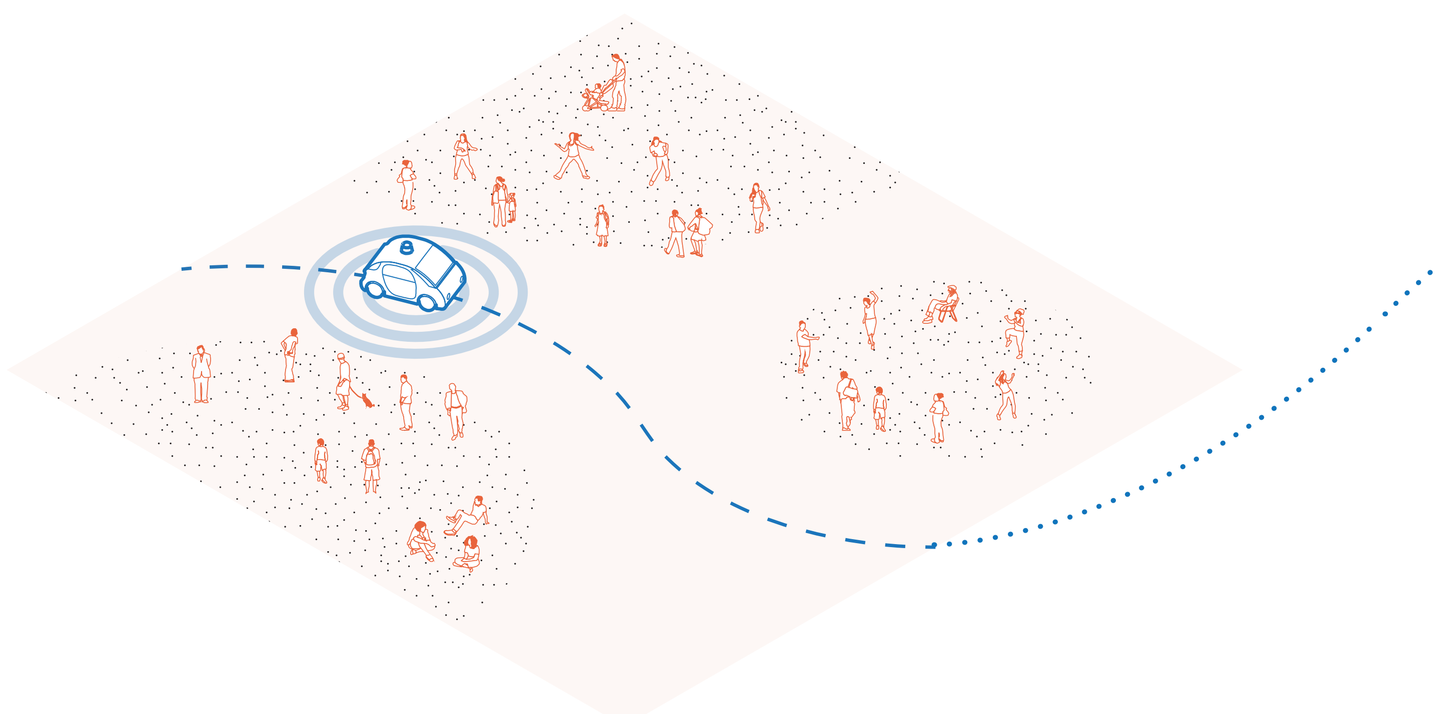
3 STRATEGY | SURFACE

Shared Surface
Efficient Surface
Transition Zone
Surface Material
Financial Model

Urban surfaces have three components, the two basic types – shared surface and efficient surface, as well as the transition zone between them.

Shared Surfaces (Default)

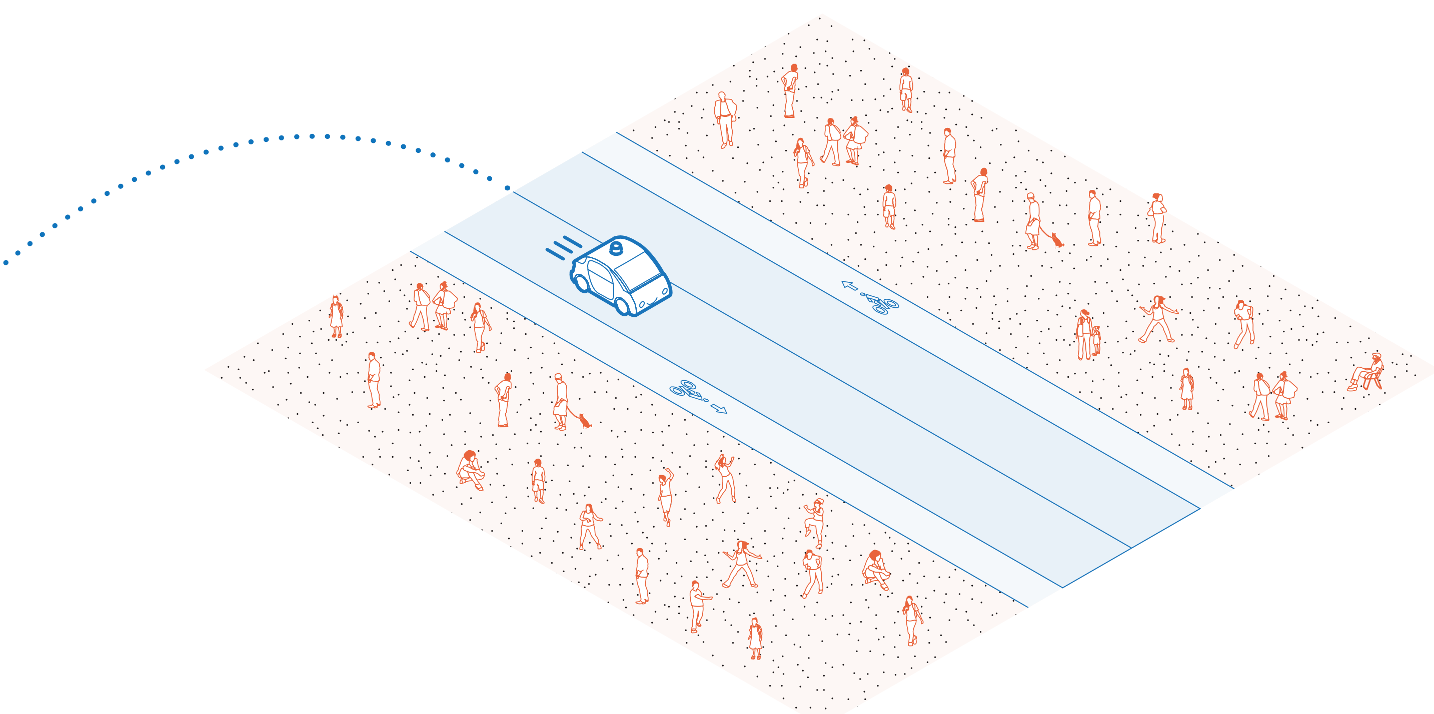
If not specified, urban surfaces are defaulted as shared surfaces used by pedestrians, cyclists, shuttles and taxis. The speed limit for vehicles is 3 mph when people are around and 20 mph when streets are less busy. Thanks to AVs' robotic features as we defined in the previous chapter, at low speed, all street users are equal and negotiate their right-of-way through social norms. In another word, people inside and outside vehicles share the same right-of-way at 3mph. The de-segregation between pedestrians, cyclists, shuttles, and taxis can lead to more efficient use of the space due to uses of the specific space at different times. Corner-to-corner service is encouraged, while door-to-door service is kept as an option for people in needs, such as passengers with



disability or businesspersons do not want to wet their suits on rainy days.

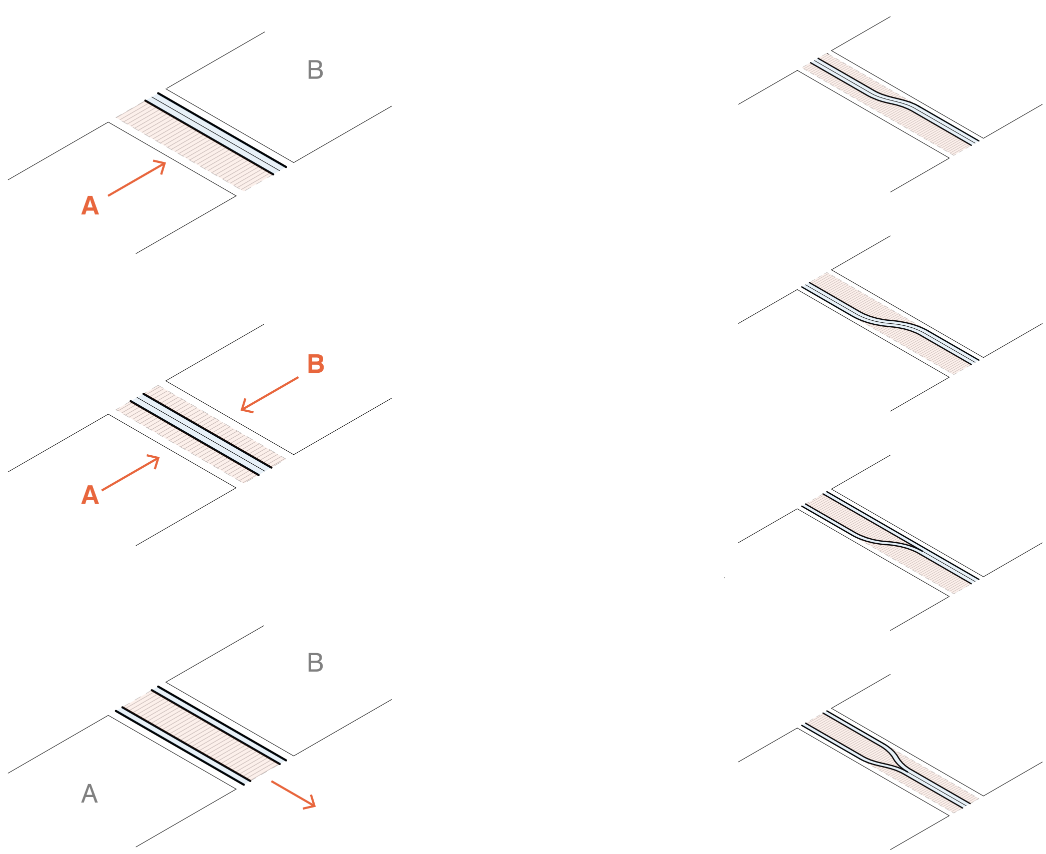
Efficient Surfaces

Efficient surfaces provide dedicated areas for buses, shuttles, and taxis to connect people to workplace, important nodes (hospitals, schools, monuments, etc.) and different neighborhoods in a timely manner. Two lanes measuring 10 feet wide each are required as traveling lanes for AVs, upon which the speed limit is 20 mph in the urban context. One thing to note is that, efficient surface is the only type of surface buses operate on. In another word, when there is bus service provided, there is always sufficient surface to deliver more people at a faster speed. In addition, if bikes are used as transport tool, they stay on the bike expressway measuring 5 feet wide each with a speed limit of 10 mph. Otherwise, for leisure cyclists, they can stay on the shared surface friendly at a lower speed.



Efficient surfaces can be placed in the center of the shared surface, be pushed to one side, or be split up into two. And The specific location is determined by traffic efficiency, environmental comfort, adjacent land use and local participants. For example, pedestrians can enjoy a wider walking and sitting surface with more street furniture and vegetation. Owners of abutting properties can extend their storefront as encroachment along the street. The lanes can also be pushed to the side where is shaded or has inactive facade.

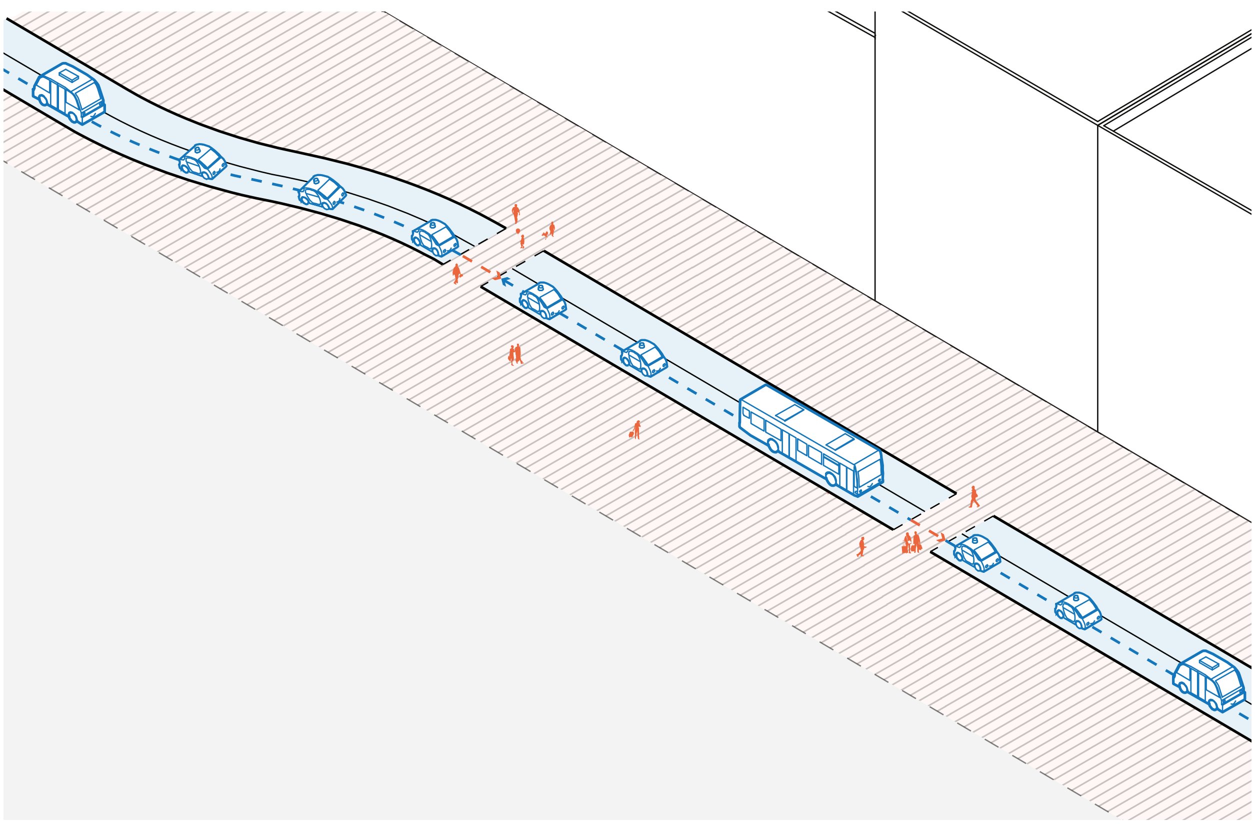
Due to different locations of traveling lanes, the turning of the lanes, frequent or not, would provide a winding experience through cities. According to the Urban Street Design Guidelines by NACTO, the turning radii is 99 feet at the speed of 20mph. The turning can also be used as a slowing-down interval to allow pedestrian crossing within long existing city blocks.



Transition Zone

1. Interval

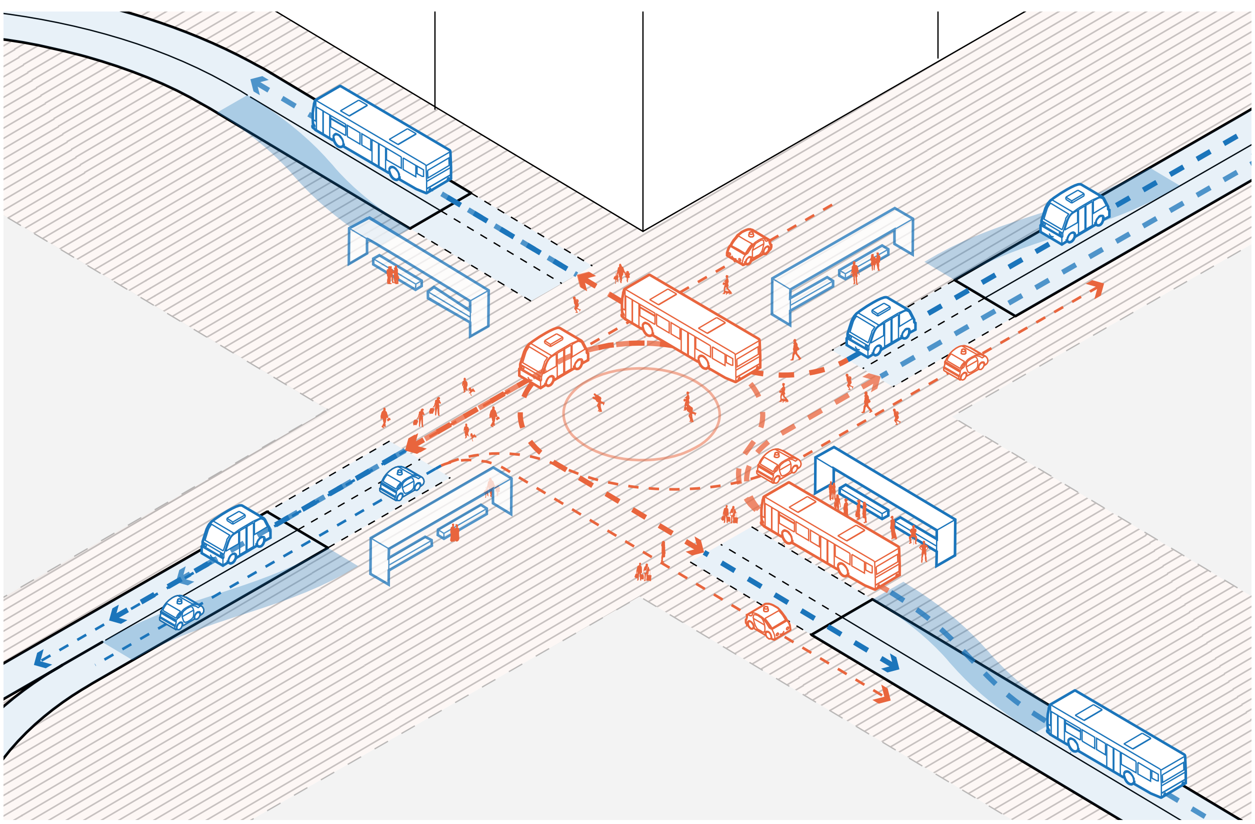
In the middle of long blocks, intervals are required for pedestrian crossing. In this scheme, there is at least one interval every 100-200 feet. Also, stopping distance and accelerating distance of 40 feet are assigned on the two ends of the interval. If there are pedestrians on the interval, vehicles stop and wait; if no, vehicles keep moving.



