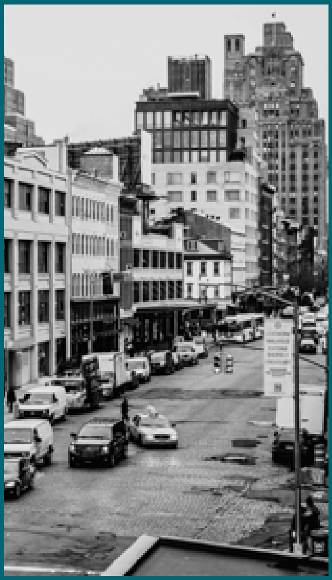
National Science Foundation Planning Grant

MULTILEVEL IMPACTS OF EMERGING TECHNOLOGIES ON CITY FORM AND DEVELOPMENT

JANUARY 2020



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EXECUTIVE SUMMARY

Autonomous vehicles (AVs) are a near future reality and the implications of AVs on city development and urban form, while potentially widespread and dramatic, are not well understood. In addition, there are other fundamentally disruptive technological forces undergoing simultaneous rapid development and deployment, including the introduction of new mobility technologies and the associated paradigm shift to thinking of mobility as a service, as well as the continued growth of e-commerce and the related rise in goods delivery. The purpose of this report is to examine how these forces of change are impacting, or will likely impact transportation, land use, urban design, and real estate, and what the implications may be for equity, health, the economy, the environment, and governance. Our aim was to identify key research areas that will assist in evidence-based decision making for planners, urban designers, and developers to address this critical paradigm shift. We identified key research questions in land use, urban design, transportation, and real estate that will rely on the expertise of these disciplines and lay the foundation for a research agenda examining how AVs and new mobility may impact the built environment.

This report describes the first order impacts, or the broad ways that the form and function of cities are already being impacted by the forces of change identified above. These impacts include:

- Change in the demand for parking
- Change in vehicle miles traveled
- Change in congestion
- Change in ease of travel
- Increasing competition for the right-of-way
- Changes in goods and meal delivery
- Shifting nature of freight
- Change in the demand for warehousing space
- Reduction of brick-and-mortar stores
- Increasing interest in experiential retail.

We then explore what effects these impacts may have specifically on transportation, land use, urban design, and real estate, which are referred to here as second order impacts:

TRANSPORTATION: Transportation is a particularly interesting topic in the context of this report because advancements in transportation technology are the primary drivers of the changes discussed, but these changes will also impact the transportation system in turn. For instance, the deployment of AVs may contribute to mode shifts and could increase transit usage by improving first- and last-mile connections, or could decrease transit ridership by directly competing with it. Mode interaction could become increasingly complex as new modes share the right-of-way with AVs and there is an increase in the need to access the curb.

LAND USE: The deployment of AVs will likely change the current balance of land uses in urban areas and where certain uses are located throughout the city. This will have impacts on planning regulations, including zoning and land use regulations, in response to the need for less parking, a shift away from auto-oriented uses and services, and potential pressures for urban dispersion.

URBAN DESIGN: AVs are likely to impact metropolitan footprints, street design, corridor and center development, densification and urban vitality in response to shifting parking needs, changes to travel ease, and multimodal travel opportunities. Additionally, a reduced need for on- and off-street parking and increased need for curbside loading access will change building types and development.

REAL ESTATE: AVs may have impacts on land value as well as on project feasibility and competitiveness as ease of transportation increases and transit potentially becomes more atomized. The need for less parking will significantly change the cost of project development, will increase the amount of development possible on any given site, and will alter real estate pro formas and overall project feasibility.

These multilevel impacts will have significant implications for society, affecting equity, health, environment, economy, and governance:

EQUITY: The deployment of AVs could have positive impacts on equity by increasing access to mobility for those who have been underserved, such as elderly populations, people with disabilities, and low-income people. However, there is also the possibility that AVs could further exacerbate existing inequities in transportation access, particularly if the deployment of AVs erodes transit to the point where it leaves the most vulnerable without options or if AVs raise the overall costs of travel. Additionally, many new mobility technologies require access to smartphone apps, smartcards and credit card accounts, further disadvantaging those who are unbanked or do not have access to the technology.

HEALTH: If AVs achieve the safety benefits they tout, automobile-related injuries and fatalities could be significantly reduced. If fully electric AVs are deployed replacing conventional gasoline-powered vehicles, they could reduce fuel use, which would have positive impacts on the level of unhealthy particulates in the air. A reduced need for parking could free up space for other uses, such as parks and open space, which could also have positive health benefits. However, AVs could further enable social isolation by allowing people to always travel alone. Additionally, the use of autonomous vehicles for goods and meal delivery could further exacerbate social isolation.

ECONOMY: The deployment of AVs could have ripple effects on municipal finance and local policy. Transportation revenue streams could be immediately and directly affected by AVs as a result of decreasing car ownership, reduction in sales tax revenue from local auto dealers, the advent of hybrid and electric vehicles, and reduced demand for parking. The decrease of municipal revenue due to the pervasive effects by AVs will likely impact policy, planning, investment and design decisions by public agencies, private business, investors and the public at large.

ENVIRONMENT: The deployment of fully electric AVs has the potential to reduce emissions of greenhouse gas emissions (GHG) and local pollutants. AVs may change and reshape urban areas and how people use space. More people may choose to live further from cities if the travel (monetary and time) costs are reduced, which could further exacerbate sprawl. This may affect the availability of natural resources and prime agricultural land as well as biodiversity and other species' habitats.

GOVERNANCE: AVs will have both direct and indirect implications on a range of government-related services and responsibilities. Because the form and timeline for AV deployment is still unknown, and it is likely possible impacts will shift quickly during deployment, government policies and processes may need to include greater ability to adapt to shifting conditions. For instance, cities may need to use responsive regulations, create structures and processes that facilitate pilot projects, and adopt flexible procurement strategies. In addition, cities will need to expand their role in data management and oversight as well as investigate new ways of working collaboratively with the private sector.

To better understand and anticipate the multi-level impacts these technologies, it is important to consider community goals and values, shifts in governance, collaborative networks, and data management and monitoring.

ABOUT THE URBANISM NEXT CENTER

The Urbanism Next Center is a research center housed within the Sustainable Cities Institute at the University of Oregon. It is a leading source for information about the potential impacts of emerging technologies—autonomous vehicles, new mobility, e-commerce, and the sharing economy—on city development, form, and design, and the implications for equity, health, the economy, the environment, and governance.

ABOUT THE SUSTAINABLE CITIES INSTITUTE

The Sustainable Cities Institute (SCI) is a cross-disciplinary organization at the University of Oregon that promotes education, service, public outreach, and research on the design and development of sustainable cities. We are redefining higher education for the public good and catalyzing community change toward sustainability. Our work addresses sustainability at multiple scales and emerges from the conviction that creating the sustainable city cannot happen within any single discipline. SCI is grounded in cross-disciplinary engagement as the key strategy for improving community sustainability. Our work connects student energy, faculty experience, and community needs to produce innovative, tangible solutions for the creation of a sustainable society.


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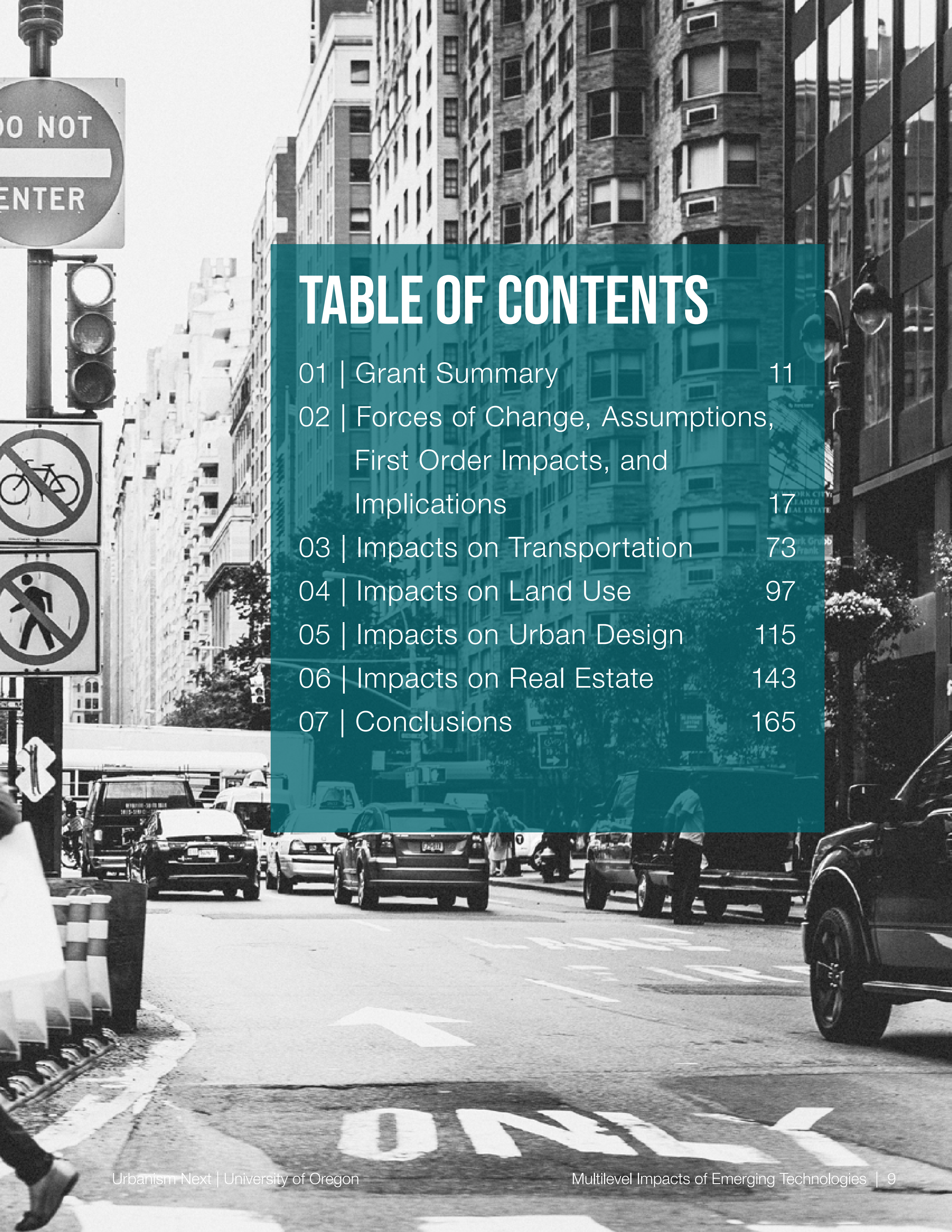

TABLE OF CONTENTS


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01 | GRANT SUMMARY

METHODS

One focus of the Urbanism Next Center at the University of Oregon is to understand and organize the various impacts of emerging technology—namely, autonomous vehicles, e-commerce, and the sharing economy—on the form and function of cities. We have accomplished this through conducting and gathering specific research, developing and disseminating reports, through an annual conference, and by building a national network of partners in the public, private, nongovernmental, and academic sectors.

Through this exploratory investigation, we developed the Urbanism Next Framework, a type of roadmap that organizes the technological impacts on cities into four key areas—land use, urban design, transportation, and real estate—and relates those to each other and to larger societal goals around equity, health, the environment, the economy, and governance.

For the purposes of this National Science Foundation Planning Grant, we explored these topics further to better understand: 1) what research exists in these areas; and 2) where there are research gaps. We convened 35 partners from the private, public, academic, and non-profit sectors to work together and help shape the research agenda. We organized our grant partners into five working groups centered around the four key areas of land use, urban design, transportation, and real estate. Two of our groups focused on transportation issues, one on active transportation and one on parking and vehicles, because understanding the range of impacts of autonomous vehicles and other new mobility technologies emerged as one of the more dominating and important disrupting forces.

Each group was assigned two co-chairs, including one University of Oregon representative and one grant partner working outside the University of Oregon. Each group held two conference calls in May and June (2018) to start to outline the potential range of impacts that emerging technologies may have on cities related to their topic areas. In July 2018, all of the grant partners came together in Portland, OR for a two-day workshop hosted by the University of Oregon to discuss the impacts, implications, and important research questions. This report summarizes the discussions and findings from all the work group meetings, and includes an extensive literature review.

ORGANIZATION OF REPORT

The disruption to urban development and the related economic, social, and environmental impacts caused by the introduction of the autonomous vehicle (AV) has the potential to be on par with the disruptions caused by automobiles a century ago. Chapter 2 outlines what we have identified to be the catalysts or **forces of change**, including the introduction of new mobility technologies and the associated paradigm shift to thinking of mobility as a service, the rise of e-commerce and the related rise in goods delivery, and the anticipated introduction of autonomous vehicles (AVs). We outline when certain technologies were first introduced, how they have evolved, what adoption rates are thus far, and what lessons we can draw on as we prepare for the commercial deployment of fully automated vehicles.

Chapter 2 also identifies what we consider to be **first order impacts**—impacts that are being caused by or may be caused by, at least in part, the forces of change identified above. We have based our assumptions about first order impacts on existing data and research, as well as input from working group experts. This chapter provides a foundation for the following chapters, which dive into the cascading impacts that these forces of change may have on land use, urban design, transportation, and real estate, and the resulting implications of those impacts.

The following chapters explore what we consider to be the **second order impacts** as they relate to transportation (Chapter 3), land use (Chapter 4), urban design (Chapter 5), and real estate (Chapter 6). Each of these chapters include discussions of the relationships between first order and second order impacts, relationships between topics, and relationships to the larger issues of equity, health, the economy, the environment, and governance. In addition, each section outlines areas of needed research.

DESCRIPTION OF SOURCES

Sources for this work include: journal articles, conference papers and presentations, white papers and reports from private companies and non-profit organizations, government planning documents and reports, news articles, and popular blogs. To the extent possible, we reference peer-reviewed articles and academic literature, but autonomous vehicles and more generally, new mobility, are rapidly developing fields. As a result, peer-reviewed studies on these topics are both in short supply and quickly dated. Given the rapidly changing environment with respect to autonomous vehicles, ridehailing, and micromobility, on occasion we reference credible popular media and other news sources where applicable and helpful.

MULTI-LEVEL IMPACTS

LAND USE

RETAIL/COMMERCIAL/ OFFICE/INDUSTRIAL (EMPLOYMENT USES)
How will the changing nature of travel, employment and shopping impact retail, commercial, and industrial districts?

HOUSING
What are the opportunities to increase housing through infill? Will people choose to locate in cities? Or move farther out in the suburbs?

PARKS & OPEN SPACE
How do we protect open space under the pressure to expand cities? What opportunities are there to reclaim parking lots for parks?

URBAN DESIGN

METROPOLITAN FOOTPRINT
When proximity to workplaces and goods/ services is no longer holding people in cities, what will happen to their already sprawling footprints?

STREET DESIGN
As cities make plans for future expansions, changes to their street network, the inclusion of various modes/complete streets, and overall street design – what should they be considering?

CENTERS AND CORRIDORS
Will AVs support transit to strengthen current nodes and corridors or will they lead to more dispersal with continuous low-density development?

DENSIFICATION
How and where will AVs and new mobility increase or decrease development density?

SENSE OF PLACE
When shopping and transportation can be acquired anywhere, what happens to business districts, shopping districts and neighborhoods?

PARKING (URBAN FORM)
How will reduced need for parking impact urban form?

TRANSPORTATION

WALKING
How will we regulate the interactions between pedestrians and vehicles? What happens when pedestrians can stop AVs by simply stepping into the street?

BIKING
Will the mixing of modes be frowned upon because it is such a limitation to AV efficiency? Will some areas ban bikes? How will bikes work around curbside deliveries and dropoff?

TRANSIT
Transit faces many challenges including economic displacement, demographics, and ridehailing. What happens to transit when AVs are deployed?

PARKING (TRANSPORTATION)
What happens if parking utilization needs drop dramatically over a short period of time. How quickly will parking requirements shift with that?

VEHICLES
Preliminary models of individual ownership of AVs show vehicle miles traveled (VMT) increasing dramatically. Will AVs be fleets or individually owned?

URBANISM NEXT FRAMEWORK

REAL ESTATE

LAND VALUE
A reduction in demand for parking will open up land for redevelopment. How will this impact land value and project feasibility?

PROJECT FEASIBILITY
Development will likely get more risky as market conditions related to parking demand and commercial and retail viability change. How do we reduce risk?

BUZZ/VITALITY
What will draw people to places in the future? How important will entertainment be a factor in to where people want to congregate? How do we create "buzz"?

QUALITY
If location in relation to other areas of the city is no longer a strong factor in housing/commercial building location, will quality of design become more relevant in attracting and keeping people in cities/neighborhoods?

IMPLICATIONS FOR ...

EQUITY
How will the impacts of emerging technologies impact vulnerable and low income populations? What opportunities are there to improve services and reduce inequities?

HEALTH
Preliminary research finds that people are replacing walking, biking, and transit trips with ridehail services. If this trend continues and is exacerbated by AVs, what will the impact be on our health? What are the impacts of E-commerce on health?

ENVIRONMENT
How can we take advantage of emerging technologies to improve sustainability and environmental outcomes? Can we reduce greenhouse gas (GHG) emissions? Can we improve stormwater treatment?

ECONOMY
Up to 4 million people drive for a living. What happens to their jobs with the deployment of AVs? Brick-and-mortar stores are closing as shoppers go online. How will emerging technologies disrupt the economy?

GOVERNANCE
Emerging technologies will disrupt revenues for cities, counties, and states. How do we provide a great level of service and support thriving communities?

RESPONSE

WHAT SHOULD WE DO?
Given the possible range of multi-level impacts of emerging technologies on **land use, urban design, transportation, and real estate**, and the implications on equity, the economy, and the environment, **how should governments, companies, and institutions respond to maximize the benefits and minimize the risks?** How do policies, programs, and infrastructure investments need to adapt and change?

02 | FORCES OF CHANGE, ASSUMPTIONS, FIRST ORDER IMPACTS, AND IMPLICATIONS

IDENTIFYING THE FORCES OF CHANGE

The proliferation of the smart phone has changed many facets of urban, suburban, and rural life, including how we travel, where we go, and how we make purchases. More specifically, there are three fundamentally disruptive technological forces undergoing simultaneous rapid development and/or deployment:

1. The introduction of new mobility technologies and the associated paradigm shift to thinking of mobility as a service;
2. The continued growth of e-commerce and the related rise in goods delivery; and
3. The anticipated deployment of autonomous vehicles.

CHAPTER ORGANIZATION

- DESCRIPTION OF FORCES OF CHANGE
  - INTRODUCTION TO NEW MOBILITY TECHNOLOGIES AND SHIFTING PARADIGMS
    - EVOLUTION OF SHARED MOBILITY
    - MOBILITY AS A SERVICE (MAAS)
  - GROWTH OF E-COMMERCE AND RISE OF GOODS DELIVERY
  - AUTONOMOUS VEHICLES ON THE HORIZON
- ASSUMPTIONS ABOUT AUTONOMOUS VEHICLES
- FIRST ORDER IMPACTS
  - CHANGE IN PARKING DEMAND
  - CHANGE IN VEHICLES MILES TRAVELED (VMT)
  - CHANGE IN CONGESTION
  - CHANGE IN EASE OF TRAVEL
  - SHIFT IN MODES
  - COMPETITION FOR THE RIGHT-OF-WAY (ROW)
  - CHANGE IN GOODS AND MEAL DELIVERY
  - SHIFTING NATURE OF FREIGHT
  - REDUCTION OF CERTAIN TYPES OF BRICK-AND-MORTAR STORES
  - INCREASING INTEREST IN EXPERIMENTAL RETAIL
- IMPLICATIONS OF FORCES OF CHANGE AND FIRST ORDER IMPACTS
  - EQUITY
  - HEALTH
  - ECONOMY
  - ENVIRONMENT
  - GOVERNANCE

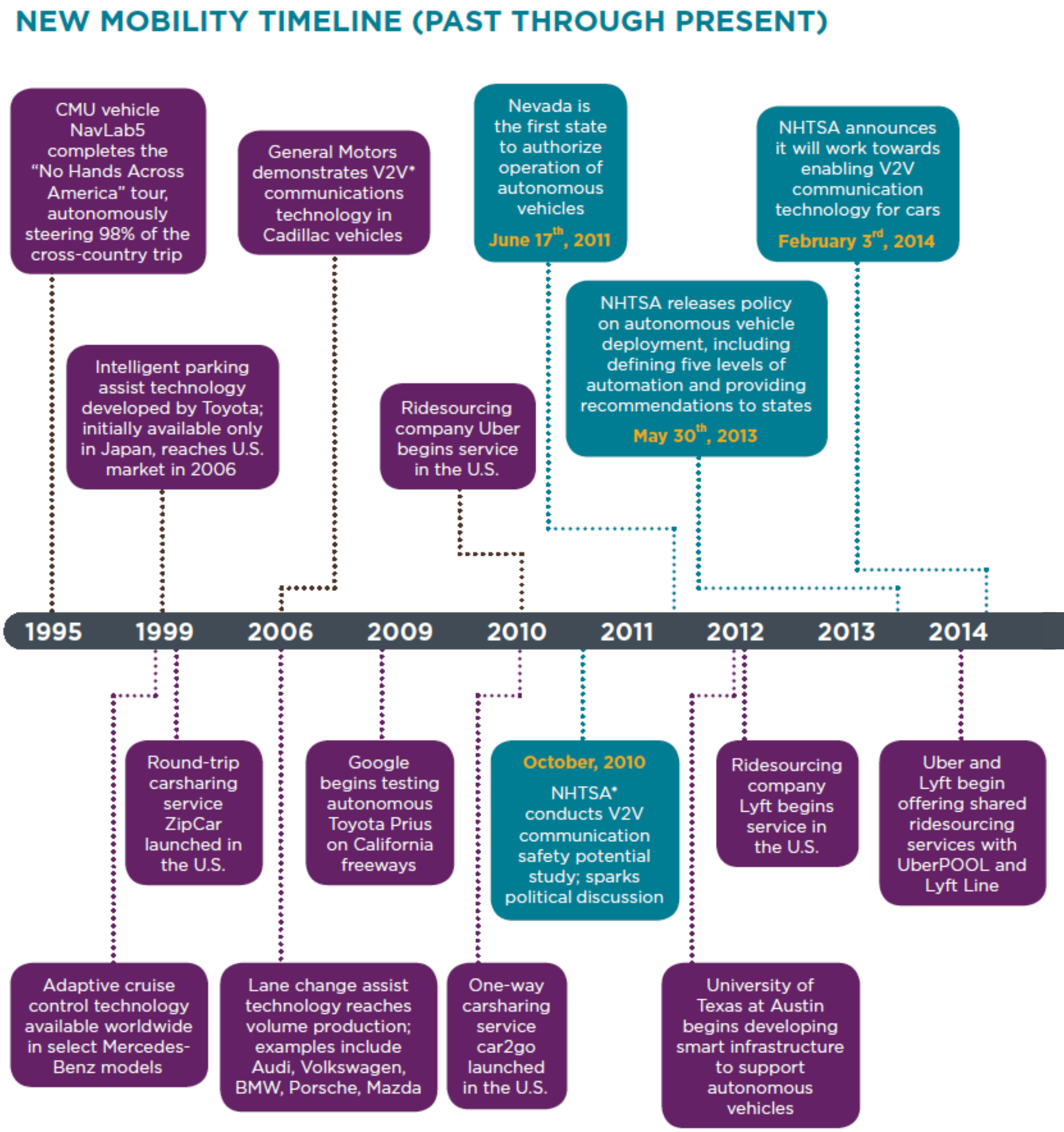
INTRODUCTION OF NEW MOBILITY TECHNOLOGIES AND SHIFTING PARADIGMS

The introduction of new mobility technologies over the past ten years has contributed to an ongoing paradigm shift from thinking about mobility as something we own, such as a vehicle, to thinking about mobility as something we purchase as a service. According to the Seattle Department of Transportation, the term "new mobility" is defined as the "emerging elements of our transportation system that are enabled by digital technology, shared, driven by real-time and often providing curb-to-curb transportation," which entirely changes how people and goods move from point A to point B (Seattle Department of Transportation, n.d.). The intersections of innovation in vehicle and device sharing—spurred by the growth of mobile technology and app development—in vehicle automation and electrification is facilitating and amplifying innovations in mobility (Grosse-Ophoff, Hausler, Heineke, & Möller, 2017).

THE MOBILITY PARADIGM SHIFT IS A SHIFT FROM THINKING ABOUT MOBILITY AS SOMETHING WE OWN TO THINKING ABOUT IT AS A SERVICE WE PURCHASE.

To illustrate the rapid development of new mobility, the International Council on Clean Transportation (ICCT) created a timeline to display milestones achieved between 1995 and 2016 (Figure 1) with the pace of change accelerating in 2009 with the introduction of on-demand ride services or transportation network companies (TNCs) like Uber and Lyft. A second timeline (Figure 2) shows anticipated developments and milestones based on announcements from companies, providers, and other entities. According to projections made by a variety of companies, the rate of change we have witnessed over the past ten years will continue, although the anticipated date of deployment of fully automated vehicles remains a moving target. For instance, Ford, Honda, and Nissan previously announced that they plan to have a fully autonomous vehicle commercially available by 2020; by 2030, IHS Automotive predicts 10.5 million fully autonomous vehicles will have been deployed globally. Whether or not those predictions will come to pass remains to be seen.

