TOOLBOX FOR NAVIGATING THE LAND-USE IMPACTS OF THE AUTONOMOUS VEHICLE ECOSYSTEM

FINAL TOOLBOX

Prepared for
NCHRP Project NCHRP 20-102(34)
Transportation Research Board

of

The National Academies of Sciences, Engineering, and Medicine

Yonah Freemark, Christina Stacy, and Jorge González-Hermoso
Urban Institute
Sebastian Castellanos, Jyot Chadha, Justyn Huckleberry, and Leah Lazer
New Urban Mobility Alliance
Alexis Robinson and Breanne Kroehler
Justice & Sustainability Associates

ACKNOWLEDGMENT OF SPONSORSHIP

This work was sponsored by one or more of the following as noted:

☒ American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted in the **National Cooperative Highway Research Program**

☐ Federal Transit Administration and was conducted in the **Transit Cooperative Research Program**

☐ Federal Aviation Administration and was conducted in the **Airport Cooperative Research Program**

☐ Governors Highway Safety Association in cooperation with the National Highway Traffic Safety Administration and was conducted in the **Behavioral Traffic Safety Cooperative Research Program**

which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

Toolbox for Navigating the Land-Use Impacts of the Automated Vehicle Ecosystem

August 2024

Table of contents

Executive Summary

Autonomous vehicles (AVs)—vehicles that can operate with little or no human involvement—are now being introduced for regular use in cities throughout the United States and the world. While AVs are currently too expensive and their technology inadequately developed to operate at a large scale, the AV industry could eventually become a multi-billion-dollar engine of the economy, fundamentally transforming the way we get around (Schwartz 2018). AV technology could be used not only to replace drivers in passenger cars, but also used for public transit vehicles, freight-carrying trucks and even automated goods-carrying robots.

The way in which AVs are rolled out has the potential to either increase social equity and environmental sustainability or reinforce entrenched inequities and accelerate climate change (Freemark et. al 2022). AVs could make transportation more affordable for low-income families and people of color, while cutting down on traffic, pollution, and greenhouse gas emissions, since AVs are likely to be electric (Tessum et al. 2021). Or AVs could increase vehicle miles traveled (VMT), traffic, pollution, suburban sprawl, and racial segregation (Wadud, MacKenzie, and Leiby 2016). If, for instance, the convenience of commuting by AV provokes a suburban exodus, residential segregation could increase, equity in access to opportunity could decline, and pollution could rise, much as was experienced after the development of the interstate highway system (Baum-Snow 2007; Rothstein 2018).

Land use in particular will play a crucial role in shaping the impact that AVs have on equity and environmental sustainability. Existing land use patterns will greatly influence the speed and locations at which AVs are adopted within a community, which will then influence further developments in land use. And, since AVs are likely to be electric, planning for electric grid infrastructure and AV planning are mutually related, which could have a considerable impact on how AVs operate, as well as on the design of the built environment. Historical evidence from previous transportation technologies suggests that AVs will significantly alter land use patterns, and, in turn, these land use patterns will influence the further deployment and integration of AV technology. But local and state governments, working with individuals and organizations, can shape AV rollout through land use policy, leveraging tools related to zoning, curb use, development planning, and more to help ensure that AVs help generate a better society for all. So far, however, there has been little concrete action on the part of cities and states around the United States to associate the AV ecosystem with new approaches to land use policy.

This toolbox is therefore designed to help policymakers and other interested stakeholders prepare for mass AV rollout to maximize benefits to equity and environmental sustainability. The toolbox takes learnings from five historical transportation examples to propose actions for the future. It contains recommendations for policies and practices tailored for different types of communities. These recommendations are designed to be applicable to both freight and passenger service and apply to situations where AVs are used on all trips or just on some trips as part of multimodal trip taking, such as through ride-shared, car-sized AVs combined with public transportation.

This toolbox comprises various policy recommendation fact sheets, including several that can help policymakers identify ways to disincentivize the sprawl and increased VMTs that may come from AVs, such as:

- Amending zoning codes to allow for increased housing density in urban cores and other population and job centers to help disincentivize AV-generated sprawl. These policies can include reduced parking minimums and allowing land formerly used for unnecessary parking and road space to be reallocated for other purposes, such as housing, parks, walking/biking lanes, and community amenities. Codes can also be altered to require traffic impact assessments that focus more on reducing total VMT than on preventing vehicular delay, and allow for more efficient locations and configurations of freight distribution centers, since they will no longer need to be located near where potential drivers live. They will also not need the same amount of parking as would be required if all drivers were human and were parking at these centers.

- Refining street curb regulations to promote shared AV use by devoting dedicated space on each block for passenger pick-ups and drop-offs, providing quality access to public transit services, appropriately charging for curb use, and allowing for reliable freight deliveries. Effective real-time operations management and enforcement are also necessary to support the effective rollout of such regulations.

- Altering policies related to greenfield development with the goal of preserving land for agricultural use and ensuring the preservation of natural ecologies, since AVs might encourage development on greenfields on the outskirts of urban areas due to both suburbanization and land needs for AV-related infrastructure. This can include updating comprehensive plans to outline long-term goals and strategies for managing growth and development in areas that are currently natural or agricultural, updating land use ordinances to limit development in peripheral areas, creating environmental regulations and standards, and incentivizing infill or brownfield development over greenfield growth.

- Expanding the transportation network to invest in public and active transit. Communities can also think carefully about where to locate transportation expansions in suburban and rural areas so that freight, information technology servers, and AV parking needs are distributed efficiently and do not negatively disrupt local ecosystems or communities with low incomes and communities of color.

This toolbox also offers suggestions for how leaders can take advantage of the opportunities that AVs may provide through reduced parking needs and road space, making land newly available in urban cores. Recommendations to help leaders take advantage of these new opportunities include:

- Transforming street designs to prioritize pedestrians and shared uses, leveraging space freed up by more efficient vehicle navigation and less need for parking. This could involve creating roadways where only AVs can enter (potentially reserving lanes for AV transit vehicles) and creating dedicated space for shared vehicles and light mobility technologies, such as bikes and scooters.

- Amending right-of-way management to create managed lanes for AV buses and other transit options that are integrated into the broader mobility system. Governments have the opportunity to consider congestion pricing and reinvesting the resulting revenue in transit options, which could include AV bus service. Communities can carefully design geofences for AV-only spaces by considering the efficiency and VMT implications of geofence locations.

- Strategically managing publicly owned land to prevent valuable properties from being used to promote the use of motorized individual transportation through AVs or otherwise. Government and community leaders may dedicate this land for uses that advance their equity and sustainability goals, such as affordable housing, public parks, community facilities, public transportation projects, or freight distribution centers.

These policy ideas require effort from local, regional, and state governments to be implemented. Communities may need to implement policies in a unique way, responding to their specific needs that are not universally shared. Different communities have varying political, economic, and social contexts that may make some policies more or less feasible than others. The successful implementation of each policy, moreover, may require an enforcement strategy; ensuring that curb space is fairly allocated, for example, relies on communities taking the steps to guarantee that residents and visitors follow the rules.

All of these policies should be created in partnership with community members who have been historically harmed by transportation and land use decisions, such as people of color, people with disabilities, and people with low incomes. Our community engagement fact sheet offers suggestions for how to ensure that community engagement with historically excluded and marginalized populations is central to AV and land use decisions.

While this toolbox focuses on policy and practice related to land use and AVs, other policies and initiatives will be needed to ensure that AVs increase equity and environmental sustainability. These may include subsidies to incentivize ridesharing, requiring a percentage of, or all, shared AVs to be compliant with the Americans with Disabilities Act to meet the needs of people with disabilities, and implementing usage fees rather than regressive gasoline taxes, which could force non-AV users to subsidize AV riders (Barnes and Turkel, 2017). The land use tools discussed in this toolbox should complement these other tools.

A one-size-fits-all set of recommendations is unlikely to work for leaders hoping to adapt their land uses and land use policies to prepare for and respond to AV rollout. Suburban communities may face increasing development pressures from residents, freight centers, and data farms, while cities may benefit from increased land available for other uses after the rollout of AVs—but may have to plan for new curb usage, increased VMT, and even potentially depopulation. Therefore, this toolbox is designed to help communities identify their "type" and then connect them to recommendations that fit their expected future conditions.

Box 1.1 Definitions

Several of the key terms used in this toolbox include (we provide more details in the appendix, available on the Transportation Research Board website):

- **Autonomous vehicles (AVs)** combine an automated driving system with a vehicle to perform a dynamic driving task (meaning steering, accelerating, braking, and signaling) within the public road right-of-way (they differ from *automated* vehicles, like automated metros, which operate on dedicated track). The AVs we describe in this toolbox are capable of level 4 (high driving automation) or 5 (full driving automation); they thus go beyond driver assistance technologies such as cruise control. AVs will most likely be mostly electric and will thus need charging infrastructure. AVs may be implemented in both passenger and freight contexts, and could come in a variety of forms, such as:
  - Robotic, small-goods carrying vehicles that could run on sidewalks but not carry passengers;
  - Passenger-car sized vehicles that could replace typical cars and light trucks;
  - Van-sized vehicles that could provide shared travel services on lightly frequented routes;
  - Bus-sized vehicles that could serve a key role in the public transportation network; and
  - Trucks of various sizes designed to carry freight.

- **Land use** includes the following elements. It can be altered by **land use policy**.
  - The form of buildings in an area (e.g., towers versus single-family homes for residences). Building form could specifically include the shape of buildings to adapt to, or orient, different modes of transportation.
  - The use of buildings or land in an area (e.g., for residences or for warehousing).
  - The preservation of land for largely non-built needs (e.g., for natural or agricultural use).
  - Transportation infrastructure itself, meaning the facilities needed to convey and store vehicles in the transportation system.

- **Equity** refers to the point at which an individual's race, ethnicity, gender, socio-economic status, sexual orientation, physical abilities, or other individual characteristics do not determine their opportunities or outcomes.

- **Environmental sustainability** means that human interaction with the natural environment and its constituent elements leaves it able to persist in a steady state into the future.

- **Built environment** refers to the man-made structures, features, and facilities in which people live and work.

1. A quick start guide to using this toolbox

We have prepared this toolbox to provide policy recommendations tailored to the specific context and needs of individual communities—keeping in mind that community engagement should always be integrated into any planning process. In this sense, we propose a series of steps for users to navigate this toolbox in the most effective way possible. However, users should feel free to leverage any of the content in this document in whatever fashion they consider to be the most valuable for their needs and circumstances, especially when it comes to policy levers. We include links throughout the toolbox that allow users to navigate easily from one section to another at a single click. We have identified six key steps to take to move forward with planning for the links between AV technology and land use.

Step 1. Gather a diverse team of stakeholders to plan your community's AV policies!

This is your opportunity to change your community for the better! Think about what objectives you have when it comes to preparing for the rollout of AVs and potential future land use changes. Think about who you're planning for. This brainstorm can help you use this toolbox more effectively. Make sure to integrate a full spectrum of your community into your team, including those with low incomes, people who live in rural areas, people with disabilities, people with limited English proficiency, veterans, and people of color. Also make sure that land use stakeholders and transportation stakeholders are working closely together at every step of this process.

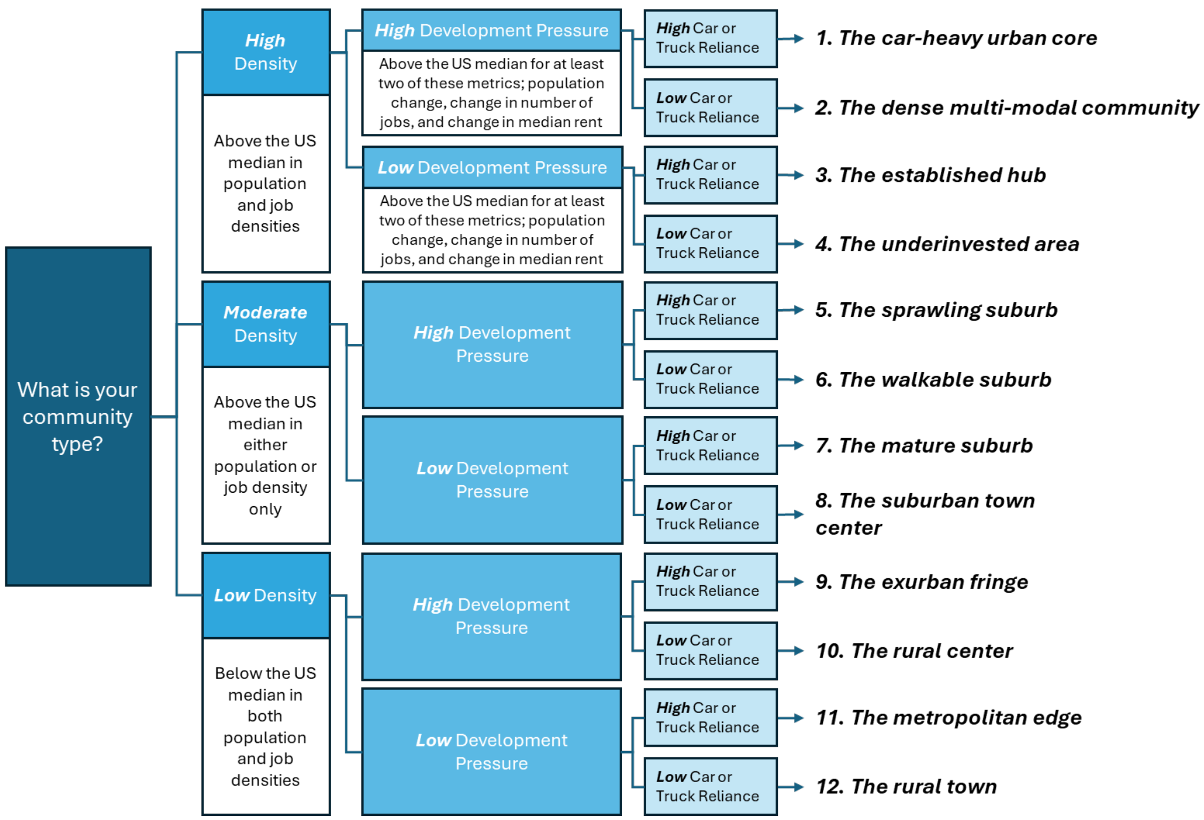
Step 2. Learn about how AVs and land use are linked

In Chapter 2 of this toolbox, we detail how AVs and land use intersect, while emphasizing the importance of public policy in this context. We identify historical examples of how transportation technologies can transform our landscape and show how community engagement is critical to uplift peoples' needs. In Appendix A (available on the Transportation Research Board website), learn more about the evidence informing this toolbox, and in Appendix B, explore the historical connections between five different transportation technologies and land use outcomes.

Step 3. Identifying your community type

In Chapter 3 of this toolbox, learn how to identify the community type that best describes your area. Figure 1.1 summarizes how to identify your community type. We describe this figure in more detail in Chapter 3.

Figure 1.1 Identifying your community type



Note: A community has a high car or truck reliance when it is above the US median for at least two of these metrics; car ownership rate, car commuters, and rail freight miles per capita. Otherwise, it should be considered having low car or truck reliance.

No one knows their community better than residents and other local stakeholders. We encourage users to use your best judgement to identify your community type, even in ways that extend beyond the model we propose. In other words, if our model suggests a community type that, after your consideration, does not really reflect the context and conditions of your area, you should feel free to leverage the information about another community type that you consider to be the best fit.

Step 4. Learn about your community's needs and the expected impacts of AV rollout

Once you have identified the community type for which you want to conduct planning, review the applicable community factsheet in Chapter 4 to learn about the expected relationships between AV rollout and land use and the recommended policy responses. Below, in Table 1.1, we list each of the community types and the policy tools that are likely most relevant for their respective needs. Click on the links to immediately navigate to the community types and policy fact sheets.

Table 1.1 Relevant issues for different community types

	Policy area								
Community type	Community engagement	Zoning	Building code	Street design	Use of the curb	Greenfield development	Expansion of transit	Publicly owned land	Right of way
1. The car-heavy urban core	✓	✓	✓	✓		✓		✓	✓
2. The dense multi-modal community	✓	✓		✓	✓			✓	✓
3. The established hub	✓	✓	✓	✓	✓				✓
4. The underinvested area	✓	✓	✓			✓	✓		
5. The sprawling suburb	✓	✓		✓		✓		✓	
6. The walkable suburb	✓	✓	✓		✓		✓		
7. The mature suburb	✓	✓	✓	✓	✓		✓		✓
8. The suburban town center	✓			✓	✓	✓	✓	✓	✓
9. The exurban fringe	✓	✓		✓		✓			✓
10. The rural center	✓	✓	✓			✓	✓		✓
11. The metropolitan edge	✓					✓	✓		
12. The rural town	✓	✓		✓			✓		✓

Step 5. Review relevant policy sheets

Review the policy sheets for your community type in Chapter 5 to learn about the specific policy levers at your disposal. These sheets include information about how a particular public policy relates to the AV ecosystem in the context of historical lessons, what specific actions can be taken to advance equity and environmental sustainability, and which stakeholders are relevant for policy implementation. We provide details about how policies may be implemented in a variety of fashions for different community types.

Step 6. Choose and develop relevant metrics

In Chapter 6, we explore how communities and stakeholders can use metrics to 1) gauge the intensity with which AVs are being used and AV-oriented infrastructure is being developed in your community, and 2) measure outcomes for this AV rollout and potential policies being implemented in response. We offer a list of metrics for each of these purposes, but we encourage you to build on them and create metrics that best serve your needs and context.

What next?

If you're having trouble thinking through how the toolbox might best be used in your community, consider examining the five example use cases we present in Chapter 7. These examples walk through the use of the toolbox in several different contexts.

If you want to think through additional approaches to study and plan for the AV ecosystem, check out our conclusions in Chapter 8. References are available in Appendix D, also downloadable on the Transportation Research Board website.

Good luck!

2. Introduction

Transportation technologies play a major role in influencing the shape of the urban environment. In turn, the shape of the urban environment has a major role in influencing the use of transportation technologies. Technology is not inherently good or bad; its impact depends on how it is used. Policy can make the difference between AVs having positive or negative impacts on society and the environment, and in many cases, policies can set off a chain of path dependencies. Proactive planning and policymaking are essential to ensuring that the AV ecosystem helps communities achieve their goals.

This relationship between policymaking and outcomes has been evidenced by the ways in which new and transformative transportation technologies have influenced patterns of land use—and how land use patterns have impacted the rollout of such technologies. For example, the expansion of the U.S. highway system, primarily in the decades following World War II, drastically changed the way people move, where they live, and how land is used. Highways made car travel cheaper and easier, while contributing to suburbanization (Baum-Snow 2007). They encouraged a shift in freight transportation from railways and canals onto trucks. They also spurred economic growth in areas near roads, while contributing to economic decline in sections of inner cities adjacent to highways and in small towns far from them. This produced a cycle of continuous feedback; increased demand for driving encouraging increased investment in new highways.

Similarly, streetcar technology had a cyclical relationship with land use. Before streetcars were introduced, the physical scope of cities was largely constrained by the distance someone could commute by walking (Jucha 1979). As the first large-scale motorized transportation option affordable to individuals with working-class professions, streetcars enabled peri-urban areas to become "streetcar suburbs," offering housing in less densely populated settings but within commuting distance of jobs. This led to large expansions in urban land area, with less dense housing developed in patterns that closely tracked the linear extension of streetcar routes (Jucha 1979; Warner 1978; Xie and Levinson 2010). These newly developed areas then experienced higher land costs and shaped the location of future streetcar lines.

Another technological rollout that interacted with land use to impact social equity and environmental sustainability was the containerization of freight transportation. Container shipping radically transformed freight transportation by reducing costs, increasing the ability to monitor movement, and enabling intermodal freight, meaning transporting goods on multiple modes. The globalization of production and shipping that this enabled altered economic activity around the world (Hesse 2008). Containerization's preeminence in global freight movement enabled increasing flows of global trade. Containerization altered port locations; this required the construction of massive container terminals surrounded by acres of flat land to handle large ships and their goods, while freeing up land along waterfronts for redevelopment. Containerization also contributed to the growth of suburbanized distribution centers and warehouses designed around truck access and to the creation of truck-oriented big box stores. To learn more about these and other technologies, see Appendix B, available on the Transportation Research Board website.

Similar to these past examples, AVs are likely to interact with land use in multiple ways. Road design, combined with public investment in new infrastructure, may affect how easily and quickly AVs roll out in certain communities. For example, Liu et al. (2019) predict that AVs will operate more efficiently in communities with many roundabouts, since AV traffic could merge efficiently, with shorter queueing times (Godsmark et al. 2015). Land use will also determine the availability of space for needed AV infrastructure and technology, such as communication networks, which require equipment like cameras, radars, and lidar sensors, and which may be located on roads and other public urban spaces.