2. Intersection

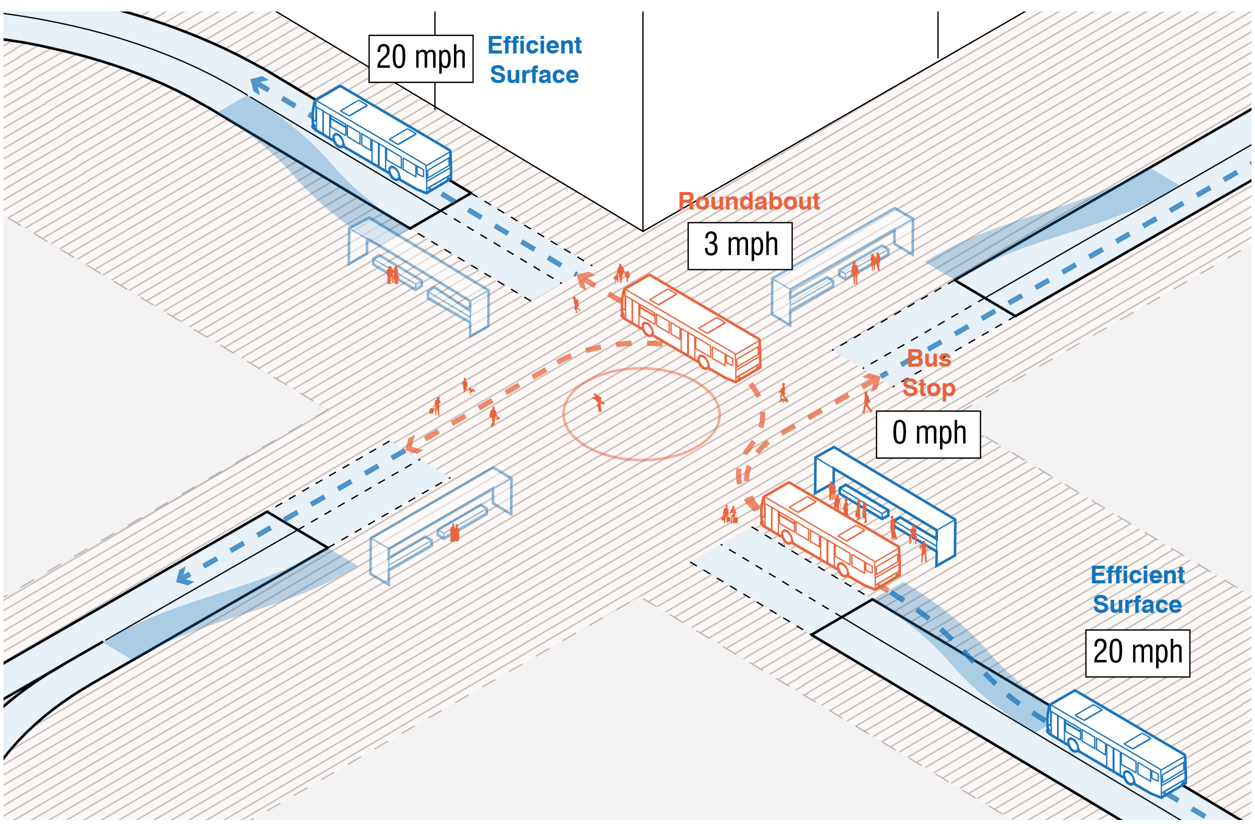
Intersections are always shared surface, sometimes with a roundabout. A slow- down zone (40' L) is provided before vehicles enter the intersection. Through the robotic features, AVs negotiate priorities with other street users and then take the way to continue their journeys.

Roundabouts are set up to mitigate conflicts between vehicles from different directions. The location of lanes on the opposite sides are mirrored or rotated 90 degrees for a safer and easier transition. If all four ways are of the same configuration, the efficiency is at the highest level because of the least possible collision points. Within the roundabouts, monuments, street sculptures and fountains can be set up for people to enjoy. Three scenarios are discussed in the following to show how to the intersection works.



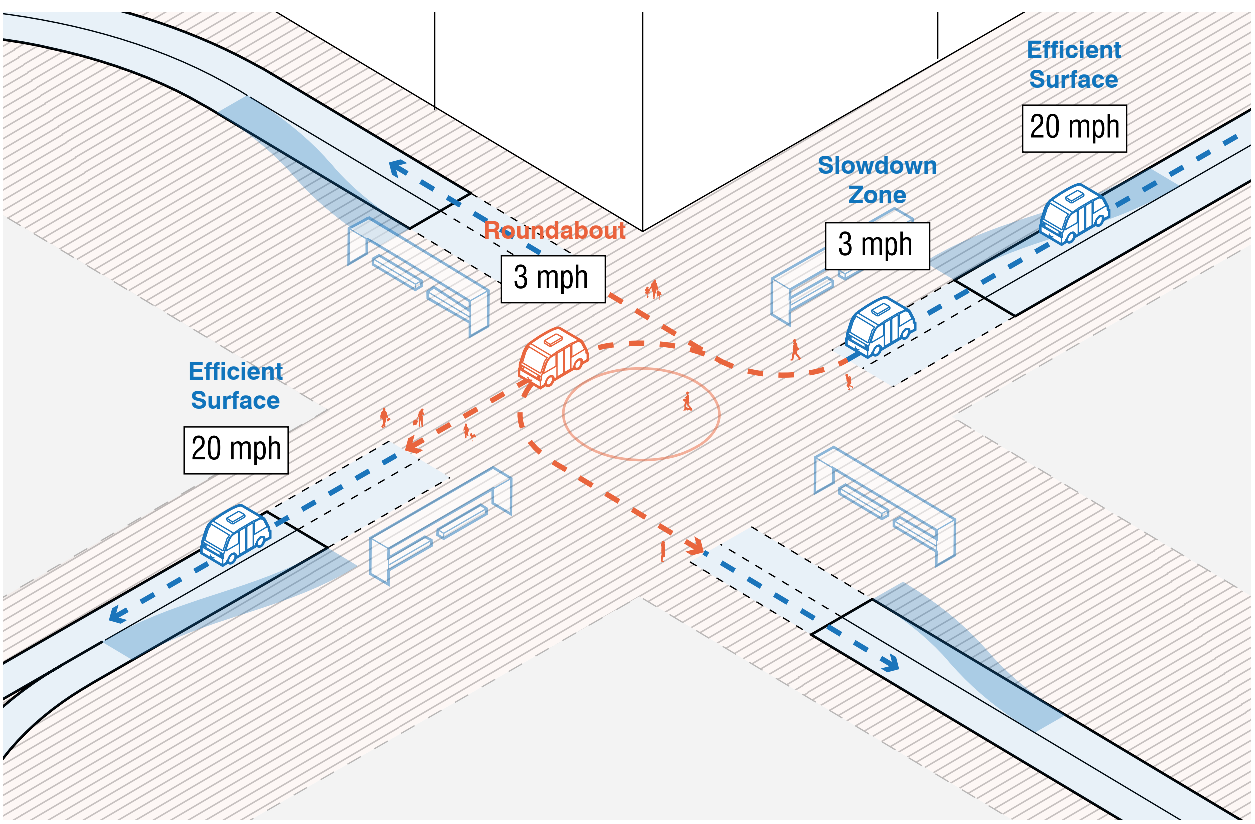
Scenario 1: A Bus Delivering Corner-to-Corner Service

Before arriving the corner station, the bus slows down, takes the right turn at the folk, stops at the station, picks up/drops off passengers, and then circles around the roundabout to the efficient surface on the other side.



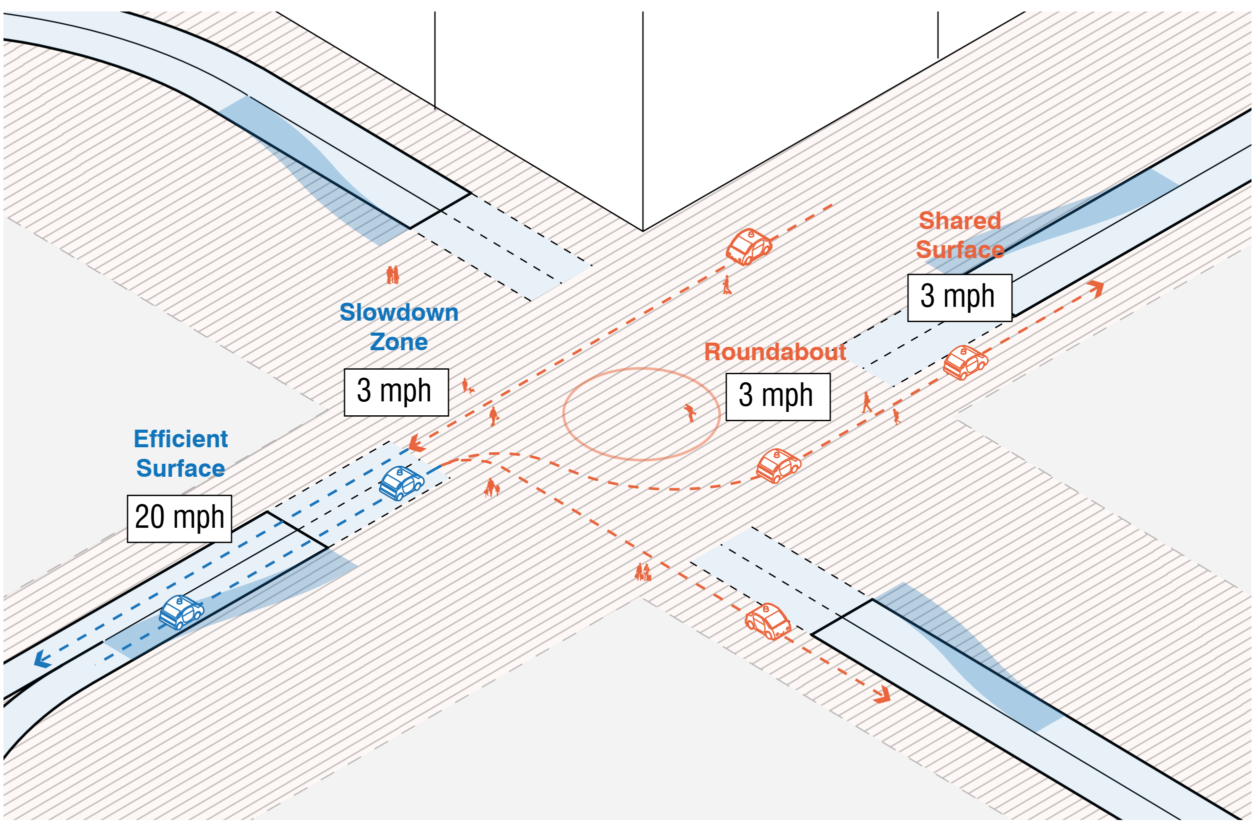
Scenario 2: A Shuttle Traveling to the Next Block

Before entering the intersection, the shuttle remains on the efficient surface, slows down to 3mph, circles around the roundabout, and continues its journey on the efficient surface at the speed of 20mph.



Scenario 3: **A Taxi Delivering Door-to-door Service**

Before entering the intersection, the taxi remains on the efficient surface, slows down to 3mph, travels around the roundabout and enters the shared surface at low speed to complete the door-to-door service. After completing the service, the taxi can either continues on the shared surface cautiously, or finds the nearest intersection or interval to get back on the efficient surface and resume to the faster speed.



3. Edge

Besides the perpendicular transition, the parallel edge between the efficient and shared surfaces can range from permanent structures (hard) to improvised devices (soft) (Figure 3.1). It can be a wall with inactive facade to create an relatively isolated condition for consistent faster speed. It can also be paints or changing LED grid to accommodate the uncertainties from future. Over the years, the edge condition will go from hard to soft as people gradually accept AVs as an integrated part of urban life.

With frequent intervals, intersections, and flexible demarcation, efficient surfaces are added segment by segment on the continuous shared surface when in need (Figure 3.2). In real practice, it requires closer collaboration with traffic engineers to calculated how much efficient surfaces, and how many interruptions are in need to achieve certain level of efficiency and livability based on specific situations.

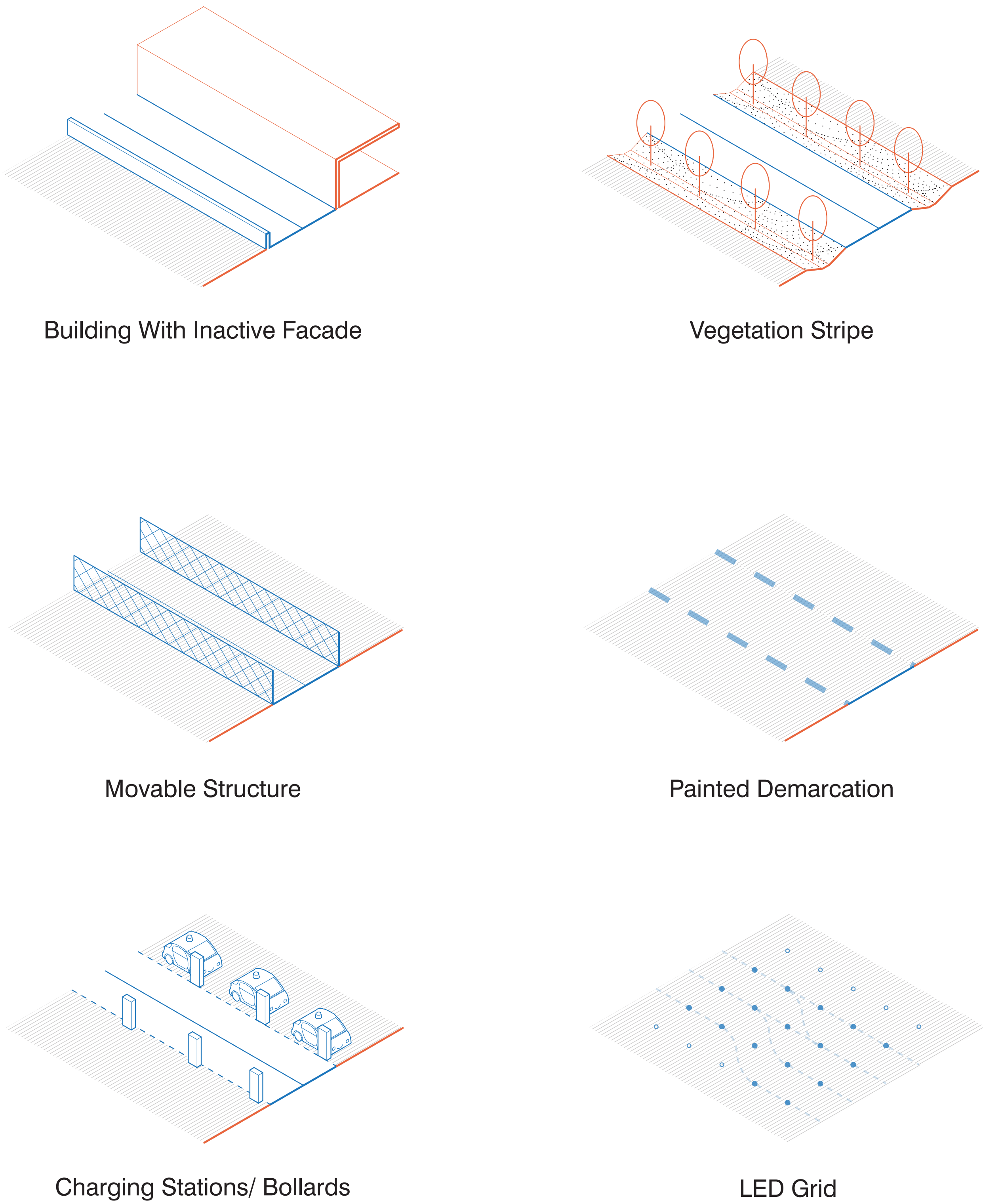
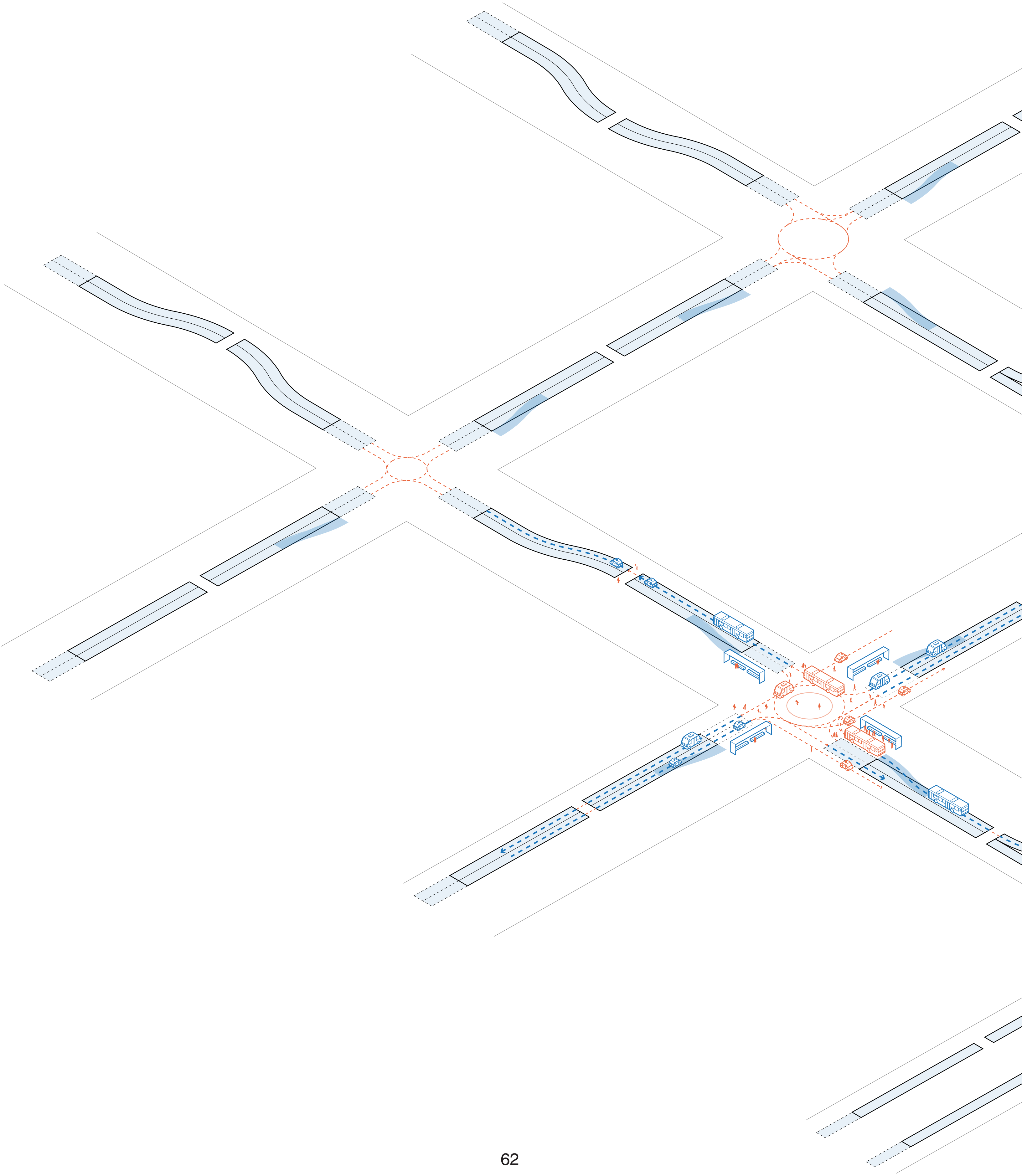


Figure 3.1: List of options for edge conditions between efficient surface and shared surface.