Figure 1. International Council on Clean Transportation's New Mobility Timeline from 1995 to 2016 (Po



* **V2V** = Vehicle-to-vehicle, **NHTSA** = National Highway Traffic Safety Administration, **DMV** = Department of M

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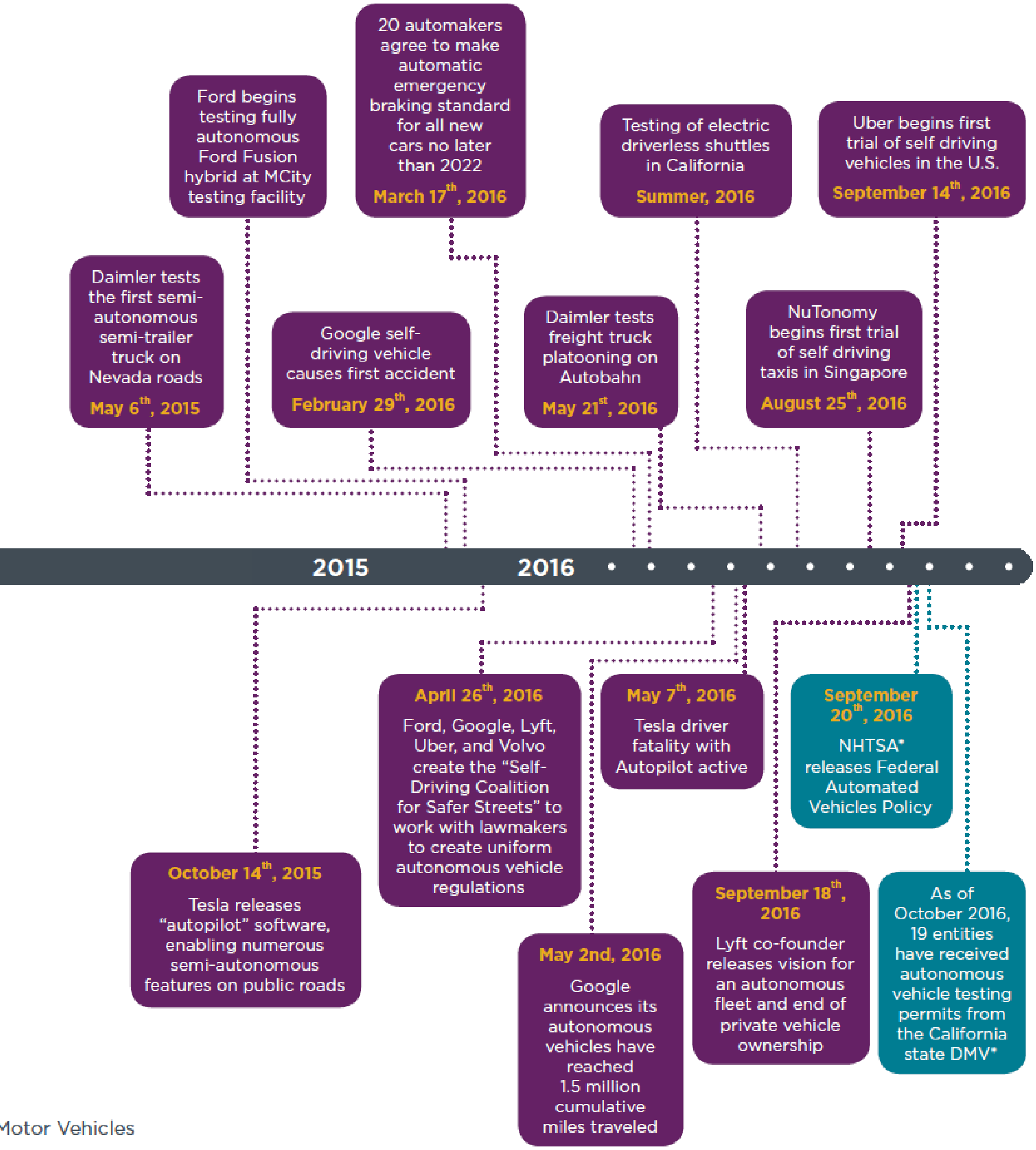
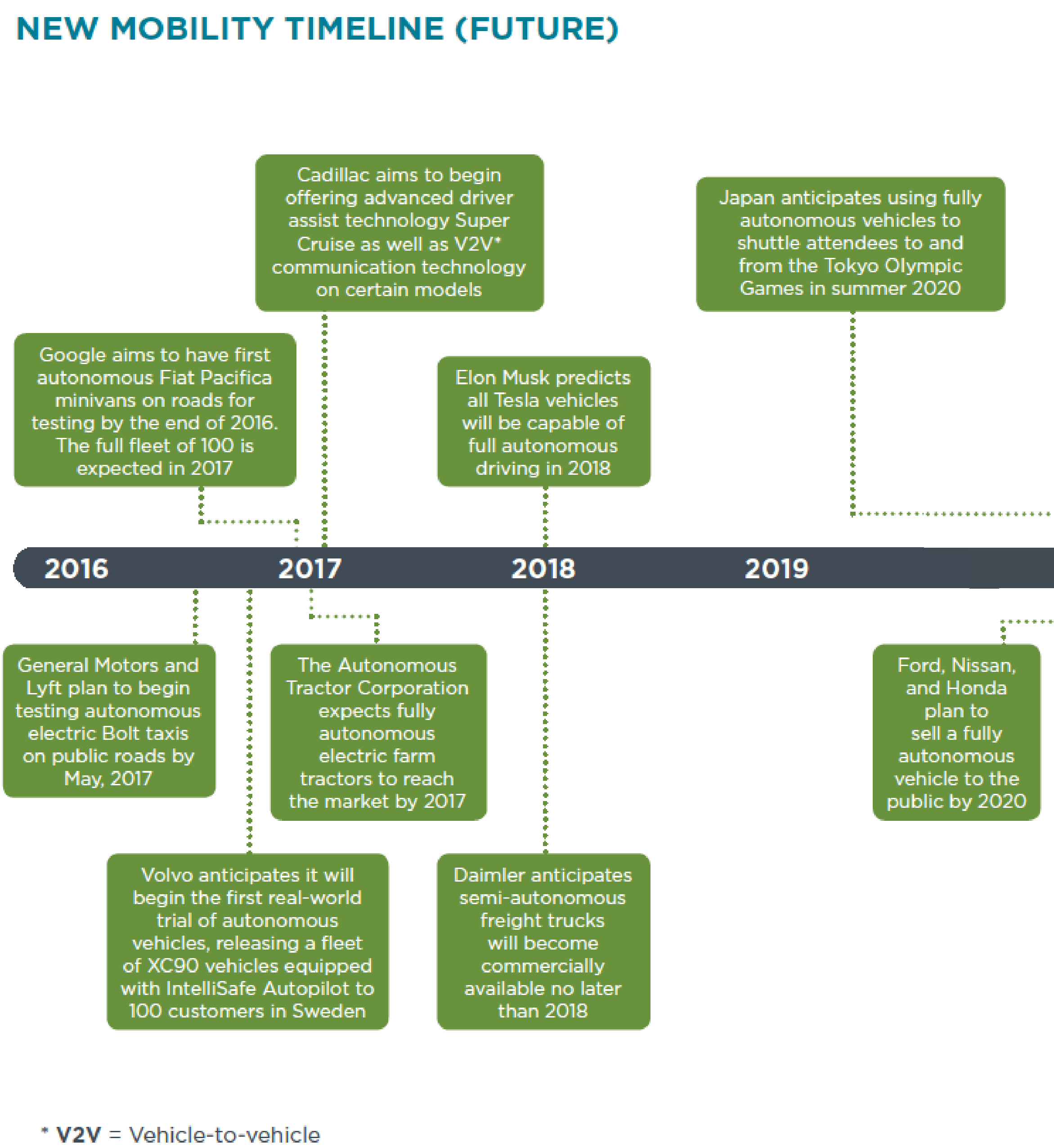


Motor Vehicles

n *https://www.theicct.org/sites/default/files/publications/New-mobility-landscape_ICCT-white-paper_27072017_vF.pdf. Copy-*

Figure 2. International Council on Clean Transportation's New Mobility Timeline from 2016 to 2030



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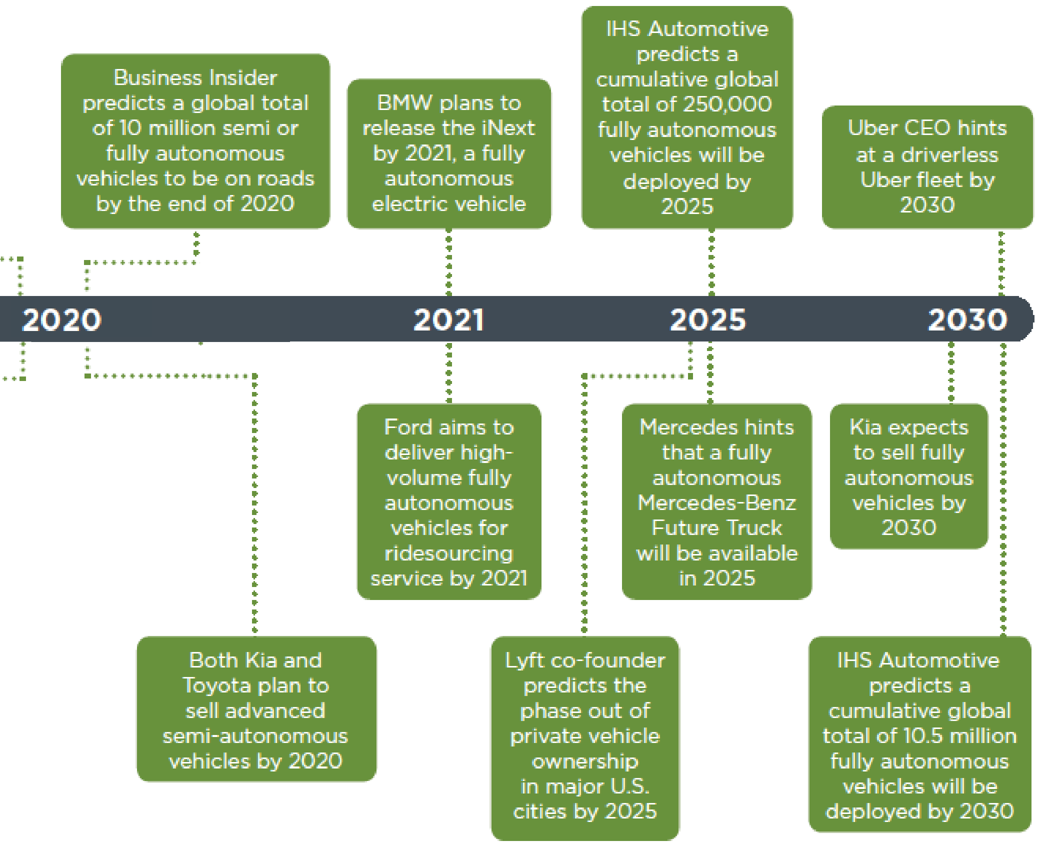

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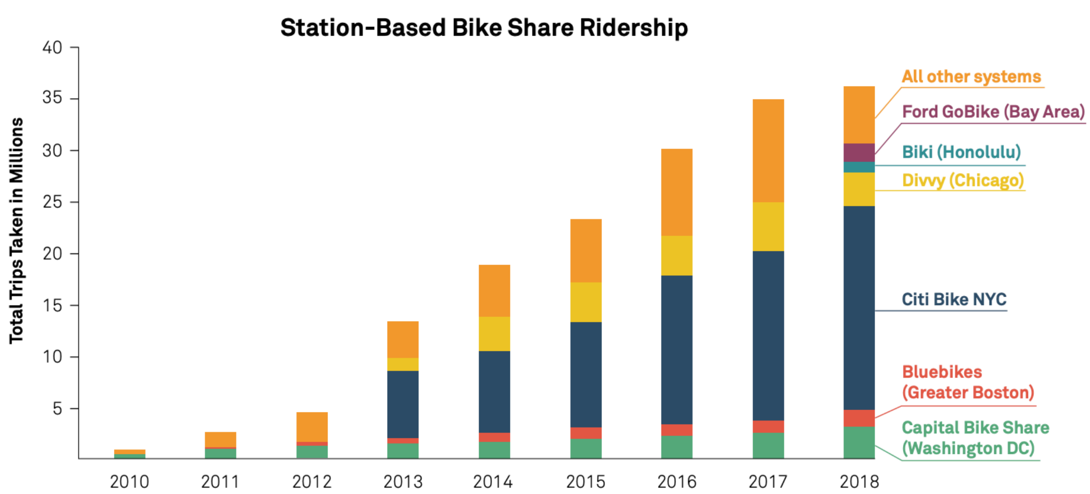
EVOLUTION OF SHARED MOBILITY

Shared mobility, which refers to transportation services and resources that are shared amongst various users (Shared-Use Mobility Center, 2019), is not a new concept. For instance, public transit is a vital and widespread form of shared mobility. However, emerging technologies that enable the renting or borrowing of a broader range of goods and services instead of owning them are driving an evolution of shared mobility. According to the Federal Transit Administration's scope on shared mobility, it now encompasses not only transit, but also carsharing, bikesharing, microtransit, ridesharing, and ridesourcing (Federal Transit Administration, 2016) as well as the newest entrant to the field, shared electric scooters. McKinsey reported that the shared mobility market in three core markets—China, Europe, and the U.S.—was nearly $54 billion in 2016, and in an aggressive growth scenario, the market could experience 28 percent annual growth from 2015 to 2030 (Grosse-Ophoff et al., 2017).

Figure 3. Bike Share Ridership in the U.S. Since 2010 (NACTO)



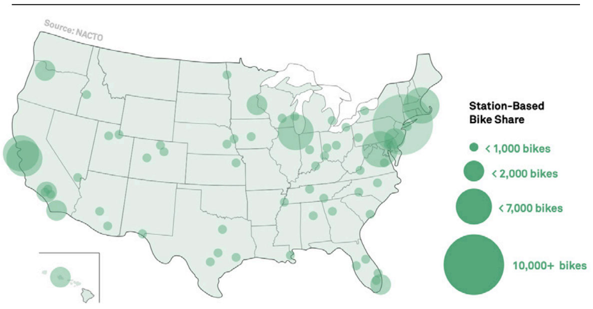
Source. Reprint from "Shared Micromobility in the U.S.:2018", by NACTO.org, 2019, Retrieved from https://nacto.org/wp-content/uploads/2019/04/NACTO_Shared-Micromobility-in-2018_Web.pdf / Copyright 2019 by National Association of City Transportation Officials.

BIKESHARING (DOCKLESS AND DOCKED)

Bikesharing has been in existence for over 24 years in North America, and even longer in Europe. The earliest bikeshare programs, which enabled users to access a shared bicycle as needed, were part of the "first generation of bikeshare" and were free to use. The first bikeshare program to launch in the U.S. was in Portland, OR in 1994, and two years later, the twin cities of Minneapolis and St. Paul launched the first Coin-Deposit system, the first of the "second generation" bikeshare programs (S. A. Shaheen, Guzman, & Zhang, 2010). Second generation bikeshare programs were categorized, in part, by the incorporation of docking stations, setting them apart from the first generation bikeshare programs where bikes could be picked up and left anywhere.

Bikeshare has grown rapidly in the U.S. since 2010. From 2010 to 2016, over 88 million trips were made on a bikeshare bike in the U.S., according to NACTO, or the National Association of City Transportation Officials (NACTO, 2017a). Bikeshare continued growing with 35 million trips in 2017, 25% more than in 2016, and the number of bikes at the end of 2017 (100,000) more than doubled compared to 2016 (NACTO, 2018). Bikeshare further grew in 2018, with a total of 52 million trips on docked, dockless, pedal, and e-bikes combined (NACTO, 2019). Interestingly, dockless systems are somewhat of a return to first generation bikeshare programs since bikes can be deployed with more flexibility, providing users more leeway in where they pick up and drop off a shared bike. Figure 4 shows the locations of station-based bikeshare systems with 1,000 or more bikes in the U.S. as of 2018 and Figure 3 shows bikeshare ridership in the U.S. from 2010-2019. The majority of the increase in bikeshare between 2010-2017 was from new dockless systems, which comprised 44% of all bikeshare bikes in the U.S in 2017. Dockless bikes continued to be a popular option through 2018, but saw a slow in growth due to the introduction of dockless e-scooters in 2018, which likely replaced some dockless bike trips (NACTO, 2019).

Figure 4. Locations of Large Station-Based Bikeshare Systems in the U.S. in 2018 (NACTO)



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Electric bikes or e-bikes have also grown significantly in popularity. According to a 2018 NACTO report on micromobility, "cities that added e-bikes to their station fleets report that, on average, e-bikes are used twice as frequently as pedal bikes" (NACTO, 2019). Global e-bike sales are expected to grow from over $15.7 billion in revenue in 2016 to $24.4 billion by 2025 (Navigant Research, 2016). Since e-bikes can provide a boost to riders by making it easier to travel further, e-bikes could increase the amount of cycling (both number of trips and total distance) and affect both commuter and leisure travel time (Fyhri & Fearnley, 2015).


Source: car2go

CARSHARING

Similar to bikesharing, it has been over 20 years since carsharing was first introduced as an innovative transportation mode in North America. Carsharing is based on the idea that users can enjoy the benefits of access to a private car without the fixed costs and responsibilities of owning a car. Most carsharing programs are "a membership-based, self-service, short-term car-access system with a network of vehicles for which members pay by time and/or distance" (Lane et al., 2015). The early days of North American carsharing in the late 1990s grew out of the "station car" idea where vehicles were made available at passenger rail stations, and by 1999 there were nine carsharing organizations in existence—five in Canada and four in the U.S. (Shaheen, Sperling, & Wagner, 1999). For more than 15 years, carsharing was run almost exclusively as roundtrip carsharing, requiring members to pick up and return a vehicle from the same location. However, the carsharing industry has expanded over the past decade, largely due to advancements in smartphone technology, and has experienced an evolution in the types of operational models available. Newer carsharing models include one-way or point-to-point carsharing, peer-to-peer carsharing where individuals access a privately owned vehicle fleet through a third party, and fractional ownership where individuals co-lease a vehicle (Shaheen, 2018).

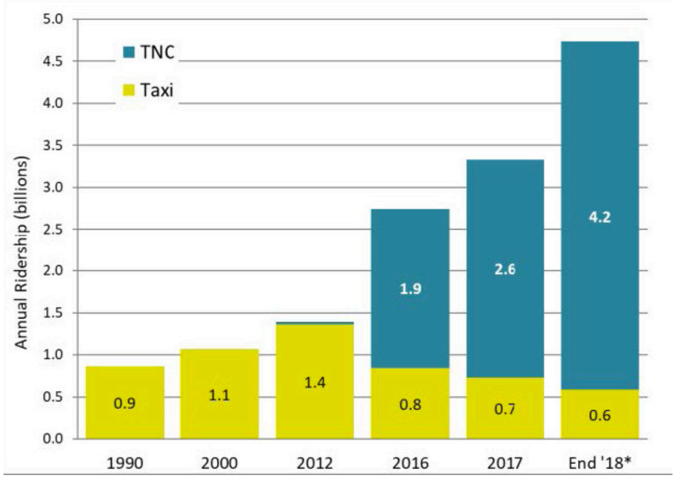
Free-floating carshare, which enables users to pick up a vehicle and end the trip anywhere on permitted streets or company-marked parking locations, has also grown in the past few years. Car2go was one of first players to try out free-floating carsharing, and by 2018, it had grown to over 2 million members across North America, Europe, and Asia with 14,000 vehicles in 30 locations worldwide (Navy, 2018). Traditional automakers such as BMW entered the U.S. and European markets with carsharing models such as DriveNow and ReachNow.

RIDEHAILING OR TRANSPORTATION NETWORK COMPANIES (TNCS)

Since 2010, a growing number of private companies have entered the for-hire transportation services market offering new travel options that use app-based technology to provide on-demand mobility, known collectively as ridehailing or transportation network companies (TNCs). Previously, for-hire vehicles were primarily taxis and users would call a dispatcher to request a ride. TNCs enable passengers to request rides directly from drivers who generally use their own personal, non-commercial vehicles to transport passengers. TNC services generally follow a point-to-point route and can be dynamically priced based on supply and demand of vehicles, customers, and roadway congestion.

TNCs, such as Uber and Lyft, have had a dramatic impact on mobility in cities. For example, in the U.S., TNCs were projected to surpass local bus ridership by the end of 2018 (Schaller, 2018). Their overall growth is the result of a number of factors, including, of course, the comfort and convenience of direct point-to-point service. While TNC ridership has increased dramatically over the past few years, taxi ridership has been steadily decreasing (Figure 5). TNC wait times tend to be substantially shorter than for conventional taxis (Wang, 2015), contributing to their increasing popularity compared to taxis. Importantly, TNC drivers have been found to be significantly less discriminatory than taxi drivers (Brown, 2018). A study of ridehailing in Los Angeles County also revealed that TNCs served neighborhoods home to 99.8% of the population (Brown, 2018), providing increased mobility options across all geographies.

Figure 5. TNC and Taxi Ridership in the U.S., 1990-2017.



Reprinted from "The New Automobility: Lyft, Uber and the Future of American Cities," by B. Schaller, 2018, Retrieved from http://www.schallerconsult.com/rideservices/automobility.htm. Copyright 2018 by Schaller Consult Inc.

MICROTRANSIT

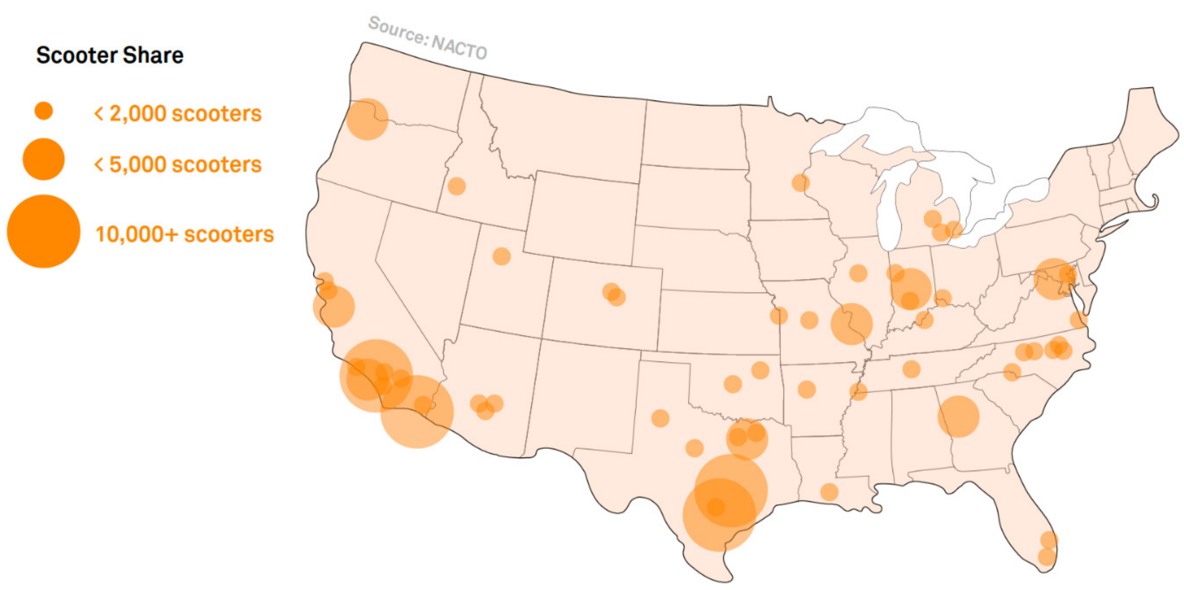
Microtransit is a relatively new entrant in shared mobility and mobility on demand. It is a form of technology-enabled “alternative transit” and can have either flexible or fixed routes and flexible scheduling. Microtransit vehicles are typically smaller than traditional transit vehicles. Other common features include limited routes or service areas, more amenities (i.e., Wi-Fi, and USB outlets), and the integration of big data into their operating systems (Fehr & Peers, 2015). Microtransit service providers typically own and manage their own fleet of vehicles and employ drivers to transport passengers unlike TNCs wherein drivers use their personal vehicles. Microtransit shuttle services have been offered by providers such as Bridj, Chariot, and Via, although Bridj and Chariot have both ceased their U.S. operations. Via continues to operate in the U.S. and has partnered with cities and agencies to help fill gaps in the transportation system. Los Angeles Metro, for instance, announced in January 2019 that they would partner with Via on a year-long pilot using the private mictrotransit service with first- and last-mile connections to major transit stops (Chiland, 2019).

Source: ridewithvia.com/news

ELECTRIC SCOOTERS

Shared electric scooters, or e-scooters, are among the most recent shared use mobility innovations and were first introduced in late 2017 in Santa Monica, CA by the operator Bird (Walker, 2018). Like privately owned automobiles and some bikeshare systems, e-scooters are another form of dockless mobility. The momentum for e-scooters ramped up quickly in early 2018, and providers Bird, Lime (formerly LimeBike), and Spin had all deployed the micromobility devices in San Francisco by April. By the end of 2018, over 85,000 e-scooters were available in over 100 U.S. cities (NACTO, 2019). The market has continued to grow since they were first introduced, and the major providers now include Bird, Lime, Spin, Skip, Bolt, and Jump, which was acquired by Uber in 2018.

Figure 6. E-Scooter Share System Sizes and Locations as of 2018 (NACTO)



Reprint from "Shared Micromobility in the U.S.: 2018", by NACTO.org, 2019, Retrieved from https://nacto.org/shared-micromobility-2018/. Copyright 2019 by National Association of City Transportation Officials.