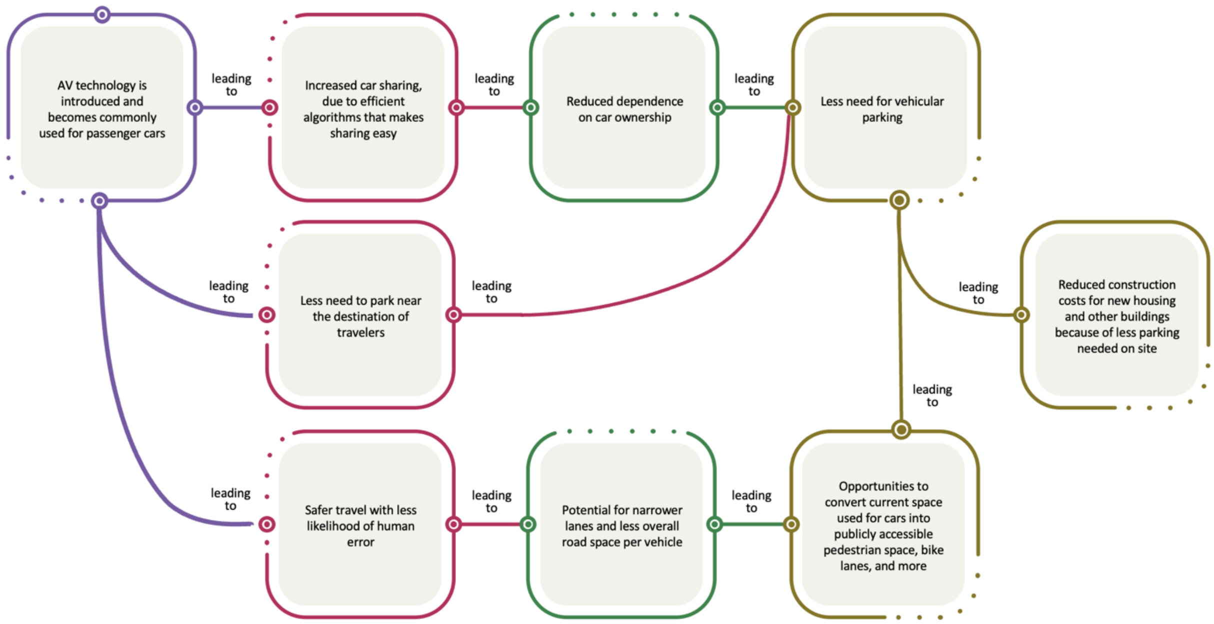
Furthermore, in the context of the fast rollout of electric vehicles, most companies investing in AVs have implied that their products will be electric. This means that the infrastructure needed for AVs will be inextricably linked to that of electric vehicles, including the location of charging stations, or even electrified roads that charge vehicles while driving. Land use may also affect the location of facilities for storing the routers and servers that AVs run on (Sudhakar 2023).

AVs are likely to then go on to further influence land uses. Some scholars predict that AVs could reduce car ownership, mainly because their more efficient algorithms could facilitate car sharing—although this phenomenon did not occur with ride hailing, despite being predicted (Cohen and Hopkins 2019; Grush and Niles 2016; Othman 2022; Zhang 2017). AVs may also reduce parking demand, with one estimate pointing to up to 60 percent of parking area being freed up, and a consequent 20 to 25 percent reduction in the cost of developing multifamily housing due to not having to include as many parking spaces (Riggs, Appleyard, and Johnson 2020).[1] AVs may free up urban space through more efficient road use. Roads are designed to account for human error, but AVs could—in theory—drive safely in narrower lanes and stay closer to other vehicles, reducing traffic congestion and the need for road space overall (Friedrich 2016; Securing America's Future Energy 2018; Wagner 2016). Congestion could also be ameliorated by AVs thanks to their built-in traffic monitoring systems (Atiyeh 2012). The public space that was previously dedicated to parking or driving could then be used for a myriad of purposes, such as transit or bike lanes, expanded sidewalks, parklets, retail, or restaurants. Or this land could also be used for housing, increasing the size or number of residential units per lot.

Another consistent prediction in the scholarly literature, however, is that AVs will increase VMT, even with traffic monitoring systems and a shrinking overall number of cars (Burns et al. 2012; Fagnant and Kockelman 2015; International Transport Forum 2015). AVs may motivate people or businesses to locate further from urban centers to lower their land costs. This could increase the population in outer suburbs and rural regions (Gelauff et al. 2017; Kim et al. 2015; Meyer et al. 2017), particularly given the post-pandemic movement toward working from home. One model estimates that AV service could lead to a 4 percent population reduction in inner cities and a 3 percent population increase in outer suburbs (Thakur et al. 2016).

In Figure 2.1, we illustrate potential ways that AV technology may relate to land use over time, Based on our review of available scholarship.

Figure 2.1 Potential relationships between AV technology and land use



Perhaps the most important thing to keep in mind when designing land use policy and practice to prevent these negative outcomes is that each community is different, and as such, there is no one-size-fits-all approach. Any policy decision, whether or not related to AVs and land use, should be grounded in extensive and meaningful engagement with groups historically marginalized or excluded from decision-making processes. These groups may include people with low incomes, renters, people who identify as LGBTQ+, people with disabilities, and people of color. While this toolbox provides insights into engagement methods and best practices, it is a complement to more detailed guides to community engagement that users should also consider using in their planning efforts.[2]

Meaningful community engagement necessitates a deep understanding of the needs of historically oppressed groups before decisions are even proposed. This can be done through comprehensive planning, but should also be undertaken on a regular basis even when planning processes are complete. Fostering trust and ongoing partnership with communities is necessary since many of the communities that have experienced the most oppression and are most excluded have lost trust with their local governments over time.

Although community engagement typically plays a role in local policymaking, it often disproportionately involves promoting the views of individuals with higher incomes and education levels, who are more likely to have the time and capacity to attend public events.[3] This can inadvertently perpetuate exclusionary practices rather than fostering equity. Therefore, designing community engagement to be accessible to people who have been excluded, such as by providing translation, childcare or selecting venues that are compliant with the Americans with Disabilities Act, is of the utmost importance. For specific recommendations on enhancing equity in engagement processes, refer to our community engagement policy fact sheet. In addition, planners and policymakers can foster a deeper culture of equity within their land use and transportation systems in the following ways (Stacy et al. 2022):

- **Create a community equity council to weigh in on reform decisions.** Such councils consist of residents and leaders from neighborhoods with low incomes and communities of color that have limited access to opportunity and who have historically been harmed by land use policies. Members of such groups should be given decisionmaking power and be paid for their time.

- **Create a mobility equity framework or transportation justice framework, with the process led by the equity council.** A mobility or transportation justice framework is an internal framework for centering transportation justice and equity in everything an agency does. Mobility frameworks include major guiding policies for the agency, including for its strategic plan, service guidelines, and climate action plans.

- **Undertake internal efforts to foster an antiracist culture**, emphasizing equity in hiring, board representation, and strategic planning, while acknowledging and rectifying past inequities.

- **Foster collaboration** across land use, transportation, and community development to promote transit-oriented development and equitable access to opportunities, incorporating community input.

- **Utilize data** to target investments and improvements in areas that will most benefit marginalized populations, addressing transportation needs for work, shopping, healthcare, and community activities.

3. Identify your community typology

This toolbox details how the rollout of the AV ecosystem could impact land use patterns—and how land use patterns could shape the deployment of these vehicles. There is no one-size-fits-all approach to ensuring that AVs contribute to socially equitable and environmentally sustainable outcomes that promote quality of life for all. States, localities, and neighborhoods differ in their spatial forms, political environments, budgetary resources, and staff capacity. They also vary in terms of their governance levers, such as their zoning policies, building code rules, budget allocations, and street designs—some of which are also mediated by state government policy. This means that each community is best served a tailored policy approach shaped by its context.

We developed a typology of communities to help policymakers and other stakeholders identify what kind of community they are working in, the likely impacts of AVs on their communities, and what approaches would be feasible and effective at encouraging an AV rollout that is sustainable and equitable. To learn more about how we developed the typology, see Appendix C, available on the Transportation Research Board website.

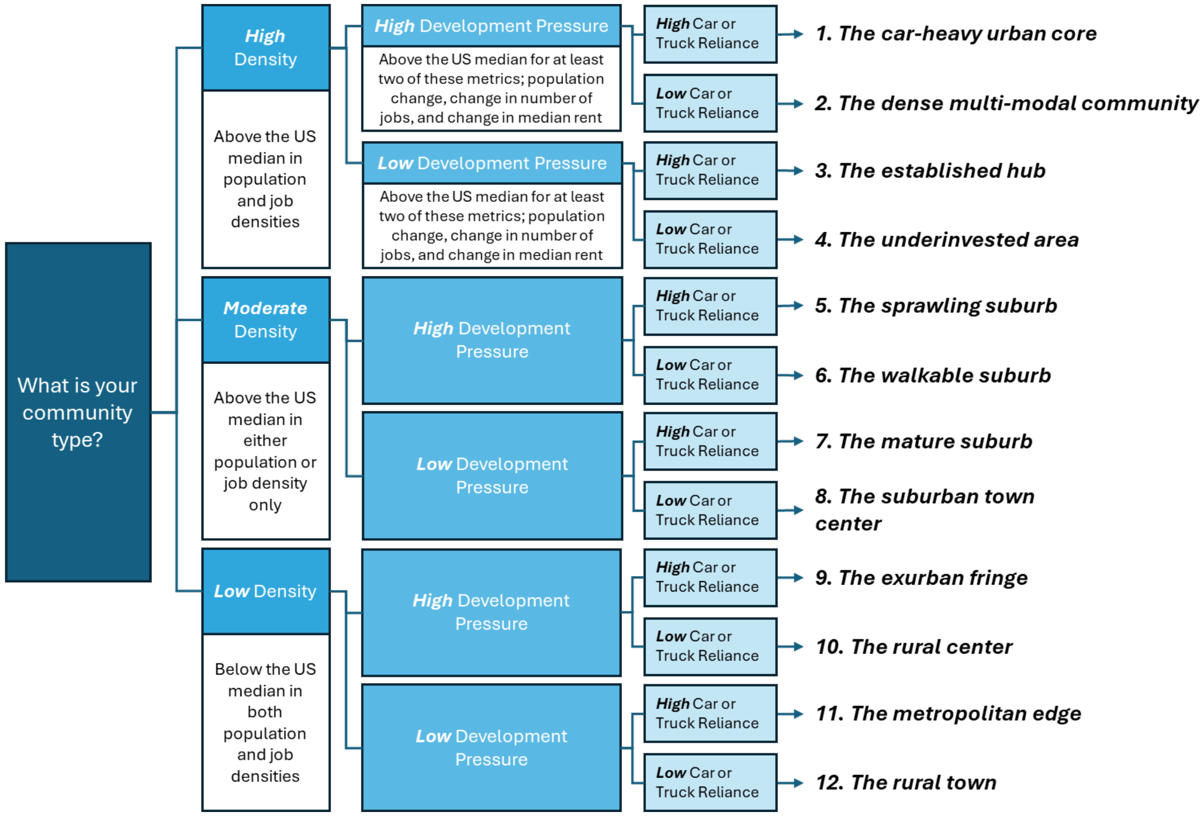
The purpose of this community typology is to make it easier for a community (which can mean policymakers, staff, community members, and interested residents) to get started with planning for AVs. However, even if a particular policy lever is not included in the recommended policy levers for a particular community type, people can still employ these policy levers if they feel that it serves the needs of their community. Everyone using this toolbox is encouraged to use the policy levers creatively regardless of their community type. For example, even if there is low development pressure in a specific community, community members may still find tools suggested for high development pressure areas useful to help them to improve the quality of life for their residents. When a community takes a baby step towards changing its path dependencies, it may still represent progress in achieving revolutionary changes for the community in the long run. In other words, your current type of community should not prevent you from dreaming big.

We have developed a series of prototypical community types, defined by their characteristics. We think that the following three measures, which we describe in further detail later in this chapter, are most relevant to how AVs and land use will interact in a given community:

- **Community density**
- **Development pressure**
- **Car and truck reliance**

To use this chapter, first consult the matrix in Figure 3.1 to identify one of the 12 community types that might apply to you. If you want to learn more about the measures we have developed to differentiate communities, read on in this chapter. Otherwise, feel free to move on to Chapter 4 to examine the fact sheet for your community type.

Figure 3.1 Identifying your community type



Note: A community has a high car or truck reliance when it is above the US median for at least two of the following metrics: car ownership rate, car commuters, and rail freight miles per capita. Otherwise, it should be considered having low car or truck reliance.

You should consider a "community type" to be applicable to any scale, from an entire state to a specific neighborhood. When identifying what type of community you will be planning for, it is important to consider surrounding communities or jurisdictions to determine what scale is appropriate for planning purposes. For example, you may be trying to plan for a low-density community that has experienced population loss but that is well connected through transit to a booming urban core, and these are all within the same city. In that case, consider reviewing tools and recommendations that would apply to an entire city or metropolitan area in order to get a full picture of the planning landscape in which a smaller community sits. Community types can differ within a single metropolitan region or city and AV policies should not be implemented without taking adjacent communities and the broader region into account. Local or community-oriented AV policies have to coalesce in order to ensure seamless travel and interoperability among communities and to ensure that no harm is done to nearby communities.

Measure 1: Community Density

Why does density matter for the AV ecosystem?

Density means the concentration of people and uses located in a particular area; density can be defined in terms of population per area. AV rollout is likely to be influenced by community density, and vice-versa. The rollout of streetcars in the late 19th and early 20th centuries, for example, was associated with the creation of mid-rise suburban neighborhoods ringing cities around the United States. Recent bike sharing systems, meanwhile, have attracted significantly more users in the densest neighborhoods than those with lower densities. AVs may have different impacts on changing land uses, depending on neighborhood density, and neighborhoods with varying densities may adopt different forms of AVs.

How is density relevant to passenger movement?

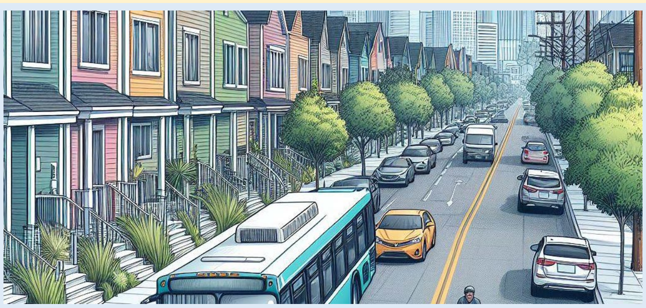
Density is relevant to passenger movement because denser places may entail shorter travel distances and because less dense places often rely more heavily on private cars vs. other modes of transportation.

How is density relevant to freight services?

In dense neighborhoods, small-scale robotic AVs may be useful for distributing packages. AV-served freight distribution facilities may become common in neighborhoods with low levels of density, where they can be placed easily.

Low density community

Such communities feature single-family homes spaced relatively far from one another. Many low-density communities are rural or on the edge of metropolitan areas. Such communities may be complemented by warehousing or manufacturing employment.



Medium density community

Such communities constitute most of US urban areas. They are typically suburban in form, with a mix of single-family homes, duplexes, and other small- to mid-rise buildings. They may be complemented by employment in office parks.

High density community

Such communities feature large buildings and many residents and/or workers on a small amount of land. Manufacturing or industrial employment uses are less common in this type of area because of the difficulty accessing them by truck.

Source: Images generated by Microsoft Bing AI.

Does your community have high or low density?

We encourage you to use your best judgement to answer this question. If you want to compare your community with others throughout the country, you can use two metrics: (A) population density, defined as the weighted number of residents per square mile and (B) job density, defined as the number of jobs per square mile. To calculate each metric, you can use free data from the US Census Bureau, like the American Community Survey 5-year estimates.

Table 3.1 below offers more details on how cities and towns (Census places) across the United States stack up in terms of their density. Based on Table 3.1, if your community is above the median for both metrics, then you may consider your community as having "high density." Denver, Colorado is an example of such a city. If your community is above the median only for one of the two metrics, then it can be considered as having "medium density," like Scottsdale, Arizona is (below the median for job density but above the median for population density). Finally, if your community is below the median for both metrics, then you can consider this place as having "low density," like Huntsville, Alabama.

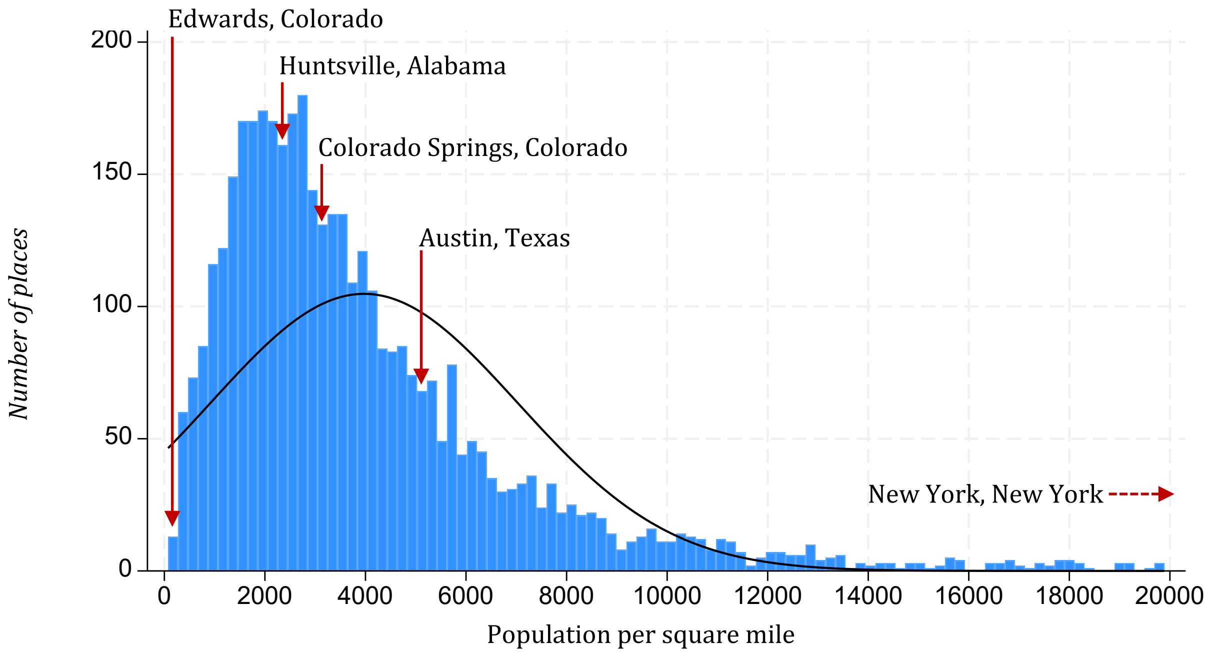
For some these calculations we used a weighted density measure. For Metric A, we calculated population density at the census tract level, and we then aggregated these values for each place (municipality), weighted by the population in each tract. This weighted measure reflects the density of the neighborhood where the typical person lives in the community. (We did not use weighted density for Metric B, job density.)

Take the following example of a place that is comprised of two census tracts, one with 9,000 people and a density of 1,000 people per square mile, and another tract with only 1,000 people but a density of 100 people per square mile. The weighted density for the whole place is 1,000*0.9 + 100*0.1 = 910 people per square mile, since 90 percent of the people live in the first tract and 10 percent live in the second tract.

We use weighted density to account for places that may have a large area but in which the population may still be concentrated in a small area within. For example, with a simple population density calculation, Anchorage, Alaska would appear as one of the least dense places in the US, due to its massive surface area. However, most of Anchorage's population is concentrated in a smaller area, which is more relevant for planning purposes.

Table 3.1 Development pressure metrics

Metric A: Population density (weighted by tract population)				
How to calculate this metric: 2021 population / 2021 square miles, weighted by tract population				
Distribution of places by population density				



Low end: 75.4 *Example*: Edwards, Colorado	*1st quartile upper limit:* 1,944 *Example*: Huntsville, Alabama	*Median (the typical city):* 3,164 *Example*: Colorado Springs, Colorado	*3rd quartile upper limit:* 5,153 *Example*: Austin, Texas	*High end:* 65,142 *Example*: New York, New York (not shown)

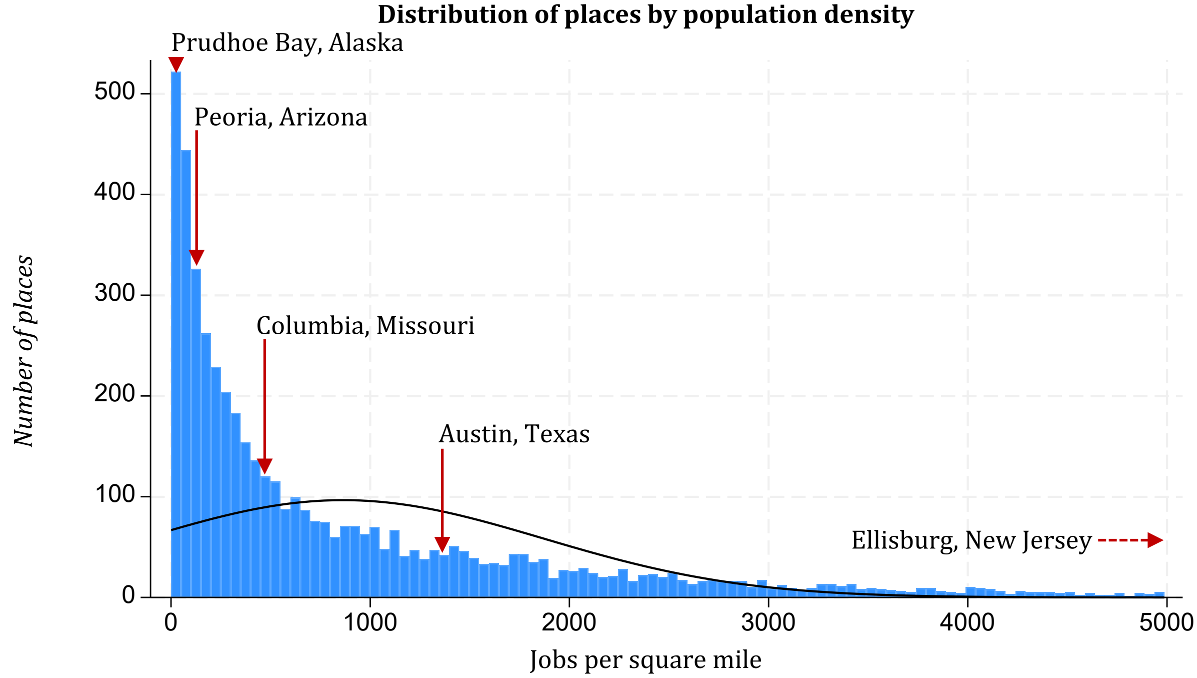
Source: U.S. Census American Community Survey 5-year data at the place (municipal) and census tract levels, 2021. Data can be downloaded at *https://data.census.gov/*

Notes: Histograms are limited in their horizontal axes to illustrate the frequency distribution more clearly. Hence, the full spread of these values is not captured by the charts, and cities like New York are not shown.