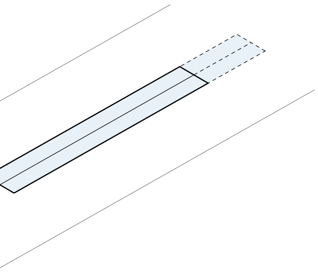
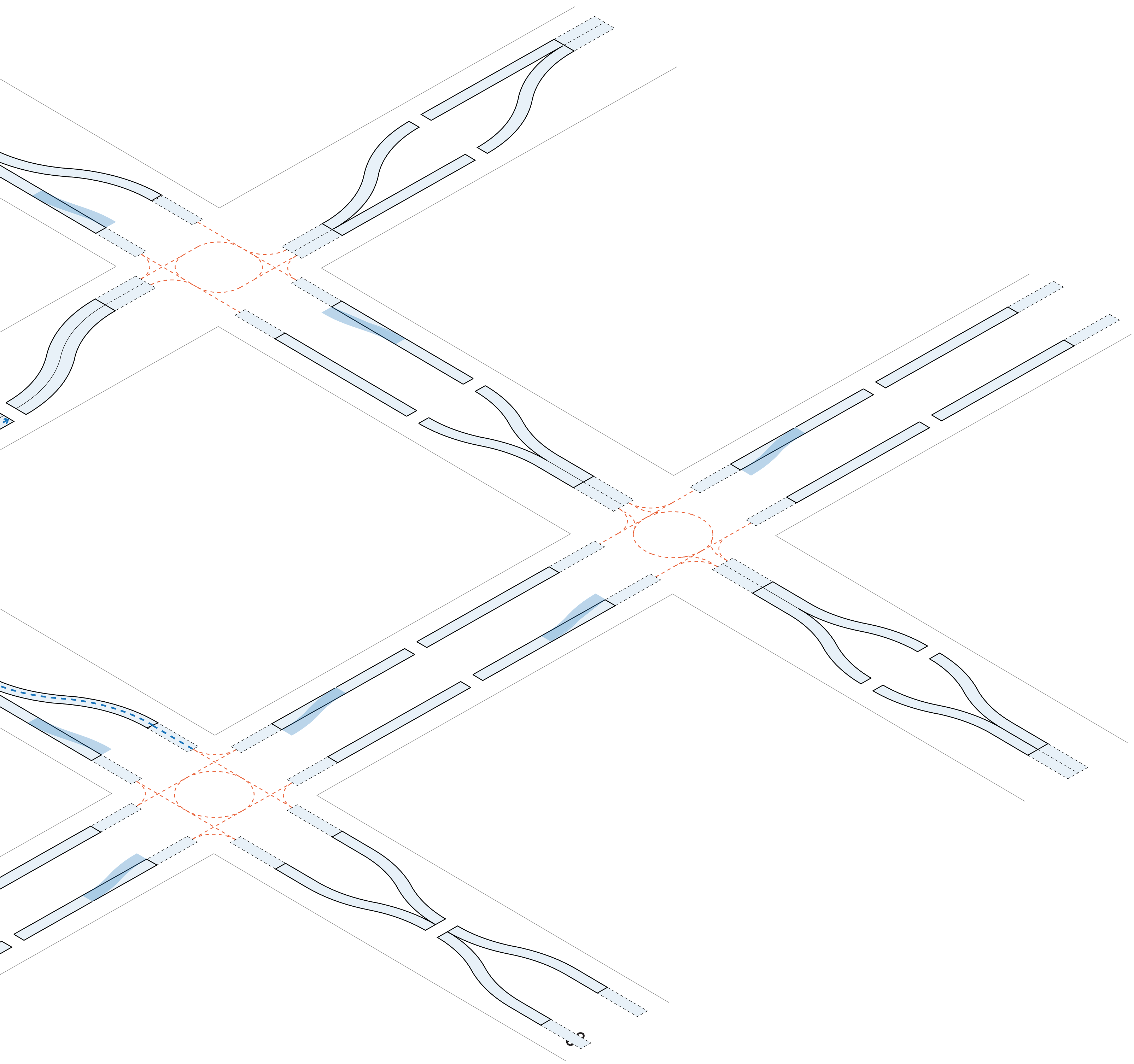
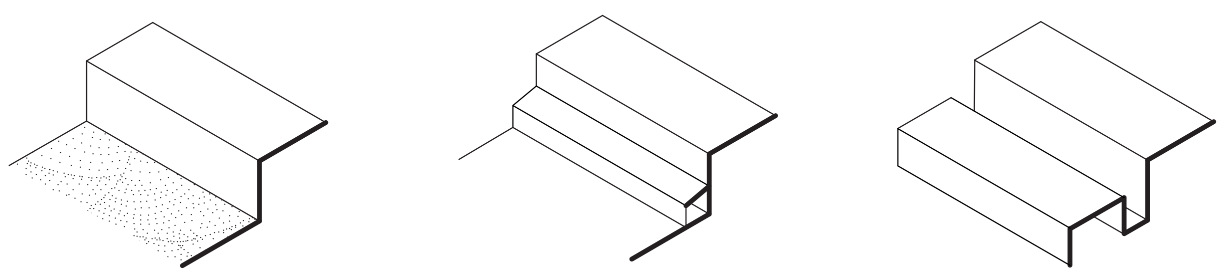


Figure 3.2: With frequent intervals, intersections, and flexible demarcation, efficient surfaces are added segment by segment on the continuous shared surface when in need.



Reprogramming Shared Surfaces

Besides the infrastructure for traveling, shared AVs also require more space for drop-off and pick up, as well as space for self-maintenance, including cleaning, charging and minor repairing (Figure 3.4). They can be clustered around the gateways or spread out as mini depots across the city. Together with public space, including social rooms, commercial devices, public accommodations, as defined by Anthony Orum (Figure 3.5), traffic infrastructure can be added on to the shared surface as open spaces, building extensions, or new structures (Figure 3.3).

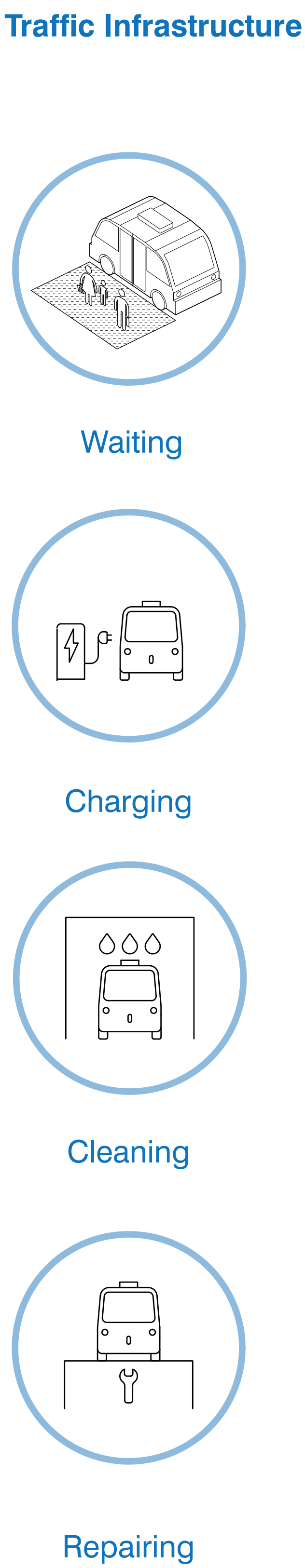


Strategy 1:
Open Space

Strategy 2:
Building Extension

Strategy 3:
New Structure

Figure 3.3: List of strategy to add new programs on the shared surface.



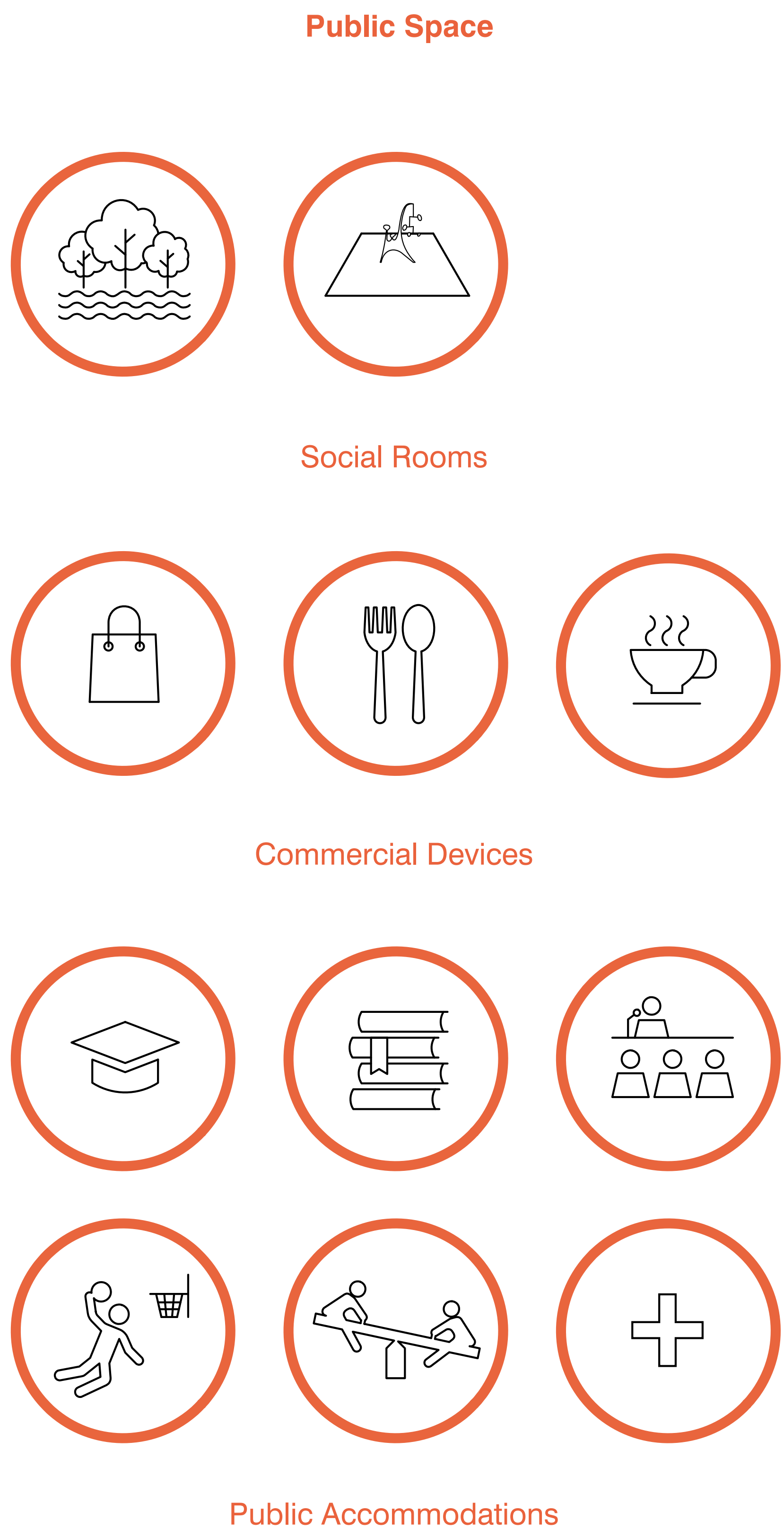


Figure 3.4 (left in blue): List of traffic infrastructure AVs require.
Figure 3.5 (right in orange): List of public amenities as defined by Anothony Orum

Surface Material

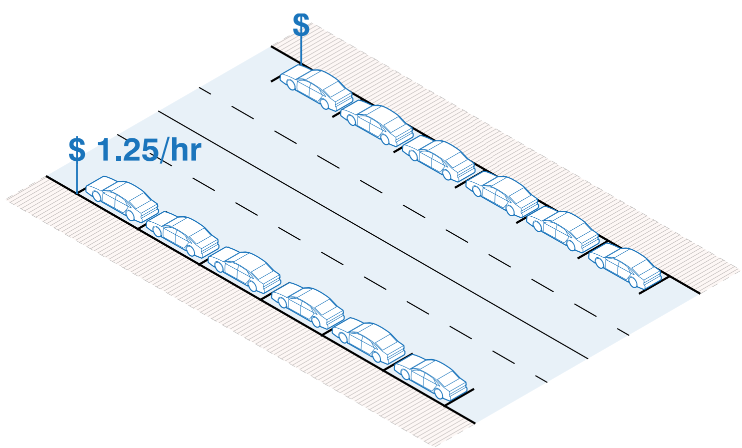
The choice of surface materials is the result of an overall consideration of unit price, durability, and flexibility for add-ons. The material choice includes asphalt, concrete, stone, brick, macadam, dirt, wood, rubber, grass (earth), water, digital surface, etc. And the way surface material aggregate can either be unified with standard tiles as Paseo de Gracia (Figure 3.6) or collaged with different patterns as contributed by abutting property owners on the commercial street in Singapore (Figure 3.7).

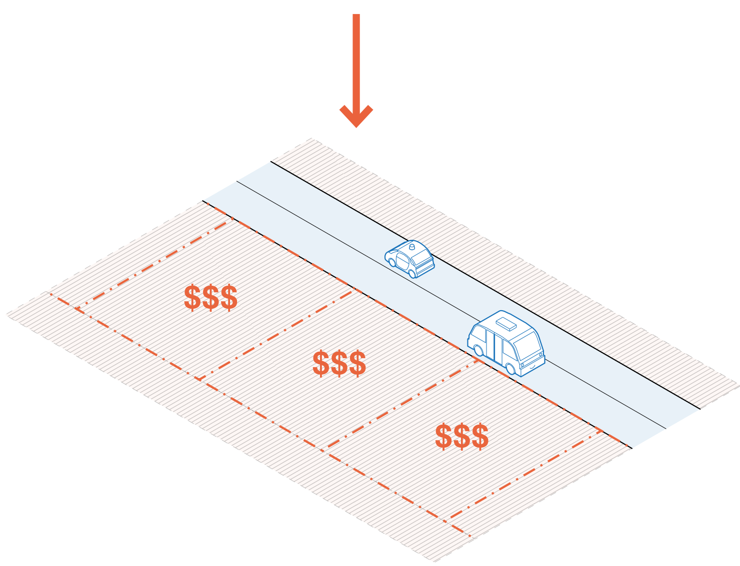
Figure 3.6: Paseo de Gracia, Barcelona with standard tiles well designed by Anthony Gaudi.

Figure 3.7: A commercial street in Singapore wither different pavements in front of each storefront.

Financial Model: From Parking Fee to Rent

As more land is freed up from automobiles in the future, city transportation commissioner will truly become “the largest real estate developer” as Jannet Sadik-Kahn suggested in her book, *Street Fight.* Kept as public inventory, the freed-up street space cannot be sold but either directly maintained by the government, or rented and operated by private developers. Therefore, rent can be collected from commercial activities to compensate the income loss from parking fee, and to maintain other public amenities, such as parks and playground.





4 DESIGN | CITY

Site: South Boston Waterfront
Existing & Alternative Plans
Examples of Urban Surfaces

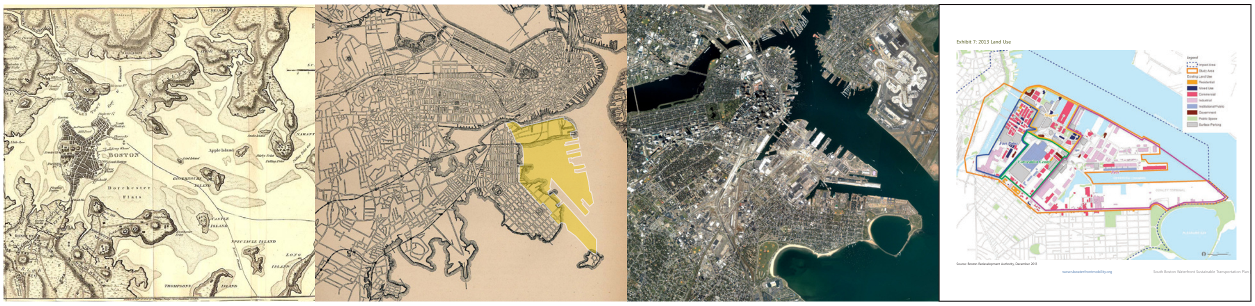
Site: South Boston Waterfront

To apply the new paradigm and design urban surfaces based on real world conditions, I select South Boston Waterfront as a case study because of its development needs, innovative ethos, and geographic location.

Much of the area in South Boston Waterfront was originally tidal marsh, and was landfilled for pier construction from 1833. The area was a robust maritime industrial center by the end of 19th century. However, as the seaport declined in 20th century, much of the land became a continuous surface parking for commuters working in downtown. While, the turn of the millennium saw a burst of redevelopment in the area, with residential buildings, office towers, and hotels being constructed along the waterfront (Boston Planning and Development Agency)(Figure 4.1).