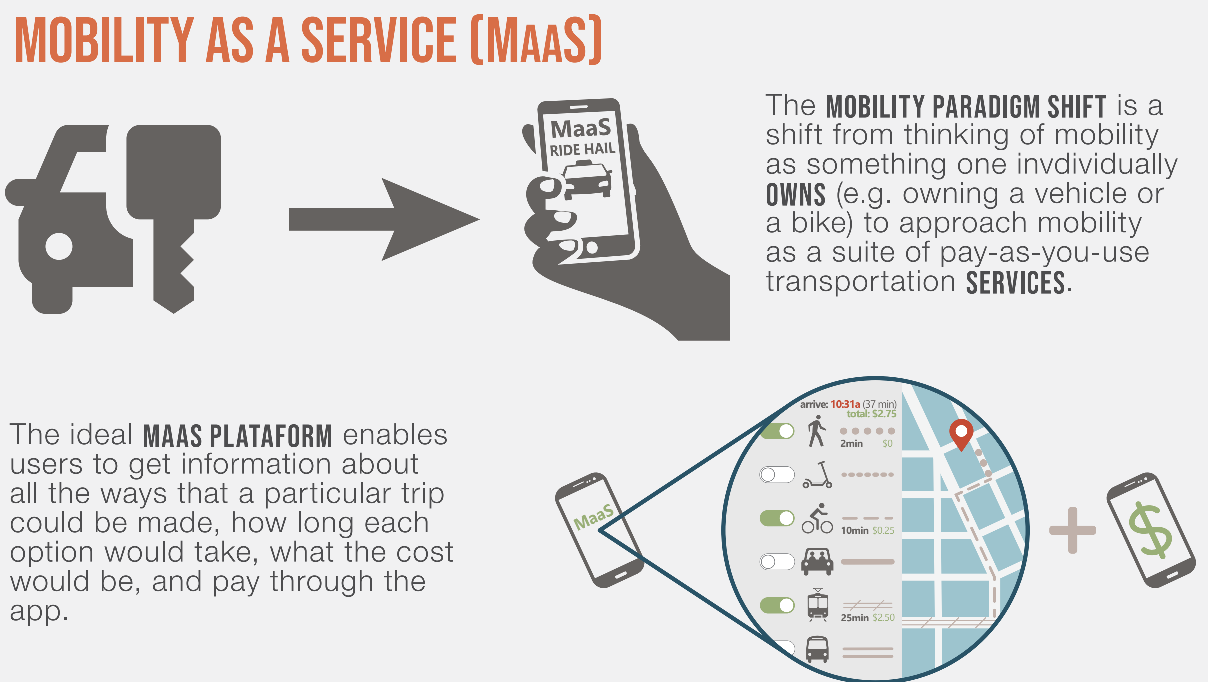
MOBILITY AS A SERVICE (CONCEPT AND PLATFORM)

Mobility as a service (MaaS), or the notion that we purchase transportation as rides rather than as commodities such as cars, is certainly not a new concept unto itself—mass transit is a longstanding and well-established example of MaaS. However, the emergence of technology-enabled new mobility options such as ridehailing, microtransit, and e-scooters has helped bring about a paradigm shift in how we think of mobility. Instead of one in which vehicles are purchased and used for a majority of trips, now rides are purchased with the mode of travel chosen on a trip-by-trip basis. The term MaaS can also be used to refer to a service platform where a trip can be routed, reserved, and paid for using one app that integrates information from a variety of services providers.

MaaS can take different forms, including the opportunity in many cities to choose from among different public and private mobility providers. Hypothetically, the range of mobility options could be provided by a single entity, public or private, offering “transportation services within a given regional environment that provide holistic, preferred and optimal travel solutions, to enable end-to-end journeys paid for by the user as a single charge” (CUBIC, 2018). There are not yet many instances where public agencies have integrated multiple services into a single charge, but there are a few examples. TriMet in Portland, OR launched the Transportation Wallet in 2018, which enables users to access an annual transit pass, streetcar pass, and a bikeshare membership in one payment rather than having to pay for each service separately. Another example of an integrated service platform is the Whim App, which was created by MaaS Global, a company based in Helsinki, Finland. MaaS Global worked with agencies in Helsinki to develop an integrated platform that enables residents to purchase mobility service subscriptions that correspond to their mobility needs. Users who need fewer mobility options (e.g., modes) can pay a lower fee that provides unlimited transit and bikeshare rides, but access to carshare and taxis requires an additional fee. People who need more options can pay a higher monthly fee that provides unlimited access to transit and bikeshare, as well as a limited number of carshare and taxi rides. The Whim App has also been adopted in West Midlands, U.K.

Paying a flat monthly fee for a suite of mobility services is the most advanced MaaS platform to date. Another application of MaaS is a platform that enables users to get information about all the ways that a particular trip could be made, how long each option would take, and what the cost would be. In that application, a user could potentially opt to pick and choose multiple modes to reach their final destination instead of just selecting one mode for the entire trip. More cities have started to pilot versions of this type of MaaS platform. Denver, CO launched the Go Denver platform in 2017, where users are able to create a profile that matches their

Figure 7. Mobility as a Service (MaaS)



Source: Marsie Surguine for Urbanism Next

transportation needs and preferences (International Transportation Service, 2017). For example, users can select all their preferred modes and filter out modes they would prefer not to take, and then plan their trips accordingly. LA Metro announced in August 2018 that they were working on developing a MaaS platform for the Transit Access Pass (TAP) Smart Card program to make it a one-stop shop for a variety of mobility services, including transit, bikeshare, and ridehailing, with the option to pay using credit cards or cash (Musulin, 2018).

Some private mobility companies have also started to vertically integrate more services for their users. Unlike some of the applications discussed above, such as the Portland Transportation Wallet or the Go Denver platform which include multiple service providers, some applications are company specific. For instance, the Uber app allows users to request a ride in a vehicle, or reserve a bicycle or an e-scooter by partnering with bikeshare operator Jump and e-scooter operator Lime (Siddiqui, 2018a). In this instance, multiple modes may be utilized to complete a single trip, but all of the modes are being operated and managed by a single private entity.

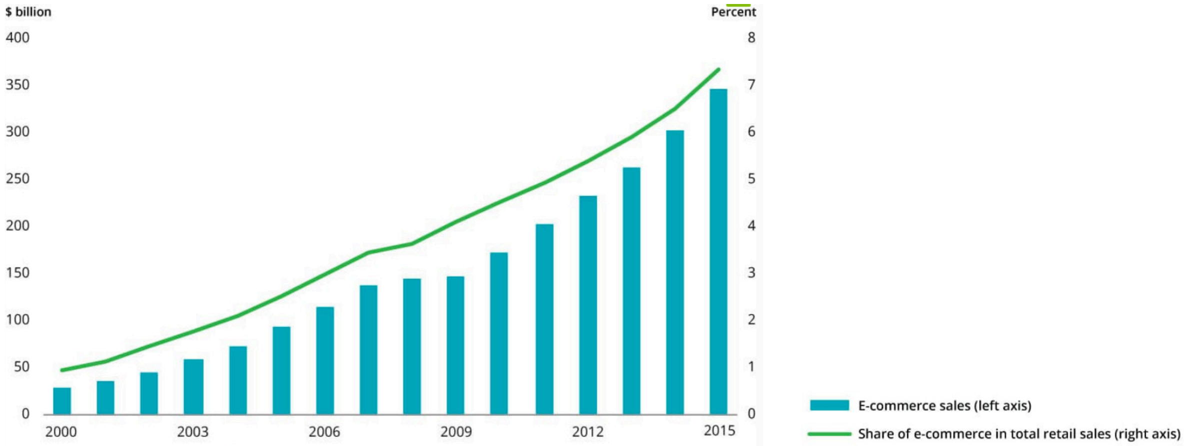
It is estimated that the MaaS market is expected to grow nearly tenfold from $38.76 billion in 2017 to $358.35 billion by 2025 (Research and Market, 2018). The acceleration of MaaS and the development of automated services may help with consumer decision-making, make travel more seamless and straightforward, and facilitate more efficient movement by combining various modes to form a holistic transport service ecosystem (KPMG, 2017).

GROWTH OF E-COMMERCE AND RISE OF GOODS DELIVERY

Another significant force of change is the continued growth of the e-commerce market, and by extension, the rise in goods delivery. Like the growth of new mobility technologies, the growth of e-commerce in recent years is also related to the evolution of mobile technology. U.S. e-commerce sales reportedly grew by 16% in 2017 (Ecommerce Foundation, 2017) and e-commerce represented 13% of total retail sales and approximately 49% of all retail sales growth in 2017 (Zaroban, 2018). Figure 8 shows the growth of e-commerce between 2000 and 2015. More broadly, technological developments such as Big Data, Internet of Things (IoT), Virtual Reality (VR), Augmented Reality (AR), Artificial Intelligence (AI), and automation are also shaping various aspects of e-commerce, changing supply chains, logistics, the customer experience, and last mile delivery (Reddy, 2018).

With the growth of e-commerce, the rate of package delivery has increased substantially, and e-commerce businesses have identified last-mile services as a key factor in maintaining a competitive advantage. Many retailers have started offering faster delivery service, such as same-day and even hour-based delivery in order to compete for e-commerce market share (Bliss, 2018a). According to a report published by McKinsey in 2016, 20-25% of consumers are willing to pay significant premiums or same-day delivery, and by 2020, it is anticipated that same-day and instant delivery will reach a combined share of 15 percent of the market (Joerss et al., 2016).

Figure 8. E-commerce Sales and Their Share in Total Retail Sales from 2000-2015 (Deloitte)



Reprint from "Ring in the new: Holiday season e-commerce sales poised for strong growth", by Bachman and Barua, 2016, Retrieved from https://www2.deloitte.com/insights/us/en/economy/behind-the-numbers/holiday-ecommerce-sales-growth-forecast.html

Source: Postmates

COURIER NETWORK SERVICES

In order to meet increasing customer demand for delivery and to expand their market, businesses are using a variety of new delivery strategies. Courier network services (CNS), or flexible goods delivery, enable for-hire delivery by connecting couriers with businesses via mobile apps or online platforms (Shaheen, Chan, Bansal, & Cohen, 2015b). Courier network services operate similarly to TNCs in that couriers are considered independent contractors and they use their own vehicles or devices to deliver goods and/or food. In the past several years, on-demand food delivery services, such as Grubhub/Seamless, Postmates, Doordash, Caviar, UberEats, and Deliveroo, have proliferated. These services have created an inexpensive option for last mile delivery and turned delivery from a small segment of the food industry (i.e., pizza) to a growing new source of sales for different types of food establishments.

Amazon has also expanded into courier service delivery, moving beyond traditional carriers like FedEx and UPS in order to keep up with growing delivery demand. Amazon Flex leverages local, nonprofessional couriers for package delivery. Amazon Flex drivers typically use their own vehicles, similar to other courier network services.

AUTONOMOUS VEHICLES ON THE HORIZON

The force of changes described above are already underway, including the limited deployment of autonomous vehicles. While many factors contribute to the adoption, deployment, and acceptance of autonomous vehicles, it is likely that this next decade will see autonomous ridehailing-type passenger services rolled out, such as those that exist in Phoenix, Arizona. Deployment will not be ubiquitous in all cities, however, as technological challenges will need to be overcome regionally. While the exact speed and scale of AV deployment is uncertain, it is clear their development and use will be disruptive to the existing transportation, real estate, design, and financial structures of cities.

PASSENGER MOBILITY

Transportation network companies like Uber and Lyft provide a good model of how autonomous vehicles are likely to be used given their on-demand nature, point-to-point service, ease in pooling customers if desired, and ability to dynamically price trips. Accordingly, understanding the use patterns and municipal impacts of TNCs can help provide initial insights about anticipated changes.

There is some evidence that AV operators will adopt a MaaS approach rather than a private vehicle ownership model, although the exact mix of personally-owned versus fleet-based trip-making is hard to predict at this time. For example, Waymo, the self-driving unit under Alphabet, Google's parent company, ordered over 60,000 AVs to be used in its own ridehailing application in May of 2018 (Boudette, 2018). Ford launched a Smart Mobility Unit in 2016, expanding its offerings beyond personally-owned vehicles and is also heavily investing in a vertically integrated MaaS strategy, including AVs (Bomey, 2016). Many also believe that ridehailing companies like Uber and Lyft are currently fighting for market share and survival as driverless vehicles may be key to their profitability (Lekach, 2019; Siddiqui & Bensinger, 2019). Other companies, such as Tesla, are betting that AVs will simply represent the next generation of the current model of private vehicle ownership. The future is likely to be a mix of these options, varying by city size, location within a metropolitan area, topography, or other factors, but what is likely different than what many cities experience currently is that the increase in ridehailing with the introduction of AVs is likely to be significant.

AV technology could allow for the emergence of shared autonomous vehicles (SAVs), which are likely be cheaper to take a ride in than human-operated ridehailing and taxi services since the labor cost of the driver would be eliminated (Litman, 2018)driverless or robotic. Ford plans to release fully automated vehicles designed for 'high-

Source: Waymo

volume' commercial uses such as ride-hailing services by 2021, and General Motors plans to provide ridehailing vehicles to its partner Lyft in the form of fully autonomous Chevy Bolts (Bliss, 2017). Audi's "Own the experience, not the car" or Volvo's "You used to buy music … the car you can subscribe to" on-demand programs can be seen as OEM's beta-testing what a shared AV future could look like.

The concept of SAVs combines elements of conventional car-sharing and taxi/TNC services, which are known as autonomous taxis, "aTaxis," or "robo-taxis" (Krueger, Rashidi & Rose, 2016). SAVs may help to facilitate accessibility for different sociodemographic groups and for those cannot drive (such as those with disabilities) in either suburban or urban areas (Litman, 2018) driverless or robotic.

Automation may also have a substantial impact on the development of microtransit initiatives. Many cities are already testing AV shuttles, partnering with operators like EasyMile, Transdev, Navya, and May Mobility. Most of these pilots have occurred on closed courses and private campuses, but some cities are beginning to pilot AV shuttles on public streets. Eventually, autonomous microtransit may be able to operate independently of predefined routes just like pooled services in Uber or Lyft, or the algorithms created by microtransit service providers like Via, calculating nearby pickup and drop-off points for passengers (Lang et al., 2017). In addition, autonomous microtransit could help redevelop specialized transit to potentially reduce travel costs and possibly optimize the efficiency of transport services, making the system more convenient, effective, and efficient. Therefore, autonomous microtransit could increase the demand for and potential to deliver more on-demand products and services (MaRS, 2016).

GOODS DELIVERY

Both long-haul freight and last-mile delivery may prove to be natural applications for driverless vehicles. Autonomous trucking is already in development and Otto, an autonomous trucking company now owned by Uber, made the first automated truck delivery using public roads in the United States in 2016 (Isaac, 2017). Companies, such as Daimler, Volvo, and others, are developing autonomous trucks and long-haul freight will likely be among the first widely deployed use cases of autonomous technology.

Last-mile delivery is also a natural application of autonomous technology, and the self-driving startup Nuro has already partnered with the grocery chain Kroger to pilot small, self-driving vehicles for grocery deliveries in Scottsdale, AZ (Dickey, 2018). The City of Scottsdale has allowed Nuro to utilize public roads for their delivery vehicles. Other companies have also been working to develop small, self-driving robots for last-mile delivery that travel on sidewalks. Starship Technologies is one such company that has been piloting its robots in places like Washington, D.C., Redwood City, CA, and Milton Keynes, U.K. to deliver packages as well as food. Amazon has also been developing its own self-driving delivery robot, Scout, which it has been testing in neighborhoods around Seattle, WA (Vincent, 2019).

Goods delivery also will likely not be limited to ground transportation in the future. The U.S. Department of Transportation announced in 2018 that it had chosen a combination of 10 states, local, and tribal governments and a handful of companies, including Alphabet, FedEx, Intel and Uber to work together on commercial drone testing (Bloomberg, 2018). Chinese e-commerce business JD.com has been starting same-day delivery of online orders in 100 rural villages in China using 40 teleoperated drones, which are 70% cheaper and faster than the manned vehicle alternative (Smart, 2018). Additionally, in April 2019, the U.S. Federal Aviation Administration (F.A.A.) issued its first approval to Wing, Alphabet's drone-delivery unit, to pilot package delivery in parts of Virginia. As autonomous vehicle technology continues to advance, it is estimated that they will be used in up to 80% of parcel delivery, saving nearly 40% in delivery costs (Joerss et al., 2016).

DEMOGRAPHIC SHIFTS

There are many simultaneous changes happening in society that will have significant impacts on the form and function of cities. In tandem with the technological advancements described above, we are also seeing demographic shifts in household preferences for housing and transportation. Young people aged 20 to 30 are less likely to move from central cities to suburbs than a decade ago (Cortright, 2016b; Dutzik, Inglis, & Baxandall, 2014). As we move more and more towards a "knowledge economy" it is worth noting what Richard Florida wrote in 2017:

> Today, clustering, not dispersal, powers innovation and economic growth. Many people still like living in suburbs, of course, but suburban growth has fallen out of sync with the demands of the urbanized knowledge economy …. The suburbs aren't going away, but they are no longer the apotheosis of the American Dream and the engine of economic growth (Florida, 2017).

In addition to this, young people, especially Millennials, are less likely than older generations to become licensed drivers (Cortright, 2016a), and they tend to live in more walkable areas or areas equipped with more active transportation options. Also, emerging technologies are providing new ways of experiencing information in urban space. Young people tend to adopt technologies (i.e., smartphones, ridehailing) faster than other age cohorts: research shows that people age between 25 and 34 have the highest usage of TNCs compared to other age groups (Schaller, 2018). According to Pew Research Center, 92% of Millennials own smartphones, compared with 85% of Gen Xers, 67% of Baby Boomers, and 30% of the Silent Generation (Jiang, 2018). As the younger generations age and the newest generation, Generation Z, grows into adulthood, we will likely see greater adoption rates as a share of the total population because the technology needed to hail new mobility services will be more ubiquitous.

Young people aged 20 to 30 are less likely to move from central cities to suburbs than a decade ago
Image Source: Trevin Rudy and Arthur Osipyan for Unsplash.

ASSUMPTIONS ABOUT AUTONOMOUS VEHICLES

Two key assumptions underpin much of this report: 1) AVs are much more likely to be deployed as MaaS fleets than as privately-owned vehicles; and 2) the majority of these vehicles will quickly become electric.

At this point in time, fleet ownership of AVs appears more likely than widespread personal ownership, at least in the near-term. While a ride in an AV may be cheaper than a ride in a TNC today, AVs will likely be expensive to purchase due to the high cost of production, as well as the need to maintain some control over updates needed by the vehicle's operating system. While private vehicle ownership rates may stay close to the same for the foreseeable future, it is likely that rates will fall once fully autonomous vehicles become readily available and people increasingly favor on-demand automated ridehailing-type services over private ownership (Pofuk, 2017). According to previous studies' estimations, private vehicle ownership rates for AVs could be dramatically reduced if fleets of AVs are owned and operated by TNCs (Fagnant & Kockelman, 2014; Pofuk, 2017). In a simulated model, researchers found that a shared fleet of AVs could incur 11% more travel compared to non-shared vehicles because they would be more consistently in service, but they also suggest that the fleet could save participating users ten times the number of private vehicles they would otherwise need (Fagnant & Kockelman, 2014). Also,

Two key assumptions underpin the report: AVs are much more likely to be deployed as **FLEETS** and the majority will quickly become **ELECTRIC.**

Source: Waymo

Source: Electric Vehicles Only by Mary and Angus Hogg
https://ccsearch.creativecommons.org/photos/cef90bee-0423-40ce-803a-61b3afc1129c

low-cost SAVs in urban areas might encourage people, especially younger urbanites, to reduce personal vehicle ownership. Therefore, carmakers may be more committed to ridehailing and carsharing services today, prioritizing fleets over personal vehicle ownership (The Economist, 2018).

Our second assumption is that AVs will likely be electric, though whether they will be all-electric is still uncertain. Steffen Hoffmann, Bosch's U.K. president projected that by 2025, 15% of vehicles worldwide will an electric component (an all-electric vehicle, a plug-in hybrid, or full hybrid; J. Silver, 2017). Companies will likely adopt electric cars faster than individual owners and using electricity instead of gasoline could have significant fuel cost savings. For instance, an electric vehicle can save $750 -$1,200 per year in fueling costs compared to a gasoline-powered vehicle (averaging 27 miles per gallon and $3.5 per gallon for fuel cost; Anair & Mahmassani, 2012). Whether AVs will be electric or gas will likely depend on their continued technological development and their overall market penetration.

Automakers such as Volkswagen (VW) are developing battery electric EVs capable of super-fast charging by plugging into machines that provide 250-450 kw/h as opposed to the current 150 kw/h machines. Additionally, researchers are pursuing commercially viable inductive charging, which would allow a vehicle to park over a pad and receive the charge through the air. This second innovation is seen as important to the future of AVs allowing the vehicles to pull into a parking area and charge themselves.

FIRST ORDER IMPACTS

The following discussion describes the broad ways that the form and function of cities are being impacted by the forces of change identified above. This section provides a foundation for the following chapters, which dive into the cascading impacts that the forces of change may have more specifically on land use, urban design, transportation, and real estate, and the resulting implications of those impacts for equity, health, the environment, the economy, and governance.

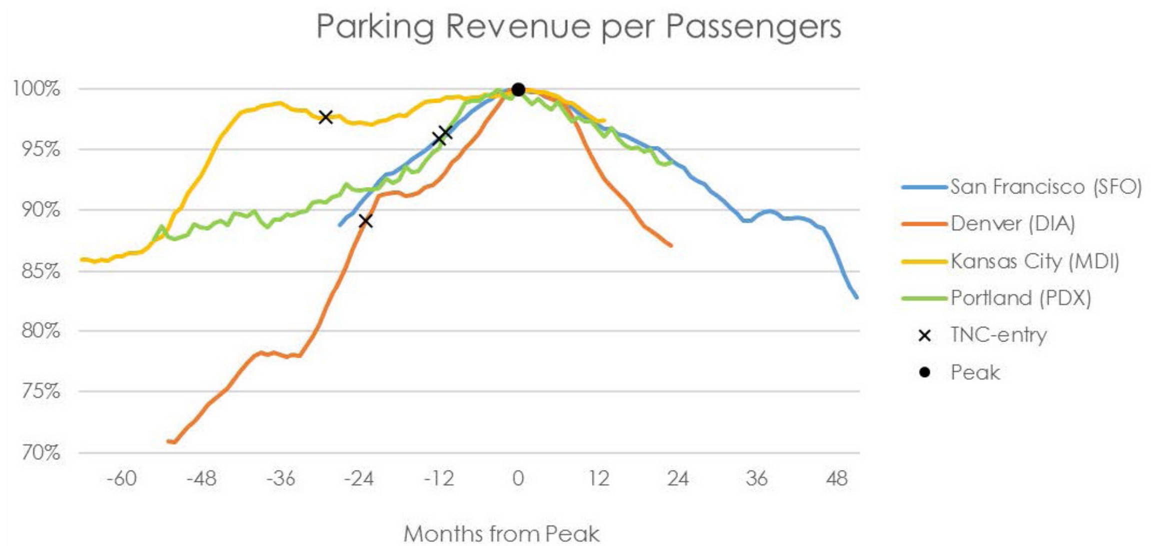
CHANGE IN PARKING DEMAND

In the United States, it is estimated that the average car is parked 95% of the time (Shoup, 2011), and while estimates of the total number of parking spots differ, they generally agree that we have far more parking than we need. In 2018, one researcher used a combination of data sources, including satellite data, to calculate exactly how many parking spaces exist in five U.S. cities—New York, NY; Philadelphia, PA; Des Moines, IA; Seattle, WA; and Jackson, WY—and found that only in New York City were there more homes than parking spaces (Peters, 2018). Seattle, however, averages more than five spaces per household and Jackson averages more than 27 spaces per household. Increasingly cities are recognizing that parking has been overbuilt and underpriced, and the emergence of TNCs and other new mobility services are already impacting parking demand in some places, such as dense downtown areas and areas with concentrated nightlife (Morris, 2018; Steele, 2018; Zipkin, 2017). One of the two most common reasons TNC users give for taking a TNC is because destination-area parking is difficult (Clewlow & Mishra, 2017).

Airports, in particular, have seen parking demand change since the introduction of TNCs. According to a 2018 study that analyzed data from four regional U.S. airports, including Portland, San Francisco, Denver, and Kansas City, airport parking revenue per passenger peaked approximately 12-24 months after the introduction of TNCs and has since steadily declined (Henao, Sperling, Garikapati, Hou, & Young, 2018). The data suggest that, taken together, the airports show an annualized declining rate of 3-7%(Figure 9). At that rate, parking demand at these airports could be cut in half in approximately 14 years. In order to manage the increased demand for curbside pick-up and drop-off many airports have created designated TNC passenger loading zones and have instituted trip fees.

The introduction of AVs could further reduce the demand for parking and will likely impact a greater variety of place types beyond heavily urbanized areas and airports. The use of SAVs in the future could further diminish parking demand since it is anticipated that SAVs will spend more time transporting passengers and much less time parked than conventional vehicles. Not only will AVs/SAVs be able to spend more time on the road overall, it is also expected that AVs will be able to park more efficiently than conventional vehicles. A 2018 study estimated that AV car-parks, which could have multiple rows of stacked vehicles, could decrease the need for parking space by an average of 62% and potentially up to a maximum of 87% of the space that's designated for parking today. (Nourinejad, Bahrami, & Roorda, 2018).

Figure 9. Airport parking revenue per passenger at four major ariports (SFO, DIA, MDI, PDX).



Henao, A., Sperling, J., Garikapati, V., Hou, Y., & Young, S. (2018). Airport Analyses Informing New Mobility Shifts: Opportunities to Adapt Energy-Efficient Mobility Services and Infrastructure (No. NREL/CP-5400-71036). Retrieved from National Renewable Energy Laboratory website: https://www.nrel.gov/docs/fy18osti/71036.pdf

CHANGE IN VEHICLE MILES TRAVELED

Recent studies have found that vehicle miles/kilometers traveled (VMT) has increased over the past several years and some of that growth has been attributed to the rise of TNCs. In a 2017 UC Davis study on ridehailing, researchers Clewlow and Mishra asked respondents to answer the question, “If Uber and Lyft were unavailable, which transportation alternatives would you use for the trips that you make using Uber and Lyft?” Twenty-two percent of respondents said they would have just made fewer trips if they hadn't used a TNC (Clewlow & Mishra, 2017). Since Uber and Lyft were an option, however, these respondents opted to take a vehicle trip that they would otherwise would not have made. This is not necessarily a bad thing since it may be that TNCs are filling transportation gaps and addressing issues of latent demand by expanding mobility for underserved populations, as research findings suggest (Brown, 2018).

At 5% market penetration **AVS COULD INCREASE VMT FROM 5-20%** depending on facility class, and could reach as high as **35% WITH 95% PENETRATION.**

Based on existing studies, AVs could contribute to an increase in travel demand due to a variety of factors including, but not limited to: increased mobility options for certain populations (people with disabilities, elderly, etc.); induced demand (people choosing to take trips they otherwise may not have taken); and people choosing to travel to destinations that are further away because the mode of travel is more comfortable. These factors could potentially yield additional VMT because more trips may be generated and more locations/destinations may be accessible (Childress et al., 2015; Correia et al., 2016). Gucwa (2014) reported that VMT could increase between 4-8% by applying different scenarios of road capacity and value of time changes through the introduction of AVs. Bierstedt and colleagues (2014) estimated that at 5% market penetration AVs could increase VMT from 5-20% depending on facility class, and could reach as high as 35% with 95% penetration.

Even if SAVs function as a form of public transportation and replace conventional, private vehicles, some studies have also suggested that SAVs may still increase VMT and generate more congestion in urban areas. One study found that SAVs could increase travel distance by 10% compared to non-SAVs and also suggest that total VMT would increase in part because of the number of out-of-service trips (e.g., zero-occupancy trips; Fagnant & Kockelman, 2014). In another simulation study of SAVs in a mid-sized U.S. city, the author found that overall VMT (for SAVs) would increase due to the need to detour and reposition vehicles for drop-off and pick-up (Schaller, 2017b).