Metric B: Job density

How to calculate this metric: 2019 employment / 2019 square miles

Distribution of places by population density



Low end: 1 *Example*: Prudhoe Bay, Alaska	*1st quartile upper limit:* 143 *Example*: Peoria, Arizona	*Median (the typical city):* 470 *Example*: Columbia, Missouri	*3rd quartile upper limit:* 1,366 *Example*: Austin, Texas	*High end:* 28,471 *Example*: Ellisburg, New Jersey (not shown)

Source of data for metric B: Longitudinal Employer-Household Dynamics, at the census tract level, 2016 (we used 2016 to obtain data for all census tracts in the US but you may be able to use a more recent year for the assessment of your own community). Data can be downloaded at https://onthemap.ces.census.gov/

Notes: In this case, we do not use a weighted measure of density, but evaluating job density with a weighted measure is also an option.

Measure 2: Development Pressure in the Community

Why does development pressure matter for the AV ecosystem?

Development pressure refers to the degree to which a community is experiencing the need to expand its infrastructure and public services—such as those related to housing, transportation, utilities, healthcare, and public safety—given an increase in population and/or employment, or associated changes, such as growth in income and housing values. A community experiencing high development pressure and thus actively building new infrastructure may design some of that new infrastructure with AVs in mind. For example, new housing developments may be built with fewer parking spaces if AVs reduce the need for them and land-use regulations are modified accordingly. Conversely, lower development pressure may correlate with depressed economic activity and wages, which may slow the rollout of AVs in that community.

How is development pressure relevant to passenger movement?

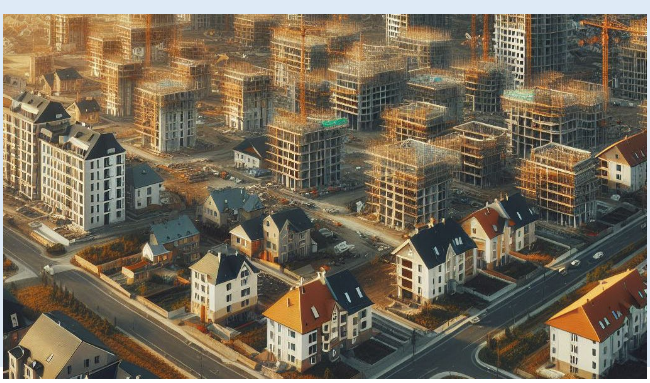
Places with high development pressure experience rapid growth, which in turn increases demand for higher passenger movement capacity—but all that growth may slow movement due to congestion. Development pressure also provides more opportunities for new infrastructure to be adapted to new technologies.

How is development pressure relevant to freight services?

A community with high development pressure may experience growing demand for goods that need to be delivered, even as rising land values push existing freight-related facilities further from the city center. Conversely, a shrinking community may find itself with unused freight infrastructure that could be repurposed.

Low development pressure community

This kind of community may be experiencing population loss, for example if it historically specialized in an industry that is declining or moving elsewhere. This kind of community may have lots of vacant lots and aging infrastructure. While the cost of living is low, wages and economic opportunities may also be low or scarce.



High development pressure community

These communities may experience rapid population growth due to large new employment centers or booming economic sectors establishing in their region. These places may need to develop new infrastructure and increase the supply of housing to satisfy a growing demand. Expanding the capacity for passenger and freight transportation becomes critical for these communities.

Source: Images generated by Microsoft Bing AI.

Does your community have high or low development pressure?

We encourage you to use your best judgement to answer this question. If you want to compare your community with others throughout the country, we propose that you use a combination of three metrics: (A) change in population, (B) change in the number of jobs, and (C) change in median rent. You can use data from the US Census Bureau, like the American Community Survey 5-year estimates. If you have access to more recent rental data from a source such as CoStar or MLS, you can use those,. Note, however, that these data are skewed toward multifamily properties and higher-cost units, so using a combination of ACS and proprietary data sets, along with any other rental registry or other local data, will provide the most complete picture.

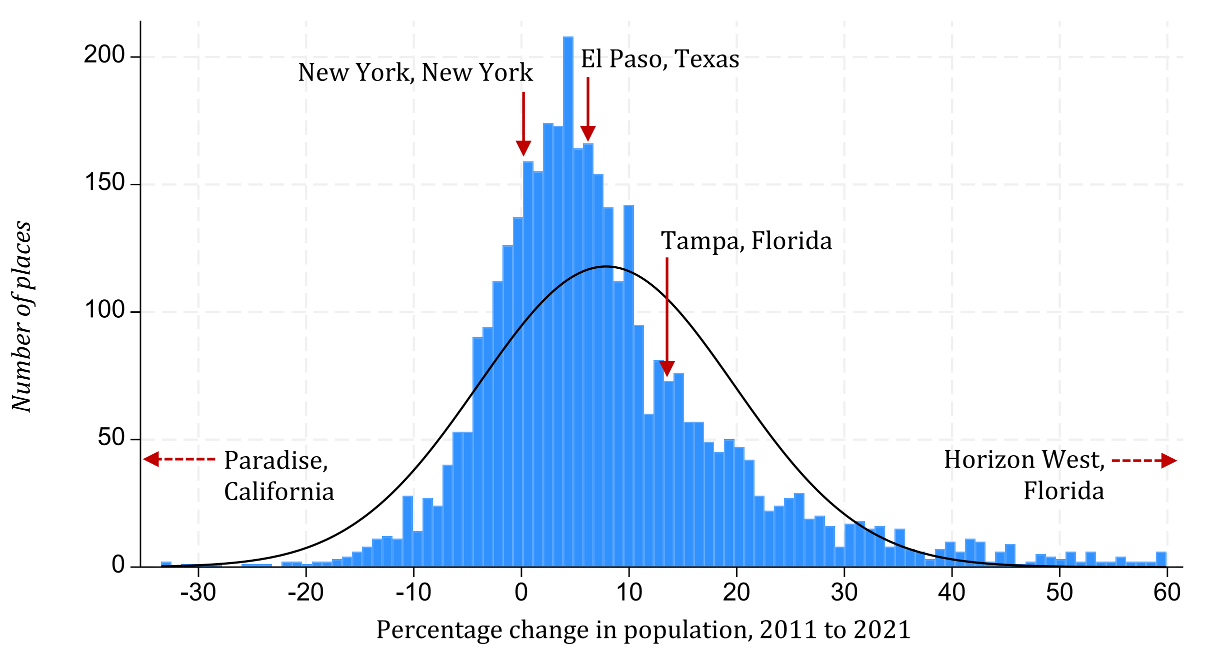
Table 3.2 below compares U.S. cities and towns (Census places) on these three metrics. If your community is above the median for two or more of these metrics, then it likely has "high development pressure." An example is Phoenix, Arizona, which is above the median for all the three metrics. If your community is above the median for one or none of the metrics, then it likely has "low development pressure." An example is Memphis, Tennessee, which is below the median for all three metrics.

Table 3.2 Development pressure metrics

Metric A: Population change

How to calculate this metric: (2021 population – 2011 population) / 2011 population

Distribution of places by population change



Low end: −71% *Example*: Paradise, California (not shown)	*1st quartile upper limit: 0.7%* *Example*: New York, New York	*Median (the typical city): 6%* *Example*: El Paso, Texas	*3rd quartile upper limit: 13%* *Example*: Tampa, Florida	*High end:* 363% *Example*: Horizon West, Florida (not shown)

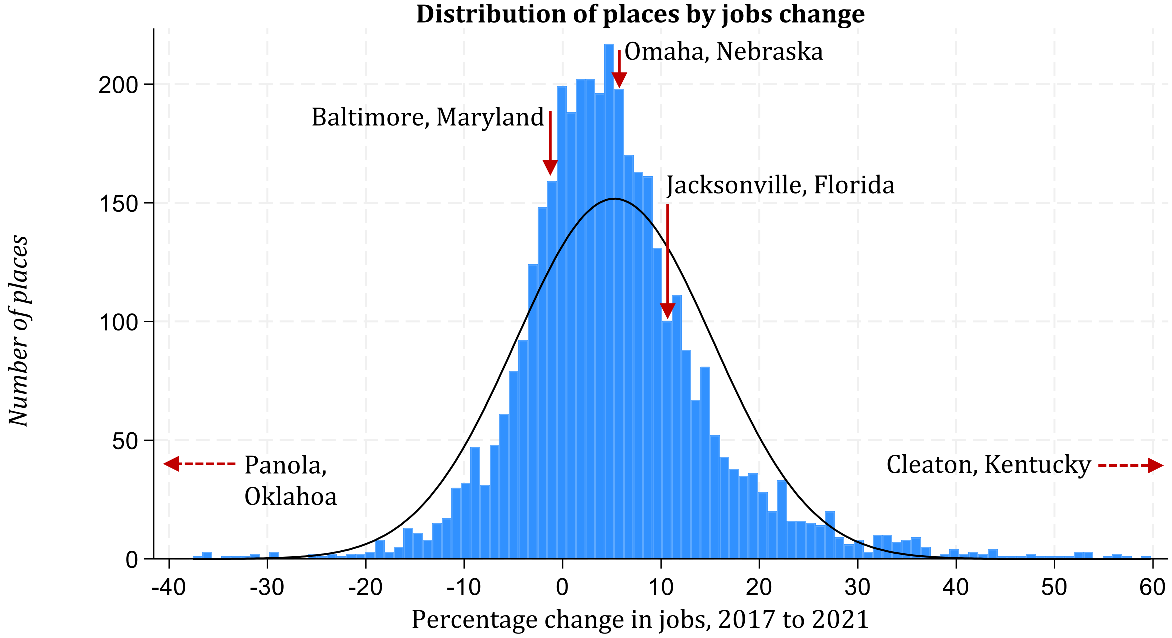
Source: U.S. Census American Community Survey 5-year data at the place (municipal) level, 2011 and 2021. Data can be downloaded at https://data.census.gov/

Notes: Histograms have been limited in their horizontal axes to illustrate the frequency distribution more clearly. Hence, the full spread of these values is not captured by the charts. Paradise, California, at the low end of the data, lost more than two thirds of its population in ten years due to wildfires in 2018.[4]

Metric B: Jobs change

How to calculate this metric: (2021 jobs – 2017 jobs) / 2017 jobs

Distribution of places by jobs change



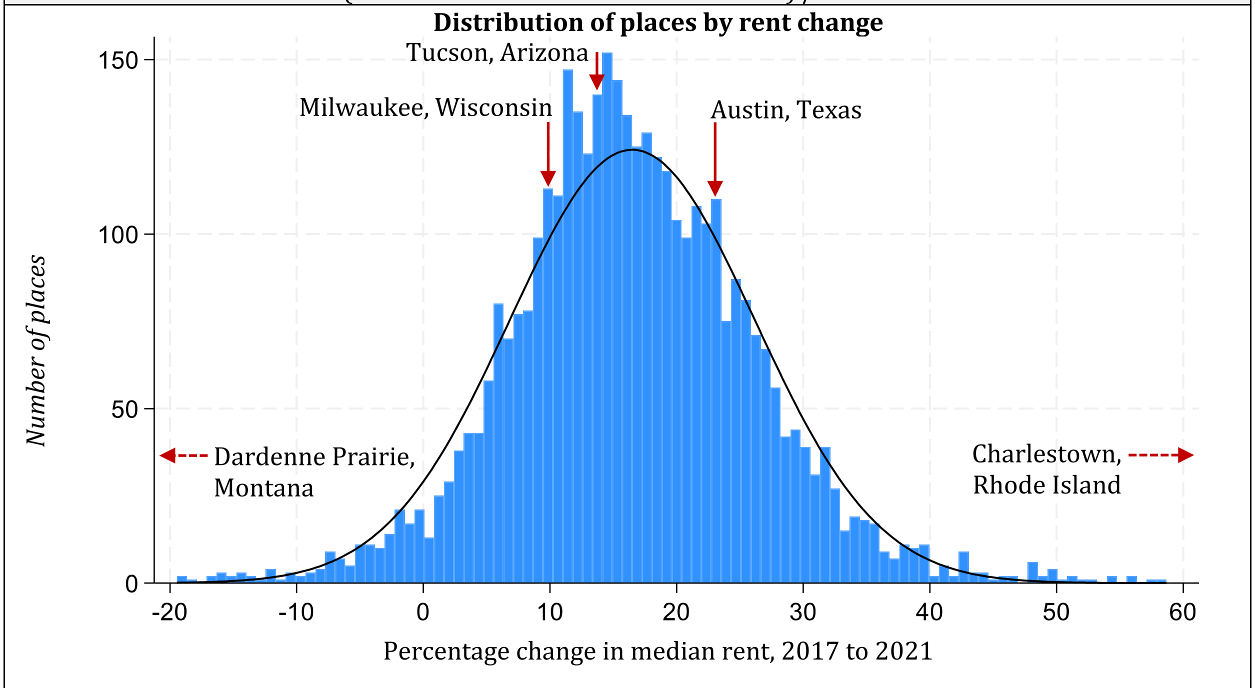
Low end: –100% *Example*: Panola, Oklahoma (not shown)	*1st quartile upper limit: –1%* *Example*: Baltimore, Maryland	*Median (the typical city): 5%* *Example*: Omaha, Nebraska	*3rd quartile upper limit:* 10% *Example*: Jacksonville, Florida	*High end: 1,100%* *Example*: Cleaton, Kentucky (not shown)

Source: U.S. Census American Community Survey 5-year data at the place (municipal) level, 2011 and 2021. Data can be downloaded at *https://data.census.gov/*

Notes: We use 2017 as the base year instead of 2011 because the American Community Survey 5-year estimate does not provide total jobs for 2011. An alternative data source for change in employment can be the Local Area Unemployment Statistics program, run by the U.S. Bureau of Labor Statistics: *https://www.bls.gov/lau/data.htm*

Metric C: Rent change

How to calculate this metric: (2021 median rent – 2017 median rent) / 2017 median rent



Low end: −46% *Example*: Dardenne Prairie, Montana (not shown)	*1st quartile upper limit: 10%* *Example*: Milwaukee, Wisconsin	*Median (the typical city): 13%* *Example*: Tucson, Arizona	*3rd quartile upper limit: 23%* *Example*: Austin, Texas	*High end: 102%* *Example*: Charlestown, Rhode Island (not shown)

Source: U.S. Census American Community Survey 5-year data at the place (municipal) level, 2011 and 2021. Data can be downloaded at *https://data.census.gov/*

Notes: We use 2017 as the base year instead of 2011 because the American Community Survey 5-year estimate does not provide median rent for 2011. An alternative data source for change in rent or housing costs can be Zillow's Home Value Index, "A measure of the typical home value and market changes across a given region and housing type." It can be accessed at: *https://www.zillow.com/research/data/*

Measure 3: Car/Truck Reliance

Why does car and/or truck reliance matter for the AV ecosystem?

Car or truck reliance means that a high share of people or goods move via private motorized vehicles or trucks, respectively, as opposed to public transit, non-motorized vehicles, or rail. While high car usage could reflect demand to drive, we use the term reliance here to emphasize that in many cases, people do not have choices beyond car use. Higher car or truck reliance in a community may make it more likely to rapidly embrace AVs for passengers or freight transportation because the people, industries, and infrastructure are already oriented towards private motorized vehicles. Conversely, communities with low reliance on cars or trucks may experience a slower AV roll out, as residents may not be as interested in private vehicle trips, or its infrastructure may prioritize rail. (Communities with more active transit systems may more readily adopt AV transit options.) Reliance on cars or trucks also influences land use (and the other way around) by designating land near highways for industrial uses, or by requiring lots of parking in new real estate developments.

How is car reliance relevant to passenger movement?

High reliance on cars means that a greater share of people travel by private vehicle and fewer use public transit, bikes, walking, or other forms of non-motorized transportation. Car reliance can mean substantial highway congestion and lack of alternatives to get around.

How is truck reliance relevant to freight services?

Communities heavily reliant on trucks move freight in this fashion, as opposed to using alternatives like rail or ship for long-distance shipping, and cargo bike for local shipping. Truck reliance can mean roadways are packed with tractor-trailers delivering goods.

Community with low reliance on cars or trucks

These communities tend to be denser, which optimizes the use of shared and active modes of transportation due to reduced distances. They tend to be larger urban centers with enough people to justify sizable investments in public transit. In terms of truck reliance, they could also be communities with connections to major rail or maritime freight routes.

Community with high reliance on cars and trucks

These communities tend to be less dense, with car and truck infrastructure, such as highways and street parking, dominating the built environment. Many of these communities could be suburban or rural, where few potential users and long distances discourage investment in public transit.

Source: Images generated by Microsoft Bing AI.

Does your community have high or low car and truck reliance?

We encourage you to use your best judgement to answer this question. If you want to compare your community with others throughout the country, you can approximate car and truck reliance using three metrics: (A) car ownership rate (percent of occupied housing units with at least one vehicle available), (B) car commuter rate (percent of workers aged 16 years and older that commuted to work by driving alone), and (C) rail freight miles per capita.

We leverage this measure of rail capacity as a counter to truck reliance, since places will be more reliant on trucks if there is no rail available. Proprietary sources of data, if available, can also help communities better understand their rail and commercial vehicle demand, such as Geotab, INRIX, Bentley, and Replica. Proprietary sources for rail would be particularly useful, since the Bureau of Transportation Statistics data for rail freight miles per capita (which we use for Measure C) includes pass-through miles, which are not likely to affect the communities they are passing through in the same way as measures of tons of freight by origin and destination or other similar measures. And, given the emergence of e-commerce, there should be as much emphasis on medium-duty vehicle congestion (e.g., parcel delivery vans), as there is on heavy-duty vehicles (e.g., tractor trailers). When possible, these types of supplemental datasets should be included in a community's assessment of its current car reliance.

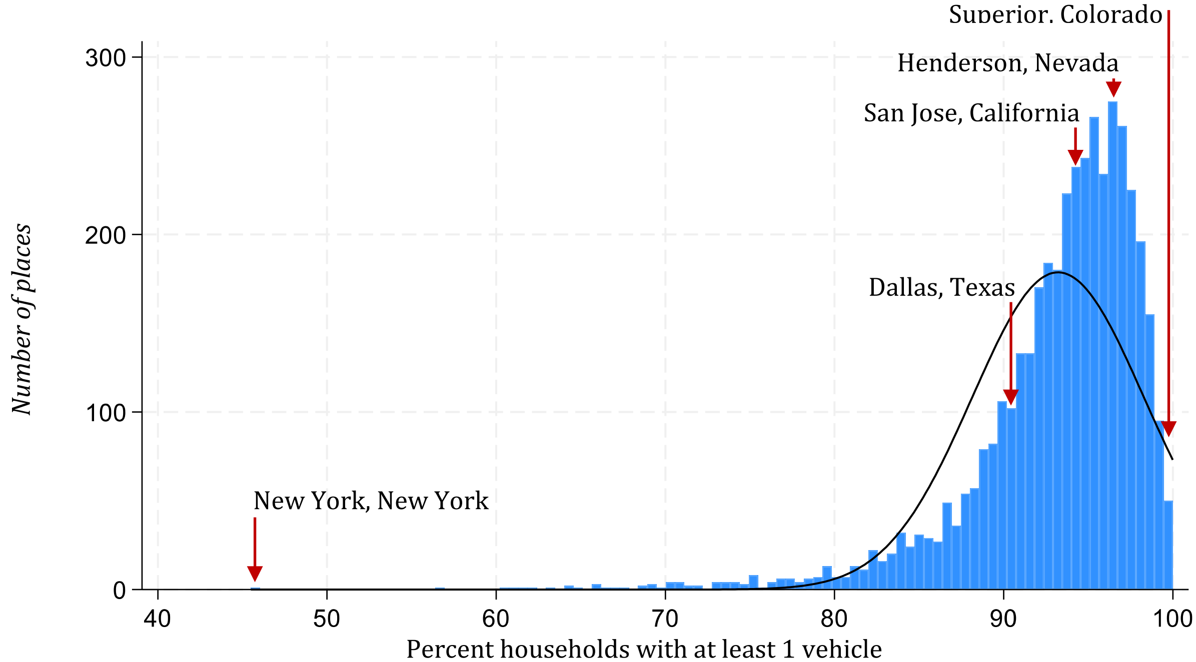
Table 3.3 compares U.S. cities and towns on these three metrics. If your community is above the median for two or more of these metrics, then you may consider your community as having "high reliance on cars/trucks." Examples include Arlington and Fort Worth, Texas, which are above the mean for all the three metrics. If your community is above the median for one or fewer metrics only, it likely has "low car/truck reliance." An example is Fort Lauderdale, Florida, which is below the median for all three metrics.