As the area is developing from an industrial wasteland into a world-class innovative district to attract people to live, work and play, two of the major challenges it will face are related to traffic efficiency and the public realm. On the one hand, the increasing traffic from the influx of people will put pressure on the already congested roads, which are now dominated by commuting cars. On the other hand, there is limited usable public open space inboard from the water that allows people to gather and connect with each other. In this case, the public streets, which typically favor the automobiles as it is today (Figure 4.2), become one of the most important open space components of the public realm as it evolves to accommodate more person-trips in the future (vhb, 2015).

Boston is always open to innovation and new technologies. In terms of transportation, it was the first American city building subway system and initiating ride-sharing service (BCG, 2017). In 2016, Boston launched an AV testing program focusing on South Boston's Flynn Marine Park. Startup firms spinning-out from MIT, including nuTonomy



Marshland	**Maritime Industrial Zone**	**Parking Lots**	**Mix-Use Redevelopment**
(Before 1860s)	(1860s -1980)	(1980 - 2000)	(2000 -)

Figure 4.1: Historical transformation of the South Boston Waterfront. Images from the Internet.

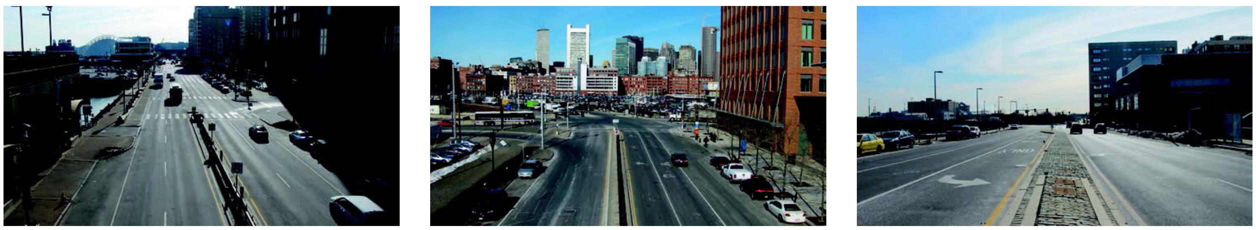


Figure 4.2: Currently, streets typically favor the automobiles, from right to left: Seaport Boulevard, Congress Street, Summer Street. Photos from *South Boston Waterfront Sustainable Transportation Plan*

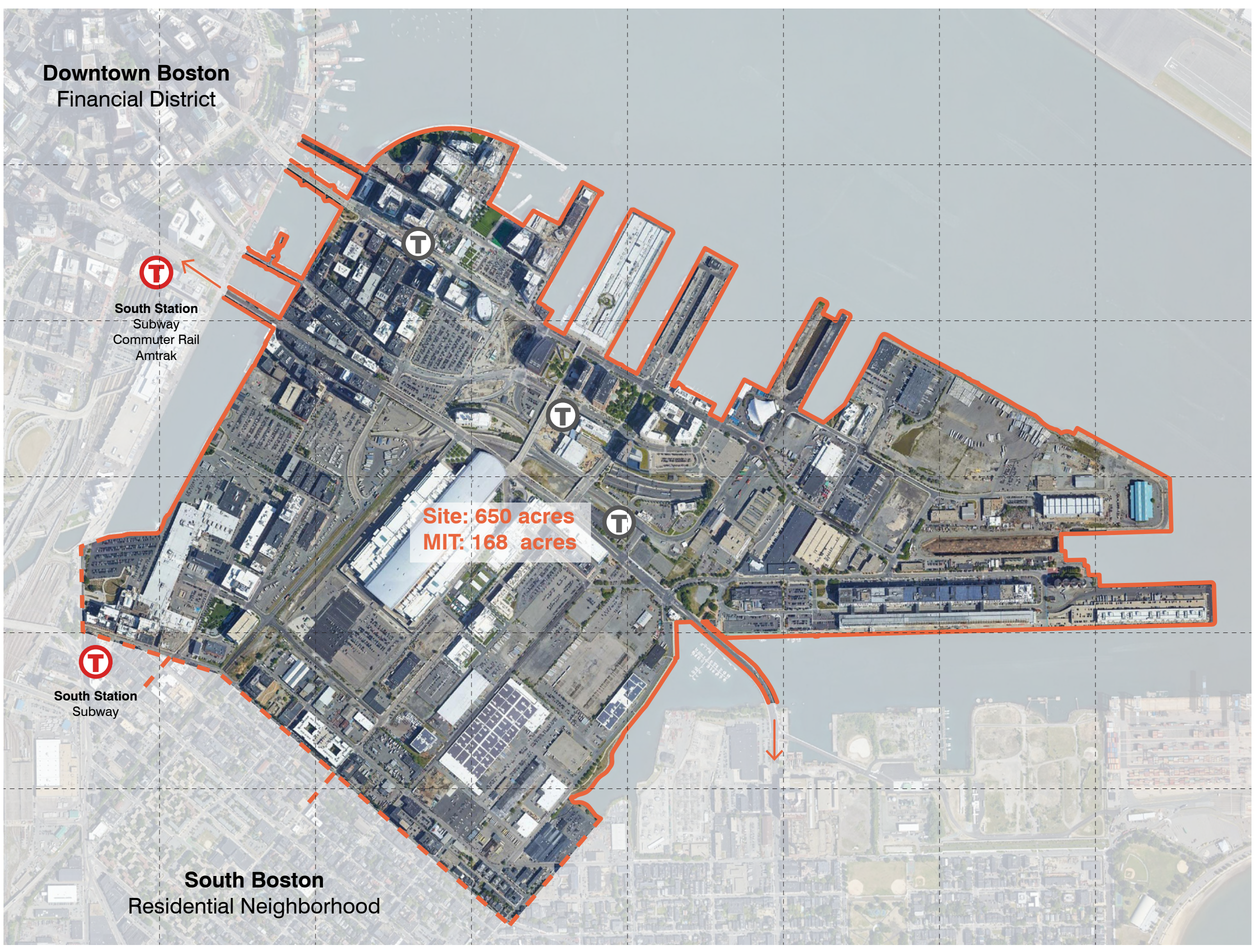


Figure 4.3: The peninsular study area with controlled accesses.

and Optimus Ride, have been running vehicles to deliver last-mile service. Recently, the city expanded its testing zone to a wider area in the Seaport and Fort Point neighborhoods after nuTonomy achieved test plan milestones (City of Boston, 2018).

The study area (Figure 4.3) is defined as the 650-acre peninsula bordered by the waterfront and 2nd street with key gateways at bridges, MBTA stations and intersections to/from the adjacent neighborhood. Because the peninsular site has a clear border condition with controlled accesses, I propose to designate it as a shared AV-only site and update the streetscape by using the new people-centered design approach in the near future.

Existing & Alternative Plans

According to Boston Planning & Development Agency (BPDA), the South Boston Waterfront is well under construction to expect the influx of people by 2035. Currently, more than 50 projects, including condominiums, office towers and tourism-related buildings have been built or are in development within the site. Those new developments are mainly located in Seaport Square, Fan Pier, Fort Point, or near Boston Convention & Exhibition Center. In addition, the warehouses in the historic area have been converted to lofts for living or working.

In terms of public space, future efforts for open space include the extension and enhancement of the Harborwalk, pocket parks and small interventions as part of an interconnected network. Cultural and civic institutions, such as Children’s Museum, Institute for Contemporary Art, Bank of America Pavilion, and John Joseph Moakley United States Courthouse, are spread out as the anchor for each sub-area. Commercials, including restaurants, cafes and retails, cluster in the historic area, or are along Seaport

Boulevard. However, as the district is still underway turning into a mix-use neighborhood, there are very few public accommodations, such as schools, libraries or hospitals, pinned on Google Map.

Regardless of its robust development at the moment, as planned by 2035, buildings only take 32% of the land use, open space only 3%. The rest 65% of land is still space mainly used by cars for moving or parking (calculated from the latest 3D model provided by BPDA Online) (Figure 4.4).

Figure 4.4:
Land use by 2035 as planned

100	%	Total:	650	acres
32	%	Building:	212	acres
3	%	Open Space:	20	acres
65	%	Space Used by Cars:	418	acres

From the optimistic aspect, those 65% land are also operable surfaces for reprogramming if it is designated as a shared AV-only site soon. After efficient surfaces are allocated for internal movement and external connectivity (Figure 4.5), all the other space can be reprogrammed either with new developments such as affordable housings or as a continuous living room for everyday life. The proposal in Figure 4.6 shows one possibility, while the real implementation will be more dynamic and flexible, to accommodate the uncertainties from the future.

Figure 4.5:
Land use by 2035, if the site becomes a shared AV-only district

100	%	Total:	650	acres
32	%	Building:	212	acres
3	%	Open Space:	20	acres
60	%	Shared Surface:	385	acres
5	%	Efficient Surface:	33	acres

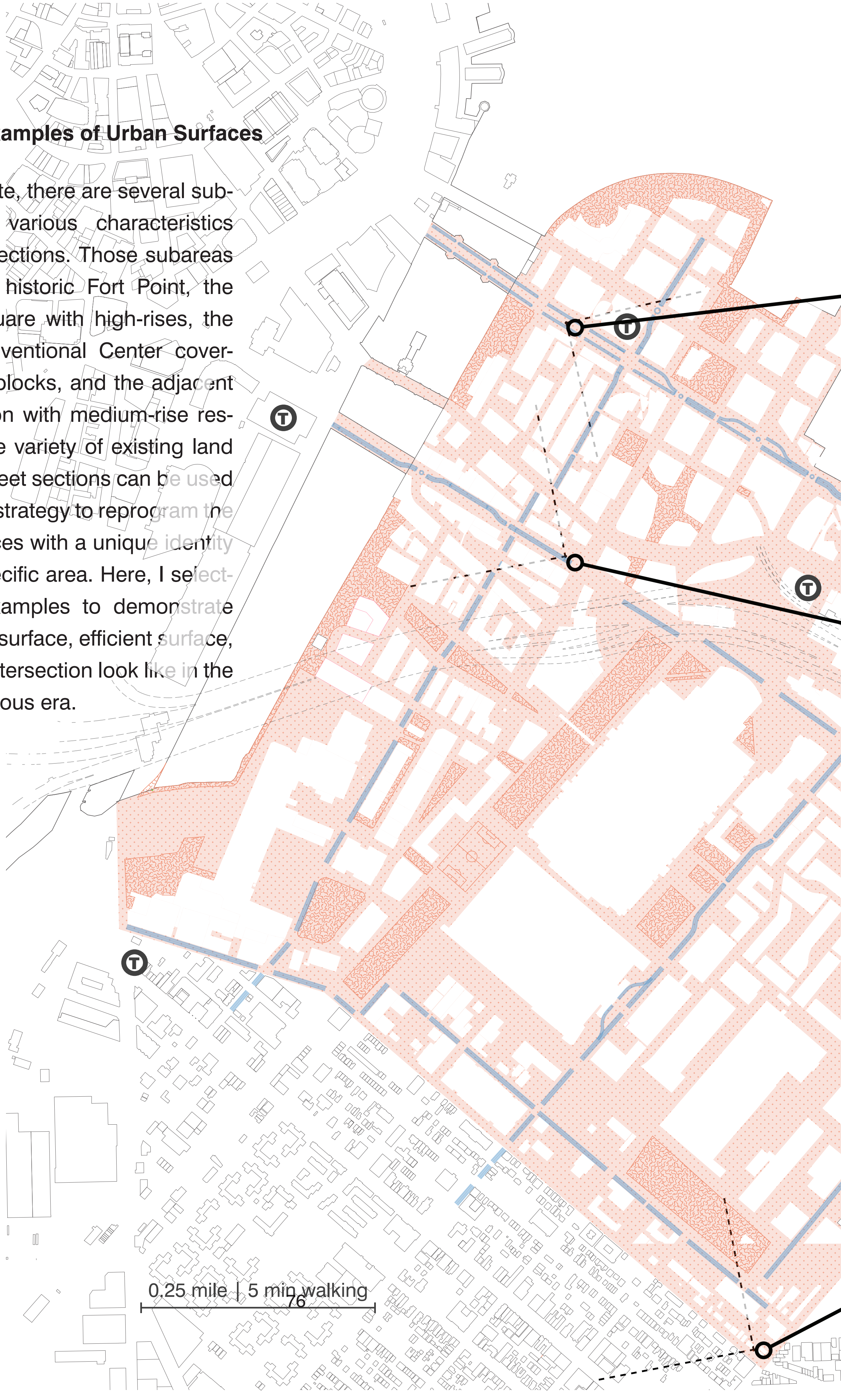
In the transition period, people enter/exit the site via public transit, walking or cycling. Drivers park conventional automobiles in the parking lots near the gateways or along the bridges, and then transfer to autonomous vehicles to their final destinations. Frequent bus service are provided to connect downtown and South Boston through Summer Street. In the future as shared AVs are in Boston citywide, those parking areas will be converted to housing, commercials and public amenities, such as a sports field, etc.

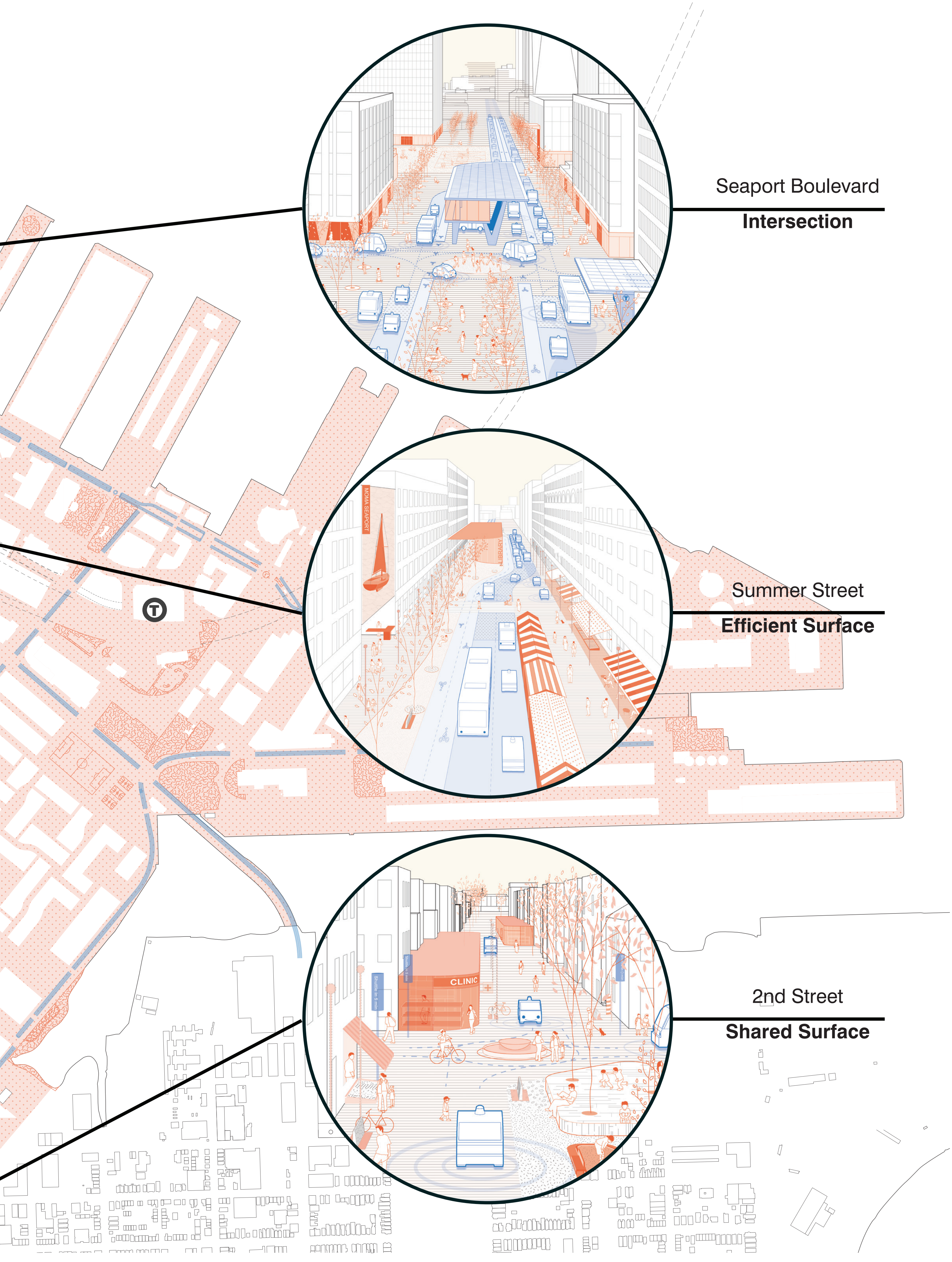
Figure 4.6:
Land Use by 2055 with reprogrammed urban surfaces.

100	%	Total:	650	acres
32	%	Building:	212	acres
3	%	Open Space:	20	acres
60	%	Shared Surface:	385	acres
5	%	Efficient Surface:	33	acres

Selected Examples of Urban Surfaces

Within the site, there are several subareas with various characteristics and street sections. Those subareas include the historic Fort Point, the Seaport Square with high-rises, the Boston Conventional Center covering several blocks, and the adjacent South Boston with medium-rise residences. The variety of existing land uses and street sections can be used as a design strategy to reprogram the urban surfaces with a unique identity for each specific area. Here, I selected three examples to demonstrate how shared surface, efficient surface, and major intersection look like in the full autonomous era.





Seaport Boulevard
Intersection
MOMA SEAPORT
Summer Street
Efficient Surface
CLINIC
2nd Street
Shared Surface

Example A:
2nd Street

The Second Street in South Boston is currently a 50-feet-wide residential street mainly for parking without street life (Figure 4.7). Its conversion to shared surface will lead to community vitality and cohesion with more space for vegetation, street furniture and service structures. Playgrounds, seating areas, and facilities, such as clinic, will burgeon out from surrounding residents' inputs.

At Intersection, AVs slow down to 3mph and interact with pedestrians and cyclists for right-of-way, and can speed up to 20 mph in the less busy area. Corners can serve as drop-off/pick-up zone for shuttles.

Figure 4.7: Existing road condition of the 2nd Street. Google Map Street View.


BOOKSTORE
Shuttle in 5 min
IC

Example B:
Summer Street

Summer Street is a four-lane thoroughfare connecting Downtown and South Boston (Figure 4.8). Efficient surfaces are added to connect neighborhoods in a timely manner, at the same time, distribute people to a variety of programs along the way.

The freed-up space between efficient surfaces and buildings can be left open as front yard for culture venues, or can be extension from ground-floor commercials to promote economic vitality. If space allows, a new building can be added to create a covered passage on one side, and display wall on the other side. Frequent intervals are provided for easy pedestrian crossing.