With the deployment of AVs, people could choose to travel to destinations that are further away because the mode of travel is more comfortable.
Source: Maximilian Watcher for Unsplash.

CHANGE IN CONGESTION[1]

Several studies examining the impacts of TNCs on congestion have concluded that TNCs are contributing to increased congestion (Gehrke, Reardon, & Felix, 2018; San Francisco County Transportation Authority, 2017; Schaller, 2017a). Researchers at the Metropolitan Area Planning Council in Boston found that 15% of ride-hailing trips are adding cars to regional roadways during morning and afternoon rush hours (Gehrke et al., 2018). In San Francisco, researchers concluded that on a typical weekday TNCs are averaging 570,000 VMT, which they consider to be a conservative estimate. In comparison, they estimate that taxis in San Francisco generate 66,000 VMT on a typical weekday (San Francisco County Transportation Authority, 2017). There are two important contributing factors: in-service VMT, or the distance traveled while transporting a passenger, and out-of-service VMT, or the distance traveled during circulation periods. With the current model of TNCs, those circulation periods represent single-occupancy trips but with fully automated vehicles, those same trips are likely to be zero-occupancy, or "zombie" trips, with no people in the vehicle.

Of course, levels of traffic congestion vary from place to place and city to city, and relate to a variety of factors including "population density, road capacity, choice of alternative modes of travel, and traffic management technologies use" (Metz, 2018). On the one hand, AVs could contribute to increased congestion resulting from a combination of induced and latent demand, and mode replacement (e.g., a person choosing to take an AV instead of walking or biking). However, the potential exists for AVs to help decrease congestion since AVs have the ability to travel in closer proximity than human-driven vehicles can today, resulting in shorter headways and narrower travel lanes. Such an improvement of free-flow capacity and flow stability could decrease congestion, though such efficiency gains will depend upon the penetration rates of connected and autonomous vehicles (Talebpour & Mahmassani, 2016). However, in planning for a fully autonomous environment we will be presented with the option of seeing these potential efficiency gains directed towards either: 1) using the same amount of roadway as today to allow for greater vehicle throughput, or 2) keeping current vehicle throughput and directing the "efficiency gains" towards other modes such as transit, walking, and biking through the reallocation of space.

If AVs are able to travel more efficiently than conventional vehicles, delays and travel costs could be reduced. This could make travel more affordable and/or attractive to those whose trips were previously suppressed, thus generating additional traffic. A simulation study in Boston found that introducing AVs and SAVs into the city could improve travel time for the city overall, but could still increase congestion, as well as travel time in the downtown area (World Economic Forum, 2018).

[1] *This section pulls from the Urbanism Next report "AVs in the Pacific Northwest: Reducing Greenhouse Gases in a Time of Automation" (August 2018).*

CHANGE IN EASE OF TRAVEL

While AVs are predicted to induce trips and increase congestion within central cities (Fagnant & Kockelman, 2014; 2018), studies have predicted that AVs might increase the speed of travel to and from suburban and exurban areas (International Transport Forum, 2015; Patel, Levin & Boyles, 2016) as they take advantage of the potential speed increases on low-conflict roads such as suburban arterials, highways and freeways. This would allow travelers to reach further into the periphery of cities while maintaining their current commute time.

Currently, average commute time in the United States is approximately 26 minutes each direction per day (U.S. Census Bureau, 2017). Although this number has remained fairly consistent in recent years, this might change with the usage of AVs as this new technology allows comuuters to shift our use of time from driving to a range of activities such as social media, working, eating, or sleeping. Thus, it is conceivable that individuals might accept a slightly longer commute time than they have now as travel time gains utility and is not seen as a lost part of the day (Harb, Xiao, Circella, Mokhtarian, & Walker, 2018). While there are conceivable absolute limits to the time individuals will spend on their commute, a slight increase in acceptable travel time, combined with the increased travel speeds offered by AV suburban commutes, could allow travelers to reach even further into the periphery of cities. Marchetti's Constant, or the notion that approximately 30 minutes of travel time has remained the consistently acceptable range across modes, eras, or geographic locations (Marchetti, 1994), could shift as commute time is liberated from needing to focus on driving.

The National Association of Realtors yearly survey of housing preferences (Dill, 2015) has consistently reported a dominant preference for larger lots, proximity to open space, and proximity to nature. If it becomes easier to reach areas further in the periphery that have these properties, individuals—without the limits imposed by our current transportation system— may preference these properties over ones closer to the center. If commute times become less important and travel speeds increase, the need for labor to be near employment, and vice versa, may be reduced. This could free up both residential and employment lands for development based on other criteria such as lower land costs, limited land use constraints, and limited neighbor opposition.

Set against this, however, are the preferences, described in Richard Florida's book "The Rise of the Creative Class" (2002), that knowledge economy workers consistently prefer environments with a "vibrant quality of place" and "an abundance of things to do," which typically favors denser urban areas. Recent trends point to Millennials (those born between 1981 – 1997), as a demographic that is more diverse than previous generations, less likely to be homeowners, and more interested in intergenerational housing typology, which is typically not found in outer suburbia (Choi, Zhu, Goodman, Ganesh, & Strochak, 2018; Y. Lee, Lee, & Shubho, 2019).

SHIFT IN MODES

Travel behavior theory suggests that the decision to use one mode over another is informed by a variety of factors including, but not limited to, socioeconomic status, age, the price of gas, urban form, and the availability of transportation options. In a 2016 white paper published by Circella and colleagues, researchers analyzed the National Household Travel Survey (NHTS) and found that while the total number of person trips increased between 1995 and 2009, mode distribution shifted away from vehicles and the percentage of person trips made by car decreased (Circella, Tiedeman, Handy, Alemi, & Mokhtarian, 2016). Buehler and Hamre found that Americans became increasingly multimodal during that same time period (Buehler & Hamre, 2015). However, several more recent reports found that transit ridership is decreasing in most major U.S. cities, which may be attributed to a variety of factors including, but not limited to: a sustained period of economic growth following the Great Recession; the rise of transportation network companies; higher rates of car ownership; neighborhood change and migration patterns related to displacement and gentrification; and declining gas prices (Manville, Taylor, & Blumenberg, 2018; Siddiqui, 2018b). There are a few notable exceptions, including both Seattle, WA and Vancouver, B.C.; both cities have seen transit ridership grow in the last year because they have invested in transit focusing on core high-capacity routes (Lindblom, 2018; Kerr, 2018).

> **"THOSE WHO RIDE TRANSIT MORE OFTEN ARE MORE LIKELY TO DROP IT FOR RIDE HAILING, EVEN WHILE DOING SO AT A HUGE COST DIFFERENTIAL."**
>
> *Gehrke et al., 2018*

The growth of TNCs in the last several years has impacted travel behavior and preliminary research suggests that TNCs are among the factors impacting transit ridership (Graehler Jr., Mucci, & Erhardt, 2019; Manville et al., 2018). In a Boston-area study conducted by the Metropolitan Area Planning Council (MAPC), researchers found that weekly or monthly transit pass holders are substituting TNCs for transit more frequently, and that those "who ride transit more often are more likely to drop it for ride hailing, even while doing so at a huge cost differential, and even when they have already paid for the transit" (Gehrke et al., 2018).

TNCs may also be replacing trips that otherwise would have been made by walking and biking. Using weighted data, Clewlow and Mishra found that only 39% of trips made using Uber and Lyft would otherwise have been made by car (i.e. drive alone, carpool, or taxi; Clewlow & Mishra, 2017). The majority of trips would otherwise not have been made at all, or would have been made by walking, biking, or transit. Transit services being too slow, not having enough stops or stations, and not having service at times needed were the primary reasons respondents cited for substituting ridehailing for transit (Clewlow & Mishra, 2017). These findings are corroborated by MAPC in Boston. According to MAPC researchers, 42% of the people they surveyed indicated they would otherwise have taken public transit for their trip and an additional 12% said they would have walked or biked (Gehrke et al., 2018).

If AVs offer lower travel costs, potential modal shifts may occur depending on trip distances and purposes (LaMondia et al., 2016). According to LaMondia's study, at certain AV travel time valuations, the cost of travel may not be a significant factor and as the perceived travel time benefits from driverless cars rise, monetary costs may become less important. Lower operating costs, lower costs of parking, increased roadway capacity, and a reduced perceived cost of travel could incentivize a mode shift to AVs (Fulton, Mason, & Meroux, 2017). This assumes, however, that other elements of the transportation system, such as transit frequency and reliability, remain similar to or the same as they are today.

SAVs or on-demand driverless shuttles could dramatically reduce costs associated with the first- and last-mile portions of a trip, which could serve to complement transit use. But a shift to SAVs could impact mode choice and spur some to switch from an active mode to an SAV. Research findings on this topic suggest that up to 10% of travelers could switch from walking and cycling to AVs (Childress et al., 2015; Davidson & Spinoulas, 2015). Also, researchers project that if AV operating costs decrease by 50% and perceived travel time costs decrease by 10-50%, public transportation and walking and cycling would decrease by 14% and 11% respectively. Truong and colleagues (2017) assume that if vehicle occupancy rates remain unchanged and mode shifts from public transportation and active modes to AVs occur, vehicle trips would increase by over 7%.

COMPETITION FOR THE RIGHT-OF-WAY (ROW)

The public right-of-way, which encompasses the sidewalk, curb, and street, plays a vital role in creating an efficient transport system. Demand for this limited space has been increasing over the past several years with the introduction of TNCs, the increase in urban delivery, the expansion of bikesharing programs, and the deployment of e-scooters. As a result, managing the competing demands for this space is increasingly complicated. If AVs proliferate, an increasing number of pick-up and drop-off areas may become necessary. Curb management for AVs will need to consider several components, including loading zones, paratransit and accessibility loading, metered parking spots, bus stops, and passenger drop-off zones (NACTO, 2017c). Because AVs may be able to travel more efficiently than conventional vehicles, ROW could be reallocated to other modes. Street design in an autonomous future could place more emphasis on walking, biking, and transit, as well as helping to establish safer speed limits, and allowing the curbside to be flexible for public and private uses (NACTO, 2017b).

Figure 10. Multiple uses of the right-of-way (ROW)

Source: Michelle Montiel for Urbanism Next.

CHANGES IN GOODS AND MEAL DELIVERY

With the continued growth of e-commerce coupled with the advent of AV technologies, goods delivery will likely continue to increase to meet consumer demand. The automation of technology will make it easier to haul goods over long distances by road, air, and sea. In a recent survey, 49% of shoppers said that same day shipping would make them more likely to shop online; however, only 15% of global retailers offer same-day delivery (Asper, 2017). Therefore, on-demand delivery provided by AVs may help to grow current and future goods delivery. More brick-and-mortar retailers and restaurants may choose to deliver their products via driverless methods to cut down on last-mile delivery costs. It also seems likely that the demand for restaurant delivery will continue to grow. UberEats, for example, has expanded to 280 cities in a four-year period between 2014 and 2018 (Kludt & Geneen, 2018). Some restaurants now operate as delivery-only in order to reduce the costs associated with running an eat-in establishment, or use shared commissary kitchens for food preparation for delivery-only meals.

Source: Starship Technologies

SHIFTING NATURE OF FREIGHT

AV technologies have the potential to profoundly impact many aspects of the freight industry and may help to tackle current issues that the industry faces, such as labor shortages and high rates of driver turnover. With new technology platforms, autonomous trucks could become integrated into the logistics chain, potentially providing players across the supply chain with more transparent information about the status of goods shipments and movements. Highly automated, driverless, or fully-automated trucks may also help increase the speed of delivery, since the need for driver rest periods would be reduced or nullified, and distribution routes could be planned differently (Flämig, 2016). Also, the ability to have autonomous trucks operate in a "platoon" with multiple vehicles tethered electronically and overseen by one driver could significantly reduce the cost of point-to-point linehaul journeys (Gibbs, 2017). Several companies that are working on developing autonomous trucks, including Uber's advanced Technologies Group, are relying on a "transfer hub" model. In this model, long-haul autonomous trucks stop at transfer stations in order to exchange trailers with conventional trucks, which are then operated by local drivers to their final destinations (Clevenger, 2018). Automation could improve freight efficiency and capacity, which would reduce transportation costs, and possibly, the cost of the goods themselves. Further reductions in the cost of delivery could also lead to an increase in the demand for goods delivery.

CHANGES IN DEMAND FOR WAREHOUSING SPACE

Package and parcel volumes have continued to accelerate year-over-year with the continued growth of e-commerce (Synchrony Finance, 2016). As a result, companies are choosing to localize warehousing construction so that supply chains and logistics are moving closer to consumers in order to increase efficiency (Cerasis, 2018). The North American Industrial Forecast Report predicts that by the end of 2019, 782 million square feet of new warehouse space will have entered the North American market (Cushman & Wakefield, 2017). Technological developments provide opportunities for businesses to make efficiency improvements, and smart warehousing solutions may become the core model.

REDUCTION OF CERTAIN TYPES OF BRICK-AND-MORTAR STORES

As e-commerce business has expanded, more mall retailers and department stores have shuttered around the country. U.S. stores closings totaled over 5,000 in 2017, and there were nearly 4,100 store closures in the first half of 2018 alone, more than double the 2,000 openings in the same timeframe (Cheng, 2018; Timmermann, 2018). More than 8,000 stores are expected to close in the U.S. by the end of 2019 (Peterson, 2019). Chains like Macy's, Best Buy, and Payless have been shuttering: Payless announced that it planned to close more than 2,500 stores after filing for bankruptcy in February 2019 (Peterson, 2019). In order to stay competitive, traditional brick-and-mortar retailers have started or expanded their own e-commerce operations. Wal-Mart Stores, Inc. spent $3.3 billion to take over e-commerce start-up Jet.com and Wal-Mart's U.S. e-commerce sales climbed 63% in the second quarter in 2017 (Bowman, 2017).

INCREASING INTEREST IN EXPERIENTIAL RETAIL

While some types of brick-and-mortar retail have been struggling to compete with e-commerce, other types of retail, especially "experiential retail," have been flourishing. Experiential retail favors immersive, interactive, and often, technology-enhanced experiences for consumers (Ruff, 2019). The most familiar "experiential retail" environment is likely the Apple Store. Apple Stores emphasize the "experience" with the physical environment replicating the sleekness of its product. Since the first Apple Store opened in 2001, other retailers have seen the value of this retail model, which typically requires a smaller footprint, and are gradually using it to replace the traditional large footprint big-box experience.

Experience-driven retail appeals to consumers who strongly favor in-store shopping experiences to online shopping. They prefer a unique experience that differentiates their spending and they are willing to pay 32% more (on average) for that experience (Synchrony Finance, 2016). With the introduction of AVs, the need for parking will likely be reduced, and delivery costs may go down, further exacerbating these retail trends. Auto-oriented strip malls and big-box stores may face more shrinkage as consumers opt to travel to experiential retail but order household goods and other items online. According to one study, customer experience will overtake price and product as the key brand differentiator by 2020 and 86% of consumers will pay more for a better experience (Walker Consultants, 2013).

IMPLICATIONS OF THE FORCES OF CHANGE AND FIRST ORDER IMPACTS

The forces of change and first order impacts previously described are largely focused on the built environment and how city form and function is changing. The following section explores what the implications of these changes may be for equity, health, the environment, the economy, and governance.

EQUITY

ACCESS TO MOBILITY

New mobility technologies and the other forces of change discussed above could have positive equity implications, but it is also possible that these changes could further exacerbate existing inequities in transportation and mobility access (Asenjo et al., 2017). On the one hand, AVs have the potential to expand mobility for people who have been underserved, such as people with disabilities, seniors, low-income populations, and people living in areas with limited modal options. On the other hand, many new mobility technologies require access to smartphones, data plans, and credit/debit cards, and have very few, if any, language options. Lower-income populations may not have the same access to technology and credit as higher-income populations. According to a Federal Deposit Insurance Corporation survey (2018), 8.4 million U.S. households were unbanked in 2017, and an additional 24.2 million were underbanked, meaning that they obtained some financial services outside of the banking system. As a result, new mobility technologies including AVs could further widen the gap of access to mobility across different income groups and geographical areas.

INCOME DISPARITY

Today's income disparities are at an outsize level, with the richest 0.1% holding the same amount of wealth as the bottom 90% of the population (National League of Cities, 2017). The emergence of new transport technologies may exacerbate geographic inequality as higher-income populations have more opportunities to choose where they live, and AVs could contribute to further stratification. Also, higher-income earners stand to gain greater financial benefits from adopting time-saving modes of transport, such as AVs, and they will likely be early and more widespread adopters (McLaughlin, 2017). Additionally, AVs could potentially eliminate some middle- and low-wage jobs, such as in the trucking industry, and may displace workers who drive for a living, further exacerbating income disparity.

WEALTH CREATION

Mobility is a crucial component of employment access, which is inextricably linked to wealth creation. A lack of reliable and efficient transportation options is a significant barrier to upward economic mobility (Chetty, Hendren, Kline, & Saez, 2014). New mobility technologies have the potential to improve services, efficiency, and quality of life if they are implemented equitably (National League of Cities, 2017).

DISPLACEMENT

New mobility can accelerate growth in a city. However, if services are limited to certain areas, they may contribute to increasingly expensive housing in those areas as demand increases, potentially resulting in displacement of certain populations. There has been some evidence to suggest that this been the case around transit stations, with property values increasing in these areas (Buyahar, 2019). New transportation technology, along with redevelopment of space and urban design, may mainly attract—and focus on serving—higher income populations who can afford to live in the places with those services.

WORKFORCE IMPACTS

The commercial deployment of AVs may have serious and far-reaching workforce impacts. One group of workers that may be displaced by AVs are truckers and for-hire drivers. The World Economic Forum estimates that the confluence of automation technology could displace approximately 5.1 million jobs across 15 major economies by 2020 (World Economic Forum, 2018). Depending on the rate of adoption, autonomous trucks and cars could directly eliminate 1.3 to 2.3 million workers' jobs over the next 30 years in the United States (Groshen, Helper, MacDuffie, & Carson, 2018). Groshen and colleagues estimate that this could raise the annual unemployment rate by 0.1% and lower the overall labor participation rate annually. Even if technological advancements have the potential to create thousands of new jobs, many of the new roles that are created will require higher skills and education, which can be a barrier to retraining displaced employees for those positions.

HEALTH

LEVEL OF PHYSICAL ACTIVITY

AVs and other new mobility technologies could have positive and/or negative implications for public health depending on a variety of factors, including the rate and manner of AV deployment, as well as decisions made by city officials regarding the built environment. Some cities may use the introduction of AVs to modify their urban and street design to make cities more encouraging of active transportation modes, such as walking and biking. This would increase the levels of physical activity and its associated health benefits. Moreover, a dramatically reduced demand for parking may result in parking lots being redeveloped in ways that could make streets and cities become more compact, which would promote active transportation (Richland, Lee, & Butto, 2016a). However, if AVs reduce the cost of travel to the point where the reliance on the automobile for travel further increases, this could negatively impact physical activity and increase sedentary behaviors (Ding et al., 2014). With AVs, people may also be willing to commute longer distances, which could exacerbate sprawl, reduce physical activity, and expand built form that lacks access to active transportation.

SAFETY

AVs could dramatically reduce the number of automobile-related injuries and fatalities that occur annually. Since human error contributes to 90% of crashes, AVs could significantly reduce crash rates (Fagnant & Kockelman, 2014). AV technology will allow vehicles to incorporate machine learning, such as safety data, and comprehensive risk predictions through sensors, cameras, radars, etc., which could help increase safety. In addition, the potential for increased road capacity and flow stability, as is anticipated by AVs, may be conducive to improving road safety. However, it is difficult to assess how safe autonomous vehicles are or will be given limited data about those currently in deployment, as well as the relative nascence of the technology. There are also varying levels of automation. Automated vehicles that share some responsibility with human operators, such as Level 3 AVs, may require intervention in emergency situations. This could make decision-making more as opposed to less complex and could negatively impact road safety (International Transport Forum, 2018).

EXPOSURE TO POLLUTION

AVs may help reduce dependence on fossil fuels if they are primarily electric, as anticipated. Compared to current driving patterns, AVs will likely be able to drive more efficiently, with less stopping and starting and fewer crash-induced traffic jams (Richland et al., 2016a). Reduced emissions would positively impact public health and could lower rates of respiratory-related illnesses and deaths. However, as discussed previously, AVs may also increase VMT/VKT which may not offset pollution reduction even if the efficiency of driving is improved, in part because they will share the road with conventional vehicles for many years.

MENTAL HEALTH

There are several ways that AVs may impact mental health. First, the potential improvement of road safety could possibly lessen the stress experienced by road users. For people in vehicles, they may be less likely to stress about common commuting woes such as congestion if AVs free up that time for activities other than driving. AVs could also increase access to places for social interaction and social support by increasing access to mobility, particularly for populations that are currently underserved by the current transportation system, such as elderly populations and people with disabilities. In a study that simulated potential AV use by providing 13 households with an on-demand chauffeur for a week, researchers found that the retiree cohort increased their VMT, the number of long trips taken, and the number of evening trips taken the most compared to the other cohorts (Harb, Xiao, Circella, Mokhtarian, & Walker, 2018).

Additionally, the potential opportunities for placemaking due to a reduction in parking (e.g., more parks and green space), and the potential for air quality improvements due to the adoption of electric AVs could be conducive to mental health (Rojas-Rueda, 2017). However, another study suggests that isolated travel periods could limit social interaction, which could have negative impacts on mental health (Boniface et al., 2015).

ACCESS TO HEALTHY FOOD

In addition to cities assisting with the provision of access to healthy food through spot zoning, AVs may increase access to healthy foods. New delivery models could decrease the time and cost of delivery services, which may benefit those who cannot afford cars or other types of mobility, or who are unable to travel. However, whether AVs will be transformational for these populations in need will depend, in part, on how the cost of accessing AVs compares to other transportation options, such as mass transit or emerging on-demand taxi services, as well as the physical proximity to goods and services (Richland, Lee, & Butto, 2016b).

ACCESS TO HEALTH CARE

AVs also have the potential to increase access to health care if they provide expanded mobility options, particularly for low-income populations, seniors, and people with disabilities. Transportation barriers can result in missed appointments and poor health management (Cronk, 2015). Researchers in New York surveyed nearly 700 low-income people living in suburban areas and found that nearly one-quarter had missed a medical appointment or been forced to reschedule due to transportation difficulties (D. Silver, Blustein, & Weitzman, 2012). Limited transit schedules and routes can be barriers to accessing health care. On-demand transportation services that are characterized by more flexible routing may help to mitigate some of these barriers. A pilot project conducted from June through November 2019 in Columbus, OH will provide free, on-demand rides to health care appointments for low-income expectant mothers (Bliss, 2018b). The extent to which AVs are able to increase access to health care will, of course, depend on their affordability and other factors.

ECONOMY

SHIFT IN INDUSTRIES/LABOR

Many industries may face upheaval if they are not able to adapt to the changes that AVs will bring to the market. According to CB Insights, fast food, real estate, military operations, and even industries like home improvement (approximately 33 industries), will shift their strategies in the wake of driverless cars (CB Insights Research, 2018). The demand for insurance may decrease as the risk of car crashes drop, and insurance companies may shift business strategies, such as charging based on the number of miles are driven. Driverless technology may also further expand food delivery services and make delivery operations more efficient, which could further impact the restaurant industry. Additionally, a reduction in parking demand could reshape the urban landscape, which will likely impact those involved in real estate. AVs will most likely be deployed as fleets rather than private vehicles, at least early on, which may have the effect of turning car dealerships into AV fleet support and service centers. Autonomous technology also requires data centers and high-speed connections to support the infrastructure of AV systems, potentially generating new jobs in information technology and data analysis.

*Many industries may face upheaval if ther are not able to adapt to the changes AVs will bring to the market.
Image Source: Priscilla Du Preez for Unsplash and Starship technologies.*

ENVIRONMENT

GREENHOUSE GAS EMISSIONS

The broad deployment of AVs has the potential to reduce greenhouse gas emissions (GHG) if AVs are primarily electric, as anticipated. One study found that AVs with electric power-trains have lifetime greenhouse gas emissions that are 40% lower than vehicles powered by internal-combustion engines (Gawron et al., 2018). Replacing conventional, gasoline-powered vehicles with electric AVs will likely reduce GHGs, but the deployment of AVs will also likely happen in stages. As a result, AVs are expected to share the road with conventional vehicles for years. If the cost of traveling is lowered by AVs and VMT/VKT increases, as previously discussed, this could have the effect of increasing GHGs since there would be more vehicles on the road overall.

PARTICULATE POLLUTION

Studies examining the environmental benefits of electric vehicles compared to conventional vehicles have generally found that EVs offer net positive benefits (Requia, Mohamed, Higgins, Arain, & Ferguson, 2018). However, EVs have been shown to have a greater impact on ground-level ozone (O3) than fine particulate matter (PM2.5) (Schnell et al., 2019). Additionally, Schnell et al. found that the source of electricity for EVs exhibits greater control over PM2.5, which suggests the impacts of electric AVs on particulate pollution could be more regional and dependent on the local fuel mix.

QUALITY AND EXTENT OF HABITAT

The potential positive and negative impacts of AVs on air quality and ecosystems are based on the assumptions mentioned above. AVs also have the potential to change and reshape urban areas and how people use space. More people may choose to live further from cities because the travel (monetary and time) costs may be reduced, which could further exacerbate sprawl. This may affect biodiversity and other species' habitats without land use planning policies to protect natural/farmland areas and restrict development. However, should the potential for improvements to streets and the public realm in cities be realized this could make urban living more attractive, thus offsetting some of the potential induced sprawl.

GOVERNANCE

MUNICIPAL REVENUES AND FINANCE

AVs could have profound impacts on government revenues. According to a survey by Governing of the 25 largest U.S cities, cities took in a total of nearly $5 billion in the 2016 fiscal year from parking-related activities (56%), camera and traffic citations (12%), gas taxes (14%), towing (2%), and vehicle registration and licensing fees (13%; Governing, 2018). These revenue streams could be immediately and directly affected by AVs as a result of decreasing car ownership, reduction in sales tax revenue from local auto dealers, the proliferation of hybrid and electric vehicles, reduced demand for parking, and a decrease in the number of citations issued. The loss of municipal revenue due to the pervasive effects of AVs will likely impact policy, planning, investment, and design decisions by public agencies, private business, investors and the public at large (Clark, Larco, & Mann, 2017; Clark & Lewis, 2018; Clements & Kockelman, 2017). Faced with potentially significant reductions in revenue due to EVs, AVs, and new mobility in general, cities will likely need to strategize on how to recover those revenue holes.