Table 3.3 Car/Truck Reliance Metrics

Metric A: Car ownership rate

How to calculate this metric: Percent of occupied housing units with at least 1 vehicle available

Distribution of places by car ownership rate



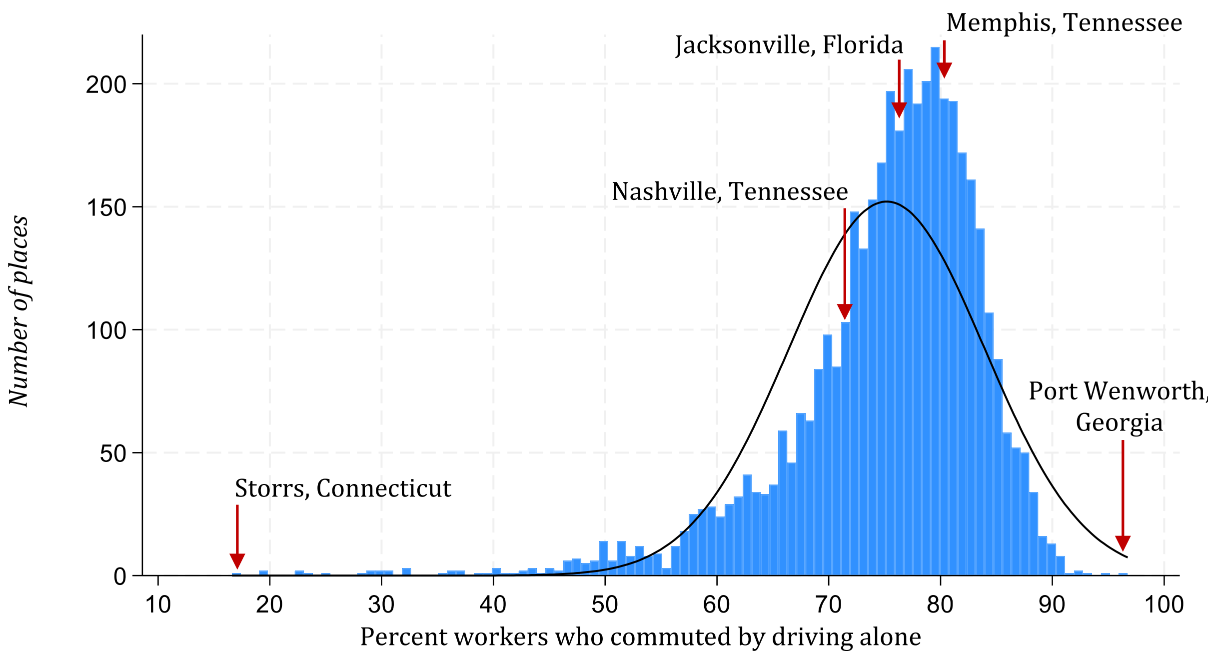
Low end: 45% *Example*: New York, New York	*1st quartile upper limit: 91%* *Example*: Dallas, Texas	*Median (the typical city): 94%* *Example*: San Jose, California	*3rd quartile upper limit: 97%* *Example*: Henderson, Nevada	*High end: 100%* *Example*: Superior, Colorado

Source: U.S. Census American Community Survey 5-year data at the place (municipal), 2021. Data can be downloaded at https://data.census.gov/

Metric B: Car commuter rate

How to calculate this metric: Percent of workers who commuted by driving alone

Distribution of places by car commuting rate



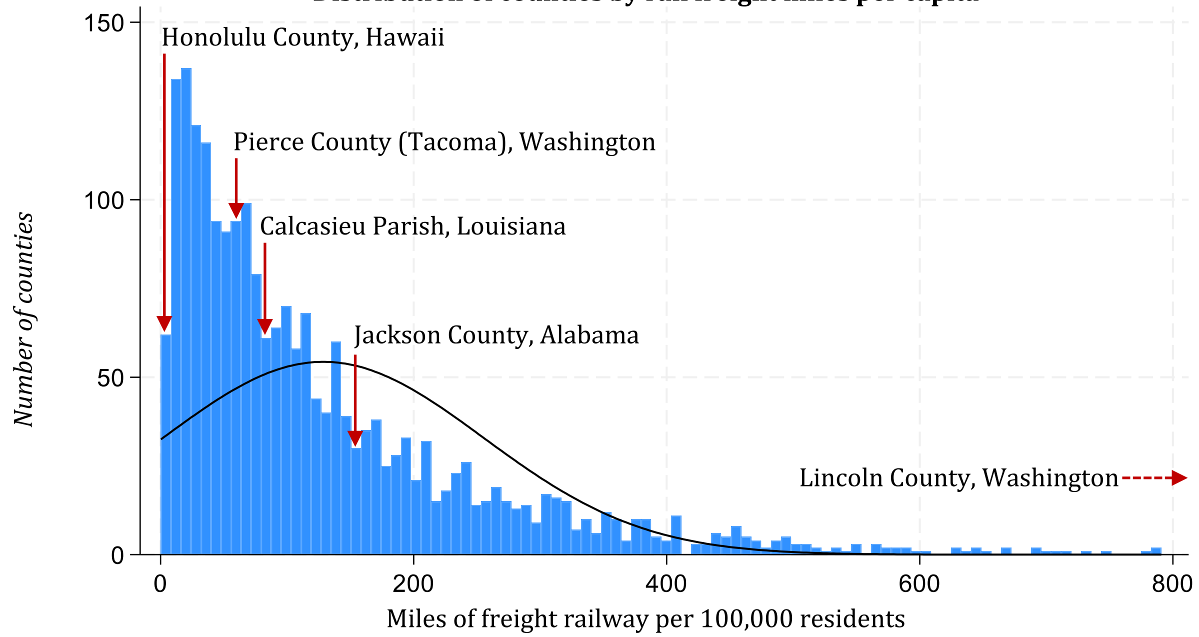
Low end: 17% *Example*: Storrs, Connecticut	*1st quartile upper limit: 72%* *Example*: Nashville, Tennessee	*Median (the typical city): 77%* *Example*: Jacksonville, Florida	*3rd quartile upper limit: 81%* *Example*: Memphis, Tennessee	*High end: 97%* *Example*: Port Wentworth, Georgia

Source: U.S. Census American Community Survey 5-year data at the place (municipal), 2021. Data can be downloaded at https://data.census.gov/

Metric C: Rail freight miles per capita

How to calculate this metric: Rail freight miles per 100,000 residents

Distribution of counties by rail freight miles per capita



Low end: 0 *Example*: Honolulu County, Hawaii	*1st quartile upper limit: 23* *Example*: Pierce County (Tacoma), Washington	*Median (the typical city): 71* *Example*: Calcasieu Parish (Lake Charles), Louisiana	*3rd quartile upper limit: 160* *Example*: Jackson County, Alabama	*High end: 1,481* *Example*: Lincoln County, Washington (not shown)

Source: US Bureau of Transportation Statistics, at the county level.

Notes: The chart does not include information about counties with zero miles of freight railways because of the large number of counties without freight railways.

Linking the measures from the community typologies with expected impacts of automated vehicles

Using the elements of the typology, we review the scholarship and the historical case studies to analyze how the AV ecosystem might impact each type of community. We consider five outcomes that are likely to be particularly important in affecting how AV roll out affects community land use, and vice-versa:

- *Car ownership*: The individual ownership of AVs by households, as opposed to firms operating ride hailing or other transportation services;
- *Car use*: Vehicle miles traveled (VMT) by AVs;
- *Capacity to change built environment*: In terms of financial, regulatory, and legal capacity by public and private actors, and in terms of land availability to develop new infrastructure;
- *Residential movement*: Patterns of residents moving to, from, and within a community; and
- *Freight*: Both in terms of the use of trucks for freight, as opposed to rail, cargo ships, and cargo bikes, and the use of motorized vehicles for product delivery.

We describe these impacts in detail in the appendix, available on the Transportation Research Board website, by using previous scholarship to estimate impacts. Our premises when generating predictions include:

- Density is linked to average trip distances and availability of undeveloped space (higher densities likely result in lower average trip distances and less undeveloped space available for new construction).
- Development pressure is linked to resident incomes and wages. For example, communities with high economic activity and higher-paid jobs will attract more people and thus experience higher development pressure.
- Areas with higher car reliance have less public transportation or alternative modes available.

We describe the impacts in more detail in the fact sheets related to each of the community types in the community fact sheets section that follows.

Creating a typology of communities based on density, development pressure, and car/truck reliance

We build out 12 community types in Table 3.4, created by intersecting the three measures of community typologies described in the previous section.

Table 3.4 Matrix of Community Types

Density	**Population change or development pressure**	**Car and truck reliance**	
		High or moderate car and truck reliance	**Low car and truck reliance**
High density	**High pressure**	1—The car-heavy urban core	2—The dense multi-modal community
	Low pressure	3—The established hub	4—The underinvested area
Moderate density	**High pressure**	5—The sprawling suburb	6—The walkable suburb
	Low pressure	7—The mature suburb	8—The suburban town center
Low density	**High pressure**	9—The exurban fringe	10—The rural center
	Low pressure	11—The metropolitan edge	12—The rural town

These community types could describe either a full jurisdiction (e.g., county or city) or to a part of that jurisdiction. For example, a single county might include neighborhoods that match the descriptions of types 1, 4, and 7.

We illustrate how the typology could be applied across different parts of a region in Figure 3.2. We then provide details about each of the typologies in fact sheets in Chapter 4.

Figure 3.2 The community types, displayed across a prototypical region

Over time, communities might transform from one type to another due to demographic or economic trends, or because of intentional decisions by local policymakers to foster that change. A community's political leadership, for example, could choose to implement policies that would encourage densification of residential housing and the reduction of car dependence over time. Geography can also play a role: for example, a low-density suburb could experience high development pressure because it is located near a large, growing city, eventually increasing its density and decreasing its car reliance. This is also an example of how elements of the typology might interact with one another.

Limitations of the Community Typology

The toolbox's typology is a simplification. Every community is unique and has characteristics that make it difficult to directly compare with another place. Moreover, the typology is based on binary or ternary metrics which are also simplifications. In reality, communities are more likely to stand somewhere on a spectrum than at one end or another. Finally, a community' characteristics may not be their desired characteristics, especially when it comes to advancing equity and sustainability. Some communities may believe that they are moving in a particular direction or hope to implement policies that encourage that movement. As such, communities may want to locate themselves in the typology based on both where they stand today and where they want to be in the future.

Other characteristics of communities may play a role in mediating the relationships between the rollout of the AV ecosystem and land use. Community demographics, geographic environment, resident incomes, and political environment may influence these relationships, and could be part of planning for AVs. And, a community's geography and relative location within a metropolitan area should be considered when preparing for AVs. Communities may need to work across jurisdictions to address challenges at the metropolitan scale.

4. Learn about your community's features, expected impacts of AVs, and potential policy solutions

In this section, we provide fact sheets for each of the community types, with policy concepts you can leverage to guide the interactions of the AV ecosystem with land use. Toolbox readers may consider leveraging the user tool in Chapter 3 of the toolbox to identify which community type and policy area is most of interest.

Below are links to each of the community types:

1. The car-heavy urban core
2. The dense multi-modal community
3. The established hub
4. The underinvested area
5. The sprawling suburb
6. The walkable suburb
7. The mature suburb
8. The suburban town center
9. The exurban fringe
10. The rural center
11. The metropolitan edge
12. The rural town

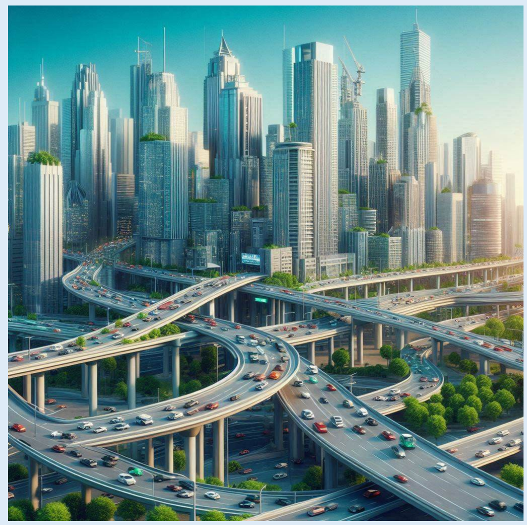
Community Type 1: The Car-Heavy Urban Core

Jump to the guide

What are the features of this community type?

This type of community features **high population and employment densities**, **a growing population, high development pressure**, and **high reliance on cars and trucks**. This community type is common in quickly growing areas of the world, where towers line highways, and some US cities and neighborhoods also feature these characteristics. In these communities, both passengers and freight currently rely on travel by road to complete almost all trips. As an example, parts of Arlington, Texas could be classified as this community type.

What might this community look like?



Source: Image generated by Microsoft Bing AI.

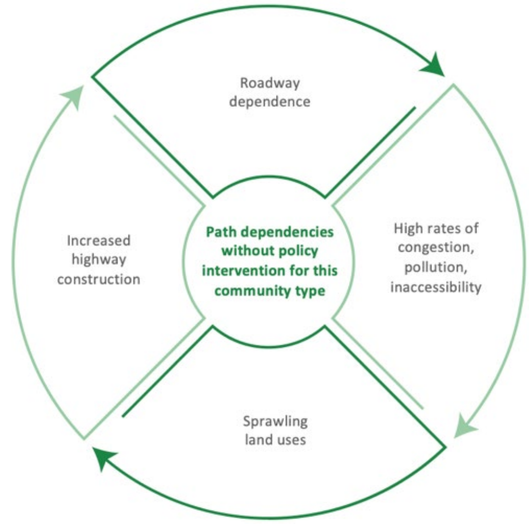
Fast growth exposes this type of community to **a number of potential problems**: increasing air pollution and roadway congestion; declining levels of accessibility to employment and other needs; and inequities in access to opportunity generated by the high costs of owning and maintaining a car.

Our historical case studies, available on the Transportation Research Board website, suggest several challenges this type of community may face in achieving a more equitable, environmentally sustainable future. Reliance on cars and trucks as the primary means to travel tends to be self-reinforcing; congestion encourages more road building, which cements roadways as the key transportation links between residences, jobs, and other local services. In the meantime, people who cannot afford to drive are left behind—and pollution from automobiles affects all residents—with people of color and less-wealthy communities often suffering the most. But, lacking an alternative, car and truck-based travel remains the primary mode.

Our analysis of historical examples also suggests that this community type could face economic challenges related to freight movement if it continues on its current path. This type of community relies on trucking to serve goods delivery, which can suffer from the effects of growing congestion. Other alternatives, like cargo bikes or freight rail service, are unlikely to be easy to implement; biking uptake requires neighborhoods with streets designed for cycling, rather than large roadways. This reality may delay freight deliveries and reduce the ability of people in the region to get goods on time and affordability.

Expected relationships between the AV ecosystem and land use in this community type

In this community type, AVs could be associated with increased car travel due to their convenience and lower travel costs. This could be associated with higher rates of traffic congestion—meaning more resident time spent in movement and longer travel times for freight delivery. In this sort of growing community, this could be associated with higher housing costs for neighborhoods with the best accessibility. Without policy intervention, this type of community may become even more oriented toward travel with cars and trucks with single occupants than it currently is. Because of the difficulty serving areas with higher densities, this may result in sprawl of both residences and employment to areas further from the center. A community of this type may have impacts on the broader metropolitan area by requiring the use of land further away for uses such as freight distribution.



Recommended AV-related policies to enhance equity and environmental sustainability

To ensure that the rollout of AVs contributes to improved quality of life, equity and environmental sustainability, several policy options are particularly relevant for this community type.

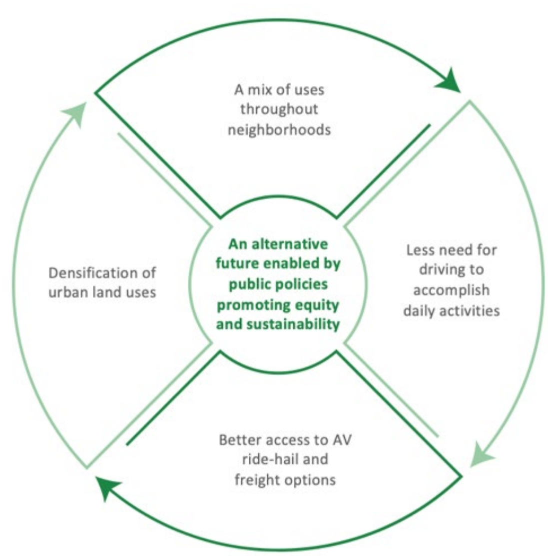
- **Encourage mixed-use, walkable neighborhoods.** Because of this community's automobile dependence, AVs could worsen accessibility to regional destinations because of more congestion. Using zoning to encourage neighborhood-level retail, employment, and services could help encourage people out of cars and trucks (see zoning policy sheet). This could be a particularly advantageous policy if linked to improvements designed to promote cycling and walking. New street infrastructure could enable the use of cargo bikes and small-scale robot freight transporters to transfer goods between urban warehousing locations and residences, retail outlets, and businesses. These alternatives to trucking are likely infeasible with most roadway infrastructure being designed for high levels of throughput and (see street design policy sheet).

- **Devote dedicated space to passenger pick-up and drop-off.** The rise of ride-hailing options has substantially increased the number of people being picked up and dropped off along streets in many crowded areas, but those passenger movements often require people to skirt around parked cars and risk traffic crashes. They also make it difficult for people with physical disabilities to use these services. AVs could make ride-hailing options more widely available, but better access is necessary to ensure people can equitably and safely use them. Localities could devote specific pick-up and drop-off zones throughout a community in order to ease access, and work with AV transportation providers to ensure that their vehicles stop there. On blocks with a high density of retail and other businesses, multiple or large zones may be needed.

- **Promote access to affordable housing in areas adjacent to jobs.** Because the heavier traffic associated with AV rollout could make areas with high levels of access to employment and other opportunities more appealing, communities could invest in affordable housing to ensure a diversity of people can afford to live there. This policy is particularly important in communities where congestion levels are high and where alternatives to traveling by car are limited or nonexistent. Even with the ability to travel by ride-hailed AVs, people with limited means will have their movement restricted if they have to travel longer distances to get to their daily needs, since most such services are likely to operate on a model that charges for travel by the mile (see zoning policy sheet, greenfield development policy sheet, and publicly owned land policy sheet).

- **Invest in AV transit options and freight delivery systems that take advantage of highway infrastructure.** This community type features a large amount of space devoted to roadways. Devoting lanes to transit or freight, or using congestion pricing to regulate access, could be an option to maintain metropolitan mobility. Dedicating lanes for these high-priority uses could ensure reliable travel for priority road users (freight and transit), and encourage car-owners to switch to alternative modes (see street design policy sheet and right of way policy sheet).

- **Allow conversions of auto-oriented uses.** As this type of community adapts to change, it may need fewer parking lots, garages, and other auto-oriented uses. The community may consider incentivizing the redevelopment of those uses, such as through zoning policies or financial incentives (see zoning policy sheet and building code policy sheet).

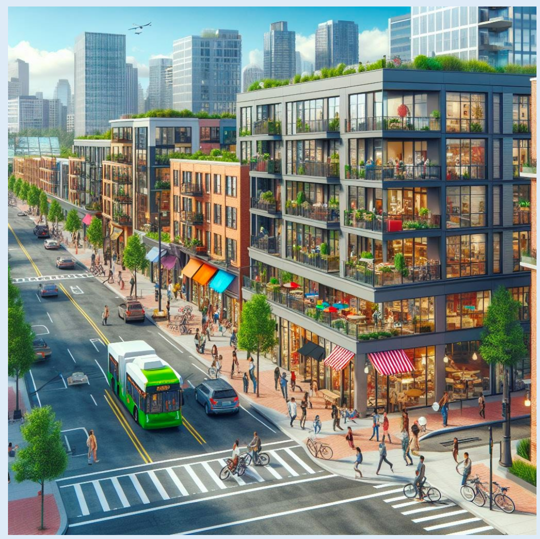


Community Type 2: The Dense Multi-Modal Community *Jump to the guide*

What are the features of this community type?

This type of community features **high population and employment densities**, **high levels of population change and development pressure**, and **low reliance on cars and trucks.** Many communities like this were originally developed a century ago and have experienced substantial growth over the past few decades thanks to the construction of new, high-density, mixed-use buildings. Throughout this community, apartment buildings are mixed in with offices, retail, and restaurants, and people can meet most of their needs within the neighborhood. People mostly travel by foot, bike, and transit, and it is well-connected to the rest of the region. Because the community it is so popular, however, it is increasingly unaffordable, and public services might struggle to keep up with growing demand And because its stores and restaurants are well-visited, the area's streets are increasingly filled with cars. As an example, parts of Seattle, Washington could be classified as this community type.

What might this community look like?



Source: Image generated by Microsoft Bing AI.

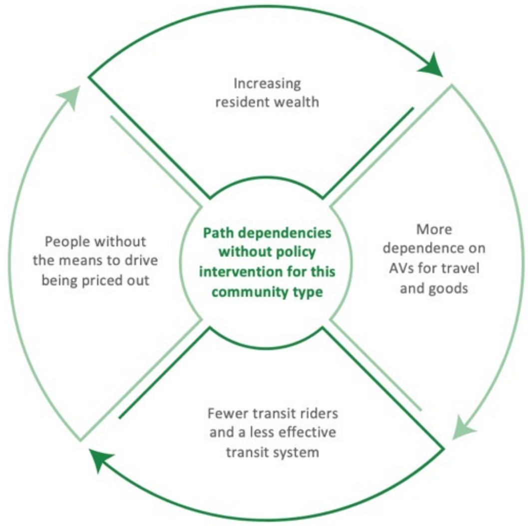
Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the rollout of bike sharing systems shows that this type of dense, wealthy community was especially likely to successfully attract users, because of its residents' disposable incomes and the convenience of destinations for people in the area. This history suggests that the rollout of passenger-serving AVs could also be successful here; people who live, work, and visit this community have the means to afford it. But this may mean that fewer people take transit. This community type may also face some challenges related to freight services. If AV delivery reduces the cost and time required to receive a package, residents may receive even more deliveries by truck.