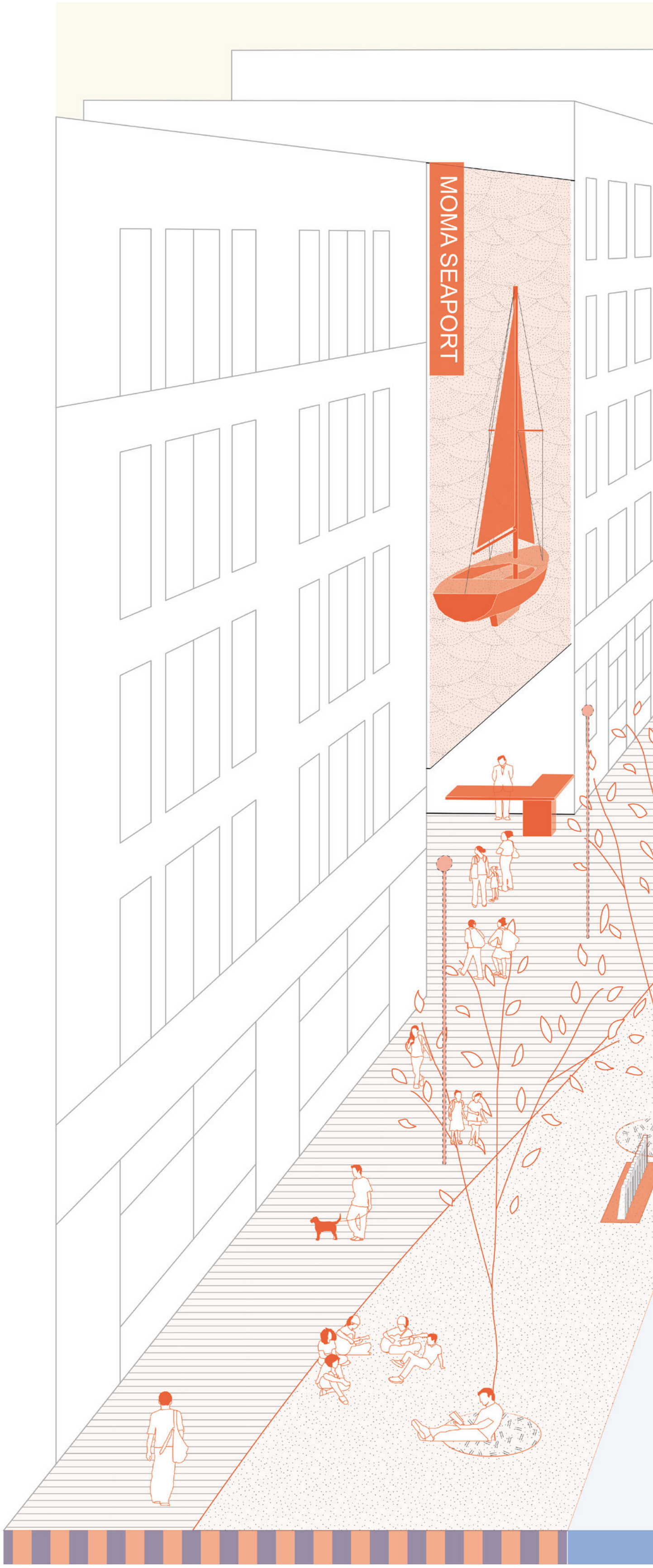
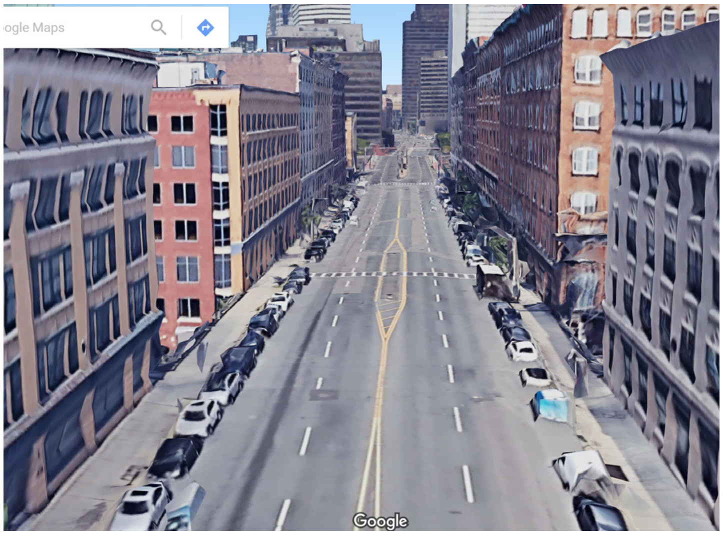
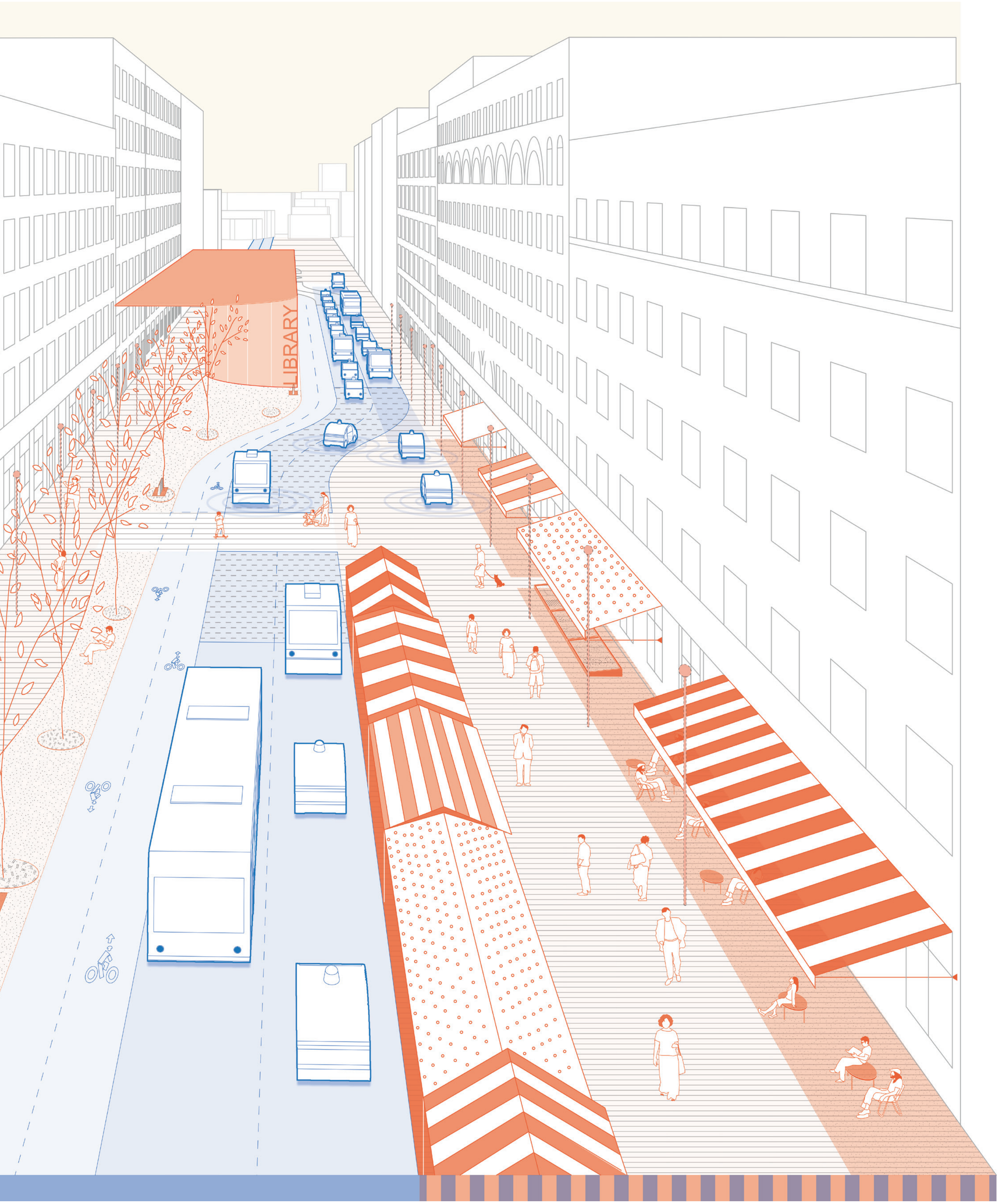


Figure 4.8: Existing road condition of Summer Street. Google Map Street View.




LIBRARY

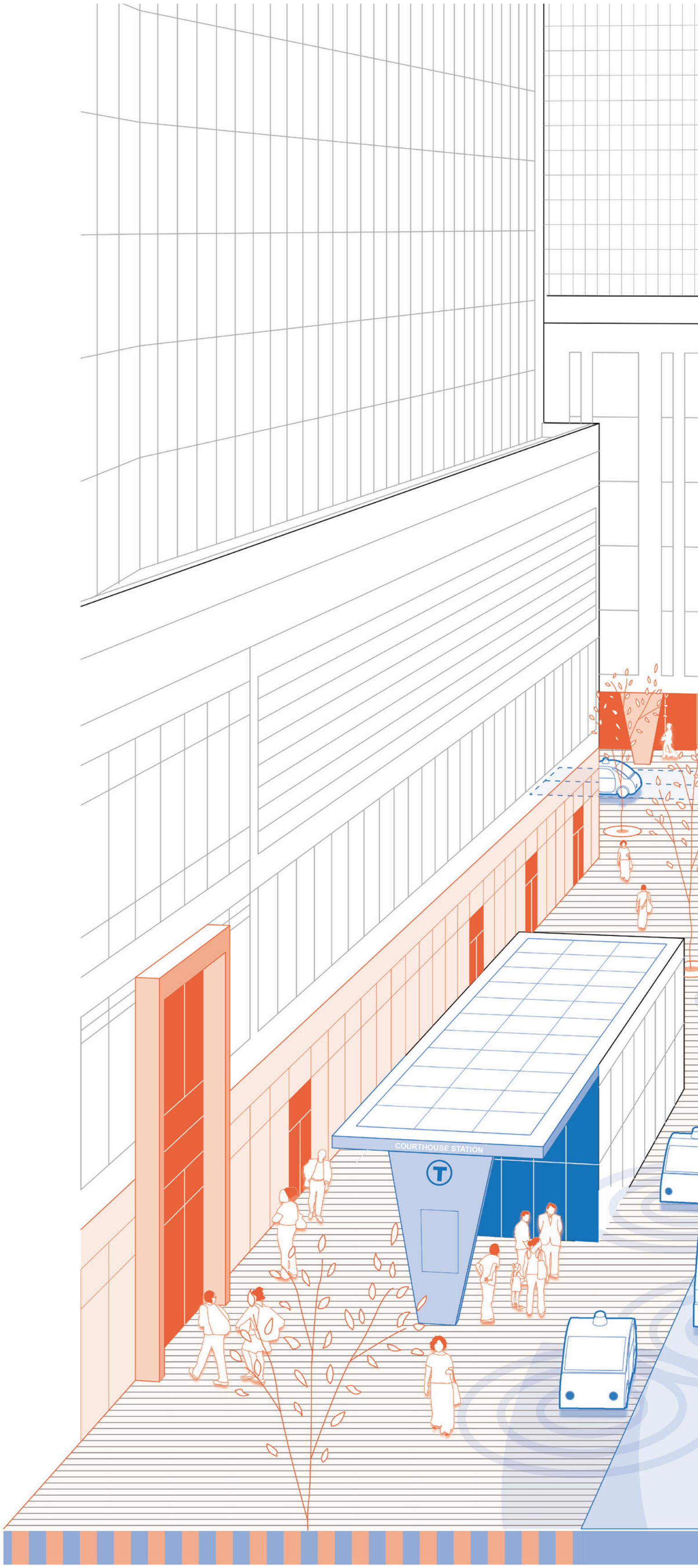
Example C:
Seaport Boulevard | Thomson Pl

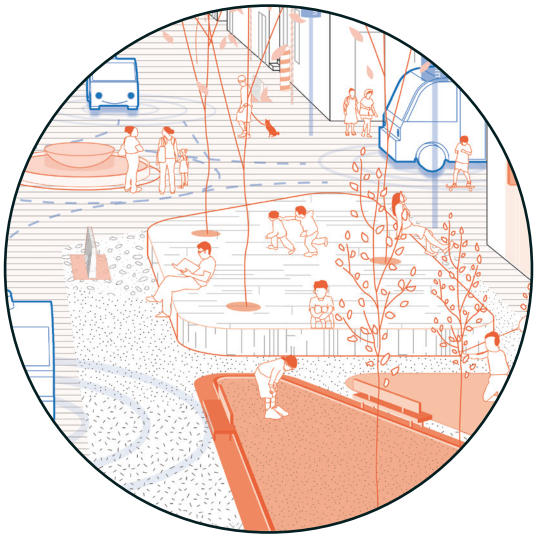
Unlike the 19th-century boulevard, Seaport Boulevard is a 135’ wide street surrounded by office towers and hotels (Figure 4.5). The crossroad between Seaport Boulevard & Thomson Place is near the Courthouse T Station and has full potentials to be converted to an intersection for exchange and interaction.

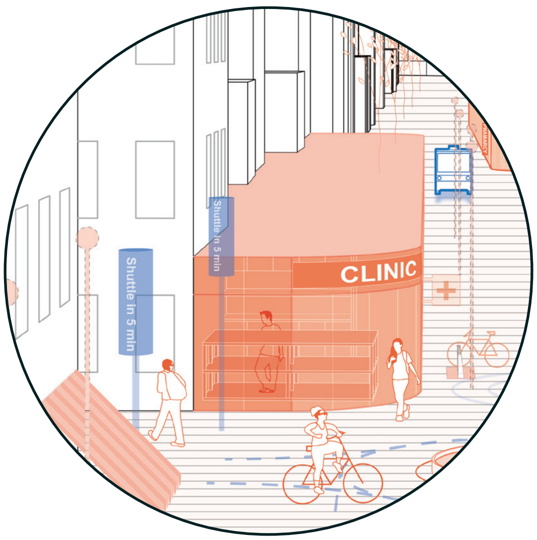
As an extension from the Rose Kenny Greenway, efficient surfaces are added on two sides of the tree-lined promenade. The wide side-surfaces can be used for drop-off/pick-up zone in front of hotels and offices, or exchange points to other modes of travel.

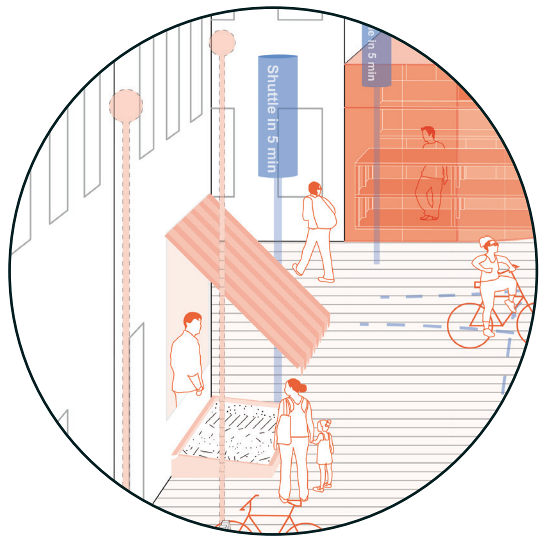
Sometimes, dead ends are created when two split efficient surfaces merge. Those spaces with lower connectivity can be used as mini depots for AV’s self- maintenance, while they still keep the flexibility to be used as event space when vehicles are out.

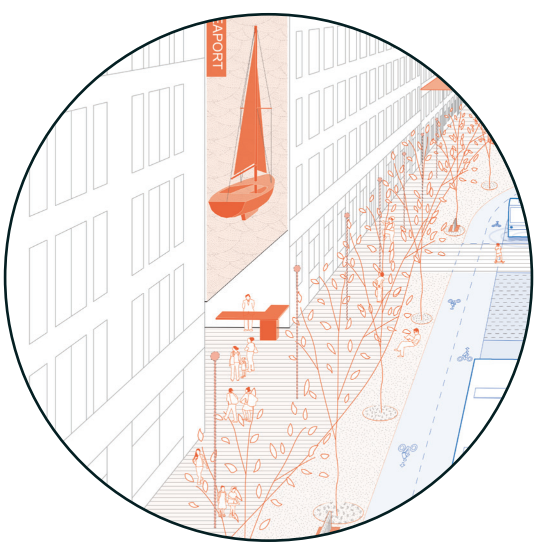
Figure 4.5: Existing road condition on Seaport Boulevard. Google Map Street View.