AVs could lead to entirely new mechanisms for collecting revenue from transportation. Governments may enact strategies to develop alternative revenue streams to offset the loss of fuel tax, such as introducing a VMT tax to replace revenue lost from gas taxes and parking (T. Lee, 2016), taxing SAVs, pricing the curb, etc. A new regulatory structure may pose different privacy and data concerns compared to the current structure. Data and information from TNCs and logistics industries can help cities adjust pricing regulations by managing the supply and demand spatially and temporally. The flip side may be that the potential for greater efficiencies of AVs could reduce current projected needs for infrastructure.

GOVERNMENT STRUCTURE AND HIERARCHY

Different levels of government have different roles in the regulation of AVs. The federal government is responsible for regulating motor vehicle design, safety, and equipment. According to USDOT, the role of the U.S. Department of Transportation is “acting as a convener and facilitator, partnering with a broad coalition of industry, academic, states and local, safety advocacy to support the safe development, testing, and deployment of automated vehicle technology” (USDOT, 2018). The National Highway and Transportation Safety Administration (NHTSA) released guidelines that offer best practices for state legislatures about incorporating standard safety-related elements regarding AV systems into their legislation (NHTSA, 2017). At the state level, the role includes regulating other aspects such as insurance and liability, enacting new traffic laws (e.g., speed limits), licensing requirements, vehicle registrations, safety inspections, etc. Local government is responsible for dealing with the immediate, on-the-ground effects of autonomous vehicles, such as parking, street design, and curb management.

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03 | IMPACTS ON TRANSPORTATION

INTRODUCTION

Autonomous vehicles have the potential to reshape car access and travel as we know it, with far-reaching consequences for urban design, land use, real estate, and other transportation modes. Cities must now begin to reconcile the potential impacts that AVs and shifting parking demand and infrastructure may yield, ranging from effects on municipal budgets to divergent futures for mobility equity.

Transportation is a particularly interesting topic in the context of this report because advancements in transportation technology are the primary drivers of the changes we have been discussing, but these changes are also impacting the transportation system in turn. More acutely than land use, urban design, and real estate, which are primarily being affected by emerging mobility technologies, transportation is both affecting change and simultaneously being affected. The advancement of autonomous vehicles, ridehailing services, and the early evidence of willingness to use new micromobility options provides new opportunities for cities to rethink their transportation systems. In particular, there are renewed opportunities to increase more sustainable modes such as walking, biking, and transit.

CHAPTER ORGANIZATION

FIRST ORDER IMPACTS
- CHANGE IN PARKING DEMAND
- CHANGE IN VEHICLE MILES TRAVELED (VMT) AND CONGESTION
- COMPETITION FOR THE RIGHT-OF-WAY (ROW)
- CHANGE IN GOODS AND MEAL DELIVERY

SECOND ORDER IMPACTS
- WALKING/BIKING/TRANSIT
- PARKING/VEHICLES

INTEGRATIVE IMPACTS
- LAND USE
- URBAN DESIGN
- REAL ESTATE

IMPLICATIONS OF SECONDARY IMPACTS ON TRANSPORTATION
- EQUITY
- HEALTH
- ECONOMY
- ENVIRONMENT
- GOVERNANCE

AREAS OF NEEDED RESEARCH

FIRST ORDER IMPACTS AFFECTING TRANSPORTATION

The rise of new mobility and e-commerce and goods delivery will dramatically reshape transportation. The first order impacts that will affect other modes, parking, and vehicles include: change in parking demand, change in vehicle miles/kilometers traveled and congestion, competition for the right-of-way, and changes in goods and meal delivery.

CHANGE IN PARKING DEMAND

Researchers to date have voraciously studied transportation network companies (TNCs), a harbinger of a new era of car access and their assumed eventual successor, AVs. TNC user surveys suggest that a primary motivator for users to hail a ride is to avoid expensive or scarce parking (Clewlow & Mishra, 2017; Gehrke, Felix, & Reardon, 2018; Henao, 2017). While potential links between TNC use and parking remain unexplored in rigorous research, anecdotal news stories suggest that parking rates have fallen in locations where TNC use is high and parking is scarce and expensive, such as sports stadiums, airports, and popular nightlife destinations (Zipkin, 2017). Such isolated stories, however, also reveal the work ahead to understand the changes that TNCs, and eventually AVs, may bring to parking demand, which some researchers suggest may reduce the overall need for parking by an average of 62% and a maximum of 87% (Nourinejad, Bahrami, & Roorda, 2018).

Some researchers suggest that parking demand may reduce by an average of 62% and a maximum of 87% with the use of TNCs and eventually AVs. Image Source: Gerry Van DerWalt for Unsplash.

CHANGE IN VEHICLE MILES TRAVELED AND CONGESTION

AVs may increase or decrease total vehicle miles traveled (VMT) in the future; most researchers predict the former, citing surveys that report mode shift from transit and active modes to TNCs (Clewlow & Mishra, 2017; Henao, 2017). Additional surveys are needed, however, to understand when, where, and for what trip purposes these potential mode shifts might occur. VMT and congestion may also rise if, for example, AVs circle blocks continuously waiting to pick up their passenger rather than parking. Finally, VMT and congestion could increase as e-commerce continues to boom, and, as some have predicted, brick-and-mortar stores take to the streets in roving AVs that deliver goods or services to peoples' doors—or perhaps perform services, like a haircut, on the journey. Additional goods-delivery services, which are already on the rise with TNC-enabled platforms like UberEats (now in 120 markets worldwide after growing by more than 24 times between March 2016 and 2017; Isaac, 2017), could also emerge and add to VMT.

COMPETITION FOR RIGHT-OF-WAY

Much of parking is currently in the right-of-way; already, TNCs and expanding goods delivery spurred by e-commerce are increasing the competition for once stagnant curb spaces dedicated to storing individually-owned vehicles. Increased competition for curb space raises questions about whether parking should remain in the right-of-way, or if curb space is better dedicated to other modes or uses, including loading zones. For example, Washington, D.C. has implemented 24/7 loading zones for both TNCs and commercial vehicles (Lazo, 2018). Increased competition for curb space has highlighted the value of the curb—what Quartz has called cities' "hottest asset" (Hao, 2018)—and cities are increasingly exploring dynamic pricing strategies to encourage turnover. While many of these programs are limited to passenger spaces, efforts to map cities' curbs (Hao, 2018) may allow dynamic pricing for goods and passenger vehicles as well as shifting functions over the course of a day.

CHANGES IN GOODS AND MEAL DELIVERY

AVs remove driver labor costs and could therefore dramatically lower the cost of delivering goods both for long-distance trucking and for last-mile goods delivery. Rising rates of e-commerce are likely to increase goods movement in the future. Goods and services could also be delivered on AVs rather than just by AVs if vehicles themselves become stores or service providers.

SECOND ORDER IMPACTS ON TRANSPORTATION

The purpose of this section is to consider how the first order impacts described above may impact transportation. The second order impacts are largely speculative in nature and are meant to summarize projected impacts along various dimensions. For organizational purposes, we group walking, biking, and transit together in this section, and discuss parking and vehicles as a separate grouping.

WALKING/BIKING/TRANSIT

MODE SHIFT

Travelers are more likely to bicycle and walk when they feel safe and comfortable (Xing, Handy, & Mokhtarian, 2010), and AVs are expected to delivery safety improvements, which could encourage more active travel in the future if the risks to pedestrians are reduced. At the same time, current studies of TNCs suggest that on-demand vehicle travel could either complement or substitute for existing modes, or both. For example, on-demand vehicles may expand transit catchment areas, improving individual access to transit (Shaheen & Chan, 2016). Numerous transit agencies are currently piloting such connections, testing the efficacy of TNC-transit partnerships in boosting transit access. Surveys of TNC users also suggest, however, that travelers replace active travel and transit—at least to some extent—with TNC trips (Clewlow & Mishra, 2017; Henao, 2017). Additional research is needed to better understand potential modal replacement, including when, where, and for what trip purposes people may substitute vehicle travel for other modes.

The implications of AVs and other on-demand vehicles for other modes will likely also vary over the short- versus long-term. For example, carshare literature suggests that being able to access a car when one needs it allows people to reduce personal car ownership or delay purchasing an additional car (Le Vine & Polak, 2017) which might in turn lead to some users no longer treating cars as their default mode for most trips. TNCs and eventually AVs may likewise allow people to limit or reduce personal car ownership, particularly in the long run, if they make other modes more attractive than traveling by personal or privately-owned vehicles. There is already some evidence to support this—there are some urban areas where the share of “car-free” households (no cars available) and “car-light” households (fewer cars than workers) increased between 2012 and 2017 (Schaller, 2019). However, if the cost of a ride in a fleet-based AV is extremely low, the opportunity for more trips to be taken by vehicle is high. Finally, if AVs have right-of-way priority, other modes may continue to be restricted due to space limitations.

SAFETY IMPACTS

Some researchers focus on the potential bicycle and pedestrian safety improvements enabled by AVs, predicting 20-65% fewer conflicts with vehicles once AVs have achieved between 50 and 100 percent market penetration (Morando, Tian, Truong, & Vu, 2018). However, as the vehicle fleet transitions from driver-based to driverless, there may be periods of confusion for other road users as to whether they have been seen by vehicles or drivers. If pedestrians become used to driverless vehicles stopping for them and cross at non-signalized intersections more frequently, it is possible that safety could decrease if a less attentive car with a driver is present rather than an AV.

MORE FIRST- AND LAST-MILE CONNECTIONS

According to the 2017 National Household Travel Survey, 35% of vehicle trips are two miles or less (Federal Highway Administration, 2017), yet many of the origins or destinations of such trips may be in lower density areas difficult to serve by transit. Whether the entire trip is two miles or less, or the end of a transit trip is such a distance (the first- and last-mile problem), increases in shared micromobility systems and AV ridehailing availability may increase the opportunities for more of these short trips to be taken using a transportation mode other than a single-occupancy vehicle.

Source: Fred Joe for Urbanism Next.

POTENTIAL FOR INCREASED TRANSIT

A combination of reallocated street space coupled with land use densification (if off-street parking lots are repurposed for housing) could increase opportunities for transit-supportive development patterns. This may lead to an expansion of transit service and frequency.

Transit vehicles are also likely to move toward automated operation, which significantly reduces costs of operation and therefore increases opportunities for increased transit frequency and extended hours of operations, both of which may lead to increased transit use.

COMPETITION FOR SIDEWALK SPACE

AVs are expected to increase the rates of passengers loading and unloading curbside, which would likely increase general activity on sidewalks. Delivery robots accessing storefronts or individual homes may further compete for space with pedestrians and sidewalk users, potentially impacting rates of walk trips.

MODE CONFLICTS

Mode interaction will become increasingly more complex as new modes (e-bikes, scooters, etc.) share the right-of-way with AVs and there is an increase in the need to access the curb with the rise of TNCs, microtransit, and goods delivery. Since AVs will, presumably, be deployed with the technology required to avoid hitting objects their utilization could potentially be disrupted by pedestrians or other road users who may choose to step out in front AVs more frequently than they do conventional vehicles today if the expectation is that it will always stop.

PARKING/VEHICLES

SHIFTING VEHICLE OWNERSHIP STRUCTURE

AVs will likely come with a high price tag, require frequent software upgrades (Anderson et al., 2014), and employ technologies that would allow fleets to operate at lower costs compared to private vehicles (Bösch, Becker, Becker, & Axhausen, 2018). As a result, we assume that large-scale AV services will most likely be rolled out as subscription-based fleets, rather than individually owned vehicles, at least initially. The long-term transition from personal- to fleet-owned vehicles would mark a radical departure from the car access patterns that have prevailed over the past 100 years, with broad implications for travel behavior and the costs of car travel. The transition would also yield infrastructure and financial ramifications as ownership and management shifts from a dispersed number of individuals to, potentially, fewer centrally-managed fleets.

PARKING DISPERSAL VS. CONCENTRATION

In addition to changing the amount of parking demanded, AVs may also affect the geography of that demand. Currently, parking is sited close to destinations and dispersed throughout cities and regions. It remains to be seen if AV parking will likewise be dispersed throughout regions to be closer to the markets they serve, or concentrated in fewer locations to capitalize on economies of scale and better service fleet-based needs (such as large-scale charging and maintenance) and/or to take maximum advantage of differences in land values across a region. In other words, will AV fleets park in concentrated parking structures near central cities where they can be deployed quickly to market, or will they gravitate toward cheaper land farther from city centers? The latter would follow the pattern seen in e-commerce distribution centers, many of which have located on cheaper land at the fringes of regions, rather than expensive land located in the densest and/or highest-income parts of regions, which are also the locations of greatest demand.

AVs will undoubtedly shift the amount and locations of vehicle parking; but the rise of new mobility also introduces new types of parking needs. Specifically, planners and policy makers are already considering how to manage parking for fleets of e-scooters and dockless bikes that blanket many cities; for example, Santa Monica has experimented with on-street e-scooter parking corrals (Linton, 2018), a need that could scarcely have been imagined just a couple of years ago.

INTEGRATIVE IMPACTS

This section explores the relationships between the secondary impacts of transportation, noted above, to land use, urban design, and real estate, and the potential integrative impacts.

LAND USE

Zoning could evolve to meet changing parking needs and land use demands. Repurposed parking garages and lots may transform land uses and open up additional land for housing, commercial districts, or parks and open space. Already, some developers are constructing adaptable parking garages, anticipating that reduced parking demand in the future will necessitate garage repurposing to alternate uses, such as retail, residential, and public space (GGLO Design, 2018; Marshall, 2016). The changing geography of parking, vehicle storage, and fleet-based maintenance will likely be strong factors shaping future land uses.

Walking, biking, and transit all benefit from and contribute to denser, more mixed-uses of land where trip origins and destinations are closer together. Cities that have made it a priority to make it easier, more comfortable, more reliable, and more convenient to use more space-efficient modes of transport see higher utilization of those modes, which in turn leads to a need for more space provided for those modes. As it becomes more convenient to use these space-efficient transportation modes, less land may be needed to move and store vehicles, allowing for other uses (e.g., mixed-use development, public parks), which in turn contribute to and benefit from these transportation modes.

URBAN DESIGN

By increasing the ease of travel while lowering the cost, AVs could increase sprawl and the metropolitan footprint; they may also reduce demand for activities in mid-range suburbs, with activities instead concentrated in the center cities and on the periphery of metropolitan areas. Another possibility is concentrated dense urban nodes connected by sprawling development.

AVs could also influence right-of-way space allocation. For example, smaller vehicles that could operate closer to one another may either reduce the width or number of lanes needed for safe operation. Changing parking needs—or perhaps the end of the need for a curb to separate vehicles from pedestrians—could also reshape the relationship between buildings and public rights-of-way.

REAL ESTATE

E-commerce is already reshaping not only goods delivery, but also the types of brick-and-mortar stores in our cities; as online shopping continues to boom—growing by $40 billion each year between 2014 and 2017 (Corkery, 2017)—big box stores are shuttering in many places, replaced with smaller experiential stores. AVs could accelerate this trend if they reduce the costs of good delivery by eliminating drivers, or if they enable some stores to uproot and take to the streets as mobile operations.

Upzoning, which can increase property values, may also occur where, and if, parking requirements are reduced. Previous research finds that housing development has increased when parking minimums are relaxed or removed (Guo & Ren, 2013; Manville, 2013) . New development or uses of parcels previously used to service individual car ownership—such as gas stations, car sales lots, and maintenance shops—may likewise transform real estate markets and land values. Specifically, the combination of a large increase in land available for housing, office space, or retail plus an increase in the intensity of such uses allowed on individual parcels could combine to depress land values in the short term. This might have positive effects on markets that are currently artificially constrained by zoning or onerous approval processes, such as housing markets in many regions.

AVs—and their accompanying effects on parking—may dramatically change land values, increasing them in some places and lowering them in others. Freeing up land from parking could flood the market with vacant land. Land use regulations could be used to ensure that supply matches demand for various land use types, hence mitigating the negative impacts on property values by better matching demand to the available land supply.


Freeing up land from parking could flood the market with vacant land available for housing, office space, or retail. Source: Randy Fath for Unsplash.

IMPLICATIONS OF SECONDARY IMPACTS ON TRANSPORTATION

This section explores the potential implications of the secondary impacts of transportation on equity, health, the economy, the environment, and governance.

EQUITY

On one hand, changes to parking and vehicles could deliver a more equitable transportation future; on the other, it may exacerbate current inequities. What is changing in the era of AVs, ridehailing, and scooter and bikeshare systems, is that more people have a range of options to match their trip purpose with a transportation mode that is appropriate, moving beyond an era where car ownership or car access is required for nearly every trip taken. Given the opportunities to "right-size" streets, price parking, curb access, and street access in new ways, as well as the opportunity to significantly adjust parking requirements, there are opportunities to address significant issues of equity in the coming era.

UNEQUAL CAR ACCESS

Currently, car ownership divides households into mobility "haves" and "have-nots," with the majority of households not owning a car due to a constraint rather than choice (A. E. Brown, 2017). Zero-car households make fewer trips, travel fewer miles, and are excluded from the positive benefits conferred by car ownership such as higher wages, finding work, and access to healthy foods (Gurley & Bruce, 2005; Raphael & Rice, 2002; Walker, Keane, & Burke, 2010). Financial constraints—including purchasing, maintaining, and insuring a car—represent a primary barrier to car ownership (Waller, 2005) with average costs in the U.S. hovering around $8,800 per year in 2017 (AAA, 2017).

Shifting car access from the current ownership model to one where people pay for auto-mobility per trip may expand household access to cars. For example, in Los Angeles, travelers living in neighborhoods with low-levels of personal auto access hailed Lyft trips more frequently, suggesting that ride-hail services may fill a latent demand for car access (A. Brown, 2018). At the same time, however, many researchers find that ridehail users are disproportionately higher-income, younger, and well-educated (Clewlow & Mishra, 2017; Conway, Salon, & King, 2018). TNCs, or AVs, therefore run the risk of pricing out lower-income travelers. Additionally, technological barriers, including smartphone access and banking access, are both necessary to hail new services; without such access, shared services could widen the existing mobility divide rather than shrinking it (A. E. Brown & Taylor, 2018). Ensuring that travelers with special transportation needs—such as wheelchair accessible vehicles—will also be imperative to ensure that they continue to have robust travel options.

Source: Laura Dewilde for Unsplash.

EFFECTS ON TRANSIT

How the relationship between for-hire vehicles and transit unfolds will likewise prove critical for equity. TNCs, AVs, and other such services may improve transit access, boosting mobility for transit-dependent populations; or they could undermine services by diminishing ridership, siphoning off higher-income riders, or miring transit vehicles in increased congestion.

SHIFTING HOUSING AFFORDABILITY

Shifts in vehicle and parking use and geography could also alter the urban footprint, land use, and real estate; such alterations would likely affect housing costs and shift the landscape of housing affordability. One risk is the continued suburbanization of poverty (Kneebone & Garr, 2010), which could exacerbate the combined housing and transportation financial burden that low-income households bear and limit transportation options to those living in far-flung suburbs. Alternatively, changes in parking geographies could lower housing costs in job-rich areas and may enable lower-income individuals to better afford areas with the most multimodal travel options.

HEALTH

MODE SHIFT

Active transportation may become more or less attractive depending on the future safety and comfort engendered by AVs. More specifically, the safety, cost, and potential effects of AVs on the built environment may either help boost bicycling and walking, or could undermine them. The fuel mix of a future AV fleet would also yield divergent emissions levels and therefore health scenarios. Health-related environmental justice issues could arise depending on which populations or communities bear the costs of fleet-related maintenance or operations, or potentially increased levels of driving.

ECONOMY

LABOR IMPACTS

Shifting from individual to fleet-based vehicle services, as well as automation, could precipitate a loss of jobs in and around the auto industry, such as car sales, mechanics, drivers, parking attendants, and valets. However, steadier use of individual vehicles may actually increase demand for maintenance and shorten vehicle lifespans, which could in turn preserve existing jobs or create new ones.

ENVIRONMENT

REDUCTIONS IN PARKING LOTS

If demand for parking lots drops with the rise of AVs and new mobility options, underutilized surface parking lots could be repurposed into other uses. Surface parking lots contribute to water pollution due to contaminants, which are picked up by stormwater runoff, and their asphalt surfaces retain heat which contributes to the urban heat island effect. Parking lots have many potential reuse options, including parks and open spaces.

ENVIRONMENTAL JUSTICE

Environmental justice issues could emerge if fleet storage and maintenance activities concentrate in low-income neighborhoods or communities of color, disproportionately burdening these populations with vehicle traffic, emissions, and noise.

EMISSIONS

The extent to which AVs are electrified and how they are used will affect emissions. The movement toward AVs will likely be electric whether privately- or fleet-operated. Additionally, an increase in trips made by non-polluting micromobility devices could hold significant opportunity to reduce CO2 emissions, as well as improve air, land, and water health. However, changes in parking facilities' size and location may also create urban heat island effects, which are associated with impaired health, increased pollutants, and worsened water quality in their immediate surroundings (Environmental Protection Agency, 2018).

GOVERNANCE

MUNICIPAL REVENUE

Both a shift to a fleet-based model of car ownership and the widespread electrification of that fleet would upset current revenue streams and finance structures. Individual ownership currently requires a variety of taxes and fees imposed at various points including sale, annual inspection, and licensing. How or if such fees would be translated into a fleet context remains to be seen. Insurance, too, remains an open question both in terms of who bears liability in the age of AVs (cities, code-writers, fleet operators, or passengers) and in terms of revenue collection. Changes in parking revenue, fees, taxes, insurance, as well as reduced gas taxes that would accompany widespread electrification could dramatically curtail revenues used to build and maintain transportation infrastructure and will likely necessitate a broad rethinking of transportation finance.

CHANGE IN POLITICAL WILL

The changing use of the street due to AVs, ridehailing, and the recent availability of micromobility provide a unique political moment for more communities to more quickly reimagine their land use-transportation mix. For example, if the need for vehicle parking decreases and it becomes less politically contentious, government officials may find it easier to dedicate that land to other modes.

AREAS OF NEEDED RESEARCH

PARKING (TRANSPORTATION)

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
What are current parking utilization rates? What (types of) locations could be use for AV storage?	Basic Research	Data analysis	Parking requirements
How much on-street and off-street parking will be required with new mobility?	Modeling	Parking demand modeling	Zoning code

VEHICLES

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
What are scenarios for single vehicles to act as both goods and people delivery?	Modeling	Transportation models	Regulations and licensing
How can goods and people delivery vehicles minimize impacts to congestion, VMT, and sustainability?	Modeling	Transportation models	Regulations and licensing

WALK/BIKE/TRANSIT

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
How will increased curbside access needs impact safety, user experience, and network efficiency of cycling, pedestrian, and transit trips?	Basic Research	Data analysis of crash/accident data	Infrastructure policy and capital improvement programming

GENERAL TRANSPORTATION

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
What are policy options for prioritizing shared rides?	Policy analysis	Experimenta-tion, before/after surveys	Taxes and fees
What are behavioral levers for increasing shared ride use?	Basic research	Surveys, experimentation	Taxes and fees
How will real-time knowledge of marginal cost of transportation change travel behavior and location preferences? How might this change with MaaS subscription services?			N/A
What's the association between walking, biking, scooters, and people throughput?	Basic research		Right-of-way and street design guidelines
What changes in street utilization (curbside use – pickup/dropoff, delivery) are being brought about by new mobility and rising e-commerce?	Basic research	Intercept surveys/ observation	Curbside regulations
What capacity pressures are streets likely to face with new mobility and rising e-commerce?	Basic research	Quantitative analysis of traffic flow	Congestion policy

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
How do different modes of travel impact the potential for overall network efficiency?	Modeling	Transportation models	N/A
How can cities prioritize modes to achieve city goals of increased network efficiency, accessibility, safety, and sustainability?	Best practice	Case studies, interviews, content analysis	Pricing, roadway use policy
What are the regulatory mechanisms that could help establish mode prioritization?	Policy analysis	Content/policy analysis	Pricing, roadway use policy
What regulatory mechanisms could be most effective in helping influence individual behavior and market viability of prioritized modes?	Basic research	Regression analysis	Taxes and fees; licensing

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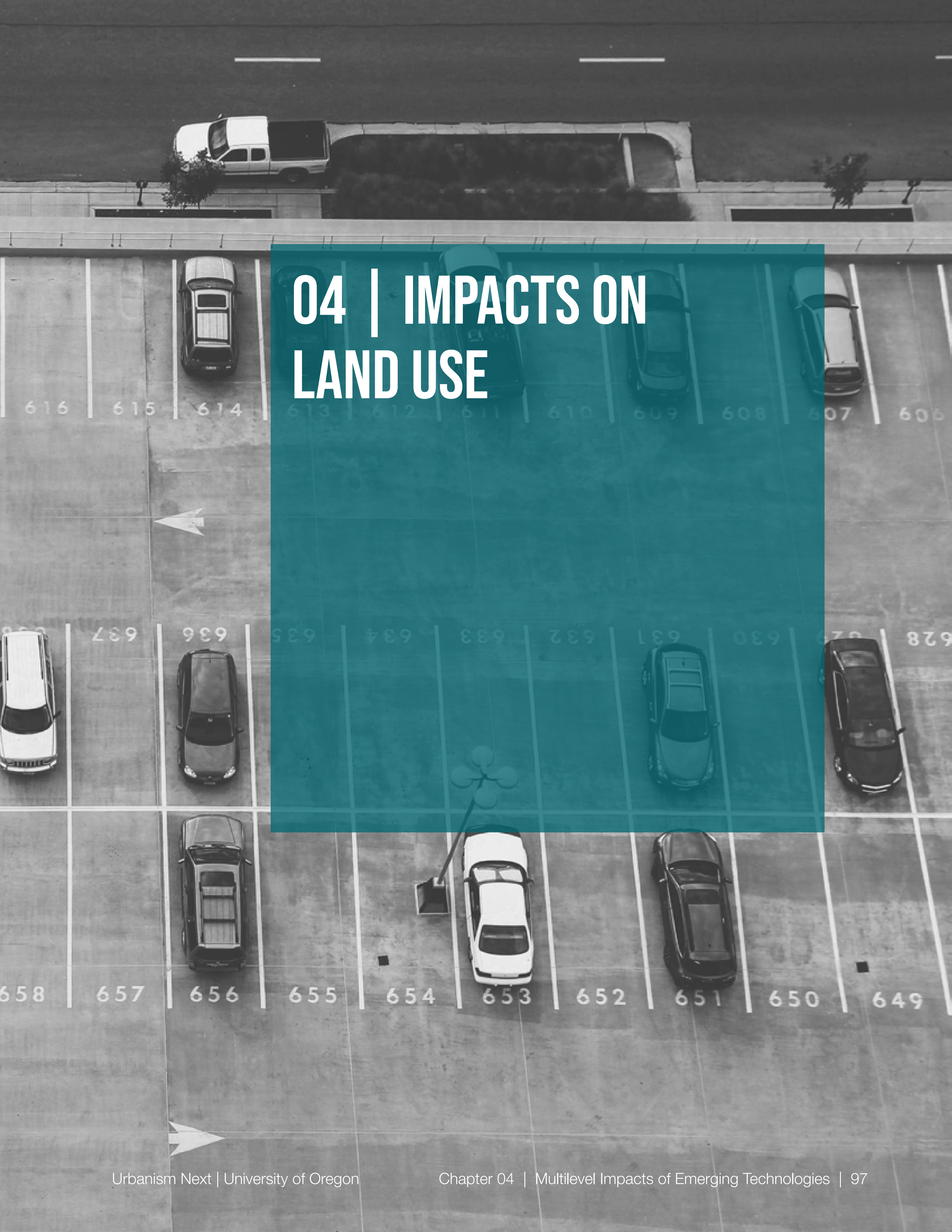


04 | IMPACTS ON LAND USE

INTRODUCTION

Land use patterns in cities are a product of evolution in planning and zoning patterns in reaction to economic and social forces guiding the orientation of land uses. Our past and current reliance on single occupancy automobiles for transportation has a strong impact on land use patterns and the amount of land we use for parking and servicing automobiles. In Los Angeles and the Midwest, there are an estimated three parking spots for each vehicle (Victoria Transport Policy Institute, 2018). In the Midwest, approximately 5 percent of the all urban land area is parking (Davis, Pijanowski, Robinson, & Kidwell, 2010). Our development patterns are dominated by reliance on automobiles. Autonomous vehicles (AVs) could reshape our land use patterns by shifting where we store vehicles (parking lots and curb space), how we provide energy to vehicles, and how much land we use for automobile-oriented functions.