Both of these trends could result in substantial congestion on the community's streets. This could make walking and biking around the community less appealing and expose people to higher levels of air and noise pollution. At the same time, this community may face challenges sharing the limited curb space among many types of users.

Expected relationships between the AV ecosystem and land use in this community type

In dense, multi-modal communities, AVs may be particularly well used, thanks to the high incomes of residents and the general appeal of traveling to and from this community. This may increase traffic congestion, both from carrying passengers and freight, as well as pollution. The increasing use of AV services, in turn, may lead to competition for curb access. If AVs make the community even more appealing than it currently is, the community may become increasingly off-limits to people with low and moderate incomes.

Recommended AV-related policies to enhance equity and environmental sustainability

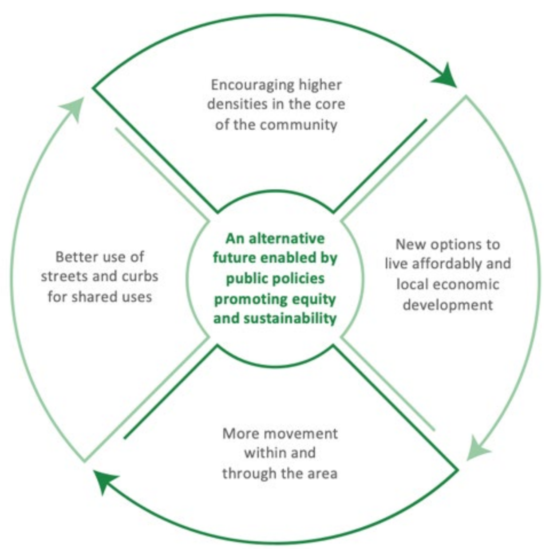


Without policy intervention, this community may experience challenges in the coming years. It may attract wealthier residents who want to take advantage of its mix of uses and high quality of life, resulting in gentrification and displacement of low- and moderate-income families in the area. These wealthier residents may dilute the aspects of the community that currently work well, such as its good access to transit and variety of nonmotorized travel options, because they are more likely to afford individual AV services and AV freight delivery.

To ensure that the rollout of AVs contributes to improved quality of life, equity and environmental sustainability, several policy options are relevant:

- **Create a policy for curb use that encourages shared vehicles and effective freight transport.** Given the high densities of this community and high likelihood of a fast rollout of the AV ecosystem, ensuring that street curbs are well managed is of paramount importance. This community should work to develop a curb use plan that replaces street parking with drop-off and pick-up zones for AV passengers and freight. The high densities of this community mean that this policy is likely to be most effective if it prioritizes people using shared services, such as AV buses and AV ride-hailing (see use of the curb policy sheet).

- **Further develop high densities in zones near transit.** Because of this community's appeal for development, it will continue to be able to attract new investors in the coming years. To take advantage of this situation, this community should consider altering its zoning policies to allow the construction of large-scale housing and mixed-use buildings in the areas that are best served by the local transit system. Higher densities may be most effective if implemented in association with the rollout of AV bus services, which could complement rail networks. New, dense housing developments could also incorporate affordable housing. (see zoning policy sheet and publicly owned land policy sheet).



- **Create nonmotorized zones in active portions of the community.** This community type has a high density of people. It also has many retail and restaurant options. To enhance quality of life, this community could consider creating pedestrian- and cycling-only zones where deliveries are only allowed at certain times of the day. This policy could be associated with a geofencing program in surrounding areas that limits the entry of non-autonomous vehicles to improve pedestrian safety (see street design policy sheet and right of way policy sheet).

- **Penalize individual and empty car use.** The rollout of AVs could be associated with more driving, especially if vehicles circle the streets empty rather parking. This community could consider implementing a fee on empty cars driving, including privately owned cars (see right of way policy sheet).

Community Type 3: The Established Hub

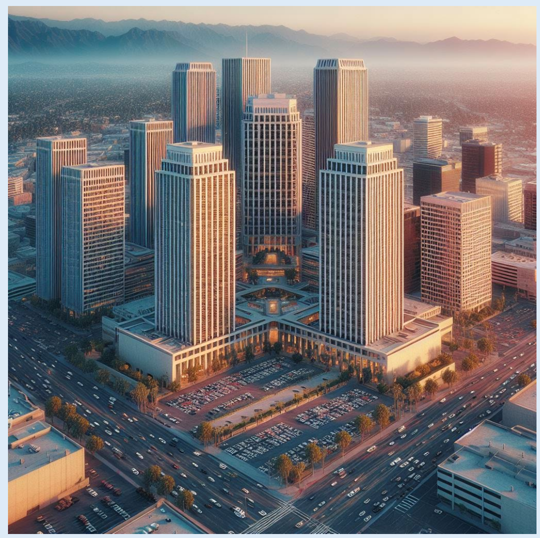
Jump to the guide

What are the features of this community type?

This type of community features **high population and employment densities**, **low levels of population change and development pressure**, and **high reliance on cars and trucks**. This community is the common downtown type in many cities that experienced rapid growth in their services and financial sectors in the 1970s through 1990s. it often features office towers surrounded by parking lots and parking garages. Those buildings, in turn, are surrounded by wide streets that are designed to move thousands of cars every hour. This community type has little mix of uses (the few retail establishments and restaurants it has are oriented toward the downtown office lunch crowd) and has struggled to retain its economic dynamism, especially in the period after Covid-19, when many of its buildings suffered from high vacancy rates. As an example, parts of Aurora, Illinois could be classified as this community type.

This community does have relatively effective public transit options linking it to other parts of the metropolitan area, but those options were often designed with a higher number of workers using them than is now common because of the high number of people working from home. It has some public amenities, such as the city central library and downtown parks, but those amenities are often empty of users on weekends and at night.

What might this community look like?



Source: Image generated by Microsoft Bing AI.

Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the construction of highways helps explain how this community was built almost entirely around serving the needs of people who drive to and from work. The results are streets that are uncomfortable to walk or cycle on, and a lack of diversity in the local economy.

The rollout of the AV ecosystem could reinforce conditions if people switch from today's human-drive cars to autonomous cars, both with single-occupancy predominating. It is unclear, in addition, whether the community will be able to revitalize its downtown if the high rates of office vacancy continue.

Expected relationships between the AV ecosystem and land use in this community type

In an Established Hub, the rollout of AVs may reinforce existing travel patterns of people working in the office towers. If people continue to commute to work with private cars—AVs or not—the community will continue to need substantial parking, but this would not be the case if people switch to ride-hailed AVs, which could park elsewhere (or drive someone else). Or, a community could choose to geo-fence downtown-oriented AVs and keep vacant ones parked within downtown so that they are readily available for an outbound ride at a moment's notice. This might be more optimal from an energy demand or maintenance perspective than allowing vacant AVs to roam until called.

Because this community has limited large retail options and its delivery needs are concentrated in a few large buildings, the automation of freight services may not have much of an effect on the community's streets. Nevertheless, this situation could change if the neighborhood shifts to more residential uses.

Recommended AV-related policies to enhance equity and environmental sustainability

Without policy intervention, this community may experience challenges. Because the community is structured around providing car access, the rollout of the AV ecosystem could simply mean replacing drivers with AVs, potentially worsen congestion if empty AVs drive instead of parking. At the same time, the AV ecosystem could further decrease for office and commercial real estate values in the area, making downtown towers less appealing as it becomes more appealing to travel to other parts of the metropolitan area to find office space.

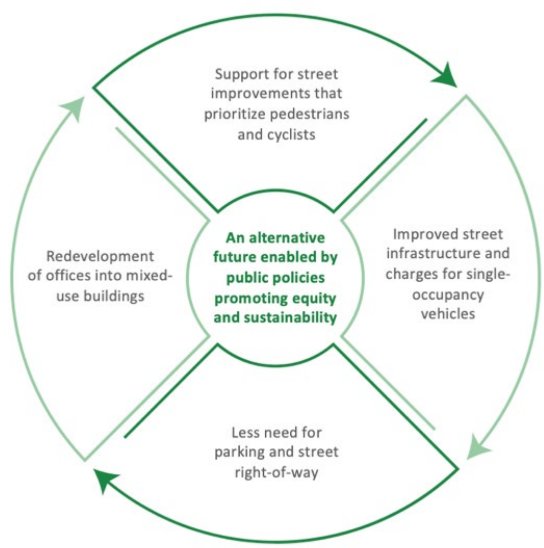
To ensure that the rollout of AVs contributes to improved quality of life, equity and environmental sustainability, several policy options are particularly relevant for this community type:

- **Support the redevelopment of parking lots and parking garages into a broad mix of uses.** This community has large quantities of land devoted to parking. The rollout of AVs offers an opportunity to redevelop parking into housing and a full mix of uses. This transition could help improve the local economy and reduce its reliance on many office uses whose occupants have come to work from home post-pandemic (see zoning policy sheet and building code policy sheet).

- **Redesign streets to encourage the use of multiple transportation modes and develop the local economy.** This community's streets are currently unappealing to walk and bike on. The community should invest in redesigning streets, including cycling lanes, widened sidewalks, and landscaping, that encourages people not to drive. Moreover, these improvements could be integrated into plans for pedestrian-oriented uses, such as sidewalk cafes (see street design policy sheet).

- **Charge single-occupancy vehicles for the use of streets and parking.** If the community remains congested, stakeholders may consider implementing a congestion charge for the use of streets and on-street parking. This charge could be integrated into AV ride-hail and AV freight systems and help discourage single-occupancy car trips.

- **Plan for goods delivery needs.** This community may not immediately experience much change



resulting from AV freight. Even so, as the community considers changes in its future, it may benefit from long-term plan for freight. Specifically, it should consider how to best leverage curb space to reduce delivery times and prevent competition among curb users. Moreover, it should evaluate opportunities to implement, and potential necessary regulations of, small-scale delivery robots (see use of curb policy sheet and street design policy sheet).

Community Type 4: The Underinvested Area

Jump to the guide

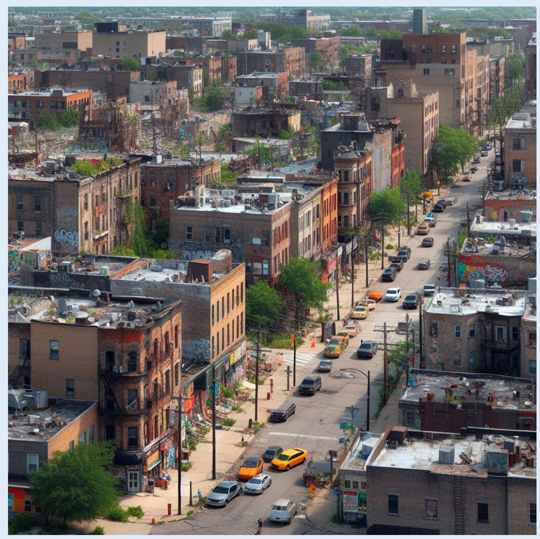
What are the features of this community type?

This type of community features **high population and employment densities**, **low levels of population change and development pressure**, and **low reliance on cars and trucks**. This community type is relatively common in Rust Belt cities that, a century ago, had high rates of growth due to surges in manufacturing, but now which have suffered from some challenges due to the movement of industrial jobs to other parts of the country and the world. These types of communities are typically surrounded by suburban areas with higher wealth and, often, better job access. Their residents also face some persistent challenges, such as exposure to pollution, long distances to suburban work, and high levels of disinvestment, which perpetuate inequality. As an example, parts of Cleveland, Ohio could be classified as this community type.

Despite the challenges faced by this type of community, it nonetheless often features some assets that differentiate it, such as access to public transportation, well-constructed and architecturally unique buildings, and nearby public amenities, such as libraries and parks.

Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the rollout of ride-hailing, for example, shows that this technology was introduced more quickly in higher-income neighborhoods, and that service has been provided more comprehensively there. Communities like this may face difficulties accessing new AV services.

What might this community look like?

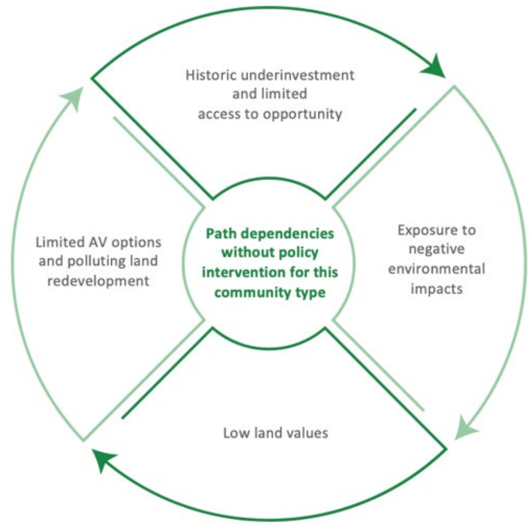


Source: Image generated by Microsoft Bing AI.

This type of community may also face some challenges related to the rollout of AV freight. The relatively low land values may attract investment in warehousing and distribution facilities, which could provide jobs for local residents but increase their exposure to air pollution and truck congestion. Dense, low-income neighborhoods in many US cities already suffer from higher rates of toxic sites, air pollution, and noise pollution. The AV ecosystem could exacerbate these difficulties if it is not implemented in an equitable manner.

Expected relationships between the AV ecosystem and land use in this community type

In this community type, AVs could increase car travel due to their convenience and lower travel costs; on the other hand, given the relatively lower incomes of residents of this community, they may be more likely to use shared ride-hailing options, if available. Residents are likely to continue to use public transportation for many of their trips, especially if AV transit expands options. The AV ecosystem could also impact the use of key parcels throughout this community. Because land values are relatively low, many parcels may be purchased by AV ride-hail operators or AV freight operators for parking, maintenance facilities, charging areas, and distribution locations. This could bring new jobs to the community but also reduce quality of life in the area by diminishing the residential and mixed-use nature of many of this community's streets.

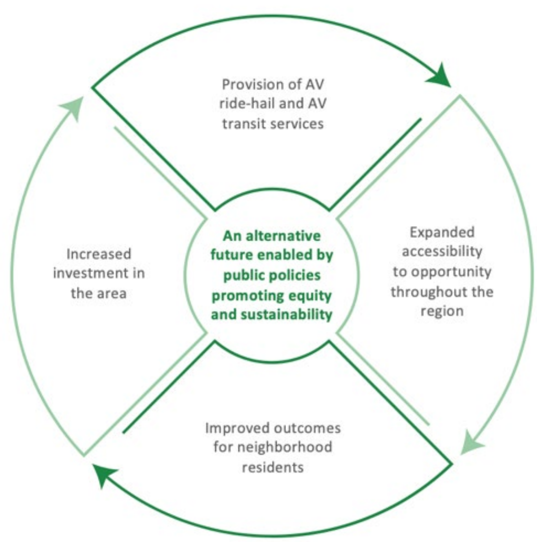


Recommended AV-related policies to enhance equity and environmental sustainability

Without policy intervention, this community type's residents could fail to benefit from the AV ecosystem's rollout, while suffering from higher levels of pollution. Path dependencies could thus worsen inequities in access and reinforce the disproportionate exposure of this community to environmental health hazards. To ensure that the rollout of AVs contributes to improved quality of life, equity and environmental sustainability, several policy options are particularly relevant for this community type:

- **Invest in AV public transit.** Given the fact that this community's residents are already disproportionally likely to use public transportation, implementing an effective AV-based transit system could substantially improve the connectivity of this community and attract high ridership. AV buses, for example, could provide frequent, all-day travel options that ensure that residents are able to move around the region and access jobs and public services. Improved accessibility by public transit could also improve the economic situation of this community (see expansion of transit policy sheet). Even if AV transit is not available, investments in human-driven transit options would also play an important role in improving accessibility for this community's residents.

- **Mandate a fair distribution of AV-based freight, distribution, garage, and maintenance facilities throughout the region.** This community may disproportionately suffer from the negative environmental impacts of the implementation of freight systems and vehicle maintenance, because of low land values. This community should work to ensure that the implementation of these uses is fairly distributed across the entire region(see zoning policy sheet) and ensure that these facilities meet environmental standards, such that they do not expose residents to outcomes such as toxic waste runoff and pollutive emissions (see greenfield development policy sheet).



- **Pilot AV-friendly redevelopment through building code changes.** Because of the low land values, it may be easier to test new forms of development that respond to the particular needs of AVs, such as building code changes that enable new buildings to allow AV freight delivery robots to enter buildings and drop off packages. This could put this community at the forefront of AV-adapted building designs (see building code policy sheet).

Community Type 5: The Sprawling Suburb

Jump to the guide

What are the features of this community type?

This type of community features **moderate population and employment densities**, **high levels of population growth and development pressure**, and **high reliance on cars and trucks.** This community type was built over the past few decades and is located on the edge of the metropolitan area. Its residents earn relatively high incomes and mostly live in large, single-family homes. Before Covid-19, they often commuted downtown to get to the office, but now they are more likely to work from home. They can meet most of their daily needs by ordering online or driving to shopping centers near their homes. As an example, parts of Overland Park, Kansas could be classified as this community type.

What might this community look like?

Source: Image generated by Microsoft Bing AI.

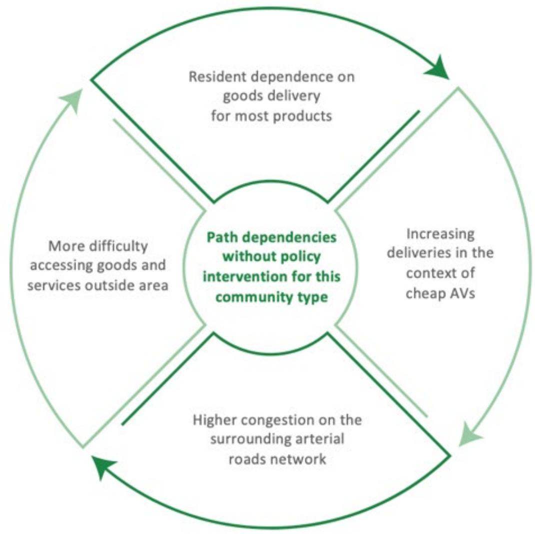
Because of its moderate densities and high levels of development pressure, people in this community now get around almost entirely by car. People who move here for the well-funded, high-quality public services do not have many public transportation options, and shops and restaurants are not within walking or biking distance. The residents are heavily reliant on goods delivery, since they order a large share of their purchases.

Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the rollout of the national highway system in the United States shows how infrastructure investments helped spur the development of communities such as this. Yet as the highway system continued to extend, the areas originally developed near roadways lost appeal. This history indicates that this type of community could experience a loss in its appeal over time in the context of the rollout of the AV ecosystem, if new neighborhoods take its place.

This community type may also face some challenges related to freight services. If AV-provided goods delivery further reduces the cost and time required to receive a package, residents of this type of community may receive even more deliveries by truck. This may expose surrounding communities to higher levels of traffic congestion from truck travel through the area.

Expected relationships between the AV ecosystem and land use in this community type

In this community type, the rollout of the AV ecosystem could increase car travel substantially. Because shared-use services (like shared ride-hail or transit) are unlikely to be effective for most trips, most people are likely to travel alone for most trips, even if they are not doing so to get to the office. At the same time, for the reasons noted, truck travel is likely to increase to serve the need for goods transport. This may increase congestion on the arterial roads surrounding the community. Finally, because of the lack of travel options other than driving, this community type is likely to remain difficult to move into for people who cannot afford the cost of personal travel.



Recommended AV-related policies to enhance equity and environmental sustainability

Without policy intervention, this community type may experience a number of challenges in the coming years. Because of this community's high car and truck dependence, if the AV ecosystem substantially reduces travel costs, the level of traffic on surrounding roadways may grow, lowering quality of life. Because of the lack of travel options, high housing costs, and the predominance of single-family homes, this community may remain unaffordable for many potential residents.

To ensure that the rollout of AVs contributes to improved quality of life, equity and environmental sustainability, several policy options are particularly relevant for this community type:

- **Create a distribution center for freight from a variety of companies at the edge of the community.** A new freight distribution center could ensure that, as shipping increases, AV trucks have a place to go in the community. This distribution center could be designed to have small-scale delivery robots and allowances for cargo bike use, to allow for centralized package pick-ups instead of individualized deliveries (see greenfield development policy sheet and publicly owned land policy sheet).

- **Use land-use policy to encourage the creation of a dense, mixed-use, walkable town center, with multiple types of housing and access to retail and services.** This community could implement a policy of higher density levels in this area and make room for people of various backgrounds by ensuring that there are subsidized affordable housing units here.

- **Link the community center with a variety of non-motorized travel options and AV shuttles.** Without policy change, such a village center could quickly become overwhelmed with AV traffic moving people individually to and from the center. But if this community invested in high-quality sidewalks, cycling routes, and greenways, it could ensure that a large share of the traffic to the village center occurs in non-motorized travel modes or in shared options, such as on-demand AV shuttles (see street design policy sheet).

- **Encourage an increase in housing density** This community's moderate housing density levels have been reinforced by land-use rules that prevent the construction of anything other than single-family homes. Because of this, the community is unable to accommodate substantial new population, despite interest in living here; as a result, housing costs go up and new construction must occur elsewhere—endangering the ecosystems of surrounding areas. This community could change this dynamic by reforming zoning laws to allow moderate density housing, such as duplexes and six-plexes (see zoning policy sheet).

Community Type 6: The Walkable Suburb

Jump to the guide

What are the features of this community type?