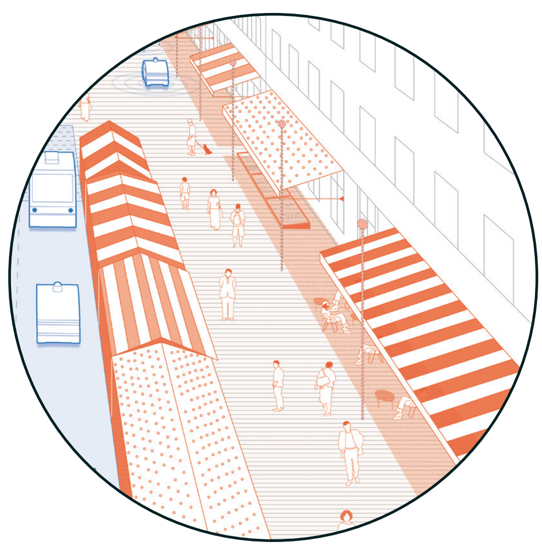




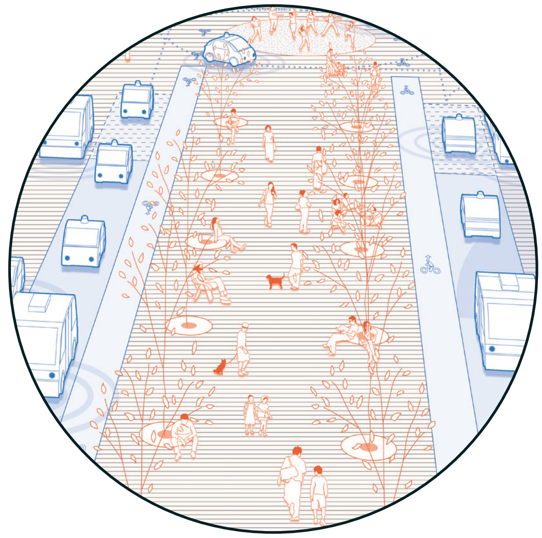
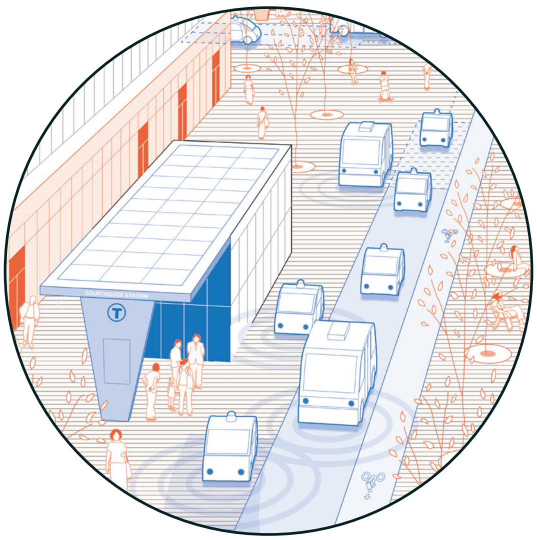
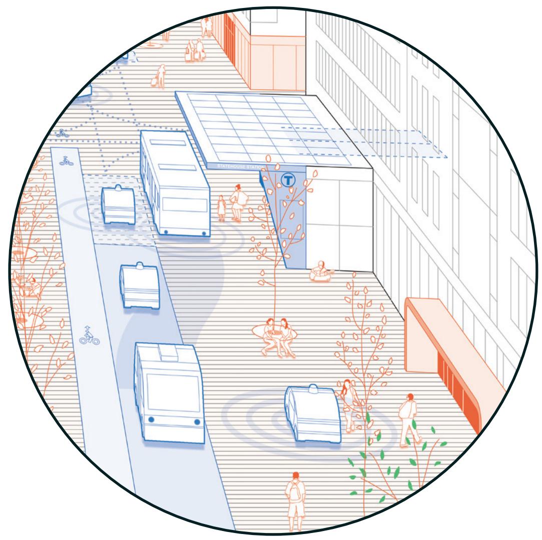
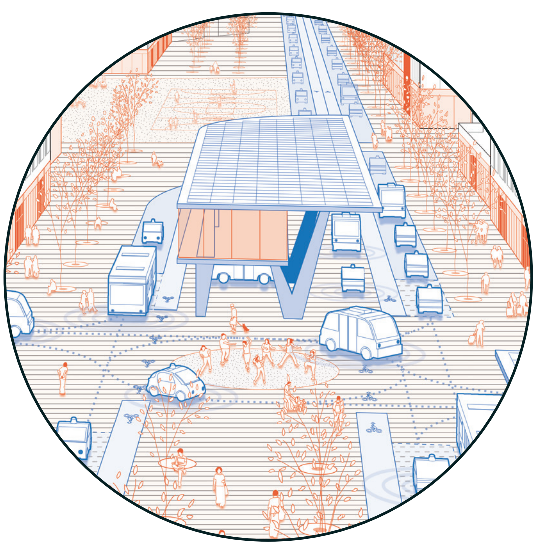
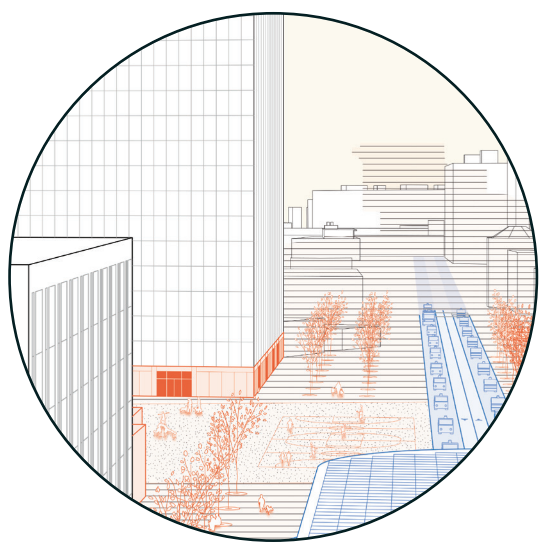








The above three examples show some possibilities to reprogram urban surfaces with public amenities and traffic infrastructure in a balanced relationship. It is for sure that the real implementation will be more

dynamic and intriguing to create a unique identity for each specific neighborhood based on local needs and participation.

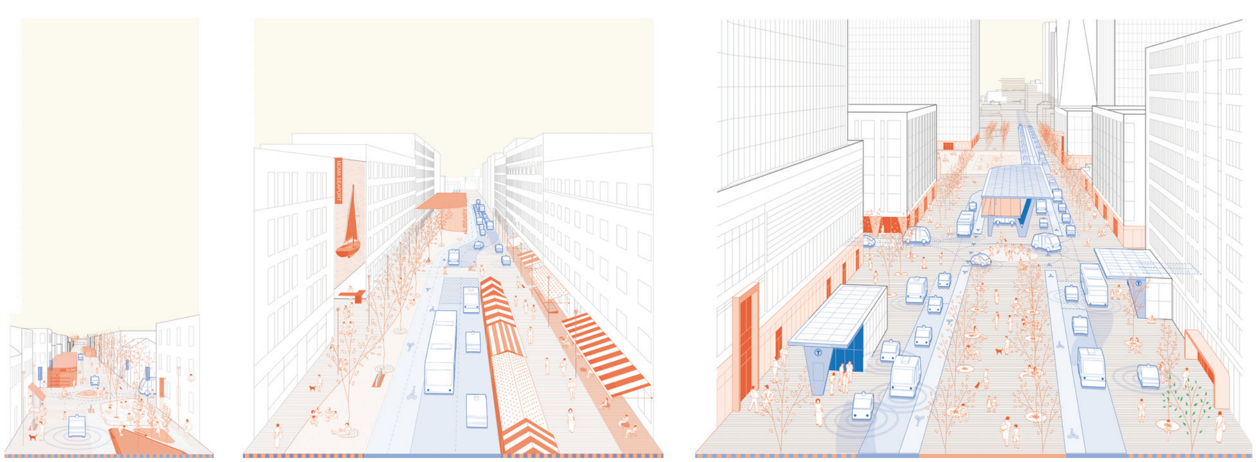
Conclusion & Future Work

At the beginning of this year, Google announced it would launch the first commercial service via a fleet of autonomous vehicles by the end of 2018. The signal is clear that the coming of autonomous vehicles is faster than we imagined. In the past century, urban planners and designers across the world made a vigorous effort to adjust our cities to the automobile. This time, it is critical to apply the new technology to benefit our lives, rather than for our lives to be planned around them. Admittedly, it is a challenging undertaking requiring interdisciplinary collaboration between experts from different fields. This thesis mainly focuses on the transformation of urban form by envisioning a new type of street in the full-autonomous era. It also gives recommendations on the development of technology and policymaking to better deliver an autonomous future for people.

One thing to keep in mind: every city is different and have different priorities in its public agenda; this thesis does not try to pave the road under the homogeneous standards as global cities did in the past century, but provide a flexible people-centered approach to give unique identity for each specific neighborhood. The design proposal based on local contexts and participation in South Boston Waterfront gives a good example to show that cities do not need to design around vehicles but can gain new spatial integrity that meets the needs of people and, at the same time, responds to the realities of urban mobility.

To conclude and to answer the question I asked in the introduction, if the distinctive sign of 19th century urbanism was Boulevard, and the hallmark of 20th-century urbanism was Highway, then the identity of 21st- century urbanism will be Urban Surfaces which integrate the traffic infrastructure with the public realm. More important, the new way of building streets as urban surfaces will initiate a new lifestyle, which values sustainability, promotes sharing, and encourages interactions.

Future work from the aspect of urban form transformation includes a more detailed phasing plan, a design proposal for border conditions during the transition period, and a prototype of mini maintenance depots which can be used for both vehicles and people at different times. In addition, a closer collaboration with traffic engineers is required to calculate the minimum efficient surfaces required for maximum efficiency.



Something Beyond What Design Itself Could Help...

Education on Street Courtesy
Q: “Purposeful Jaywalker”
A: Technologies are not here to cultivate people to be ruder. It should not be an excuse for people to disrupt AVs with evil deeds on purpose.

Site: Sea Level Rising
Q: South Boston is facing threatenings from sea level rising, how to solve this problem?
A: 1. Indirect effects: More active modes of travel will lead to less GHG emission.
2. Existing underground garages can be converted to retention ponds.
3. Swales with vegetarian can be added to the free-up space, serving both ecological and recreational functions.

Terrorist Drivers Struck Pedestrians
Q: Currently, many cities, such as NYC and Toronto, witnessed terrorist drivers struck pedestrians. If you remove all barriers and bollards, and mix pedestrians and vehicles, are you risking pedestrians’ safety?
A: 1. Safety is the first priority when introducing AVs to cities.
2. Human drivers are sometimes unpredictable, we probably want to forbid human drivers on the road soon. If all AVs are monitored by security department, terrorist attack can be controlled.
3. Cyber security needs to be improved.

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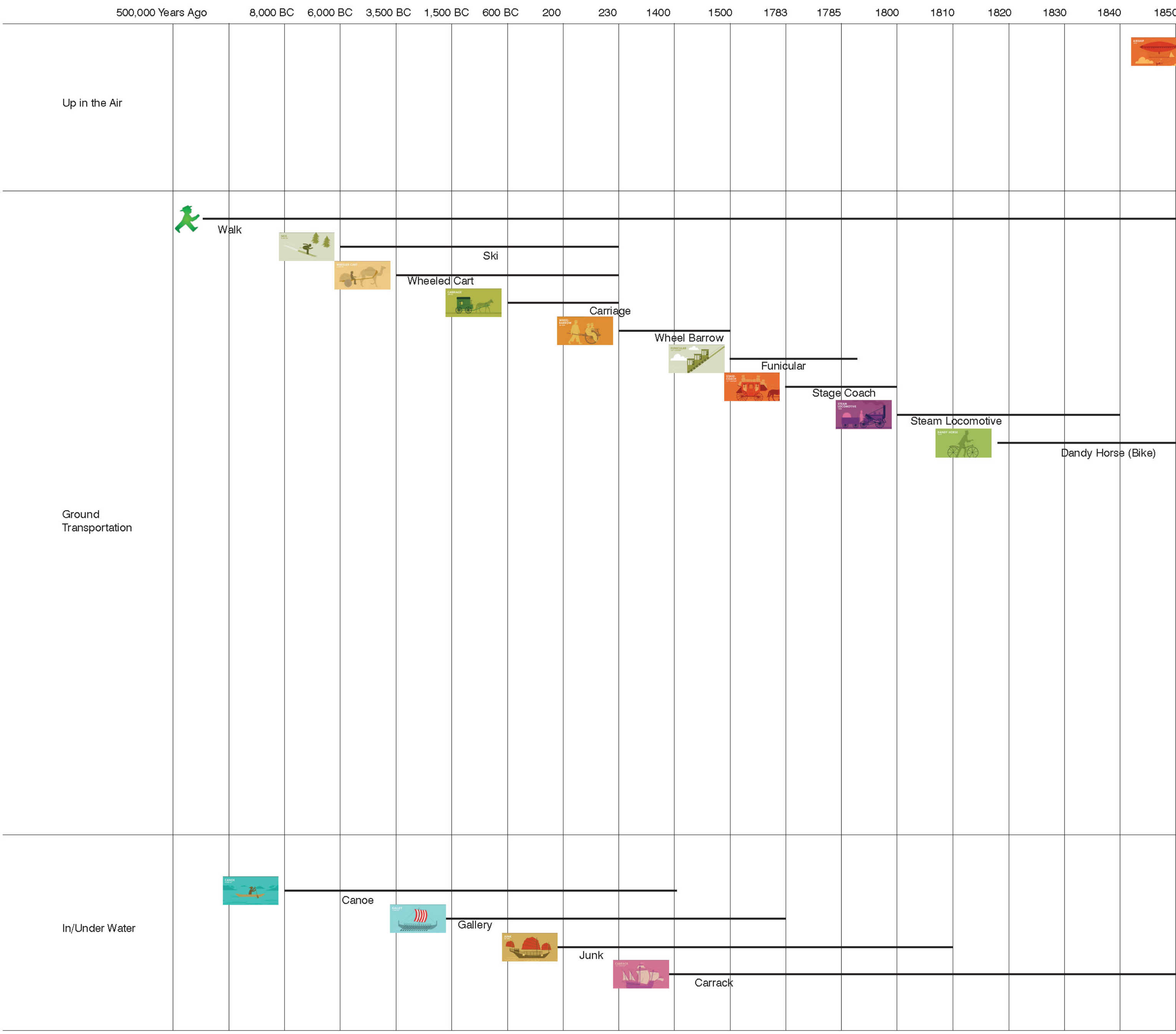
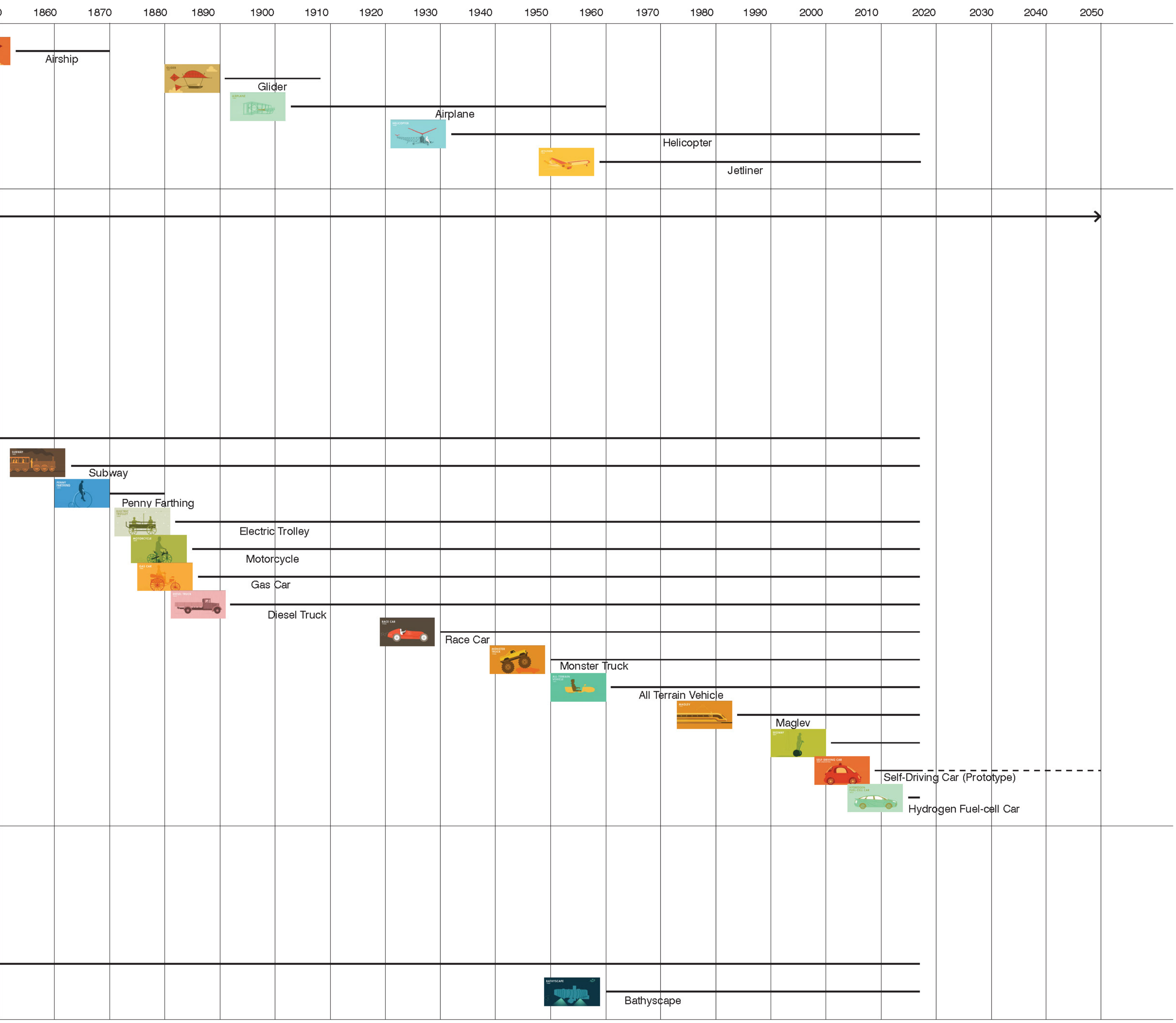
Appendix 1: History of transport technology in the format of timeline.

Reproduced based on the video *Here to There: An Animated History of Transportation*, https://www.theatlantic.com/technology/archive/2015/12/driverless%ADcars%ADare%ADthis% ADcenturys%AD-space%ADrace/417672/?utm_source=fbb




1860
1870
1880
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1900
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1930
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1950
1960
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1980
1990
2000
2010
2020
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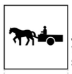
2040
2050
Airship
Glider
Airplane
Helicopter
Jetliner
Subway
Penny Farthing
Electric Trolley
Motorcycle
Gas Car
Diesel Truck
Race Car
Monster Truck
All Terrain Vehicle
Maglev
Self-Driving Car (Prototype)
Hydrogen Fuel-cell Car
Bathyscape

Appendix 2: From Carriage to Car to Autonomous Vehicle

[Motor Ag

[Carriage Age]

600BC | 1886 | 1908 (Ford Model T)



CARRIAGE | 600 BC

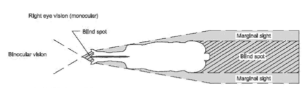
aka.
Wagon
Stage Coach (for public)

A carriage is a wheeled vehicle for people, usually horse-drawn. The carriage is especially designed for private passenger use, though some are also used to transport goods. A public passenger vehicle would not usually be called a carriage – terms for such include stagecoach, charabanc and omnibus. Working vehicles such as the (four-wheeled) wagon and (two-wheeled) cart share important parts of the history of the carriage, as does too the fast (two-wheeled) chariot.