Additionally, shifts in retail, e-commerce, and delivery are changing needs for industrial and commercial land. Historically, we have sought to separate industrial land from residential land for health and public safety. The increasing need for warehouse space for e-commerce signifies shifts in where industrial land for warehousing should be located. E-commerce warehousing includes large fulfilment facilities located adjacent to Interstates, often in the outer areas of regions, and smaller distribution facilities located closer to residents. Further, the demand for big-box retail is changing while the desire for experiential retail is increasing, leading to shifts in the types and sizes of commercial land needed.

When it comes to land use impacts it is important to note that the changes described in this chapter will occur at varying rates in different parts of the country, and in different parts of individual metropolitan regions. Recent examples of emerging technologies such as electric vehicles (EVs) and transportation network companies (TNCs), services such as Lyft and Uber, demonstrate that these technologies are deployed in cosmopolitan tech hubs such as the Bay Area, Los Angeles, and New York first. Within these metropolitan areas the technology debuts initially in denser, more urban environments, and in affluent communities. These services then spread throughout the metropolitan region. In the case of AVs, current pilots and demonstrations are taking place in suburban areas because of the wide low traffic street network.

There are two major forces affecting land use: 1) increasing the supply of land from the reduction of parking and automobile uses; and 2) shifts in the types and locations of industrial and commercial land needed.

CHAPTER ORGANIZATION

FIRST ORDER IMPACTS

- CHANGE IN PARKING DEMAND
- CHANGE IN GOODS AND MEAL DELIVERYE
- REDUCTION IN BRICK-AND-MORTAR STORES
- INCREASING INTEREST IN EXPERIENTIAL RETAIL

SECOND ORDER IMPACTS

- EMPLOYMENT USES
- RESIDENTIAL USES
- PARKS AND OPEN SPACES

INTEGRATIVE IMPACTS

- TRANSPORTATION
- URBAN DESIGN
- REAL ESTATE

IMPLICATIONS OF SECONDARY IMPACTS ON LAND USE

- EQUITY
- HEALTH
- ECONOMY
- ENVIRONMENT
- GOVERNANCE

AREAS OF NEEDED RESEARCH

FIRST ORDER IMPACTS AFFECTING LAND USE

The growth in new mobility and e-commerce/goods delivery will have key implications for land use. The primary first order impacts that will affect land use are change in parking demand, change in goods delivery and demand for warehousing space, reduction in brick-and-mortar stores, and increasing interest in experiential retail.

CHANGE IN PARKING DEMAND

The change in parking demand due to TNCs and eventually AVs will drastically impact zoning and development regulations. Preliminary studies suggest that AV parking may reduce the need for parking space by an average of 62% and a maximum of 87% (Nourinejad, Bahrami, & Roorda, 2018). In addition to the total amount of land, AVs may also affect the location of parking. Rather than situating parking near destinations of interest, a shift to pick up and drop offs could reduce the need for parking in some locations and lead to a concentration of parking for fleet-based vehicles in hubs located across the region. These considerations will affect how we zone for land use types and incorporate parking requirements into development regulations.

CHANGE IN GOODS AND MEAL DELIVERY

Goods delivery is likely to increase with the ease of same-day delivery. The concurrent rise in e-commerce and deployment of AVs could lead to shifts in the demand for warehousing and distribution centers to handle last mile delivery. Additionally, brick-and-mortar stores may shift their businesses to a delivery model. The shifts in demand for goods that are delivered rather than picked up at stores may lead to a shift in the amount and orientation of land used for certain purposes, particularly warehousing. Smaller distribution centers, that provide the goods for the last leg of the trip, may need to be located closer to population and employment centers. Those shifts could also change the demand for industrial land overall. Shifts in goods delivery could also lead to a decline in parking needed for brick-and-mortar stores.

Source: City of Alexandria https://www.alexandriava.gov/LandmarkVanDorn

REDUCTION IN BRICK-AND-MORTAR STORES

The expansion of e-commerce has coincided with closures in brick-and-mortar stores. In 2017, retailers closed 102 million square feet of store space, followed by 115 million square feet in 2018 (Peterson, 2019). The trend is continuing, with more than 8,000 stores expected to close in 2019 (Peterson, 2019). Store closures create vacancies and redevelopment opportunities. Cities may need to consider how they zone for retail space.

INCREASING INTEREST IN EXPERIENTIAL RETAIL

While traditional brick-and-mortar stores are declining, consumers have expressed interest and willingness to pay for experiential retail. As described in Chapter 2, experience-driven retail appeals to consumers who strongly favor in-store shopping experiences. They prefer a unique experience that differentiates their spending and they are willing to pay 31.6% more (on average) for that experience (Synchrony Finance, 2016). The size and orientation of these stores differs from traditional commercial retail.

SECOND ORDER IMPACTS ON LAND USE

This section hypothesizes about how the first order impacts may impact land use, considering employment, housing, and parks and open space. The purpose of this section is to consider how the first order impacts described above will impact land use. The secondary impacts are largely speculative in nature and are meant to summarize projected impacts along various dimensions.

EMPLOYMENT USES

DISTRIBUTION OF WAREHOUSING

As e-commerce grows, the need for warehouses to support it will rise. In addition to large fulfillment centers on the outskirts of urban areas, new warehouses and distribution centers may be located closer to population and employment centers to facilitate quick and easy last mile delivery. To encourage new patterns of industrial land use, land development regulations around siting, parking, and transportation access to warehouse and distribution centers may change to be oriented for automated delivery. In some cases, there may be a second life for smaller industrial properties that no longer serve modern manufacturing or warehousing needs.

DEMAND FOR RETAIL LAND V. EXPERIENTIAL RETAIL

Big box stores and brick-and-mortar retail have been declining as e-commerce has risen (Peterson, 2019; Timmermann, 2018). The amount of land for big box stores and traditional retail may decline with shifts to e-commerce. Additionally, the rise in e-commerce might correspond with a decline in the need for land zoned for big box retail. For brick-and-mortar retail that remains, the demand for experiential retail has been rising. This could lead to an increase in demand for land zoned for small, experiential retail near urban centers. Within retail space, the development regulations around parking may shift for retail, diminishing the need for minimum parking requirements.

Abandoned Walmart in McAllen, TX gets converted into Public Library. Image source: Alucobond

REDEVELOPMENT OF MALLS / BIG BOX RETAIL

Over the past several years, malls and big box retail have been marked by store closures leading to vacancies (Peterson, 2019; Timmermann, 2018). Accompanying this trend, large areas of parking may become available for redevelopment around suburban uses. However, land use regulations will need to be adjusted to allow for redevelopment of these uses, particularly for the purposes of warehousing or distribution centers. Redevelopment of traditional enclosed malls into open air destination shopping districts can be accompanied by redevelopment of the parking lots into residential uses. This will require changes to mixed use zoning, and the development of visionary specific plans.

DECREASED NEED FOR GAS STATIONS AND AUTO-ORIENTED LAND USES

Autonomous vehicles are likely to be electrified. A shift in the type of fuel will reorient the land uses related to gasoline. Rather than gas stations, AVs will rely on charging stations. Like parking, it is likely that charging and storage infrastructure will be combined into hubs located across the region. The shift from gasoline as a fuel source may lead to vacancies in gas stations. This could result in the creation of potential brownfield areas in need of redevelopment. Cities will need funding to clean up vacant brownfields and potential areas for redevelopment.

Development codes for parking with residential may change, allowing higher density for residential development. Image source: Sergio Souza.

LAND FOR FLEET STORAGE

As the demand for parking declines with the adoption of autonomous vehicles, the location of vehicle storage may shift. Parking may shift to concentrated hubs with electric charging and vehicle storage.

Fleet storage may be located across the metropolitan area, possibly on cheaper land at the edge. The design and location of vehicle storage will depend on the mix of privately-owned AVs, and AVs owned by ridehailing companies such as Lyft and Uber.

RESIDENTIAL USES

AVAILABILITY OF PARKING LAND FOR REDEVELOPMENT

The decreased demand for parking may free up space for redevelopment in urban areas. This may create new space for residential development on land occupied by parking. Further, this may allow density to increase because of the reduction of cost due to no longer providing structured parking. This could encourage infill housing and improve financial viability of affordable and market rate housing. Development codes for residential parking with residential may change, allowing higher density for residential development.

PARKS AND OPEN SPACE

AVAILABILITY OF PARKING LAND FOR REDEVELOPMENT

Like residential development, a decreased demand for parking could free up curbside parking for redevelopment in urban areas. This could create new space for wider sidewalks or linear parks on land occupied by parking.

A decreased demand for parking could free up space for redevelopment and creation of new spaces. Image source: Robert Bye for Unsplash.

INTEGRATIVE IMPACTS

This section explores the relationships between the secondary impacts of land use, noted above, to transportation, urban design, and real estate, and the potential integrative impacts.

TRANSPORTATION

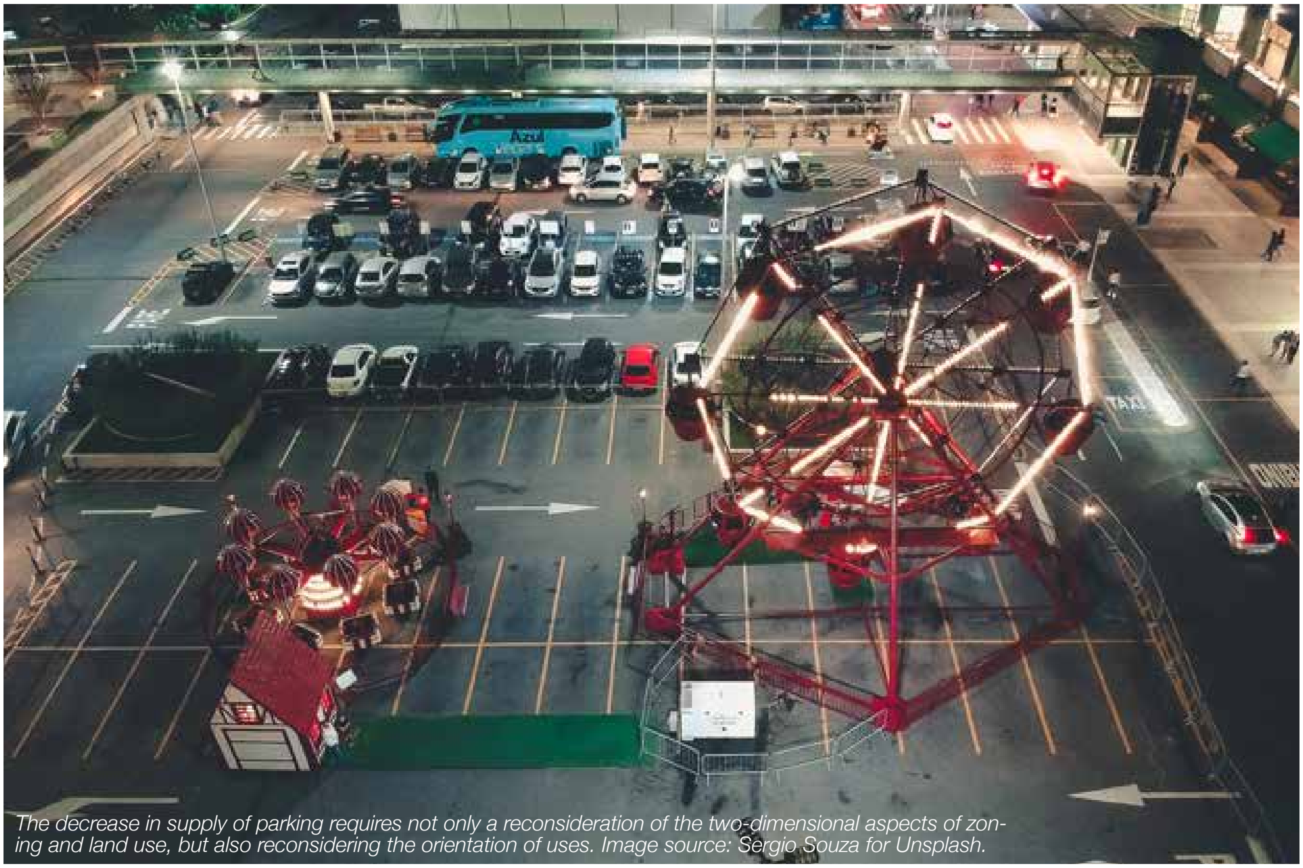
The allocation of land uses by zone and land development regulations have important implications for transportation. The location of warehousing, EV charging, and AV parking have implications for VMT/VKT. As AVs are adopted, space is freed up in the ROW and off street from parking so that land can be appropriated for other uses. The location of pick up and drop off zones within the public right-of-way or on private land will affect transportation patterns.

URBAN DESIGN

Urban design is currently centered around parking. When a developer begins to develop financial models that will drive the design of the project, the first consideration is how much parking is required for the desired land use. The decrease in supply of parking requires not only a reconsideration of the two-dimensional aspects of zoning and land use, but also reconsidering the orientation of uses. Embedding new uses like warehouses into land use patterns will require new thinking about the relationship between residential, commercial, and industrial land.

REAL ESTATE

Depending on the rate of adoption of AVs, freeing up land from parking could flood the market with vacant land and change land supply and land value. Though the shift in the amount of parking need is likely to occur over time rather than all at once, the increase in land availability by specific land use types may affect land values. Further, the increase in demand for certain types of land, like warehousing, may cause an increase in prices of that land because of scarcity in the amount of land zoned for warehousing. Conversely, the decline of brick-and-mortar stores and big box retail could lead to an oversupply and devaluation of commercial land. Land use regulations can be used to ensure that supply matches demand for various land use types. For example, cities may need to rezone land that was parking to industrial for warehousing and distribution centers.



The decrease in supply of parking requires not only a reconsideration of the two-dimensional aspects of zoning and land use, but also reconsidering the orientation of uses. Image source: Sergio Souza for Unsplash.

IMPLICATIONS OF SECONDARY IMPACTS ON LAND USE

This section explores what the implications of the secondary impacts on land use could be for equity, health, the economy, the environment, and governance.

EQUITY

CHANGE IN PARKING DEMAND

Key questions of equity arise in determining who benefits and loses from the new land that opens up from parking. Using this land for affordable housing could benefit lower income populations. But allowing the market to decide the highest and best use could signal negative consequences for this population.

REDUCED VIABILITY OF TRANSIT

The current transportation system in the United States reflects disparities in transit access. Shifting demand for land and shifting transportation modes could lead to displacement and exacerbate the lack of accessibility. If transit is no longer available, the accessibility of neighborhoods that are well-served by transit could shift, which would affect accessibility to jobs and services.

LOCATION OF INFRASTRUCTURE

The location of fleet storage and electric charging infrastructure may pose access challenges or environmental justice issues for lower income populations. Low-income neighborhoods may not receive an adequate share of charging infrastructure to have access to EVs and AVs. Further, fleet parking areas may choose to locate close to low-income neighborhoods which could negatively impact these neighborhoods.

HEALTH

SHIFT IN FUEL TYPE

The orientation of land uses has important implications for public health. Air pollution could decrease as the fuel source for vehicles shifts to electricity. As the need for parking declines and uses shift to parks and greenways, public health may improve as access to parks and open space increases. However, AV parking/charging hubs and warehousing may pose negative impacts on health.

ECONOMY

LARGE SHIFTS IN LAND VALUES

The economic impacts on land use hinge on the new uses of land. The tax base may grow or shrink depending on redevelopment of land, and new uses of land will also affect the types of employment that occur on that land. Freeing up swaths of land could shift property values. The forces that drive property values may shift as transportation access changes.

ENVIRONMENT

SHIFT IN FUEL TYPE

The adoption of AVs brings several land use-related environmental benefits and challenges. Shifting from gasoline to an electric fleet can reduce CO2 emissions and create cleaner land uses by moving from EV charging to gas stations. While land may be freed up for redevelopment, the shift from gasoline stations will require brownfield redevelopment. The location of warehousing and industrial land could raise environmental justice concerns.

GOVERNANCE

SHIFT IN REGULATIONS AND MODELS

The land use effects of AVs pose challenges for governance. We base our comprehensive plans and zoning regulations on historic trends. Our land use models are not yet set up to consider the shifts in demand for various types of uses (like the increase in industrial) and a decline in the amount of land needed for parking and public right-of-way. Land use models will need to be revised to examine and plan for these trends.

BURDEN ON MUNICIPAL BUDGETS

The effects of shifts in land use carry implications for revenue generation as well. Many cities are heavily dependent on property taxes and sales taxes. The closure of big box stores and malls has strained municipal budgets because of the loss of sales tax revenue. On the other hand, shifting from vacant lots for parking to more intensive uses could increase property tax generation.

AREAS OF NEEDED RESEARCH

While preliminary data points to trends in the decline in need for parking, local governments need more information to monitor trends and adjust regulatory frameworks to respond to these anticipated trends. One of the largest issues facing local governments is the uncertainty of timing of some of the anticipated impacts. The research questions below reflect the key issues and questions related to land use.

GENERAL LAND USE

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
What land uses will decrease or disappear? What new land uses will be needed?	Basic research	Parcel data analysis	Zoning code
What land uses have reuse potential? Which need to be redeveloped? (e.g., parking)	Basic research & Prototypes	Parcel data analysis; Prototypes of re-use of land and parking structures	Economic development policy
What are the characteristics and supply of existing land? (e.g., parking spaces)	Basic research	Parcel data analysis	N/A
What can we learn from areas that have seen a large share of land become available for development over a short period of time?	Basic research	Case study analysis	N/A
What are the changes in land use in centers and corridors based on new mobility and ecommerce?	Basic research	Parcel data analysis	Zoning code; growth management policy
How much land is currently used for parking? What is the current utilization rate of parking? How will this change with new mobility?	Basic research	Intercept surveys; parcel data analysis	Parking minimums

EMPLOYMENT USES

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
What are the changes in land use that occur because of e-commerce?	Basic Research	Parcel data analysis; interviews	Zoning code
Where will new warehouses be located? New offices? New retail spaces?	Basic Research	Parcel data analysis; interviews	Zoning code

HOUSING

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
How does demand for sprawl shift based on new mobility?	Basic Research	Surveys	Buildable lands inventory and zoning code
How does demand for densification/centralization shift based on new mobility?	Basic Research	Surveys	Buildable lands inventory and zoning code

PARKS AND OPEN SPACE

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
How can parking areas become parks?	Case studies	Case study analysis	Zoning code

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05 | IMPACTS ON URBAN DESIGN

INTRODUCTION

AVs and new mobility could have a wide range of impacts on urban design, including an expansion of the metropolitan footprint, changes to street design, a shift in urban center and corridor development, changes in density, and a shift in where urban activity and vitality occur.

The continued expansion of metropolitan footprints has been an ongoing concern for city planners and urban designers as low-density, sprawled developments are a strain on municipal budgets, impact habitat, reduce water quality, and reduce social cohesion (Ewing & Hamidi, 2015). Despite these concerns, sprawl has remained the dominant form of development for more than six decades, largely limited only by the need a relative amount of proximity to employment, shopping, and entertainment centers. AVs and e-commerce seem poised to substantially change the existing need for proximity. On the one hand, this could potentially exacerbate sprawl, allowing a large expansion of metropolitan footprints in cities throughout the country. On the other hand, this could also contribute to the further densification of certain areas, which would impact urban form and city centers.

The growth of new mobility services and e-commerce is already impacting street design as there are increasing demands being placed on limited space. The curb in particular has assumed a new level of importance given all the competing demands for the space: parking for vehicles and/or micromobility devices, passenger and/or goods loading and unloading, transit-only travel lanes, and many other potential uses. The introduction of AVs will likely exacerbate many of these existing issues since it is anticipated that they will primarily be used for pick up and drop off and will spend far less time parked than vehicles do currently. Although AVs will likely be programmed in order to work on existing streets, some street design changes may be necessary in order to accommodate the increased need for loading/unloading and the decreased need for parking.

CHAPTER ORGANIZATION

- **FIRST ORDER IMPACTS**
  - CHANGE IN PARKING DEMAND
    - SHIFTING NATURE OF FREIGHT
    - REDUCTION OF CERTAIN TYPES OF BRICK-AND-MORTAR STORES
    - INCREASING INTEREST IN EXPERIENTIAL RETAIL
  - CHANGE IN CONGESTION
  - CHANGE IN EASE OF TRAVEL
  - SHIFT IN MODES
  - COMPETITION FOR THE ROW
- **SECOND ORDER IMPACTS**
  - METROPOLITAN FOOTPRINT
  - STREET DESIGN
  - CENTERS AND CORRIDORS
  - DENSIFICATION
  - PLACE AND IDENTITY
- **INTEGRATIVE IMPACTS**
  - TRANSPORTATION
  - LAND USE
  - REAL ESTATE
- **IMPLICATIONS OF SECONDARY IMPACTS ON URBAN DESIGN**
  - EQUITY
  - HEALTH
  - ECONOMY
  - ENVIRONMENT
  - GOVERNANCE
- **AREAS OF NEEDED RESEARCH**

FIRST ORDER IMPACTS AFFECTING URBAN DESIGN

The growth in new mobility and e-commerce/goods delivery will have key implications for urban design. The primary first order impacts that will affect urban design are change in parking demand, change in congestion, change in ease of travel, shift in modes, competition for the right-of-way, shifting nature of freight, changes in demand for warehousing space, reduction of certain types of brick-and-mortar stores, and increasing interest in experiential retail.

CHANGE IN PARKING DEMAND

The demand for parking is predicted to drop as much as 90% as TNCs and AVs reduce the need to store cars at destinations (Zhang, Guhathakurta, Fang, & Zhang, 2015). Parking has become a primary determinant of urban development, so a change in parking demand will have dramatic effects on urban design. If AVs and new mobility models lead to a reduced need for on-street parking, streets could see an increase in available right-of-way. The reduction in parking needs could also create opportunities to increase the density of urban and suburban areas as former parking lots and structures could be repurposed with usable programed space. This could also improve the vitality of areas as increased density leads to increased activity and a reduction of parking lots erases gaps in the urban fabric that often diminish the vibrancy of an area. Conversely, if everyone is dropped off directly in front of their destination, the number of people walking to and from parked cars would be reduced, eliminating some of the activity seen on streets and placing additional burden on the curb.

CHANGE IN CONGESTION

TNCs are already contributing to increased congestion in urban areas (Schaller, 2018) and AVs are predicted to exacerbate the problem. The increase in congestion could put pressure on street design to facilitate increased travel speeds. In mitigating for this congestion, streets will continue to be a battleground of competing strategies, especially as on-street parking needs are potentially reduced, freeing up usable space in the right-of-way (ROW). Based on present conditions, some will likely advocate for using the newly available ROW to increase vehicle travel lanes while others will argue for more dedicated ROW for transit, pedestrians, and cyclists. High degrees of congestion in urban areas may improve the comparative advantage of non-auto modes as a way to more efficiently use the ROW.

CHANGE IN EASE OF TRAVEL

AVs are projected to increase travel speeds to and from the periphery, raise the acceptability of increased commute times as drivers become riders who can make better use of their travel time, and reduce the need of labor's proximity to employment. All of this may result in AVs allowing travelers to more easily reach further into the periphery and could have a dramatic impact on the extent of sprawl and the expanse of the metropolitan footprint.

SHIFT IN MODES

An increase in AV auto use coupled with a reduction in transit, walking, and cycling trips could have substantial impacts on urban design as it might increase the demand for additional vehicle travel space. Additionally, a reduction in transit use could reduce the vibrancy and viability of transit-oriented development. Shifting from transit, walking, and biking to AVs (ostensibly a mobile, enclosed, private space) could also reduce the vitality these more active modes add to street life.