This type of community features **moderate population and employment densities**, **high levels of population growth and development pressure**, and **low reliance on cars and trucks**. This community is located near the city center and was developed along streetcar lines in the first half of the 20th century. It features a mix of building types, including single-family homes and walk-up apartment buildings. It also has a mix of uses, including neighborhood cafes and businesses, that provide services to residents and enable them to fulfill their needs without having to leave. As an example, parts of Bloomington, Minnesota could be classified as this community type.

What might this community look like?

Source: Image generated by Microsoft Bing AI.

This community has frequent and reliable public transportation connections with the rest of the city. It also has relatively pedestrian- and cycling-friendly streets, encouraging many residents and visitors not to drive. Thanks to its quality of housing stock, access to services, and connections to the rest of the region, this neighborhood has attracted a growing population over the years. That said, local zoning policies have largely left its housing stock unchanged for many decades, which has limited the community's ability to respond to growing housing demand.

Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the rollout of electric vehicles suggests that this community may see a slower adoption of AVs, since road space is limited (there is less space for chargers) and residents already enjoy good mobility (residents may not need the travel options new technologies provide).

In terms of freight, however, increasing demand for goods delivery by both residents and businesses may clog the streets and result in competition over access to the curb. More truck traffic could increase air and noise pollution.

Expected relationships between the AV ecosystem and land use in this community type

In this community type, the rollout of the AV ecosystem may have limited impacts on the movement of passengers, as they currently use public transit, biking, and walking to be meet most of their needs. High development pressure brought on by continued good accessibility of the neighborhood, combined with limited housing construction, may result in gentrification. AV freight, however, could lead to more deliveries, causing more congestion, air and noise pollution, and competition for curb access.

Recommended AV-related policies to enhance equity and environmental sustainability

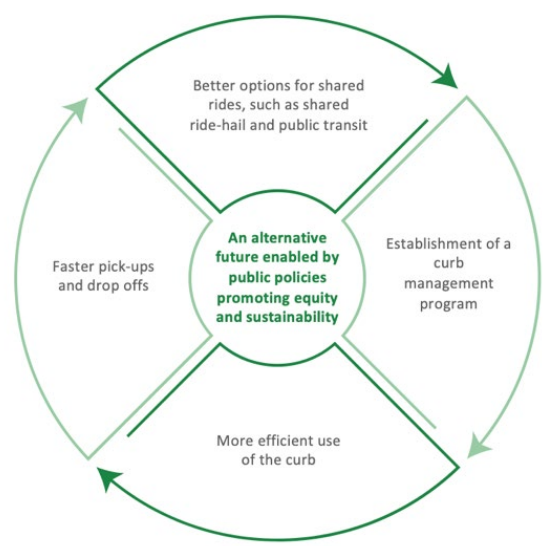
Without policy intervention, this community type may experience a number of challenges in the coming years. The rollout of the AV ecosystem could worsen the community's existing challenges with access to the curb. This could make it more difficult for people who ride public transportation or shared AV ride-hail services, while delaying deliveries by making it more difficult for trucks and other cargo haulers to park. These difficulties could worsen quality of life in the community and reduce the community's appeal in terms of being a good place to walk, bike, or take transit.

To ensure that the rollout of AVs contributes to improved quality of life, equity and environmental sustainability, several policy options are particularly relevant for this community type:

- **Provide the space for AVs to replace privately driven cars.** To encourage the use of shared AVs, the community may consider developing an AV ride-hailing program. It could also designate AV parking spaces in busy commercial areas, so that they do not drive empty. These spaces could prioritize shared-use AVs operated as a fleet (see building code policy sheet).

- **Work with the local transit authority to improve transit service and potentially implement AV bus options.** This community already has good bus service. But the community could use AV technology to complement the existing workforce; as transit agencies continue to struggle with operator shortages, AV options may allow agencies to maintain or increase service levels on existing or expanded routes (see expansion of transit policy sheet).

- **Ensure the effective use of curb space to maximize use of shared vehicles.** Given the competition for access to the curb, this community should work to develop a plan for efficient, fair curb use. This could mean replacing on-street parking with pick-up and drop-off zones, and providing preference for people with disabilities, people using shared services, and freight delivery. The community may consider establishing a time-based curb use program, in which access fees are charged by time of day and amount of time used. (see use of curb policy sheet)



- **The neighborhood could reform its zoning regulations to encourage a denser mix of housing units to accommodate new residents.** Given the community's population growth, building new housing can help ensure affordability. But current zoning rules make this difficult; in some cases, current buildings would be prohibited under today's zoning code. Reforming these rules to allow mid-rise buildings could help address this issue (see zoning policy sheet).

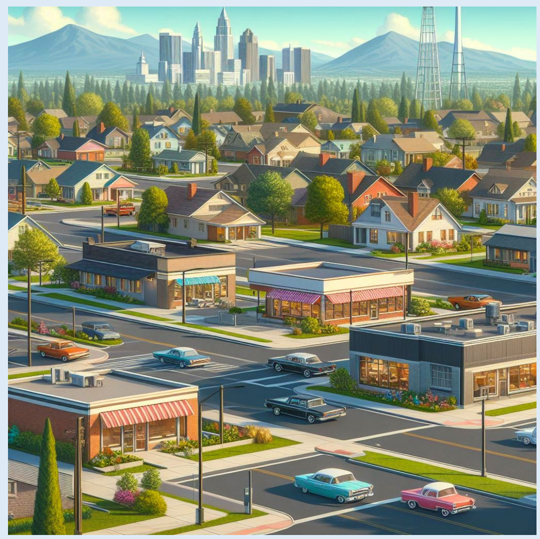
Community Type 7: The Mature Suburb

Jump to the guide

What are the features of this community type?

This type of community features **moderate population and employment densities**, **low levels of population growth and development pressure**, and **high reliance on cars and trucks**. This community type was developed in the second half of the 20th century to respond to growing population, car use, and increased household purchasing power. It was often constructed outside larger cities, and integrated a mix of single-family homes, small-scale apartment buildings (especially along arterial roads), and drive-up strip malls where people can visit retail outlets, restaurants, and office parks. This community enabled upwardly mobile middle-class families to live in newer or larger homes, but in recent decades has suffered from declining home values, high vacancy in retail space, and reduced quality of life thanks to longer commutes to jobs and underfunded public services. This community has had difficulty attracting new residents and has not had much new construction in recent years. As an example, parts of Livonia, Michigan could be classified as this community type.

What might this community look like?



Source: Image generated by Microsoft Bing AI.

This type of community has relatively easy access to the city center, a high level of green space, and high levels of housing affordability. It offers redevelopment potential if new demand for construction arrives in the area.

Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the rollout of bike sharing technology shows that this technology was implemented more quickly, and used more effectively, in areas with high population and employment densities. This history indicates that, if AVs follow a similar pattern, this type of community may struggle to attract services using this technology that effectively improve accessibility for its residents.

This community type may also face some challenges related to AV-provided freight services. Its moderate densities may make it difficult to distribute goods through light modes, such as cargo bikes and small-scale AV robots. This could increase truck congestion. This type of community may also have difficulty attracting freight-related warehousing and distribution, due to a lack of available land on large parcels and with good access to highways and rail systems.

Expected relationships between the AV ecosystem and land use in this community type

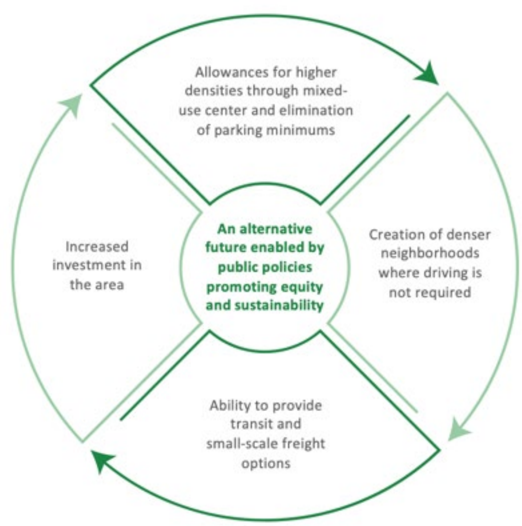
In this community type, the rollout of the AV ecosystem could increase car travel substantially. Because shared-use services (like shared ride-hail or transit) are unlikely to be effective for most trips, most people are likely to travel alone. At the same time, truck travel is likely to increase to facilitate goods transport. This increase in congestion could reduce the appeal of the community, reducing property values and discouraging reinvestment in the community's strip malls and business parks. Ultimately, people may have to rely on AVs to travel to other areas to fulfill their daily needs.

Recommended AV-related policies to enhance equity and environmental sustainability

Without policy intervention, this community type may face slow but continued decline in the context of AV rollout. Path dependencies could result in increased congestion, which would reduce the ability of residents to access opportunities in other parts of the region, while diminishing the appeal of local retail and office offerings. These changes would be particularly difficult for low-income residents with limited income to afford spending on travel. To ensure that AV rollout contributes to improved quality of life, equity and environmental sustainability, several policy options are relevant:

- **Encourage the transformation of strip malls and business parks into walkable centers.** This community is filled with underperforming strip malls and business parks. These areas, with large parking lots and—in the post-pandemic period—high vacancy rates, are prime candidates for redevelopment because they can accommodate density without displacing residents or businesses. This community could implement zoning changes that encourage higher densities and a mix of uses, including residential apartments, office space, retail, and restaurant uses, in these areas. The community could also change its building code to make it easier to convert commercial properties to other uses (see zoning policy sheet and building code policy sheet). Together, these areas could thus become new centers for this community and provide for economic development.

- **Pilot small-scale freight delivery options in certain parts of the community.** Though cargo bikes and AV robots are unlikely to be able to effectively serve the entire community, in areas near distribution hubs, those options could supplement or replace truck freight delivery. The community could pilot this approach to freight distribution by working with a goods delivery company and implementing this new option in one area. Implementing this approach may also require adapting streets and curb management for automated delivery vehicles (see street design policy sheet and use of the curb policy sheet)



- **Identify key corridors for the implementation of better transit services, including some operated with AV buses.** This community's moderate densities make it difficult to provide cost-effective transit service. With AV buses, however, this could change due to reduced operating costs. This community could invest in establishing AV transit services on key routes to provide residents an alternative to driving and reduce competition with freight movement (see transit expansion policy sheet and right of way policy sheet).
- **Eliminate parking requirements.** The single-family neighborhoods of this community are aging. Parking requirements for new developments—often one to two parking spaces per housing unit—impede new construction, particularly of multi-family apartment buildings and accessory dwelling units. This community can take advantage of the AV ecosystem to reduce or eliminate those requirements and encourage more investment (see zoning policy sheet and building code policy sheet).

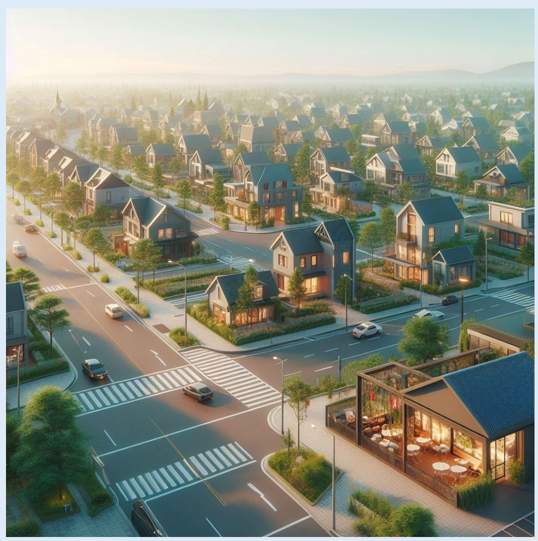
Community Type 8: The Suburban Town Center

Jump to the guide

What are the features of this community type?

This type of community features **moderate population and employment densities**, **low levels of population growth and development pressure**, and **low reliance on cars and trucks**. This community was developed in the first half of the 20th century and has remained relatively stable in the decades since. It features a combination of single-family homes and walk-up apartments, as well as commercial space scattered about, particularly on the major streets. Many of its residents have aged in place and, though the neighborhood was initially appealing as a place for the upwardly mobile working class, the income of new households entering the community has declined in the last few decades. Many residents of the area work service-sector jobs and take advantage of the area's relatively affordable housing. This community has struggled to attract much new development, and, though it has some stores and restaurants within easy access, it has not been able to fund many public services to the level of the newer suburban developments elsewhere in the region. As an example, parts of Anderson, Indiana could be classified as this community type.

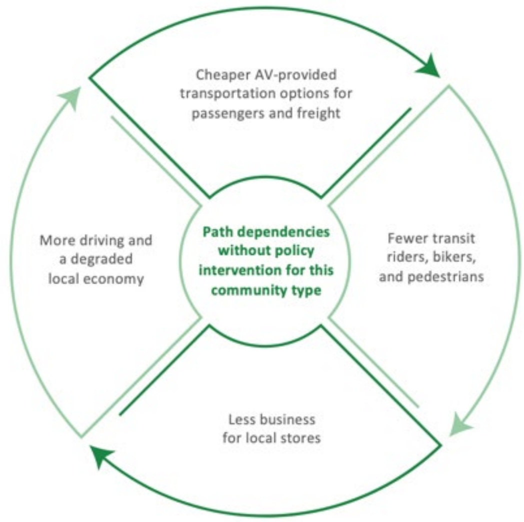
What might this community look like?



Source: Image generated by Microsoft Bing AI.

Because of a combination of the built form of the community and its demographics, this area's residents are less dependent on cars to get around than many other suburbs in the metropolitan area. There are bus routes that run along the community's main streets, and there are sidewalks in front of every home and retail store. The community has been installing some new cycling infrastructure, but it is not yet developed enough to feel safe enough for many amateur bikers to use.

Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the rollout of bike sharing systems suggests that this community will struggle to be attractive to private-sector investors in AVs, at least at first, because of its moderate densities and relatively low wealth. This means that there may be inadequate service for those who want to use ride-hailing to get around. Nevertheless, this community is affordable—both in terms of housing and transportation. It is accessible to the city center. And it has plenty of room to grow—if community members can help make the case for new investment.



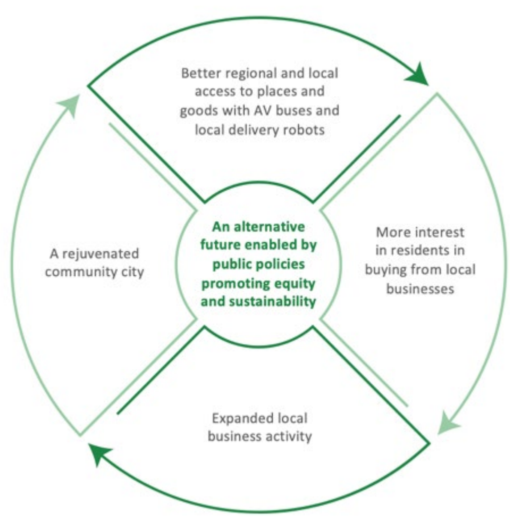
Expected relationships between the AV ecosystem and land use in this community type

In this community type, the rollout of the AV ecosystem may be delayed by lack of private sector investment. Nonetheless, over the long term, the availability of AV service may reduce the likelihood that people in this community use transit, walk, or bike. The community's bus service today—while better than in some parts of the metropolitan area—nonetheless is relatively infrequent and can be unreliable. AV ride-hailing options may improve access considerably for neighborhood residents. The availability of low-cost AV freight options may be an obstacle for local businesses in this community, since it may encourage residents to buy more from online stores, rather than shop locally.

Recommended AV-related policies to enhance equity and environmental sustainability

Current residents of the area are more likely to walk, bike, or take transit than those living elsewhere in the region, but that may change with the introduction of relatively cheap ride-hailing AV options. This could result in environmentally damaging VMT. Cheap delivery could reduce the ability of local stores to compete with chains that can deliver goods quickly. This could damage their business model and empty out this community's downtown. To ensure that AV rollout contributes to improved quality of life, equity and environmental sustainability, several policy options are relevant:

- **Work with the transit agency to implement frequent bus routes, potentially made possible thanks to AV operation.** One mechanism that this community can leverage to reduce the likelihood that its residents replace their walking, biking, and transit trips with single-occupancy AV trips is improving bus service. Better bus service could ensure that people in the community are able to travel conveniently by transit. This approach would also reinforce the core of the community by better connecting it with the rest of the region (see [transit expansion policy sheet] and [right of way policy sheet]).
- **Ensure that the state government mandates that AV ride-hail services are available for all parts of the metropolitan region.** In order to address the fact that this community may face challenges attracting AV ride-hailing service, this community could advocate for state-level policies that require private operators to provide adequate service (e.g., with a minimum waiting time) to all parts of the metropolitan area, including this community. This kind of policy would ensure some fairness in the availability of ride-hailed AV options into the future. While such regulations are not necessarily handled through land use, communities may incentivize



more equity in service through right of way policies that enable AV ride-hailing in specific or all areas (see right of way policy sheet).

- **Pilot a robot delivery program that provides cheap and easy deliveries from local businesses and restaurants to residents.** The community could work proactively to support its local businesses. It could work with a private contractor to implement a network of AV delivery robots that connect retail and restaurants with their customers. This delivery network could allow local businesses to compete with offerings from other parts of the metropolitan area and improve the local economy. These services may require changes to street design and curb management (see street design policy sheet and use of the curb policy sheet).

- **Support public-private partnerships to redevelop parcels into dense housing options on key sites.** Taking advantage of the improved bus service, this community could proactively seek to reinvest in underused or vacant parcels at the center of the community (avoiding greenfield development). The community could integrate both market-rate and affordable housing into new buildings to allow a diversity of people from different backgrounds to live there (see greenfield development policy sheet and publicly owned land policy sheet).

Community Type 9: The Exurban Fringe

Jump to the guide

What are the features of this community type?

This type of community features **low population and employment densities**, **high levels of population growth and development pressure**, and **high reliance on cars and trucks**. This community is at the far edge of the metropolitan area and is currently largely agricultural and natural in terms of uses. The few residential uses it has currently are in the form of farming homes, though that situation is changing rapidly. Over the past several years, there has been growing demand to live in the region as a whole, and the result has been an outward sprawl of development into the hinterland. This community is one example of where this sprawl is now headed. As an example, parts of Goodyear, Arizona could be classified as this community type.

What might this community look like?

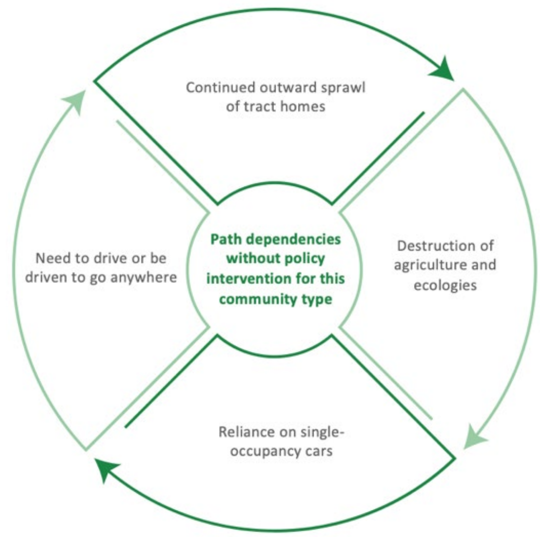
Source: Image generated by Microsoft Bing AI.

The new development that has occurred is mostly in the form of large single-family homes. These homes are widely spaced and are designed with two- or three-car garages to accommodate the transportation habits of the people who are expected to live in this area. There are no public transportation options and poor access to biking and walking trails.

This community does have access to some retail options, such as in the form of big-box stores located within a few miles of many of the homes. These stores are located off highways and also can only be accessed by people who are driving. People who live in this area hold a variety of jobs, but few go all the way downtown to offices.

Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the implementation of bike sharing systems suggests that this type of community is unlikely to be particularly attractive to travelers using transportation modes that are not single-occupancy automobiles. The low density of this community, combined with no mix of uses and roads that are hostile to everyone who is not in a car or truck, make serving people who want to use other transportation modes difficult.

The land use of this community, combined with its lack of a variety of transportation options, makes it environmentally unsustainable. Its construction requires eliminating agricultural or ecologically sensitive land. And its residents must drive long distances to get anything done—increasing pollution.



Expected relationships between the AV ecosystem and land use in this community type

In this community type, the rollout of the AV ecosystem may have little effect without policy change. The low housing densities of the area are likely to mean that, even if people in the community switch to AVs, they will continue to need to own their own vehicles for daily travel. Ride-hailed AV services would not come frequently enough to serve most of the travel demands of people who live in this area. People in this community, however, would potentially benefit from better freight delivery options with the rollout of AVs, however, since they could be relatively close to new distribution and warehouse facilities serving the rest of the metropolitan area.

Recommended AV-related policies to enhance equity and environmental sustainability

Because this community is already physically structured around providing access for car users, the rollout of the AV ecosystem could simply mean replacing drivers with AVs. In this way, AVs could reinforce the continued outward sprawl experienced in this community. They will likely have to be privately owned, as people will not be able to rely on shared rides to get around the community. The reliance on privately owned cars could make it difficult for people from all backgrounds to afford living in this community. Not only would they be required to own an AV outright to be able to fulfill their daily needs, but they would also have to have the ability to own a single-family home.

To ensure that the rollout of AVs contributes to improved quality of life, equity and environmental sustainability, several policy options are particularly relevant for this community type:

- **Implement a greenbelt to protect the community's most environmentally sensitive and agriculturally important areas.** This community could work actively with the state government and surrounding jurisdictions to establish a greenbelt that preserves sensitive land. This would reduce the amount of land available for new development, but in the process, it would help discourage construction in places that might be better preserved for other, non-developed uses (see greenfield development policy sheet).