Energy	*Fuel*	Animal Power (Hay)
	Emission	Horse Manure
Speed (Range, Extenstion)		- 10 mph - limit by horse power - limit by driver's physical condition ~ both need to sleep and eat, may be sick, reaction to emergency
Ownership (Car Pride, Sharing Economy)		- usually privtely owned by the rich - Omibus } Shared - Stage Couch } Shared

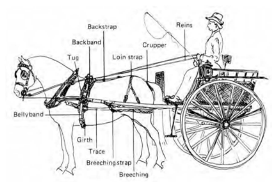
__Relationship__

Horse ~ self- conscious
Human ~ self- conscious



Within (Communication System)

User Interface (Chauffeur & Horse):
- Reins- thin leather straps attached around a horse's neck which are used o control the horse



w/ City (Pedestrian, Infrastructure, etc.)

The Boulevard Montmartre on a Winter Morning
Camille Pissarro | 1897

__Impacts__

Land Use

Large portion of land was dedicated to Hay Producition

Infrastructure Requirement

- Carriagehouse (parking)
- Stable (feed, rest) -> Convert to restaurant, etc.
- Animal clinic
- Rest -stop (Hotel along the road)

-Road maintenance ??? who cleans horse manure

Urban Form

- Hausmann's boulevard 1854
  speed up carriage
  mix- used by carriage and pedestrian
- Now horse riding is for leisure

Assemble
" The distinctive sign of 19th century urbanism was the boulevard, a medium for bringing explosive material and human forces together..."
" The Napoleon- Haussmann boulevards created new bases - economic, social easthetic - for bringing enormous numbers of people together."

- Marshal Berman

Transition from Carriage to Car
Horseless Carriage

"Horse -"
"???+"

Equilibrium here???

Horseless Carriage: transition from carriage to car

Horseless Carriage: the early model automobiles were called horseless carriages. (From Wikipedia-Carriage)

 # Streets and the Shaping of Towns and Cities

- P61
- "Restore human legs as a means of travel. Pedestrian rely on food for fuel and need no special parking facilities." – Lewis Mumford (1895-1990)
- Steam vehicles appeared in England as early as 1769 and developed rapidly until 1866 when Parliament passed the "Red Flag Law." This inhibiting ordinance required self- propelled vehicles on public roads to be
  - limited to a maximum speed of 4 mph
  - carry a minimum of two people
  - be accompanied by a third person on foot who carried a red flag to give warning and help control frightened horses.
- In 1896 the act was withdrawn and the speed limit increased to 14 mph (22 kph).

From the late 1890s to the 1920s, carriages and automobiles overlapped on city streets. Early cars were expensive and unreliable, regarded more as amusing novelties than as a serious means of transportation. But by 1910 innovations in mass production and engine technology had created a vehicle that was both more reliable and more affordable; it soon became clear that the car was here to stay. While there were still more than 4,600 carriage companies operating in the United States as late as 1914, by 1925 there were barely 150. By 1929, there were fewer than 90.

AUTOMOBILE | 1886

aka.
Horseless Carriage
Car

A car (or automobile) is a wheeled motor v
eight people, have four tires, and mainly tr
oped economies depend on them. The ye
Benz Patent-Motorwagen. Cars did not be
masses was the 1908 Model T, an America

Energy	*Fuel*	Steam 1769 -> Electric 1833 -> Gas 1886
	Emission	Pa
Speed (Range, Extenstion)		- 30 - 60 mph - limited by engine and petrol capcity - limited by human driver's physical condition
Ownership (Car Pride, Sharing Economy)		Majority ~ Private Uber, etc ~ Semi- private Taxi Bus Shared Rent

__Relationship__

Machine ~ no
Human ~ self- conscious

You know
is who's b

Within (Communication System)

User Interface:

- Dashboard
- Mirrors
- Steering wheel

} Machine

w/ City (Pedestrian, Infrastructure, etc.)

- Traffic rules
- Signals (traffic light, signs)

} Infrastructure

- Pilor lamp
- Eye contact
- Gesture

} Peer drivers Pedestrian

__Impacts__

Land Use

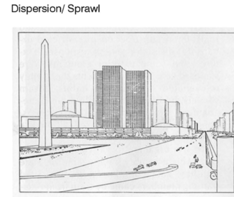
- 25% urban land is dedeicated to cars (road, p
- Oil Extraction
- Global Manufacture

Infrastructure Requirement

- Gas Station
- Garage
- Shopping Mall
- Car Repair Maintenance Shop

Urban Form

Dispersion/ Sprawl



ge]

AV Age (tbd)

2009 (Google Prototype) 2017-18 2030 2050

ehicle used for transportation. Most definitions of car say they run primarily on roads, seat one to
ansport people rather than goods. Cars came into global use during the 20th century, and devel-
ar 1886 is regarded as the birth year of the modern car, when German inventor Karl Benz built his
come widely available until the early 20th century. One of the first cars that was accessible to the
n car manufactured by the Ford Motor Company. Cars were rapidly adopted in the US, where they

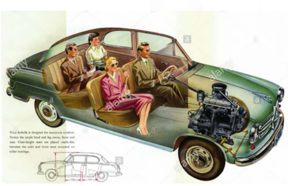
-> Petrol
1892

rticles, Greenhouse Gas

~ need to sleep and eat,
may be sick,
reaction to emergency

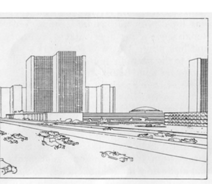
Ownership Control: - Car Plate
- Rush hour fee
- High tax/ price

it doesn't matter wht's under the hood. <u>The only thing that matters</u>
<u>ehind the wheel.</u>" - Dom, *Fast and Furious 8*



arking, etc)

Segrategate
"... the hallmark 20th century urbanism has been the highway, a means for putting the asunder ..." - Marshall Berman



Transition from Car to AV
Driverless Car

"Driver -"
"???+"

Driverless Car: transition from car to autonomous vehicle (take Boston metropolitan as example)

#***GoBoston2030*** by Boston DOT

nuTonomy Inc., a MIT-born startup, but no affiliation with CAU (first trip made on Jan 4, 2017)

Founded in 2013 by a pair of MIT robotics researchers, nuTonomy doesn't make cars. It's a software developer that outfits other companies' vehicles with sensors and cameras to navigate city streets. (In Boston, nuTonomy will dress up an electric car from French automaker Renault to scoot around the streets.)

At first, any company will be constrained in the time, place, and manner of their testing. Before testing on streets, companies must meet — off-street — our important standards, including:

- ease of manual takeover from autonomous mode
- emergency braking and emergency stop functionality, and
- basic driving capabilities, such as staying within a lane.

We'll only allow testing during good weather and daylight hours. Once a company reaches certain milestones, we may allow them to begin testing in other areas of Boston.

- Vehicle can only operate on roads with a speed limit at 30 mph or less.
- Vehicle must have a safety driver behind the wheel.

Driverless Car: transition from car to autonomous vehicle (take Boston metropolitan as example)

CAU involvement in Driverless Car

- CAU
- After viewing photographs of the Lexus, Ryan C.C. Chin, an MIT Media Lab researcher who is also CEO of a self-driving car startup called **Optimus Ride**,
- Alan Berger's NYT article: The Suburb of the Future, Almost Here

"In a future suburban development, a homeowner will order an autonomous car, via an app, from a remote solar-charging lot. As a car approaches, it will "talk" to a home: Lights and other utilities are activated or shut off for greater energy efficiency. Because these suburban homes will not have driveways or garages, front yards can be bigger, devoted to ecological functions or recreational activities."

#Toyota Motor Corp. has established a research office in Cambridge (One Kendall Square), where it is developing self-driving car technology.

#The city of Somerville and Audi plan to test driverless parking systems at the Assembly Row complex, Somerville.

Driverless Car: transition from car to autonomous vehicle (take Boston metropolitan as example)

NuTonomy
MIT alumni start-up

Optimus Ride
Media Lab affiliated (MIT)

Delphi
BMW +Intel

Toyota
Research office at One Kendell Square

Audi urban future initiatives
City of Somerville

AUTONOMOUS VEHICLE | Level 5 not yet

aka.
Driverless Car
Robotic Car
Self-driving Car

Multiple definitions for various levels of automation (USDOT)
- Level 0, the human driver does everything;
- Level 1, an automated system on the vehicle can sometimes assist the human driver conduct some parts of the driving task;
- Level 2, an automated system on the vehicle can actually conduct some partsof the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task;
- Level 3, an automated system can both actually conduct some parts of the driving task and monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests;
- Level 4, an automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate only in certain environments and under certain conditions;
- Level 5, the automated system can perform all driving tasks, under all conditionsthat a human driver could perform them.

Energy

Fuel: Petrol — Hybrid — Electric

Emission: Particles, CO_2
- Using coal powered electricity electric cars do nothing to cut emissions, using natural gas electricity they're like a top hybrid and using low carbon power they result in less than half the total emissions of the best combustion vehicle, manufacturing included.
- Replace engine to cell -> Reduce car weight -> Less Energy consumption

Speed *(Range, Extenstion)*
- 30 - 60 mph (currently limited on city road for testing)
- limited by power capacity
- limited by data input
- not limited by human

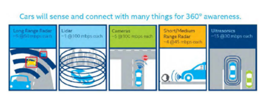
Ownership *(Car Pride, Sharing Economy)*
proposed to start from
- Taxi (Singapore)
- Sharing mobility service (Lyft, Uber)

Should it allow private ownership?
How???

<u>Relationship</u>
AI ~ self- conscious ~ make decisions at Level 5 automation
Human ~ ??? driver becomes passengers

Within *(Communication System)*
User Interface:
- App: Hail car / Track car
- Touch Screen (for display)

w/ City *(Pedestrian, Infrastructure, etc.)*
- Sensors { Radar, Lidar, Camera, Ultraonic } Micro
- HD Map ~ Macro



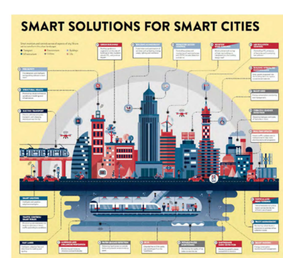
<u>Impacts</u>

Land Use
parking repurpose
- parking move out to city center

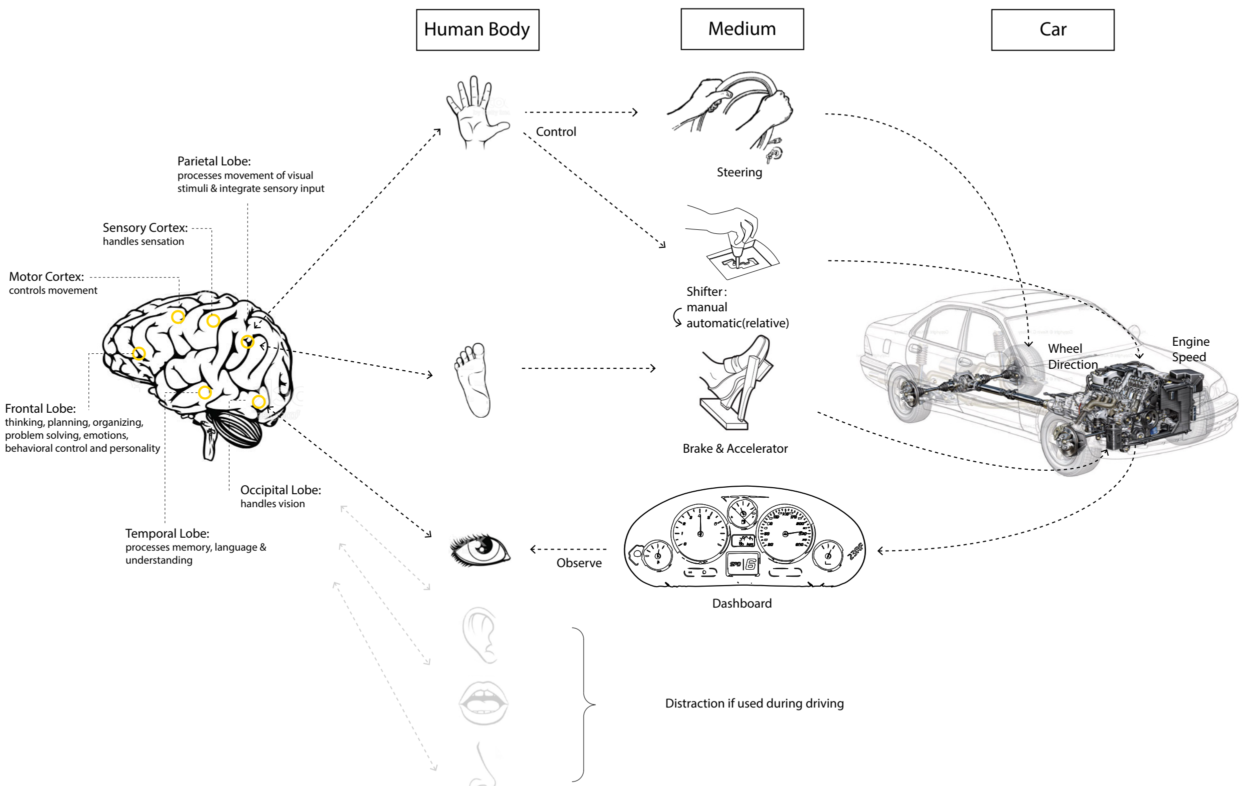
Infrastructure Requirement
- Evening Delivery
- Self- maintenance store
- For those who could not driver before
  the elders peole
  the disabled people

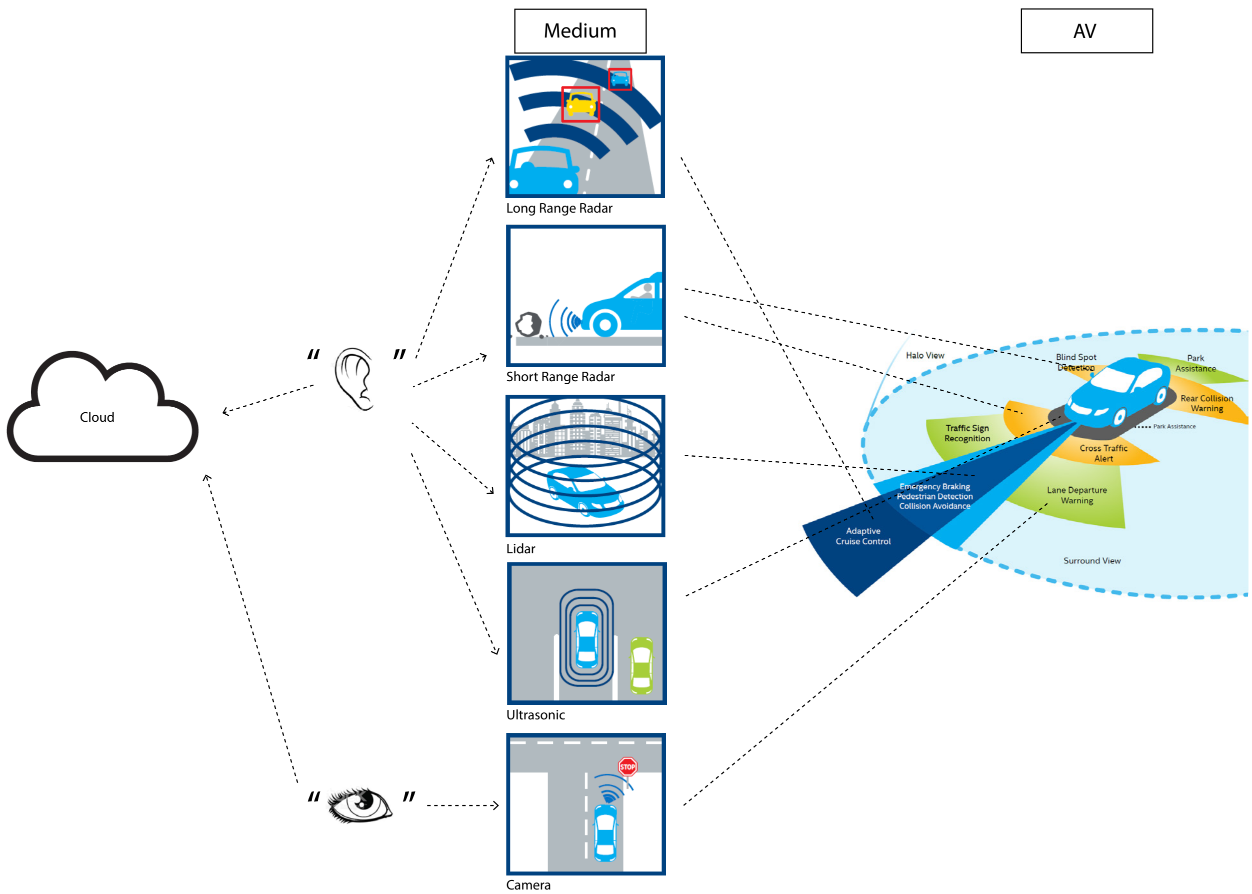
- Dedicated Lane for AVs??????????