TNCs are already contributing to increased congestion in urban areas and AVs are predicted to exacerbate the problem.
Image source: Ray Bay for Unsplash

COMPETITION FOR THE RIGHT-OF-WAY

Increased competition for the ROW impacts street design and particularly the amount of space that is allocated to each mode. It could also impact the priority given to each mode along the street and could exacerbate current areas of mode conflict. These types of concerns are already leading to calls for defining mode prioritization for streets and increasing the efficiency of ROW use, particularly in regards to curbside access (Fehr & Peers, 2018). In addressing the need to prioritize, and recognizing that not all streets are the same, the input of all street users and city stakeholders needs to be included so that modality prioritization reflects the needs of particular neighborhoods or locations.

SHIFTING NATURE OF FREIGHT

One of the criteria that keeps cities relatively compact is the burden of travel time to get to goods and services. Both suppliers and consumers prefer shorter travel times to acquire goods and services. A combination of AVs and e-commerce could reduce the importance of this preference for consumers as the delivery of goods masks consumer's perception of the burden of travel. Unless the cost of delivery is differentiated by fairly specific geographies (urban, inner suburban, outer suburban, exurban, etc.), proximity to places to shop might lessen its impact on residential preferences.

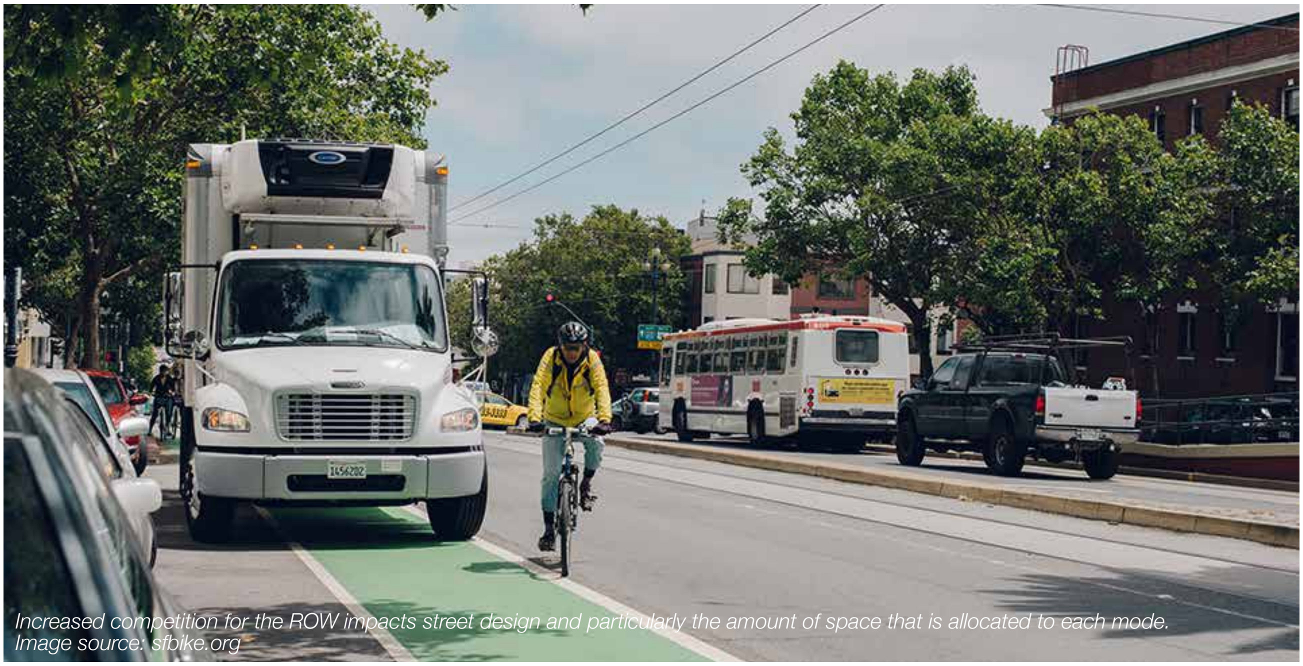
As warehouses are often uninviting spaces that reduce an area's vitality, an increase in warehouse space could reduce the vibrancy of urban areas, particularly if there is a trend towards locating warehouses near dense areas of housing and commerce to reduce distribution time. Warehousing space could also expand to auto-oriented sites such as gas stations which could be adapted to neighborhood distribution sites as they become obsolete due to the gradual replacement of the internal combustion engine fleet by electric power.

REDUCTION OF CERTAIN TYPES OF BRICK-AND-MORTAR STORES

As a larger share of retail shifts to e-commerce, the number of stores could diminish and locations that are marginal today could no longer be viable. This could impact the vitality of urban areas with less people on the street and less storefronts that help generate street-level activity.

INCREASING INTEREST IN EXPERIENTIAL RETAIL

With the current trend in retail of expanded interest in the experiential aspect of shopping (as opposed to a sole focus on the object to be purchased), the design of urban areas becomes more important. Urban design helps define the identity and vitality of an area and can become a critical draw as quality of experience becomes more central.



Increased competition for the ROW impacts street design and particularly the amount of space that is allocated to each mode. Image source: sfbike.org

SECONDARY ORDER IMPACTS ON URBAN DESIGN

This section hypothesizes about how the first order impacts may impact urban design, considering metropolitan footprint, street design, centers and corridors, densification, and place and identity. The purpose of this section is to consider how the first order impacts described above will impact urban design. The secondary impacts are largely speculative in nature and are meant to summarize projected impacts along various dimensions.

METROPOLITAN FOOTPRINT

EXPANSION OF METROPOLITAN FOOTPRINT

Based on the causes described above, residents and businesses may no longer feel the constraint of proximity as a critical aspect of their location preferences and may gravitate to less expensive, less regulated, sparser, and more open/natural properties at the furthest periphery of cities (Milakis, Kroesen, & van Wee, 2018). The increased ease of transportation could lead to residential and employment location preferences further from city centers, especially for families with children (Zhang & Guhathakurta, 2018), and for construction and manufacturing uses (Zhang & Guhathakurta, 2016).

DEPOPULATION OF MIDDLE-RING SUBURBS

As the friction of transportation is reduced, businesses and residents could migrate to areas that provide desired mixes of amenities and costs. Middle-ring suburbs might be the most impacted in this scenario as these areas generally lack the amenities of higher density central cities, but at the same time lack the periphery's availability of large areas of undeveloped land, reduced existing regulations, and access to natural areas and open space.

UNEVEN IMPACTS ON LAND USES

The expansion of the metropolitan footprint may not affect all land uses equally. Housing locations may potentially see dramatic shifts as the desire for larger, less expensive areas proximate to nature draw individuals and families further into the periphery. Another land use potentially most impacted will be large lot employment uses. Campuses and large industrial areas that have difficulty finding suitable and available large lots within current metropolitan regions could be drawn further out where larger properties are easier to acquire or amass. However, this needs to be set against the understanding that knowledge-worker based employers seem to be gravitating towards denser urban environments preferred by their workforce. Finally, land uses that are considered nuisances or hazards, such as industrial sites, landfills, and airports, may also be drawn further into the periphery to areas that have less opposition from neighbors and fewer logistical constraints.

SATELLITE SMALL TOWNS AND COMMUNITIES

Large metropolitan areas are typically surrounded by a series of smaller towns and rural communities that are reliant on the central city's economic power, but are sufficiently distant to feel little impact from urban development. If sprawl accelerates, these areas will be surrounded by new development, accelerating and expanding familiar patterns of growth seen in existing sprawl development. Currently, these types of communities are either largely subsumed by new development or become semi-urban centers in a poly-centric model of metropolitan development, acting as nodes or anchors in new residential and commercial growth. A combination of lower cost of housing and a semi-urban (re)development of their existing town centers could become draws for the growth of these poly-centric hubs.

INCREASED NEED FOR HIGH CAPACITY TRANSPORTATION CORRIDORS

If sprawl increases, there will be continued pressure to create ever larger capacity transportation corridors that can connect the inner city to the expanded periphery. If these corridors are serving low-density areas that are difficult to serve via transit, it is most probable that they will be largely auto-dominated. These corridors will not only impact the nature of the peripheral communities they travel through, but also areas of central cities they traverse as well.

STREET DESIGN

COMPETITION FOR CURBSIDE ACCESS

As TNC and AV TNC activity increases, curbside access will become a major area of conflict in high-volume, high-access streets. Street design will need to allow increased access while mitigating or avoiding potential mode conflicts such as cars blocking curbside bike paths or curbside transit lanes. This trend already exists in a growing number of streets in large cities with high TNC and e-commerce presence.

LESS PARKING COULD MEAN MORE AVAILABLE ROW SPACE

Demand for on-street parking could subside, potentially reducing the total amount of space needed for on-street parking. The re-allocation of this space will likely become an important issue for cities to contend with. Some are currently arguing that priority should be given to strategies that increase capacity. For instance, Fehr & Peers recently conducted a study with Uber which analyzed the "curb productivity index"—a measure of the number of people served by a specific length of curb, using a particular mode (parking, drop-off, transit stop) over a set time period. This study showed that parking was the most inefficient use of curbside space when considering the number of people served per linear foot of designated curb space for TNC pick-up and drop-off, transit stops, and goods delivery (Fehr & Peers, 2018, 2019).

INCREASING DEMAND FOR DEDICATED MICROMOBILITY STREET INFRASTRUCTURE

Demand for new dedicated micromobility infrastructure could grow as the use of these modes increases and safety concerns become more prominent. This is already starting to occur with the expansion of bikeshare and scooter-share and the safety concerns due to the lack of suitable infrastructure for these modes.

IMPACTS ON DRIVING LANES

If, as predicted, AVs have better vehicle control than humans, then widths of driving lanes may be reduced for AVs as less space is required to operate safely. In addition, some streets may see increased capacity per lane as AVs are more efficient in their movements and increase throughput of vehicles. This will vary by condition with the largest increases in capacity potentially seen in low-conflict roadways such as freeways and highways. All of this could lead to an overall reduction in travel lanes required. But, this may be thwarted by the projected increased trips and congestion brought about by AVs (Schaller, 2018), leading to pressures to increase the number of travel lanes.

ROW SPACE DESIGNATION BASED ON SPEED

With the increasing number of modes on streets (AV automobiles, AV transit, low-speed AV shuttles, an increase in bicycles, and scooters) and the unknown new modes that may be introduced, designation of space within the ROW may need to shift from being based on modes and motorization to being based on speed and access needs. Slower lanes might include bikes, scooters, and low-speed AV shuttles, while the faster lanes might include AV automobiles and AV transit.

POTENTIAL MODE CONFLICTS

Mode interaction will become increasingly more complex as new modes (e-bikes, scooters, etc.) share the right-of-way with AVs and there is an increase in the need to access the curb with the rise of TNCs, microtransit, and goods delivery. These conflicts could lead to innovative solutions of ROW design, or they could lead to a defensive position of attempting to further separate modes and limit any shared access.

VARIABLE IMPACTS DEPENDING ON STREET TYPE AND ACTIVITY

Street design impacts will vary depending on urban form, density, street volume, and amount of local access on street. Low-volume, low-access, suburban streets may see little to no impacts, while high-volume, high-access, urban streets in dense areas will likely see the largest impacts.

Image source: Zach Inglis for Unsplash.

CENTERS AND CORRIDORS

INCREASED GROWTH OF SELECT URBAN AND SUBURBAN CENTERS

While some centers may grow due to impacts of AVs, others may shrink or disappear due to a reduction in brick-and-mortar retail because of the rise in e-commerce and the potentially reduced role of transit.

Reduced parking needs allow for the development of existing parking lots and the redevelopment of existing garages. As parking is often a key factor limiting the amount of development possible on a lot, reduced parking needs could also essentially increase the amount of development that can happen on any single property, depending on local zoning regulations. In desirable urban centers that have significant development pressure, this could lead to increased development.

In suburban areas, which often have large expanses of parking, the impact could be even larger as strip malls and office parks find themselves with ample amounts of land available for redevelopment. This could lead to a consolidation of suburban centers, the mixing of uses, especially commercial and residential uses, and potentially the growth of bike and pedestrian travel in these areas if infill development reduces travel distances and the dominance of the automobile.

TRANSIT 'CORRIDOR' ORIENTED DEVELOPMENT

If current trends continue and transit use continues to decline, in part due to being supplanted by AV TNCs and microtransit, the idea of transit-oriented development might shift. AVs and microtransit may pick-up and drop-off passengers at their specific destinations, the way Uber and Lyft currently function, and/or they may pick up and drop off at designated locations, such as how UberPOOL and Lyft Line operate. Both of these options could atomize the location of pick-ups and drop-offs compared to transit, potentially reducing the activity of any one transit node and replacing it with a more evened out level of activity focused at or near a corridor. This could reduce the nodal model of transit-oriented development (development around a transit stop) and transform that into transit corridor-oriented development. Cities do have the power to shape how and if this shift occurs by implementing policies that incentivize or solely allow pick-ups and drop-offs along specific corridors or at nodes along those corridors.

DENSIFICATION

REDUCED OVERALL DENSITY IN METROPOLITAN AREA

If metropolitan growth is spread over an expanded developable area, average densities could diminish. At the same time, if AVs enable an expansion of the metropolitan footprint, the overall land supply could increase, potentially reducing land values. This reduction in land values could reduce the economic incentives for density. This could impact both employment and residential uses. Industrial uses that need large areas of land, are hazardous, or create nuisances could move even further away from city centers.

INCREASED DENSITY IN SPECIFIC URBAN AND SUBURBAN AREAS

Density could increase in desirable urban and suburban areas if more land is made available for development due to diminished parking needs and the reduction in need for auto-oriented services (e.g., gas stations, mechanic shops, parts stores). While this may have limited impacts on single-family neighborhoods where converting home garages to new units or uses may be less efficient, this could have a substantial impact on development types such as multifamily housing, commercial centers and events venues, as they include large expanses of parking.

If TNCs become a dominant form in transportation, they could become a new political force interested in promoting density. The TNC model is most efficient in areas with dense development as origins and destinations are closer together and, because of the proximity, areas are easier to serve with fewer vehicles. This could impact urban and suburban areas with the potential to create semi-urban nodes within current suburban development.

DYING AREAS IN CITIES

While a few desirable centers may flourish because of the increased development potential of reduced parking, others may wither due to the reduction of brick-and-mortar retail and the atomizing of transit. Some areas within cities could see a reduction in activity and development pressure if AVs change the ease of access. If AVs become a dominant means of transport and cities do not take steps to shape their deployment, areas that are underserved due to urban form complications, security concerns, or profitability reasons may see diminished growth.

Additionally, because of the increased ease of travel, particularly in commuting, areas that offer fewer amenities may see a reduction in overall development interest, investment, and activity. For instance, the inner ring suburbs may suffer most as they are too far out to offer the amenities found within the urban core, and may be characterized by unremarkable housing and urban design quality, but are too close in to offer the newness and access to open space found in outer suburbs.

If AVs become a dominant means of transport and cities do not take steps to shape their deployment, areas that are underserved due to urban form complications, security concerns, or profitability reasons may see diminished growth. Image source: Khachik Simonian for Unsplash.

PLACE AND IDENTITY

PLACE AND IDENTITY AS A DRAW

If AVs truly increase the ease of travel and increase the accessibility of most urban areas, the importance that proximity plays in guiding our decisions of where to spend time may be diminished. While we may currently visit a specific destination because it is convenient, an increase in the ease of traveling would make competing locations further away similarly easy to access, potentially reducing the importance of how close we are to them. This may increase other factors in deciding which stores or restaurants, for instance, to visit. Factors such as the quality of place, quality of experience, quality of goods, and the price of goods may take a more central role. This may cause a "quality sort" where areas that have higher quality design, a more distinct identity, and/or sense of placemaking might outperform areas that are more generic or of poor-quality design and experience, thereby creating a larger catchment area for these developments.

FACTORS IMPACTING STREET ACTIVITY AND VITALITY

If AVs become a dominant mode of travel, more vehicle entry and exits may be occurring on-street due to pick-up and drop-off activity instead of within parking lots or garages. This exchange happening within the public realm might enhance the level of activity and vitality of certain streets, particularly during commute times.

Conversely, AVs might reduce the level of street activity and vitality. The activity generated by people parking in a lot or garage and then walking down a few blocks to arrive at their destination may diminish if people are increasingly dropped off directly in front of their destination.

INTEGRATIVE IMPACTS

This section explores the relationships between the secondary impacts of urban design, noted above, to transportation, land use, and real estate, and the potential integrative impacts.

TRANSPORTATION

Changes in density and urban form will impact various aspects of transportation. Increased density would increase the trip generation rates of an area. Various factors related to urban design such as street design, density of development, metropolitan footprint, and the building street interaction will all impact mode choice and the viability of transit. The ease of pick-up and drop-off for AVs may shape how these modes are used, much like parking availability shapes automobile use today. New land uses such as AV TNC fleet parking locations and the trips and potential congestion they generate could impact the urban design of the area.

LAND USE

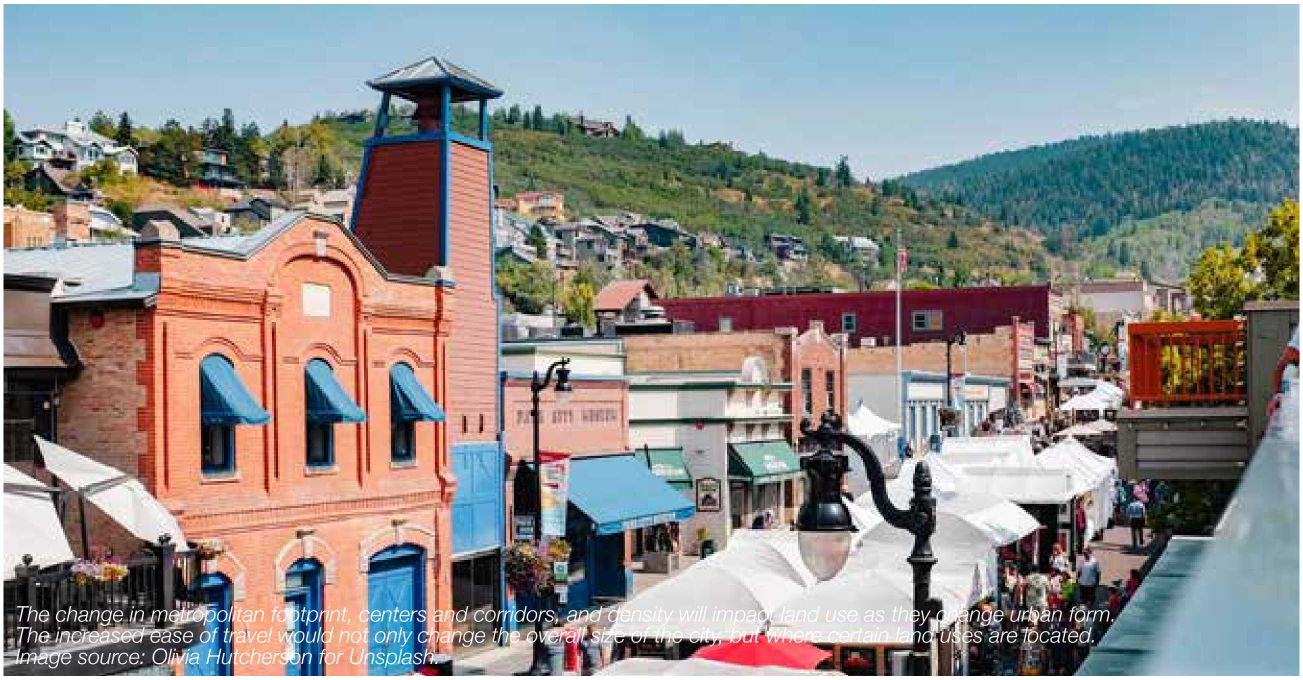
The change in metropolitan footprint, centers and corridors, and density will impact land use as they change urban form. The increased ease of travel would not only change the overall size of the city, but where certain land uses are located. Proximity between the labor force and employment might not be as important as it is today. Additionally, land uses that are noxious or require large tracts of land may now have the opportunity to move even further away from the city. At the same time, the potential for densification and increased activity along corridors and in centers may be a draw for certain land uses. This could change the location, and potentially the density, of housing, commercial and manufacturing uses throughout the city.

An equally large impact to land use could come from a reduced need for parking. This would free up large areas of land that could be redeveloped. What land uses fill these voids will have a large impact on urban design.

REAL ESTATE

Changes in density, the importance of centers and corridors, and the expanse of the metropolitan footprint could translate into changes in land values. Desirable nodes, both in urban and suburban areas, could increase in value, while a general decrease in density due to the expanded metropolitan footprint could reduce overall land values. Expanded catchment areas and the heightened role of place and identity could also impact land values.

Access to curb space and curbside management could play a similar role as parking does today, limiting or increasing property value as it limits or increases accessibility. Because of this, street design, and particularly curbside access design, might have an overall effect on property values.



The change in metropolitan footprint, centers and corridors, and density will impact land use as they change urban form. The increased ease of travel would not only change the overall size of the city, but where certain land uses are located. Image source: Olivia Hutcherson for Unsplash.

IMPLICATIONS OF SECONDARY IMPACTS ON URBAN DESIGN

This section explores what the implications of the secondary impacts on urban design could be for equity, health, the economy, the environment, and governance.

EQUITY

REDUCED VIABILITY OF TRANSIT

The expansion of the metropolitan footprint is tied to an increase in low-density development around central cities. This type of development has historically been difficult to serve with transit, both reducing accessibility options for residents and also creating pressure for accommodating single- and low-occupant vehicles in central cities. This reduction in the viability of transit can create inequities as low-income populations feel the largest impacts to accessibility.

Conversely, urban design that facilitates some type of TNC and AV use might help solve the first- and last-mile problem and could increase the viability of transit. This will depend largely on the priorities and controls municipalities put in place.

INCREASED ECONOMIC SEGREGATION

An increase in the metropolitan footprint could exacerbate geographic economic segregation. Economically impoverished communities could continue to be pushed to the least desirable— and also often the least accessible—areas. The current pattern of economic segregation seen in suburbs could be greatly increased in this scenario.

HEALTH

ACTIVE TRAVEL AND HEALTH OUTCOMES

Urban design has a large influence on an individual's level of activity. While new mobility and AVs could increase mobility for many people, they may do so at the expense of active modes of travel, which could have detrimental impacts on health outcomes. It is important to better understand the health impacts of urban design that prioritize TNCs, for instance, at the expense of other, more active modes. If health is a primary concern, street redesign should focus on incorporating a safer and more attractive environment that encourages active mobility, including walking and biking.

STREET DESIGN AND SAFETY

New mobility and AVs could create more conflict points and mode interactions as an increasing number of vehicles (TNCs, AVs, microtransit) all attempt to access the curb, crossing transit, bike and/or micromobility lanes.

ECONOMY

An increase in metropolitan footprints and an expansion of sprawl will require a continued increase in the construction and maintenance of infrastructure in low-density areas.

LARGE SHIFTS IN LAND VALUES

Similar to what happened with the rise of suburbia in the last century, an increase in the ease of travel could lead to an increase in demand for land outside of city centers. This might lead to a decrease in urban land values and an increase in value of properties previously considered too far from centers to be developable. Dense and desirable areas, especially in centers and corridors, could see significant increases in land value if parking is no longer a limitation to growth and densities can increase further. This will not only affect the economics of specific properties, but depending on how taxes and jurisdictions are organized, could create large economic windfalls and/or hazards in the economic vitality for entire municipalities and metropolitan regions.

INCREASED COST OF INFRASTRUCTURE

An increase in metropolitan footprints and an expansion of sprawl will require a continued increase in the construction and maintenance of infrastructure in low-density areas. This type of construction and maintenance is already a burden on suburban municipalities and could eventually become an unsustainable economic burden.

ENVIRONMENT

INCREASED ENERGY CONSUMPTION

Expanded metropolitan footprints and low-density development require increased amounts of energy used for transportation (Newman & Kenworthy, 1989). While there is the potential that AVs may also usher in a shift to electrified fleets, low-density development requires increased energy use when compared to compact and dense development (Rode, Keim, Robazza, Viejo, & Schofield, 2014).

HABITAT DESTRUCTION

Low-density development and sprawl consume habitat and extend the impacts of urban development into natural areas. Water and air quality are often negatively affected by the increases in impervious surfaces and pollution often seen with low-density development.

AGRICULTURAL AND NATURAL RESOURCE LAND CONSUMPTION

Expanded metropolitan footprints often consume valuable agricultural land with high-grade soils and water access. This development also consumes land with natural mineral, forest, and environmental resources, eliminating the economic and environmental benefits of these areas.

NEW OPEN SPACES AND HABITAT

Changes in land use and urban design, particularly in the reduction in the need for parking, may potentially leave large areas of property open to redevelopment. How this is done— potentially as parks and open space, new habitat, habitat connections, and increases in permeable surfaces —could have significant impacts in the overall environmental health of a region.

GOVERNANCE

BURDEN ON MUNICIPAL BUDGETS

Low-density development tends to be burdensome for cities as they require more infrastructure per capita and are costlier and more difficult to serve with fire, police, educational, and social services.

MITIGATING LAND VALUE CHANGES

Cities need to understand the potential changes in land value based on urban design impacts so they can buffer declines and have means to capture some of increased value created.

LAND BANKING

As parking wanes in importance, parking lots and garages might become key areas for municipal land banking.

CROSS-AGENCY COORDINATION

Impacts of urban design will be wide-ranging, so coordination across departments and agencies will be critical to ensure disruptions and negative repercussions are minimized while change is leveraged to reach community goals.