- **Encourage the creation of mixed-use nodes where community residents can take advantage of shopping and basic services without having to drive.** To provide residents options that do not require driving, the community could zone for one or more mixed-use nodes that provide basic services (see zoning policy sheet).

- **Create shared-use streets for child's play.** Because of the community's low densities, its streets are unlikely to be congested with traffic anytime soon. As a result, AVs offer an opportunity to create new shared spaces where children can play with their neighbors. This could require certain parts of the community to be reserved only for AV access, but it could have considerable benefits in terms of expanding public space. This would also require assurances that AVs are safer than human-driven vehicles (see street design policy sheet and right of way policy sheet)
- **Experiment with small-scale AV shuttles to support travel around the community.** Though this community's densities are too low to support traditional transit—even with the reduced labor costs made possible by AVs—other options are feasible. This community could implement an AV shuttle for travel within the community, such as between homes. While not an intervention that could necessarily be tackled through land use, this policy could provide an essential resource for young, old, and disabled residents who are looking for ways to get around.

Community Type 10: The Rural Center

Jump to the guide

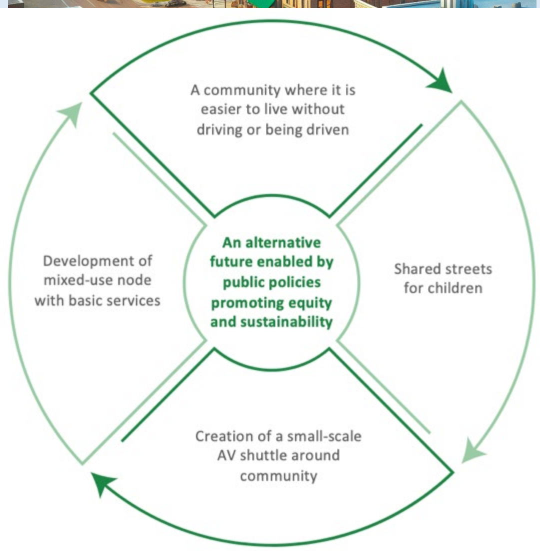
What are the features of this community type?

This type of community features **low population and employment densities**, **high levels of population growth and development pressure**, and **low reliance on cars and trucks**. This community type features a bustling, walkable downtown in a small town surrounded by agricultural or natural land. The center includes shops and restaurants, and even a few apartments, allowing people to walk and cycle around to get to most needs. This community was originally built a century or more ago and has flourished thanks to migrants coming in from larger cities elsewhere in the country and because of tourism. Because of its attractiveness, this community has faced challenges in terms of housing affordability, and some residents may no longer be able to live here if they cannot find an alternative place to live. As an example, parts of Lebanon, New Hampshire could be classified as this community type.

Because of its high levels of development pressure, this type of community has been able to fund effective, quality public services for residents. It struggles, however, to provide residents access to goods from large retail centers. And while residents are able to move around much of the community by walking and biking, because of the low densities in the town center, public transportation options are nonexistent.

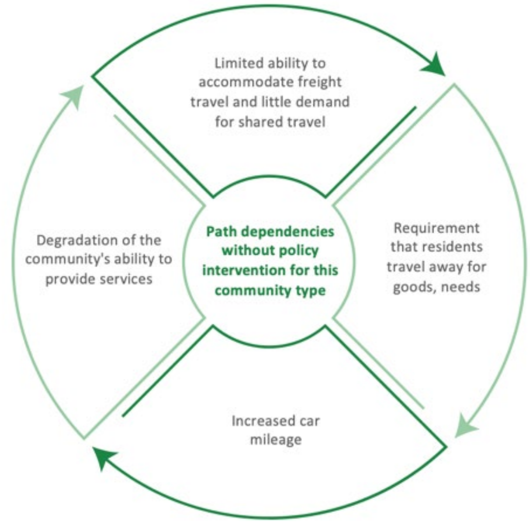
Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the rollout of streetcar systems shows that this technology helped encourage the development of relatively dense neighborhoods, similar to this community type. But once the streetcar networks were eliminated, affected areas were left with few mechanisms to grow. This

What might this community look like?



history indicates that this type of community, without alternatives, may have difficulty accommodating growth of new residents in the coming years unless it provides for some transit options.

This community type may also face some challenges related to freight services. Because of the low densities in this community, it may be unable to secure reliable, rapid goods delivery, even with AV trucks. Because of this community's small streets, deliveries by large truck may be difficult to provide. This could restrict the ability of shops and restaurants to receive the goods they need.



Expected relationships between the AV ecosystem and land use in this community type

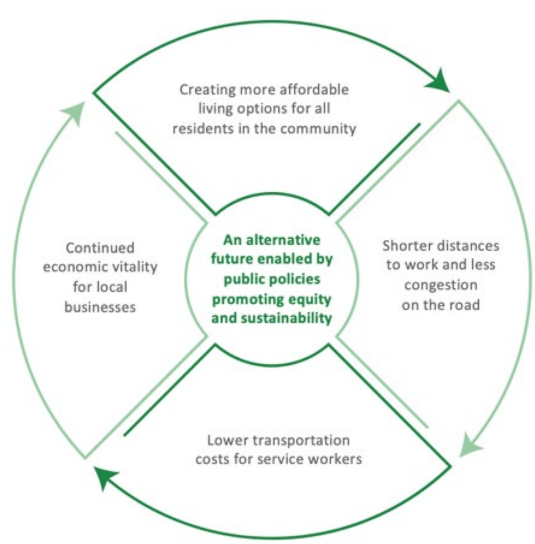
In this community type, the rollout of the AV ecosystem could increase car travel substantially. Because shared-use services (like shared ride-hail or transit) are unlikely to be effective for most trips, most people are likely to travel alone, and they may use AV services to travel to get goods at big-box stores further away. At the same time, for the reasons noted, truck travel is likely to increase in the community in order to serve the need for goods transport. This may be difficult, however, because the streets of the community were built decades ago and not necessarily designed for truck movement. This may limit the ability of stores to operate in the community, which could degrade the area and, in turn, result in more development far from the town, which would encourage yet more travel.

Recommended AV-related policies to enhance equity and environmental sustainability

Because this community has difficulty accommodating deliveries and does not have the transportation infrastructure to accommodate large amounts of travel, retail and commercial uses may increasingly move out. This could require residents to travel more to accomplish their basic needs. At the same time, the community may face continued challenges related to access to affordable housing because of gentrification. This may make life difficult to afford for people who work in the community's stores and restaurants. To ensure that AV rollout contributes to improved quality of life, several policies are relevant:

- **Create a distribution center for freight at the edge of the city center.** A freight distribution center could ensure that, as shipping increases, AV trucks have a place to go. This center could be designed to have small-scale delivery robots and allowances for cargo bike use, to allow residents and business to be able to access their goods. Proper zoning levers and changes, as well as management of greenfield development, could help in this endeavor (see zoning policy sheet and greenfield development policy sheet).
- **Link that distribution center to a retail outlet that provides essential goods for residents and local businesses.** The distribution center could be linked to a retail outlet, like a mini big-box store, providing useful goods to people of the community. Freight transportation could be done through lanes equipped for AV technology. This could ensure that people are still able to access their daily needs without having to travel long distances outside the community to do so (see right of way policy sheet).

- **Invest in housing affordable to existing residents and people providing essential services.** This community has experienced rising housing costs due to its attractivity. This has made it difficult for people who provide important services—such as working at restaurants and the local health clinic—to afford living there. As a result, they have had to travel longer distances, increasing congestion and pollution, while upping their own transportation costs. These issues could get worse with AVs. The community could consider investing in affordable housing to provide these individuals access to housing they can afford, which should be paired with the appropriate zoning and building code changes that would enable this type of housing to be built (see zoning policy sheet and building code policy sheet).
- **Cooperate with regional and statewide stakeholders to create transit operations that extend beyond the community.** Because of the community's low densities, people are likely to continue taking most motorized trips using private cars, AV or not. To ensure that people can access the community without having to rely on a car, the community could consider working with regional and state stakeholders to establish a regional transit service, potentially operated by AV buses, that enables travel between communities (see transit expansion policy sheet).



Community Type 11: The Metropolitan Edge

Jump to the guide

What are the features of this community type?

This type of community features **low population and employment densities**, **low levels of population growth and development pressure**, and **high reliance on cars and trucks**. This community type is at the edge of the metropolitan area, relatively close to recently developed suburbs but also currently largely occupied by agricultural and natural uses. This community is crisscrossed by large highways and though it has some current residents, they do not work in the other parts of the metropolitan area, as the region has grown to them over time. This community is entirely served by cars and trucks, with no other options for getting around. As an example, parts of Brandon, Mississippi could be classified as this community type.

What might this community look like?

Source: Image generated by Microsoft Bing AI.

Because of its location, this community type is appealing to long-distance shippers and freight operators. They already have rest stops along the highways that run through the area. And they are having an increasingly difficult time affording paying for land in other parts of the metropolitan area that are closer in, and where new residential development is in demand.

Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the rollout of freight containers shows that this type of community has become increasingly popular for distribution facilities and warehouses because, though the price of land is increasing, it is still both relatively cheap and relatively close to customers throughout the metropolitan area, so trucks can serve people and businesses with the packages they order.

If AV trucking reduces transportation costs, this community could face further growth pressure in the coming years. Shipping companies may seek to develop new facilities that allow them to move products from trucks traveling cross-country to those that are serving the metropolitan area itself. This is especially likely to be the case if AV trucking and distribution can be conducted with minimal human labor since communities such as this one are located far from centers of population. Without coordination, our examination of the history of freight containers suggests that these facilities may be scattered throughout the area, rather than centrally located, such as near freight rail hubs. All in all, these circumstances could result in more conversion of greenfield land into developed areas and higher vehicle miles.

Expected relationships between the AV ecosystem and land use in this community type

In this community type, the rollout of the AV ecosystem may be associated with a substantial expansion of trucking, combined with associated warehouse and distribution facilities. This may expand congestion on the region’s highway system and increase the transformation of agricultural and natural land to fill the needs of the freight system. This could have detrimental effects on the environment and increase the distance between farms and the centers of population.

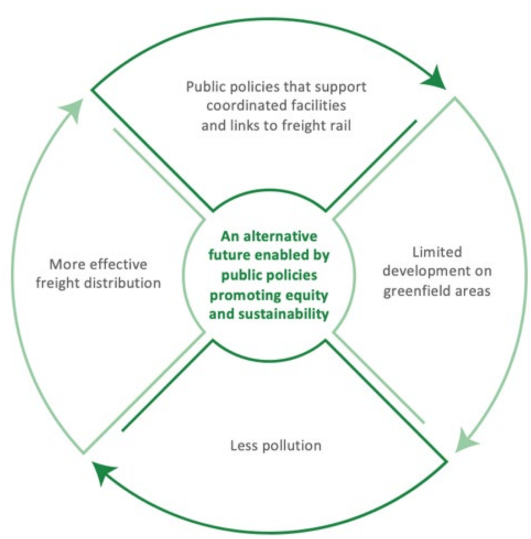
Recommended AV-related policies to enhance equity and environmental sustainability

The rollout of the AV ecosystem could further reduce the cost of freight shipping and distribution, which could expand the demand for new facilities on the edge of metropolitan areas, such as in this community. This could threaten agricultural and natural land and further increase VMT, which could mean more air and noise pollution. To ensure that AV rollout contributes to improved quality of life, equity and environmental sustainability, several policy options are relevant:

- **Develop cooperative arrangements between shippers to coordinate facilities in a certain area.** This community could work to establish agreements between shippers to develop a single coordinated freight warehouse and distribution facility. This kind of coordination could reduce VMT and ensure that the negative impacts of such facilities are not widely distributed across the community (see greenfield development policy sheet).

- **Encourage intermodal shipping, with a focus on moving goods by freight rail if possible.** Freight distribution by truck has taken on an increasing share of the market in the United States for decades. This has had negative consequences, including more congestion on the national highway system (resulting in more damage to roads) and higher levels of pollution (because freight trains are far more efficient than freight trucks). This community could consider developing mechanisms to encourage more freight rail options, such as by locating coordinated warehouse and distribution facilities in areas very close to railways, and even building railway spurs when necessary to make the final connection (see greenfield development policy sheet and transit expansion).

- **Consider implementing a greenbelt policy to ensure the continued survival of agriculture and the preservation of key natural spaces on the region's edge.** Because of the fact that currently agricultural and natural (e.g., forested or swamp land) areas have low land values, they can be easily purchased for conversion into freight-focused developed uses. This community can consider identifying key areas of land that deserve protection, whether for continued agricultural use, or to guarantee the persistence of certain ecologies. A greenbelt strategy could focus development in key areas (see greenfield development policy sheet).



- **Limit competition for new businesses between individual jurisdictions by preventing the use of economic development subsidies for freight-related uses.** Competition between jurisdictions for jobs in the United States has often resulted in states, counties, and cities subsidizing new employment to attract it into their communities. But this has been shown to have had little meaningful impact on actually increasing job availability. While not a policy necessarily conducted through land use levers, this community could consider signing an economic development non-compete compact with other jurisdictions in the region to avoid siphoning off public resources in this way.

Community Type 12: The Rural Town

Jump to the guide

What are the features of this community type?

This type of community features **low population and employment densities**, **low levels of population growth and development pressure**, and **low reliance on cars and trucks**. This community is small, outside of a metropolitan area, and surrounded by agricultural and natural land. All of its residents live in single-family homes or trailers, and while it has a town center, it has just a few uses: A church and a diner, notably. Residents in this community are relatively low income; most work in agriculture in the surrounding areas and have families that date back generations in the area. The community's residents need their cars to get to other parts of the region, but within the town, they can live relatively car-light, thanks to close connections between neighbors and light traffic on the roads that pass through the town. As an example, parts of North Adams, Massachusetts could be classified as this community type.

What might this community look like?

Source: Image generated by Microsoft Bing AI.

This community has attracted little economic development in the last few decades. Its lack of connection to a major employer, and long distance from the nearest large city, mean that it has not brought in much investment in recent years. That has not necessarily been to the detriment of residents, since they have taken advantage of the limited change in the community to have low housing costs.

That said, community residents do have some challenges related to accessing goods. Though it is possible to receive deliveries to homes in the area, it typically takes much longer to receive them in this community than in places nearer to the metropolitan area. There are big-box stores located along the highway a few dozen miles away, but they can be hard to get to because of the tight and winding roads that head there.

Our historical case studies, available on the Transportation Research Board website, suggest several challenges this community may face in achieving a more equitable, environmentally sustainable future. Our analysis of the rollout of ride-hailing shows that this sort of community never received the travel options offered by ride-hailing companies, due to limited potential ridership. The densities in the town simply are not high enough—and the people who might use the service do not have high enough incomes to afford the cost of trips. This has meant that people in this community who do not have access to a car—or are not able to drive one—do not have many options other than relying on others to get them around the community, or simply walking from place to place in the community.

Expected relationships between the AV ecosystem and land use in this community type

In this community type, the rollout of the AV ecosystem may have little effect without policy change. The low housing densities of the area are likely to mean that, even if AV technology is present, people in the community will likely have to own their own cars. Ride-hailed AV services would not come frequently enough to serve most of the travel demands of people who live in this area. Given the community's low densities, the area may also not experience much of a change in terms of accessing additional products, because delivery services may be limited in the area.

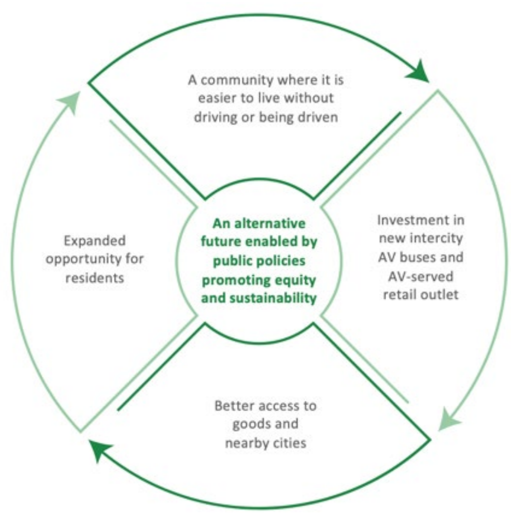
Recommended AV-related policies to enhance equity and environmental sustainability

AV service may have little impact on this community, either for passengers or for freight. This, in turn, could cut the community's residents off from the potential benefits of improved mobility offered by the vehicles. Members of the community may buy private AVs to ride in, but those cars are likely to continue to be more expensive than human-driven cars for many years. As such, the promised expansion in mobility offered by robot-driven vehicles may not extend to this community at all. Even so, that might be a positive thing for the environment: It could mean people in the area continue to walk around for many of their local needs. To ensure that the rollout of AVs contributes to improved quality of life, several policy options are relevant:

- **Encourage the state government to invest in intercity AV buses to improve connections with other parts of the region.** While the community had access to intercity buses several decades ago, that access is now gone after ridership declined and the cost of providing daily bus service increased. The community, as a result, is isolated from the surrounding region and residents cannot make short trips to other towns nearby without a car. The community could consider working with the state government to introduce intercity AV bus service that provides a new option for getting around (see transit expansion policy sheet).

- **Cooperate with nearby retailer to establish a branch presence in the town, served by AV freight services.** There is a big-box store located several dozen miles from this community, but it can be difficult for people of this community to get to, especially those who do not have car access. The store does not offer delivery options. The community could work with the retailer to open a branch location within the town that provides a subset of goods to residents. The branch location could be located in the center, near the church, and could be served by AV freight shuttles that transport products from the larger store down the road. This would improve residents' ability to get the products they need. Such an intervention could be supported by the appropriate zoning changes (see zoning policy sheet).

- **Experiment with small-scale AV shuttles to support travel around the community.** Though this community's housing and population densities are too low to support a traditional transit system—even with the reduced labor costs made possible by AVs—other options are feasible. Specifically, this community could implement a small-scale AV shuttle just to provide travel within the community, such as between homes. This could provide an essential



resource for young, old, and disabled residents who are looking for ways to get around. At the same time, if this community implements this technology, it should be careful that this does not replace walking, which plays an important transportation role in this community. While this is not an intervention necessarily conducted through land use levers, it could benefit from the appropriate street design and right of way policies (see street design policy sheet and right of way policy sheet).

5. Explore policies to address potential challenges and capitalize on opportunities at the intersection of AVs and land use

In this section, we provide fact sheets for each of the community types and policy concepts for practitioners to leverage as they are planning approaches to link the AV ecosystem with land use. You can use the tool in Chapter 3 to identify which community type and policy area is most relevant to you. Here are links to the policies we discuss in this section:

- Community engagement
- Building codes
- Street design
- Use of the curb
- Zoning
- Expansion of the transportation network
- Right of way management
- Greenfield development
- Publicly owned land

Chapter 7 provides examples of how different agencies and/or stakeholders can think through policy options to address the needs and circumstances of their communities in the context of the AV ecosystem and land use. These examples include:

- A state department of transportation
- A city department of housing and urban planning
- A metropolitan planning organization
- A university
- A neighborhood association

Policy: Community Engagement

Jump to the guide

Community engagement obstacles to AV ecosystem equity and environmental sustainability

Historically, engagement practices and public involvement related to transportation and land use have prioritized the perspectives of people with higher incomes, White people, and homeowners (Einstein, Glick, and Palmer 2020). For example, new developments, especially multifamily buildings, often require special permits or other approvals from planning or zoning boards, which hold public hearings to receive feedback from the community. During these sessions, members of the public can provide input, and local governments formally seek these opinions through notifications to adjacent property owners or neighbors regarding proposed developments. But older people, men, longtime residents, voters in local elections, and homeowners are significantly more likely to participate in these meetings (Einstein, Palmer, and Glick 2018). These individuals tend to express strong opposition to new housing construction, a sentiment that they hold more strongly than do members of the general public.

Deep and meaningful community engagement with historically excluded populations is necessary to ensure that land use changes related to AVs increase equity and sustainability rather than reinforce the inequities already built into our current land uses and zoning codes.

What is community engagement?

Local government community engagement refers to the process by which local governments involve and interact with community members in decision-making processes, policy development, service delivery, and other initiatives that directly affect their lives and well-being. This engagement can range from one way information sharing to consulting with community members, collaborating with community members, and even empowering community members by supporting grassroots initiatives and capacity building initiatives.

How could community engagement be altered to respond to the AV ecosystem equitably and sustainably?

Genuine community engagement means earning trust from, listening to, and understanding the needs and challenges of a community before proposing solutions. It also means shifting power structures to give more power in decisionmaking to historically excluded communities, such as people of color, people with low incomes, and people with disabilities. Some methods for increasing equity in community engagement include the following (drawn from Stacy, Christina Pierhoples, Karolina Ramos, Donovan Harvey, Sonia Torres Rodriguez, Jorge Morales-Burnett, and Sabina Morris. 2022. "Disrupting Structural Racism: Increasing Transportation Equity in South Dallas." Urban Institute):

- **Focus on engaging individuals with low incomes, people of color, those with disabilities, and other historically excluded groups.** Achieve this by hosting events at locations people frequently visit, like recreation centers, schools, or service centers, or by partnering with grassroots or community-based organizations that regularly serve these populations. Another key approach is hiring local residents to conduct outreach within communities of color and low-income areas, which can further enhance inclusive engagement.

- **Offer a variety of options for discussion and input.** Online participation in community engagement tends to favor higher-income and White individuals, often excluding those without access to computers or broadband. That said, this approach creates opportunities for those unable to attend in-person meetings due to being immunocompromised or having constraints like childcare duties or lack of transportation. By providing both in-person and online engagement options, the likelihood of inclusive participation increases. Offering multiple discussion opportunities, including smaller sessions for people with similar backgrounds (e.g., those who do not speak English), can enhance comfort and encourage engagement.