Urban Form

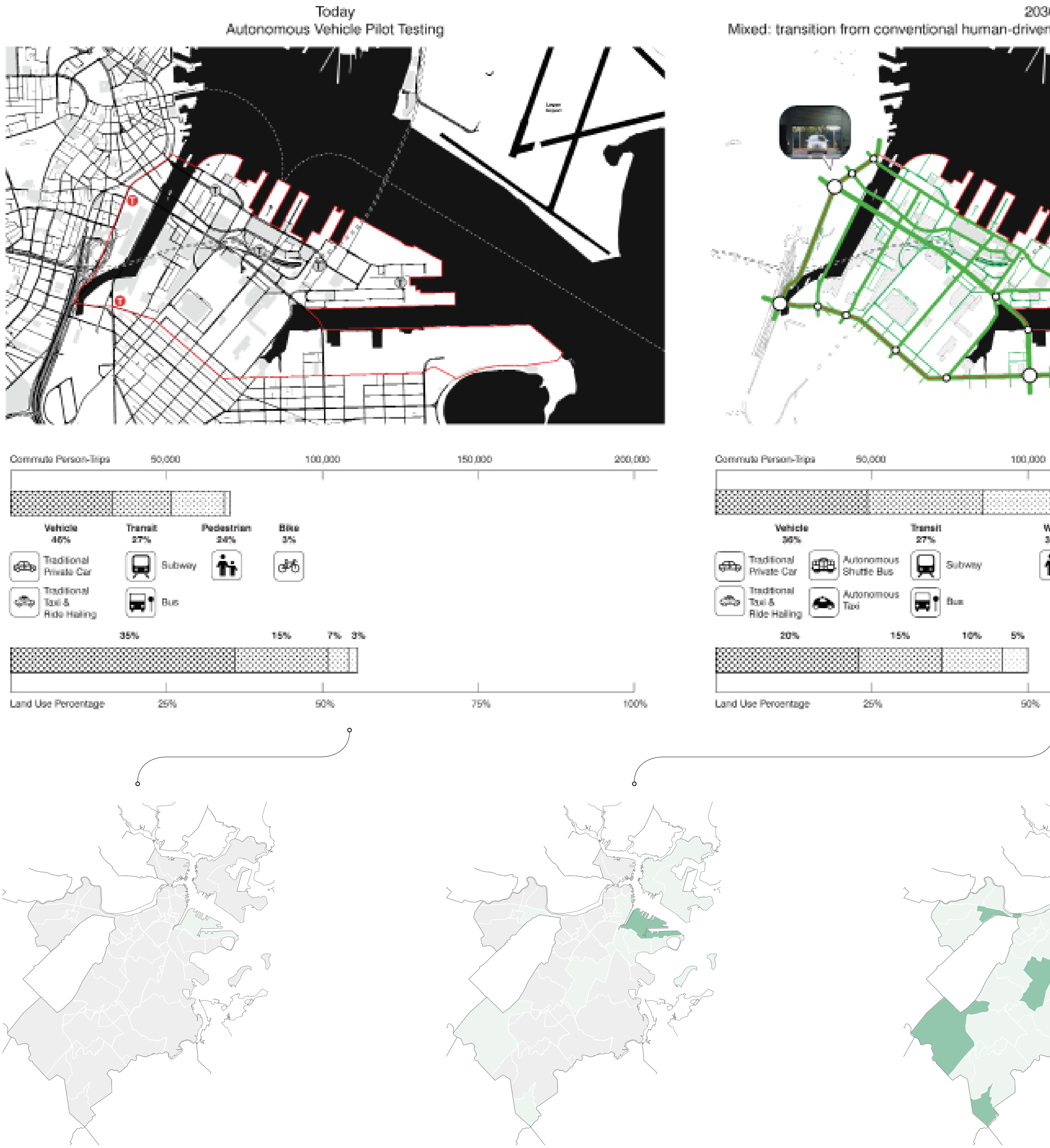


Appendix 4: From Human Driver to AI Driver



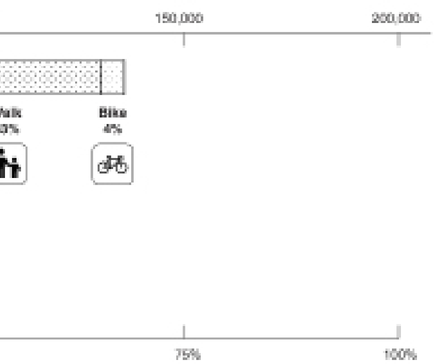

Medium
AV
Long Range Radar
Short Range Radar
Lidar
Ultrasonic
Camera
Cloud
Halo View
Blind Spot Detection
Park Assistance
Rear Collision Warning
Park Assistance
Traffic Sign Recognition
Cross Traffic Alert
Emergency Braking
Pedestrian Detection
Collision Avoidance
Lane Departure Warning
Adaptive Cruise Control
Surround View

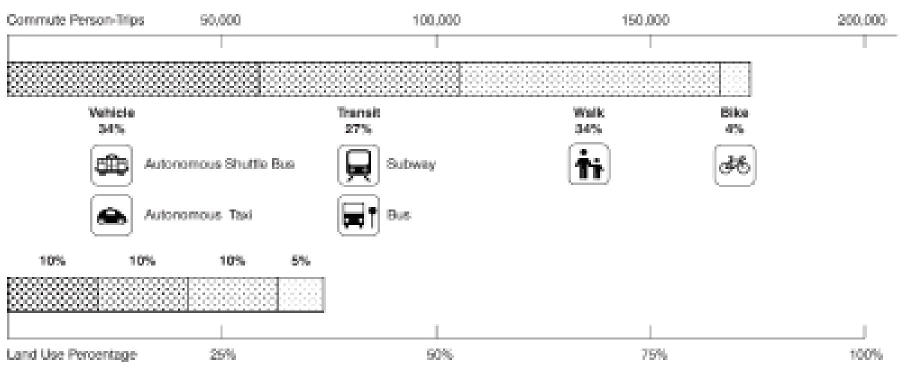
Appendix 3: Design Progress- Phasing Proposal (Version 1)

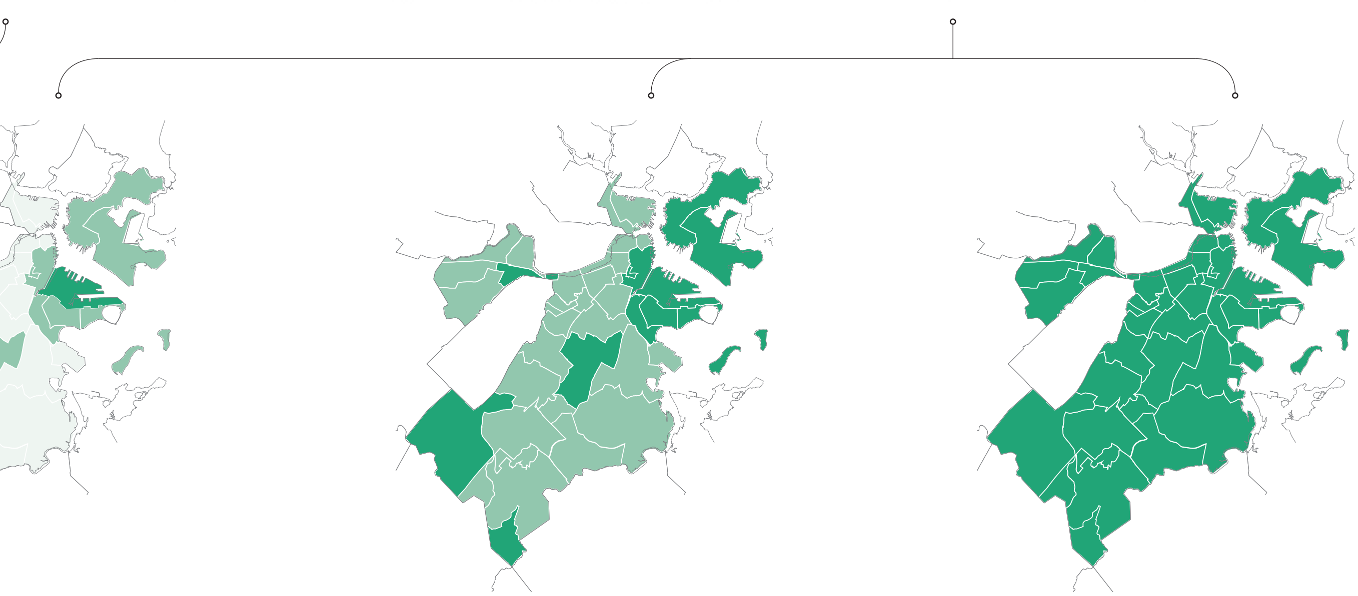


0
n cars to shared, electric, autonomous vehicles

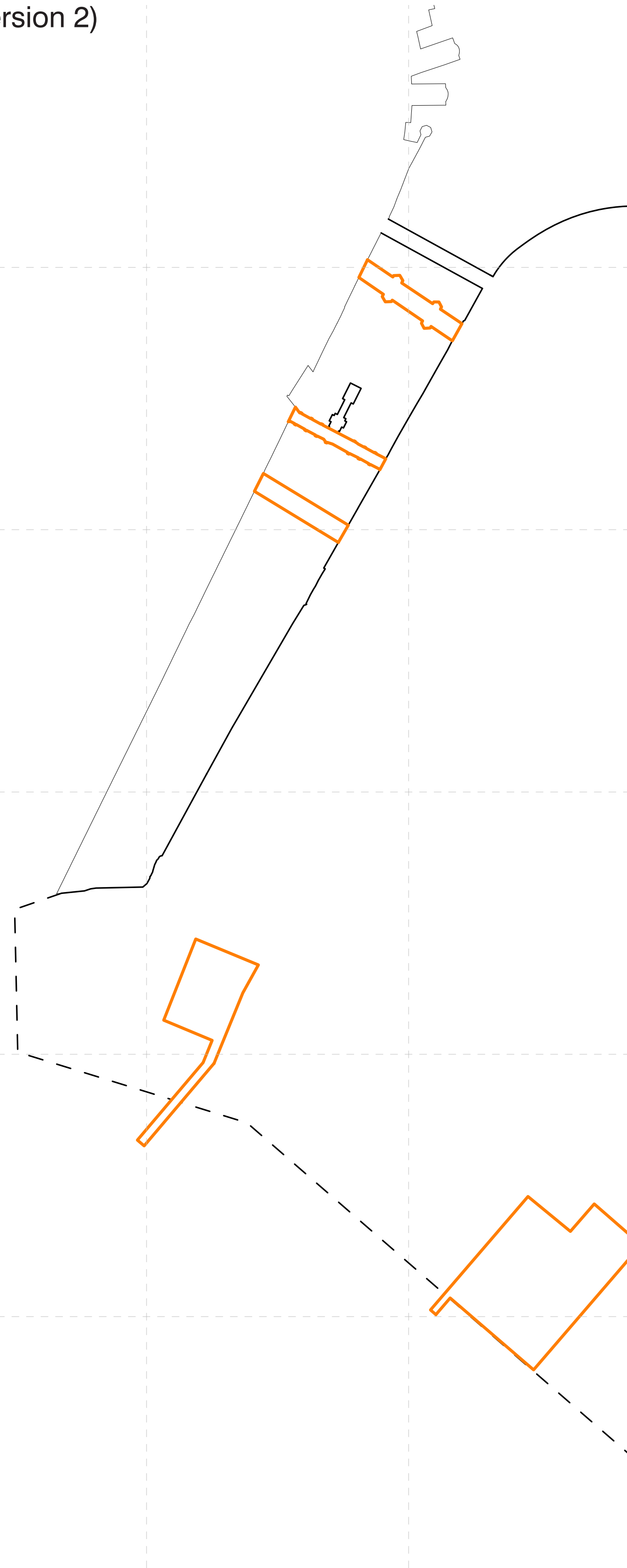
2050
AV only: within the area, there are only shared, electric, autonomous vehicles







Appendix 3: Design Progress - Phasing Proposal (Version 2)



2030: AVs only within the Site

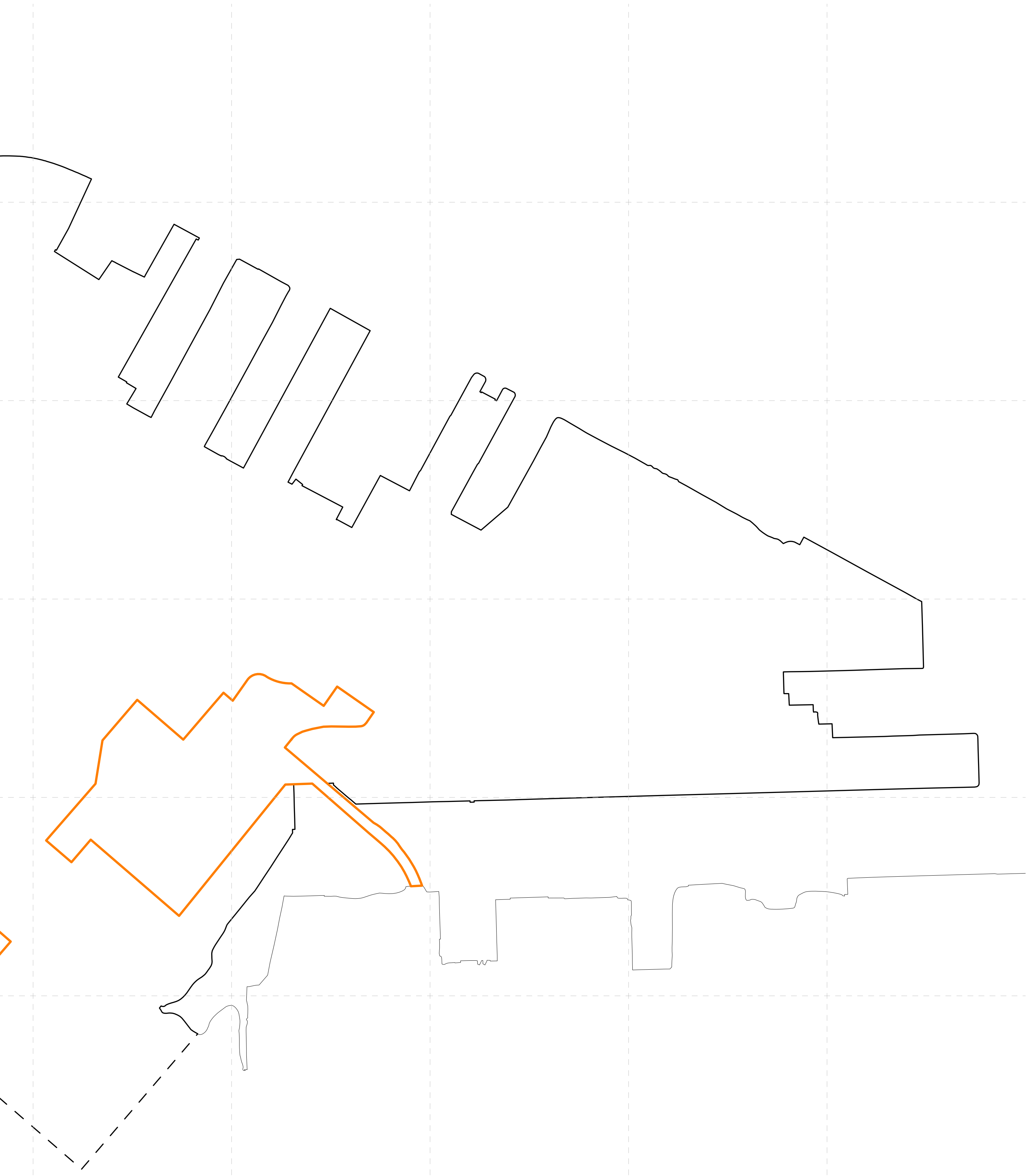
Conventional Cars park near the gateways and transfer to AVs.

Gateways connecting to Downtown Boston has better transit connection, people are expected to come via transit and transfer to AVs to enter the area. Although the area is fully built out, conventional cars can park on the bridge, with two lanes left for AVs.

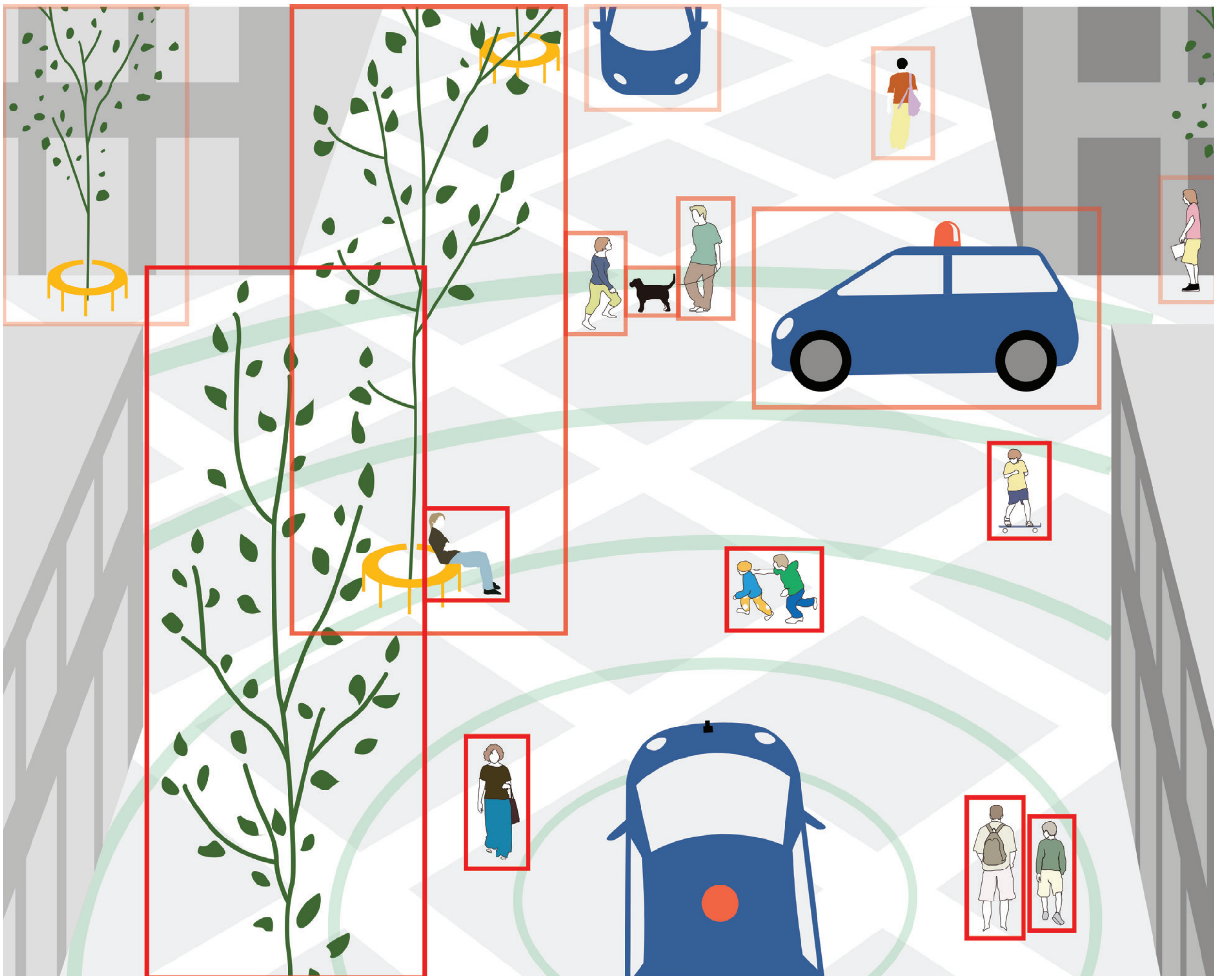
Gateways connecting to South Boston are currently adjacent to surface parking lots, where conventional cars can park during the transition period

2050: AVs in all Boston

Those parking areas can be converted to housing and public amenities, such as parks, sports field, etc.



Appendix 5: Design Progress- First Iteration of Shared Surface



Appendix 6: Learning about Autonomous Vehicles at SMART center in Singapore during the summer of 2017

Autonomous Vehicles in the warehouse

Autonomous vehicle moving at 3mph on NUS campus