AREAS OF NEEDED RESEARCH

STREET DESIGN

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
How might street design changes (especially regarding curbside access, location of access points and length of curbside allocated to any given mode) best accommodate new curbside access needs?	Prototyping	Design prototyping	Urban design guidelines and street design guidelines
What curb management policies maximize equity?	Policy analysis	Content analysis	Street design guidelines
What areas are most efficient for pick up and drop off?	Modeling	Analysis of on-street, off-street, shared, by parcel, urban v. suburban	Curb management policy
What is the demand for curb space?	Modeling and data analysis	Intercept surveys, observation, counts	Curb management policy
How will lane width requirements change with AVs?	Prototyping	Design Prototyping	Street design guidelines
How can street design changes best accommodate new modes and increased need for capacity/curbside access?	Prototyping	Design Prototyping	Street design guidelines

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
How would organizing streets by speeds affect network efficiency, safety, and user comfort?	Basic research	Experiential surveys	Street design guidelines
How might street use (capacity/access needs) change over time of day? (Consider e-commerce deliveries, flexibility of lanes/ modes, etc.).	Basic research	Intercept surveys, observation, counts	Curb management policy; flex lane policy
How does street design impact the use (execution, ease of use, and individual's preference/acceptance) of different modes in new mobility?	Basic research	Intercept Surveys/ Experiential Surveys	Street design guidelines
What specific street design changes would be most necessary/ effective in improving curbside access/ overall network efficiency?	Modeling	Transportation modeling	Street design guidelines; curb management policy
What are potential disruptions in network efficiency, safety, and access during the transition from legacy to automated vehicles?	Modeling	Scenario modeling	Street design guidelines
What types of street configurations, intersections, and street conditions are most difficult for AVs to navigate/manage?	Basic research	Experiments	Traffic laws
How can cities prioritize needed new mobility infrastructure changes to streets to meet community goals?	Policy analysis	Policy analysis	Street design guidelines and capital improvement programming

CENTERS AND CORRIDORS

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
What are possible typologies of land use and development along new mobility Transit Oriented Corridors (TOCs)?	Prototypes	Design analysis	N/A

GENERAL URBAN DESIGN

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
How does new mobility affect the use of suburban commercial retail?	Basic Research	Design analysis	Zoning code
How can big box retail be retrofitted to become distribution centers?	Prototypes	Design analysis	Zoning code

PLACE/IDENTY

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
How might e-commerce and new mobility affect the number of users, vitality, and sense of place of different areas?	Basic research	Surveys	Zoning Code

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06 | IMPACTS ON REAL ESTATE

INTRODUCTION

Owners and developers of real estate are sensitive to changes in mobility technologies and patterns of consumption, particularly because consumers of real estate are sensitive to these changes. Shifts in parking, travel, and movement of people and goods require reimagining the ways buildings are occupied and designed. Changes brought about by AVs will inform how buildings and sites are valued by tenants, investors, and developers.

Though interrelated, the influence of AVs on the real estate sector can be distinguished from the impacts on land use and urban design. Land use concerns the value of location, changes in land uses, open space, proximity of homes to work, and regulating what is built where. Urban design involves the features of a city between the buildings, such as streets, intensity of development, and neighborhood characteristics.

The impact of AVs on real estate will involve changes to buildings and sites, particularly tenant composition and accessibility, and how that influences the relative value of land uses. In a future with widespread AV adoption, successful real estate projects will feature building owners, tenants, and services that are responsive to people and goods traveling in AVs.

CHAPTER ORGANIZATION

FIRST ORDER IMPACTS

- CHANGE IN PARKING DEMAND
- CHANGE IN VMT AND EASE OF TRAVEL
- CHANGE IN CONGESTION AND COMPETITION FOR THE ROW
- SHIFT IN MODES
- CHANGE IN GOODS AND MEAL DELIVERY
- SHIFTING NATURE OF FREIGHT
- REPLACEMENT OF CERTAIN TYPES OF BRICK-AND-MORTAR STORES BY EXPERIENTIAL RETAIL

SECOND ORDER IMPACTS

- REAL ESTATE ECONOMICS
- LAND VALUE
- PROJECT FEASIBILITY
- BUZZ/VITALITY
- QUALITY

INTEGRATIVE IMPACTS

- TRANSPORTATION
- LAND USE
- URBAN DESIGN

IMPLICATIONS OF SECONDARY IMPACTS ON REAL ESTATE

- EQUITY
- HEALTH
- ECONOMY
- ENVIRONMENT
- GOVERNANCE

AREAS OF NEEDED RESEARCH

FIRST ORDER IMPACTS AFFECTING REAL ESTATE

The growth in new mobility and e-commerce/goods delivery will have key implications for real estate. The primary first order impacts that will affect real estate are change in parking demand, change in vehicle miles/kilometers traveled, change in congestion, change in ease of travel, shift in modes, competition for the right-of-way, change in goods and meal delivery, changes in demand for warehousing space, reduction of certain types of brick and mortar stores, and increasing interest in experiential retail.

CHANGE IN PARKING DEMAND

The proliferation of on-demand autonomous ridehailing services could potentially lead to a large decrease in car ownership, which is likely to reduce the demand for parking spaces. Already the demand for parking appears to be decreasing in certain areas, such as airports, dense downtowns, and areas with concentrated nightlife, as people increasingly choose to use ridehailing services like Uber or Lyft for those trips to/from those locales (Morris, 2018; Steele, 2018; Zipkin, 2017). Parking is a major constraint in developing properties because people desire easy access to their cars and often possess a very low willingness to pay for parking. For instance, a researcher that examined the results of the American Housing Survey found that households with bundled parking (i.e., parking spaces are not rented separately from units) were 60-80% less likely to be car-free than household with unbundled parking (i.e., parking spaces are rented separately from units; Manville, 2016). The cost of providing parking stalls on site can be as much or more than providing similar-sized leasable space, so eliminating these parking-related costs can make many more projects feasible (Shoup, 2011).

In addition, reduction in demand for existing parking capacity will create opportunities to modify existing properties. While parking facilities could be occupied by expanding existing uses, such as building an office building wing where surface parking existed or converting a garage into a room in a house, parking facilities may also need to be repurposed to accommodate various ways in which AVs will change transportation. Parking facilities, for instance, may be repurposed into new "access points," or "mobility hubs," created for delivering goods and dropping off and picking up passengers, though existing design may make this difficult or unfeasible.

CHANGE IN VEHICLE MILES TRAVELED (VMT) AND EASE OF TRAVEL

AVs will likely enable people to travel farther, longer, and more frequently. Commuting to work and traveling for leisure may be less costly, both perceived and real cost (Litman, 2019)driverless or robotic, since the travel time can be used more productively for work or leisure (Anderson et al., 2016). Increased comfort in the travel experience may mean that people are less sensitive to travel distance and more selective about their destination. Such changes could lead to greater agglomeration and more intense development, including larger buildings where the increased demand makes such development feasible.

CHANGE IN CONGESTION AND COMPETITION FOR THE RIGHT-OF-WAY

The introduction of TNCs into major cities is already increasing congestion because they compete with private vehicles, transit, bicycles, and pedestrians for the right-of-way (Schaller, 2018). Similarly, AVs are likely to increase congestion in urban and downtown areas as long as they remain unintegrated with other modes of transportation. Moreover, induced demand for the movement of people and goods will likely further increase congestion. Cities may also become more congested if AVs open up travel options for those populations that currently do not drive, such as those who are physically unable to drive.

To mitigate congestion, drop-off and pick-up facilities may be accommodated outside of the right-of-way, near the ground level of buildings. Increased congestion could drive away firms because the benefits of agglomeration, such as higher productivity and better job-skill match, become limited as congestion increases. At the same time, property values appreciate with walkability (Leinberger & Rodriguez, 2016; Yates & Miller, 2011). Therefore, while AVs may conveniently connect people from one place to another, the inconvenience of congestion could fuel the development of more walkable areas within short distances.

SHIFT IN MODES

The impact of AVs on real estate development will depend on the changing nature of travel. If AVs are substitutes for transit, people could work and live farther away from transit stops, leading to new construction in more remote, less developed areas, even within urban cities. Even so, change to the built environment could happen slowly and incrementally as developers figure out ways to modify existing buildings to accommodate a new prioritization of travel modes.

CHANGE IN GOODS AND MEAL DELIVERY

E-commerce and the sharing economy are facilitating the growth of on-demand delivery services. Today, goods and meals can be ordered online and delivered quickly. AVs could further decrease the cost and increase the frequency of delivery services, thus increasing the traffic flow in and out of buildings. Real estate developers may need to dedicate a portion of the property for new forms of delivery stations and building services that address logistics and security concerns related to deliveries. Already some developers and residential building managers are adding and/or expanding package areas to manage the increase in deliveries and incorporating package concierge service stations (Kaufman, 2015; Zimmer, 2016). While the number of food vendors or goods providers may fall due to consolidation, there could be a greater demand for shared spaces to consume delivered food or storage space for easy-to-procure goods.

SHIFTING NATURE OF FREIGHT

Integration of AVs into e-commerce and on-demand delivery services will require the rethinking of supply chains and distribution nodes. Fulfillment centers will have to be designed or redesigned to work seamlessly with AVs, accelerating current shifts to locate fulfillment centers closer to final destinations to reduce delivery time (Simpson, 2018). Because AVs will be able to operate without drivers, they may be in more continuous operation than vehicles today. Moreover, residential and commercial areas could see fulfillment centers taking up tiny parcels of land in order to locate goods extremely close to consumers. Tenant composition in mixed-use areas could become even more varied, including more logistics functions, should zoning regulations allow it.

Also, goods may originate from fewer large warehouses that are accessible to many metro areas. Warehouses are strategically dispersed to minimize shipping costs and to fulfill orders under the trucking industry's hours of service regulations. But, AVs may drastically reduce shipping costs and AVs will likely be able to travel farther distances over longer hours. Therefore, the proximity of warehouses to fulfillment centers may become less important.

REPLACEMENT OF CERTAIN TYPES OF BRICK- AND-MORTAR STORES BY EXPERIENTIAL RETAIL

Ease of access to places and goods will change the demands for certain types of stores and may cause retail to congregate around anchor stores where the foot traffic is higher. As the need for storage and shelf space decreases with the continued increase of e-commerce, there will likely be a continued reduction in the footprint of stores selling goods that can be easily bought online and delivered (Meyersohn, 2019). Instead, people are likely to spend time in experiential retail (Wertz, 2018), as well as in stores that can generate attention by selling limited-offering, specialty, or made-to-suit goods.

At the same time, there could be more mixed-use buildings with experiential retail, high-end restaurants, and bars as developers make complementary services even more convenient and accessible in a single trip. Anchor retailers, those with high margins and sizable advertising budgets, may shift to transport-based marketing, offering free or reduced-price travel to AV passengers who opt to travel to their destination.

As the need for storage and shelf space decreases with the continued increase of e-commerce, there will be a reduction in the footprint of stores selling goods that can be easily bought online and delivered and instead, people are likely to spend time in experiential retail. Image source: Robert Bye for Unsplash.

SECONDARY ORDER IMPACTS ON REAL ESTATE

This section hypothesizes about how the first order impacts may impact real estate, considering land value, project feasibility, buzz/vitality, and quality. The purpose of this section is to consider how the first order impacts described above will impact real estate. The secondary impacts are largely speculative in nature and are meant to summarize projected impacts along various dimensions.

REAL ESTATE ECONOMICS

At its core, the shifts in the real estate sector in response to AVs, the sharing economy, and e-commerce will be defined by the fundamental economics of land use and development. In this market-driven segment of our economy, the role of real estate owners and developers is to deploy capital to the types of buildings and amenities that will satisfy the users' demands for space. As transportation changes in the coming decades, shifts in user preferences and ability to pay will transform how buildings are designed and produced.

Given the finite supply of existing buildings and available land, developers compete for sites where new buildings can be created and users compete for desirable space. Subject to regulatory constraints, developers who can pay the most for a site will generally dictate what is provided on the site, which is typically called the "highest and best use" of the property. Furthermore, the highest and best use of an existing building can be influenced by how easily the property can be changed for new uses. Developing new buildings is dependent on whether there exists sufficient unmet demand for suitable space. These fundamentals will underpin how AVs will impact real estate in the future.

LAND VALUE

The impact of AVs on land values will likely be mixed. For one, the change in parking demand could allow for more intensive land uses. Thus, residential investors can add more rooms or housing units and commercial investors can accommodate more tenants in the same property. New tenants may include regional warehousing companies that rent out spaces for local fulfillment. As people become less sensitive to travel distances, agglomerative effects could lead to even greater variety and intensity of uses in accessible nodes. The resulting increase in income potential for both existing and new tenants will result in higher rents. More renters at higher rents will contribute to appreciating land values in high-demand locations.

AVs are unlikely to unlock unlimited intensity of uses and land value appreciation. For example, some parking spaces may be replaced by access points required to accommodate people, goods, and meals arriving by AVs. Single-family homes may install secure delivery receptacles, offsetting the space saved by reducing parking. Likewise, multi-family residential and commercial offices may add on-site delivery offices or secure delivery kiosks. Open and outdoor spaces may be demanded within or next to buildings if existing public spaces, particularly roadways, become more congested. With AVs, costly and space-intensive features could become distinguishing factors of high-quality buildings.

Historically, land values have been strongly influenced by accessibility to main roads and transit (Parsons Brinckerhoff, 2001), but AVs could change those demand drivers. For example, locations that were once in demand, such as retail stores visible from highways and major thoroughfares, may transition to other uses. Also, the value of properties around transit stations may fall if AVs replace transit as a preferred mode of transportation. People may choose to live in other areas that are not as transit-accessible since their AV rides can take them directly to their final destinations. The implication for experiential retail is that they will need to consider both AV-accessibility and transit-accessibility.

Moreover, ease of travel and proliferation of delivery services will likely mean that some people will consider living farther away from retail businesses. Thus, some pockets of currently undeveloped residential areas may experience new residential growth. If AVs assist in transporting people to and from transit stations, some population and property growth can be expected to continue around existing property agglomerations.

Image source: Saner Dalhuisen for Unsplash.

PROJECT FEASIBILITY

Certain projects are poised to become more physically and financially feasible with the adoption of AVs. As discussed above, the intensity of uses and corresponding agglomerative benefits may yield sufficient demand in certain submarkets to make new development feasible. Other markets will see shifts in demand that correspond with lower financial feasibility and less intense land uses. But, there may also be a change in the physical feasibility of real estate projects.

Because parking demand is often a constraint in developing properties, especially in land-constrained business districts, AVs' influence on parking demand is expected to increase the number of feasible projects. For example, feasibility is optimal on sites where an efficient parking design can be accommodated, typically rectilinear parcels with dimensions in increments of 60 feet, the width of a double-loaded parking bay. However, oddly shaped parcels and smaller parcels could become feasible for development if traditional parking spaces are no longer in demand.

If retail becomes more experiential and does not rely on voluminous, regular deliveries, then truck loading bays could be redesigned to create more space for other uses. If shipments and deliveries can be conducted in smaller AVs, then large yards will not be required to serve truck turning radii, allowing for densification of warehouses. Labor intensive facilities that must provide parking for employees may no longer need to provide as many parking spaces, allowing certain uses, like manufacturing, to be physically feasible in more locations, including small urban sites.

Changes in goods movement will also impact the construction industry. Projects that were difficult to construct due to site sizes and loading constraints may benefit from on-demand, small-scale AV shipments to job sites.

BUZZ/VITALITY

Foot traffic is important for the vitality of retail stores, which are often located near larger stores or transit corridors to attract more people. The combined forces of change between AVs and e-commerce are likely to shrink the size of traditional retail and draw stores into denser areas with the greater foot traffic. While retail business may shrink overall, any growth in foot traffic will likely be concentrated around experiential retail, higher-quality restaurants, and bars, with demand for them greatest near population centers. Thus, it is likely that a limited number of places that are already highly populated will draw in more mixed-use tenants.

This concentration of retail stores may not necessarily occur in dense, urban spaces. If people become more selective about their destinations and more willing to travel farther distances, foot traffic can grow in shopping districts developed in nodal patterns around metropolitan areas. Thus, developers may need to identify the retailers that will appeal most to customers, which could include those that use transport-based marketing to subsidize customers' trip costs. Additionally, these locations may not need to be transit-accessible if AVs effectively replace transit. Thus, the anchor retailers of the future could potentially be distinct from today.

QUALITY

Changes in travel patterns due to AVs could impact the quality of places, leading some real estate investments to retain or accumulate value while others decline in value. Because AVs are expected to make transportation less burdensome, people and goods are expected to travel more frequently and over longer distances. With less real or perceived transportation costs, people could travel further and longer, thus allowing them to be more discerning about their destinations. This would result in real estate investors focusing on creating the most attractive, unique, and desirable destinations.

However, the quality of places can deteriorate if they become too congested or difficult to navigate. An increase in the number of fulfillment centers in urban areas could increase congestion without adding potential retail customers on the streets. Overburdened roadways could impact the quality of places along major routes, leading to disinvestment and decline. Moreover, if requirements for drop-off and pick-up facilities take up entire ground floor spaces, then the relationship between buildings and streets could become even more fraught than it already is.

The quality of places and buildings will also depend on how rooftops are used. While building surfaces offer an opportunity to increase greenspace, thus enhancing the value and attractiveness of a building, the introduction of aerial drones in goods movement could reduce the amount of greenspace on rooftops.

INTEGRATIVE IMPACTS

This section explores the relationships between the secondary impacts of real estate, noted above, to transportation, land use, and urban design, and the potential integrative impacts.

TRANSPORTATION

Growth in land value may be less concentrated around transit corridors and highway access points with the proliferation of AVs. Homes and businesses may relocate away from access nodes if people can ride further and longer in AVs to reach their destinations. Still, the growth in some commercial centers is unlikely to stagnate as long as there are key tenants who are able to sustain a high volume of foot traffic. Businesses in these areas may need to plan for access by both high-capacity transit and AVs.

Congestion in urban areas is tied to the integration among different modes of transportation. Although AVs are expected to reduce the number of street parking spaces, traffic may increase as AVs compete for the right-of-way with existing modes of transportation. Congestion will also depend on the number and design of access points that AVs can use during pick-up and drop-off. The combination of transportation planning, law enforcement, and economic incentives will determine whether AVs will stop on the streets, park on curbsides, or enter private driveways maintained by building owners.

LAND USE

Changes in real estate development could be constrained by zoning laws and other land use policies. Growth in residential areas will be limited if zoning laws do not allow more residential density or mixed-use development. Parking requirements and lot coverage ratios could continue to constrain development in desirable districts. Cities may need to adjust their land use laws to accommodate AVs, and investors may prioritize capital allocation to cities that quickly and robustly change their regulations, such as parking requirements and zoning laws, to promote high-quality places that accommodate shifts in preferences and demand.

URBAN DESIGN

The relocation of tenants will inevitably affect the urban landscape. Many neighborhoods will likely experience the closing of traditional retail and certain brick-and-mortar stores. Meanwhile, local fulfillment centers may enter into vacant spaces. Some neighborhoods will grow denser as new businesses, sit-down restaurants, and experiential retail congregate together. If mixed-use buildings become more commonplace, the feel of the streets and ground floor spaces will change and residential areas will blend more with commercial areas. Urban designers will need to contend with the changes in intensity and types of uses around the city.

Although building entrances and lobbies would need to be modified to accommodate transportation and deliveries by AVs, the extent of the change will depend on the resources provided in the public realm, which will have a huge impact on real estate values. If street parking spaces are converted to travel lanes to deal with the challenges related to integrating AVs with existing modes of transportation, real estate developers will need to devote more on-site space and resources to make their properties more accessible to AVs. If the public sector chooses to use right-of-way to accommodate on-street AV movements, then developers may be able to deliver buildings at lower cost with fewer driveway interruptions along sidewalks.

Although AVs are expected to reduce the number of street parking spaces, traffic may increase as AVs compete for the right-of-way with existing modes of transportation. Image source: Adrian Williams for Unsplash.

IMPLICATIONS OF SECONDARY IMPACTS ON REAL ESTATE

This section explores what the implications of the secondary impacts on urban design could be for equity, health, the economy, the environment, and governance.

EQUITY

Real estate developments will create new economic opportunities in some areas as resources are lost and property values decline in others. Neighborhoods where vulnerable and low-income populations reside are likely to face greater economic segregation as new developments agglomerate, likely concentrating near wealthier neighborhoods. Land value may appreciate where buildings, roads, and nearby amenities are best suited for AV-related uses. Building owners with substantial financial capital will be better suited to invest in the renovations required to prepare for goods deliveries and passenger drop-offs by AVs.

Still, economically disadvantaged neighborhoods may experience some benefits if AVs increase people's access to goods and places. Employment options may increase as transportation friction decreases, and geographic barriers to nutritious food may disappear as AVs make food access easier throughout regions.

Ultimately, the distributional effects of AVs will be partly determined by the affordability of the new technology and its geographic reach, which may be dictated by regulatory requirements imposed on the sector. If the costs of AVs remain too high, they may still become dominant, but the convenience and time-saving feature of the technology may not be available to low-income populations. Further, if fleets are deployed to maximize profit, they are unlikely to serve low-income populations as well as those populations with greater financial means. Moreover, since AVs consume and process reams of data, availability of AVs may be decided by access to high-speed broadband, which is not evenly distributed across geographies and socioeconomic groups.

HEALTH

Travel by AVs and densification of urban areas may mean less walking and biking between destinations. Although investments in walkability may improve in certain areas to counterbalance road congestion, walking distances are likely to shrink, which could have detrimental impacts on health. However, an awareness of these effects of AVs may trigger greater demand for open areas, parks, and gyms in dense areas. Real estate developers may end up devoting more resources to recreation spaces and health-related tenants.

ECONOMY

If AVs produce consumer surplus, then consumers could pay more for goods, services, and space, so land value would be expected to rise overall, though it may rise dramatically in some places while declining in others. If AVs are relatively inefficient, then we would not see their widespread adoption, but may see some sectors and populations take up the technology for niche uses, which would result in fewer changes to the real estate sector.

The impact of widespread AV adoption on jobs will be mixed, which will result in diverse impacts in the real estate sector. Certain construction work will be more in demand as roads and buildings are renovated to accommodate AVs. Fewer auto technicians will be required to service AVs and vehicle-oriented workplaces may consolidate to more remote areas.

Roads and curbsides may need to be transformed to allow AV-related uses without disrupting other modes of transportation. Image source: Thomas Reaubourg for Unsplash.

ENVIRONMENT

Increased demand for open areas and parks near redeveloped buildings may result in more tree planting. Vacated parking lots and retail spaces in more remote parts of cities could encourage projects that create more natural habitats. Moreover, agglomeration of businesses into smaller areas may lead to more efficient use of energy if economies of scale are achieved. Yet, sprawl of some developments away from existing residential and commercial properties could consume natural habitats and impact water and air quality.

Increased demand for open areas and parks near redeveloped buildings may result in the planting more trees. Vacated parking lots and retail spaces in more remote parts of cities could encourage projects that create more natural habitats. Image source: Neonbrand for Unsplash.

GOVERNANCE

The introduction of AVs into urban cities will require greater public investments in roads and other infrastructure, placing greater pressure on municipal budgets. Roads and curbsides may need to be transformed to allow AV-related uses without disrupting other modes of transportation.

There will likely be a redistribution of the tax base. Some locations will benefit from agglomeration, with jurisdictions garnering higher municipal revenues from those locations. However, some locations may suffer. For example, there will be less sources of revenue from retail as brick-and-mortar stores close. Property tax revenue may change both in terms of who pays the taxes and where the tax base is concentrated.

To encourage new developments to take place in less developed or less desirable areas, cities will need to update their zoning laws, address infrastructure, and potentially subsidize individual projects. Land banking of vacated parking lots and retail spaces may become a key tool in influencing redevelopment.

Also, transit farebox revenues will shrink if AVs lead to reduced transit ridership. Therefore, cities may start considering new forms of sales taxes and fees related to AV transportation, including congestion pricing.

As cities begin to respond to changes in their tax base, infrastructure needs, and other costs, cities could implement revenue models that inform where new developments and redevelopments occur. For example, impact fees, sales taxes, and property taxes all influence real estate development choices.

AREAS OF NEEDED RESEARCH

REAL ESTATE

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
What are policy options for capturing economic benefits of reduced parking requirements?	Policy analysis	Content analysis and policy analysis	Development code
How does livability affect land values?	Basic research	Surveys	Community development, business development departments
How does transit, biking, walking affect land values?	Basic research	Hedonic price studies	N/A
How do developers and decisionmakers respond to consumer preferences?	Basic research	Interviews	N/A
What are policy options for bundling housing costs and transportation subscriptions?	Basic research	Content analysis/case studies	Equity, housing, transportation costs, housing burden
How do shifts in parking utilization affect land values?	Basic research	Hedonic price studies	Development code

BUZZ/VITALITY

QUESTION	TYPE OF QUESTION	METHOD	POLICY IMPLICATIONS
How do e-commerce uses like data centers and warehouses affect vitality and walkability of neighborhoods?	Basic research	Surveys and data analysis	

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07 | CONCLUSIONS

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THE PURPOSE of this project was to coordinate and collaborate with a network of academics and public sector and private sector experts from multiple disciplines about the multilevel impacts of new mobility, e-commerce, and autonomous vehicles on city form. We worked with planners, architects, urban designers, engineers, and economists to analyze the impacts on transportation, land use, urban design, and real estate and to consider implications for the environment, equity, economy, health, and governance.

In this report, we mapped out the latest research on the forces of change, first-order impacts, and multi-level impacts in a series of thematic chapters. It is important to note that the private sector players are constantly changing and the research is progressing rapidly on these topics. This report is meant to document the trends and provide some guidance to academics and public sector officials to monitor and study the impacts of technology on urban form.

To better understand and anticipate these impacts, it is important to consider **community goals and values**, **shifts in governance**, **collaborative networks**, and **data management and monitoring**.


Source: Fred Joe for Urbanism Next

1) COMMUNITY GOALS AND VALUES

The conversation about autonomous vehicles and new mobility requires a consideration of community goals and how new mobility may advance or hinder progress towards community goals. If cities and metropolitan regions have clear priorities to guide policies—preferably before new technologies arrive—there will be a stronger opportunity for policies to support community goals and not simply react to the next immediate problem.

2) SHIFTS IN GOVERNANCE

In order to accommodate the pace of change in the new mobility realm, government agencies may need to make changes to traditional organizational structures in order to be nimbler and more responsive. For instance, government agencies may need to modify procurement processes to enable more flexibility. Additionally, city officials will likely need a new set of flexible policies and codes that allow them to match the speed of policy change to the speed of transportation behavior change in order to meet the needs of their community today, while also being able to quickly iterate and adapt as conditions on the ground change.

3) COLLABORATIVE NETWORKS

The realm of new mobility and autonomous transportation includes a diverse set of players from the public sector and private sector. The relationships between the public sector and private sector are changing, and the need for communication and collaboration on these topics is apparent. Given the current pace of technological change, the public sector may need to adopt some of the flexibility of the private sector, while the private sector may need to adopt some of the accountability of the public sector.

4) DATA MANAGEMENT AND MONITORING

New technology has provided new opportunities and challenges for using data to address public issues. Our research found that we need better data to track and monitor issues like change in parking demand, change in land use (at a temporal and spatial scale), and transportation demand.

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