- **Compensate participants and provide additional supports at meetings.** While it may not be financially feasible to pay everyone who attends community meetings, offering compensation when possible can enhance inclusivity by removing financial barriers for low-income community members and demonstrating that their time and expertise are valued. Localities should especially consider compensating residents in key leadership roles, such as committee members and leaders, and advertise these positions to underrepresented groups. Additionally, offering travel vouchers, child care, and food at meetings can help increase regular participation.

- **Maintain communication with community members.** After analyzing input and making decisions, leaders should update community members both in person and online about outcomes and next steps, and give people the opportunity to share their experiences with the engagement process. Without transparency about post-engagement actions, the trust built during the input process can be undermined. To foster long-term trust and transparency, it's crucial for community members to clearly understand what comes next, including how their input was utilized and the timeline for implementation.

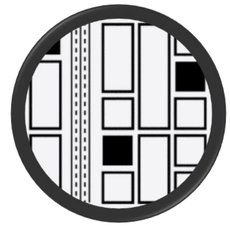
- **Track and monitor outreach and inclusion goals.** Communities should continuously assess the inclusivity of their engagement processes in real time. For instance, towns and cities should gather demographic data on participants to determine if they reflect the overall population. They should seek to identify if historically marginalized and excluded groups are underrepresented. Additionally, staff and policymakers should conduct in-depth discussions and focus groups with community members to identify successful aspects of the process and areas for improvement.

- **Undertake comprehensive planning.** Community engagement plays a crucial role in informing, shaping, and implementing the goals and strategies within a comprehensive plan. Comprehensive planning can help local leaders better understand the unique needs and desires of a community and ensure that engagement comes before policies are proposed. Localities should be sure to engage community not only in the design of the plan, but also in the implementation and evaluation of the plan over time.

- **Utilize community benefit agreements.** Community benefits agreements can serve as a formalized mechanism for communities to participate in decision-making processes related to development projects or initiatives that may impact them. CBAs are negotiated agreements between developers, community groups, and sometimes local government agencies. They outline specific benefits and commitments that the developer agrees to provide to the community in exchange for community support or acceptance of the project. These benefits often include provisions for affordable housing, job opportunities for local residents, environmental protections, infrastructure improvements, and other community investments.

Policy: Zoning

Jump to the guide



Zoning obstacles to AV ecosystem equity and environmental sustainability

Zoning regulations play a critical role in how AV technology will affect equity and environmental sustainability. Since individuals' willingness to endure longer commutes may drive migration from cities to suburbs or exurbs, density allowances will be crucial in influencing the extent of urban sprawl facilitated by AVs. AVs will also open up land for development through less need for parking, but minimum parking requirements could hinder the pace at which land is repurposed for more efficient, equitable, and sustainable purposes. Zoning determines the availability of space for AV infrastructure, including communication networks such as cameras, radars, and lidar sensors, plus the location of charging stations (Liu et al 2019; Stein 2021). Zoning may also affect the location of parking, which is likely to be situated outside urban cores, and of space for routers and servers necessary for AV software (Sudhakar 2023). And current zoning regulations may limit how efficiently AVs will be able to operate at a large scale when trying to pick up and drop off passengers (Riggs, Appleyard, and Johnson, 2020; Stein 2020).

Zoning may regulate many components of freight delivery that are relevant to the equitable and sustainable rollout of AVs. For example, zoning regulates the location, shape, and operation of distribution centers, and the size and configuration of loading areas (Richards 2018). As AVs become more prevalent, the most efficient location and configuration of distribution centers and allowable delivery times may change, since they will no longer need to be near potential employees and will need less employee parking.

What is zoning?

Zoning involves a government dividing land into different "zones," each with specific regulations for new development. Zones can be designated for single uses (like residential or industrial), multiple compatible activities, or governed by form-based regulations focusing on building density, size, and shape. Planning rules within each zone dictate whether development permission is granted, specifying outright and conditional land uses, lot sizes, building forms, and scales

How could zoning codes be altered to respond to the AV ecosystem equitably and sustainably?

Several changes to zoning could help the rollout of the AV ecosystem to be more equitable and environmentally sustainable:

- **Consider upzoning.** Reforming zoning codes to allow for increased housing density in the urban core could help disincentivize AV generated sprawl by reducing housing costs and dissuading people from moving into the suburbs or exurbs where housing and land are cheaper (Greenaway-McGrevy and Jones 2023; Stacy et al 2023). While some places use urban growth boundaries to mitigate sprawl, these can inadvertently increase housing costs in the urban core (Ball et al. 2012). However, pairing urban growth boundaries with upzoning can help to mitigate sprawl while also reducing housing costs (Mathur 2013). Increasing investments in public transit and reducing investments in highways can also help mitigate sprawl.

- **Support Transit-Oriented Development (TOD).** Local leaders can support TOD to create compact, walkable, pedestrian-oriented, mixed-use communities centered around high-quality train systems.[5] This could help minimize the increase in VMTs likely to be caused by AVs and help support access to opportunity for people with low-incomes, people of color, and people with disabilities. Some policies to help support TOD include upzoning near transit stops, siting affordable housing developments that are accessible for people with disabilities close to accessible transit stops, and reducing or waiving parking requirements near transit.

- **Employ adaptive reuse.** Leaders could also consider altering zoning codes to support adaptive reuses which allow for the redevelopment of existing buildings for other purposes, such as allowing easier conversion of commercial properties to housing, turning former industrial warehouses into cooperative spaces, or converting former shopping malls into workforce development centers. Adaptable site designs could also help accommodate the dynamic nature of AV traffic. This could include considerations for drop-off/pick-up zones, charging stations, and designated AV lanes. These types of adaptive reuses can allow the building stock to respond to changing demographics and needs as AVs become more widely available, plus increase access to opportunity and environmental sustainability. Amending zoning codes to allow for alternative uses on parcels zoned for one use can support these types of reuses.

- **Use zoning to increase environmental justice.** While allowing for adaptive reuse and other reforms can be helpful, zoning rules should be carefully designed to ensure the health and safety of residents while also paying close attention to the racial equity of proximity to pollution emitting uses. Zoning can be used to ensure equity in exposure to environmental toxins by ensuring that polluting industries are not near residential zones, particularly communities of color who have disproportionately borne the burden of living near such facilities (Tessum et al. 2021).

- **Reduce parking minimums and amend rules for opened up road space and parking lots.** As AVs become more prevalent, planners can amend parking minimums and zoning codes to allow for land formerly used for parking (and road space) to be used for other purposes. They could also institute parking maximums that incentivize the use of AVs, particularly ride hailed or shared AVs. If zoning codes evolve with AVs, they could open up land that used to be used for parking (and road width, which may be shrunk) for other uses like housing, green spaces, walking/biking lanes, and community amenities that serve people with low incomes and people of color.

- **Alter regulations on access points.** AVs may require fewer but more strategically placed access points to buildings, considering their precision and reduced need for wide turning radii. As such, leaders should re-evaluate existing regulations regarding the minimum number and type of access points. This can cover potential changes in traffic flow, safety considerations, and land use efficiency.

- **Require traffic impact assessments to focus on total VMT.** Traffic impact assessments predict the impact that proposed changes in land use will have on traffic and are often used for new developments and zoning reforms (Combs, McDonald, and Leimenstoll 2023). Conventional traffic impact assessments prioritize cars at the expense of other modes, undermining efforts to build more sustainable, multi-modal transport systems and encouraging single-use development in suburban and peripheral areas, where existing surplus traffic capacity minimizes the need for mitigation (DeRobertis et al. 2014; Walters, Bochner, and Ewing 2013). Local leaders could require traffic impact assessments that focus more on reducing total VMT rather than on vehicular delay to help minimize these potential negative impacts and maximize benefits for the environment. They could also require equity impact assessments, health impact assessments, and/or environmental impact assessments for these reforms and developments, but balance should be struck between requiring too many assessments which may mitigating development and progress, versus too few which may cause leaders to miss important impacts of such reforms.

- **Amend zoning codes to allow for freight distribution in new areas and formats.** Zoning codes can be amended to allow for more efficient locations and configurations of distribution centers. Changes have already taken place with the rise of e-commerce and will likely continue as AVs become more prevalent (Richards 2018). For instance, delivery is moving away from infrequent activity by large vehicles and toward more frequent activity by smaller vehicles, necessitating different types of loading spaces. If AVs accelerate that trend, it will be important to amend zoning codes to allow for these efficiency increases while also avoiding negative environmental or equity impacts. See the building code fact sheet for more information about how building codes can be amended to allow for new types of freight delivery.

Which stakeholders are relevant to implementing zoning codes?

In most US states, **local governments** are the primary decisionmakers about zoning. **State governments**, however, can preempt local zoning laws by either disallowing certain types of reforms or requiring them. If designed well, having the state government establish a baseline for zoning in communities throughout the state can help to increase efficiency, equity, and sustainability as AVs rollout.

Developers are also likely to play an important role in influencing zoning policy, since most large projects undergo negotiations between those who are leading developments and the government with zoning authority. Ensuring that developers have a clear sense of how to integrate AVs into their project plans can smooth the way.

What can we learn from historical examples related to zoning code changes?

The expansion of the interstate highway system revolutionized travel, residential patterns, and land utilization. Highways facilitated cheaper and more convenient car travel, fostering suburbanization and shifting freight transport from railways to trucks (Baum-Snow 2007). Highways, however, often exacerbated racial disparities by displacing communities of color during their construction and then by segregating communities of color far from opportunity. Moreover, highways contribute to air, water, noise pollution, and the destruction of natural habitats, not only through increased VMT but also because localities have enabled sprawling development through accommodating zoning. Similar impacts could arise with AVs unless zoning and other policies are intentionally crafted to address their deployment.

How could implementing zoning code changes differ based on community type?

Upzoning, changes to parking requirements, and traffic impact assessments will be most relevant for denser communities with high development pressure (including community types 1 and 2), as well as for less-dense locations near the urban core where density could still help to reduce exurban sprawl (6 and 8). Zoning code amendments for distribution centers will be most relevant to suburban and rural communities (such as community types 5, 9, 11, and 12).

What does community engagement look like for zoning and what are best practices?

Homeowners and people who are White are overrepresented in community engagement for zoning, which reinforces inequities in our housing markets (Einstein, Palmer, and Glick 2018). As AVs are deployed, care should be taken to ensure that people of color and renters, along with other historically excluded populations, such as people with low incomes and people with disabilities, are deliberately engaged in the process and given a voice in decisionmaking processes. For best practices on how to transfer this power, see the community engagement fact sheet.

Policy: Building Codes

Jump to the guide

Building code obstacles to AV ecosystem equity and environmental sustainability

Building codes are typically designed around human-driven cars. This has the impact of increasing the sizes of parking garages, since they assume that people need a margin of error to be able to navigate tight turns. Building codes also assume that visitors' cars will be parked during their stay, as opposed to ride-hailed vehicles that will leave after drop-off (see the zoning codes policy sheet for more details).

Building codes sometimes include provisions for freight delivery. For example, larger buildings are often mandated to include delivery docks explicitly to enable drop-offs without blocking the street. Yet these docks are not designed for variation in truck size, for instance, and thus are unable to accommodate alternative vehicle sizes, such as small-scale robot freight delivery systems. The mandated scale of delivery docks could be changed by the code to encourage a diversity of delivery options.

What are building codes?

Building codes mandate minimum human health and safety standards for structures, and typically incorporate construction standards, accessibility requirements, fire safety rules, electrical, plumbing, and mechanical regulations; energy efficiency standards; and rules related to permits and inspections. The International Code Council produces an International Building Code that is used by some communities, but codes vary by state and city throughout the US. The city of Seattle, for example, follows an amended version of the 2018 International Building Code; the city's code also must abide by statewide requirements introduced by the Washington State Building Code Council.

How could building codes be altered to respond to the AV ecosystem equitably and sustainably?

AV rollout could change several aspects of the transportation system that are relevant to building codes. AVs may be better able to negotiate tight turns; they may have doors in different locations; and they may come in new shapes and sizes that do not have to fit a human. AVs may also reduce the need for any kind of parking, a baseline assumption in almost any current building code. Several changes to building codes could respond to the rollout of the AV ecosystem:

- **Allow for AV-only parking garages.** Building codes can be reformed to allow for AV-only garages, equipped with electric chargers or options for vehicle-to-grid electrification. To reduce garage footprint (and thus reduce cost of construction, plus encourage better use of the limited space available in many urban environments), codes could be rewritten to allow for reduced distance between spaces, tighter turning radii, and reduced width of parking spaces themselves. These changes reflect the fact that, when parked, AVs do not need to be accessible by people through doors (or could be accessed via doors in the front or back of vehicles, depending on design), and they can navigate around garages with less error than human drivers. Because AVs—like the rest of the vehicle fleet—are likely to be electrified and powered with batteries, they may be heavier on average than the gas-powered vehicles in common use today, at least given the same size. This would be a particular concern if vehicles were packed more tightly against one another. As such, building codes could be rewritten to ensure that garages can handle the increased weight of such cars. Localities should implement this policy carefully so as to ensure it does not increase parking overall.

- **Amend codes to allow for different types of freight delivery.** Building codes often make allowances for freight delivery through special loading areas (these are often required for larger buildings to prevent on-street loading). With AVs, codes could be rewritten to allow buildings with a lower level of expected freight delivery to accept deliveries through small-scale freight-carrying electric AVs. This would require codes to allow the creation of new rules for the passage of such vehicles into buildings, such as through tight tunnels, or different sorts of entryways that do not have to be accessible to humans.

Which stakeholders are relevant to reforming building codes?

In most states, **local governments** are primary decisionmakers when it comes to building codes. But **state governments, state building code councils, and the International Code Council** can implement minimum standards for localities to ensure uniform building design changes to accommodate AV services for freight and passengers. Having the state government establish a baseline for building codes in communities throughout the state can assist landlords and developers that are considering constructing buildings.

The ultimate implementers of building codes are **landlords, architects, and developers**, who choose how renovated and new buildings are adjusted to reflect the law. For them to adapt to AV rollout, they must have a clear sense of what the building code entails. This means that they should be made fully aware of how the code works and what changes might be made possible with AVs. In some cases, landlords that own large, continuous parcels of land (such as universities or hospitals) may consider adapting their buildings as a group to new building regulations. This could enable them to provide neighborhood-wide small-scale robot AV freight delivery within and between buildings, with the goal of reducing the trucking footprint in the area.

How could implementing building code changes differ based on community type?

Changes to building codes designed to encourage eased AV–land use connections in the case of parking garages are likely to be more useful in the densest areas, where garages are more common (including community types 1, 2, and 3), though they may also be meaningful in less-dense locations where there have been recent efforts to introduce higher density levels.

Changes that enable AV-freight delivery may be particularly common in areas where distribution and warehousing facilities exist or are being planned, such as community type 11. In these areas, building codes can be adjusted to reflect the need to accommodate a variety of vehicle sizes. At the same time, small-scale delivery robot AVs could serve most community types.

What can we learn from historical examples related to building code changes?

The widespread introduction of electric cars has already begun to influence thinking about building codes in cities throughout the United States. Because of their heavier weights, these vehicles require adjustments to load requirements in parking garages. This situation is likely to become more of a concern in the coming years as electric cars become more popular and as AVs are likely to be mostly electric. Consider that the introduction of the freight container also had some influence on building codes historically. The design of the container itself resulted in the creation of specialized warehouses and distribution facilities designed to allow tractor-trailer trucks to unload directly into the facilities. Codes in numerous cities and states were adjusted to allow for this freight transfer.

What does community engagement look like for building codes and what are best practices?

Residents can play a key role in public policy related to building codes. Historically, engagement practices and public involvement have both prioritized the perspectives of people with higher incomes, White people, and homeowners. Ensuring that any building code reforms incorporate the perspectives of a more diverse group of individuals is necessary to guarantee equitable planning for the AV ecosystems, including potential future residents of new housing developments (as opposed to only current residents) or employees of an industrial or transportation facility. For more guidance on engagement with historically excluded populations, see the community engagement fact sheet.

Policy: Street Design

Jump to the guide

Street design obstacles to AV ecosystem equity and environmental sustainability

Because of the dominance of the automobile in American life, most streets are designed to prioritize their movement. For city streets and suburban arterials, this often means wide lanes, little room for sidewalks or bike lanes, and no dedicated facilities for transit. These conditions make travel difficult for people who do not have access to their own cars by slowing their movement and making them more likely to get hit by a car. This disproportionately negatively affects people of color and people with low incomes. In addition, the prioritization of automobiles over other modes of mobility has led to negative environmental impacts such as particulate pollution and carbon emissions. Local policymakers have a large degree of latitude over how much street space should be devoted to different users and needs; they have the opportunity to make significant changes related to this issue.

Street design also has important implications for freight. Currently, many city streets and suburban arterials are designed to accommodate tractor-trailer trucks, which need broad turning radii and adequate space for streetside deliveries. Nimbler and smaller vehicles—both possible with the rollout of AVs—could make this less of a concern. Freight vehicles are also subject to the challenges of competition with other traffic and human-driven cars sitting in delivery areas, which can delay deliveries. (These outcomes are particularly important when it comes to the use of curb space; see the curb space policy sheet for more details).

What are the components of street design?

Streets constitute a large share—sometimes even the majority—of publicly owned land in urban areas. Public policy can thus play an important role in influencing how streets look and work—and importantly, what types of transportation they prioritize. Streets can be designed to host a whole variety of different users, including pedestrians, bikers, buses, rail transit, delivery vehicles, and automobiles. They can integrate landscaping, lighting, and signage, too. Making choices about how much space in the public right-of-way should be devoted to different uses is a key decision to be made by local departments of transportation and has major impacts on surrounding land uses

How could street design be altered to respond to the AV ecosystem equitably and sustainably?

If AVs achieve their promised goals of increasing street safety compared to human-driven cars and trucks, occupy less street right of way, need less parking, and provide new transportation services in different types of vehicles, localities and state governments may consider altering their approaches to street design. In addition to the access and site design recommendations detailed in the zoning and building code section, several street design changes could encourage further social equity and environmental sustainability in the context of an AV rollout:

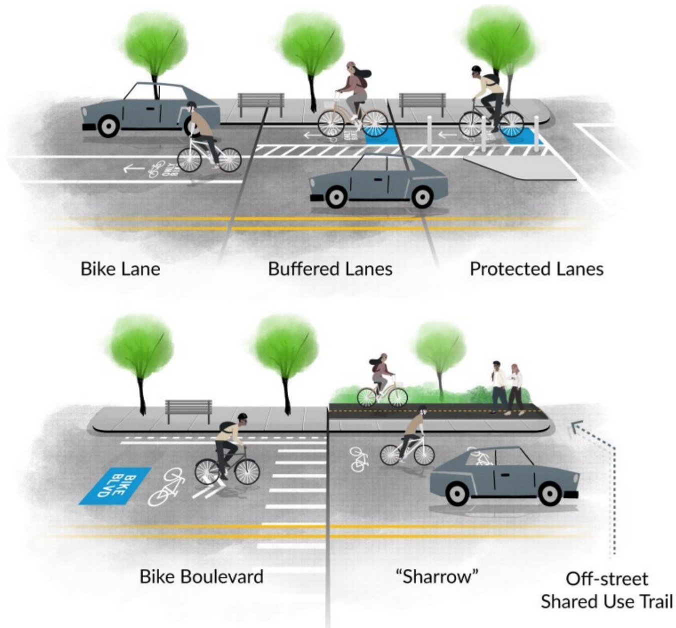
- **Prioritize pedestrians.** Localities could invest in street design upgrades that maximize safety for walkers, whether or not AVs rollout broadly. There are a number of options to achieve this goal, such as implementing additional pedestrian crossings (such as crosswalks), installing curb bulb-outs that shorten pedestrian crossing distances, and devoting more street space to sidewalks rather than car lanes. Localities can also install additional stop signs, speed bumps, and signalized intersections to reduce car speeds. In some cases, where good transit options or other shared AV vehicles are available, **entire blocks could be** pedestrianized. If AVs do not **turn out to be safer** than human drivers, these changes could be particularly important to ensure safety for all.

- **Creating AV-only environments.** If AV technology is associated with a substantial reduction in vehicle speeding, combined with better lane compliance, localities can leverage it to create AV-specific zones where street design is less oriented toward compensating for the mistakes made by human drivers. In these zones, local departments of transportation can introduce narrow lanes and tight corner radii at intersections. The first of these transformations can open up more street space for sidewalks or other modes of transportation; the second can reduce the likelihood of pedestrians being hit by cars because of fast-moving traffic. In order to introduce these transformations, localities may have to limit entry by all but AVs, though experimentation with these changes in areas with human-driven vehicles may also produce useful outcomes. One option could be to introduce AV-only zones in neighborhoods built from scratch. In these areas, localities may consider working with AV manufacturers to ensure that the vehicles automatically respond to pedestrian movement, either through automated sensors, or through pedestrians being able to indicate their presence, such as pressing a button.

- **Enabling different vehicle sizes and types.** Vehicle lanes are currently designed practically exclusively for cars and trucks. This may no longer make sense once vehicles of various sizes enabled by AV technology are introduced. In particular, if AV robots become relatively commonplace as a means to move goods around neighborhoods, it will be necessary to ensure that they have adequate space on the public right-of-way. These types of vehicles could reduce emissions and congestion compared to the trucks that now carry most freight if they are able to more efficiently carry goods. On the other hand, larger trucks may have economies of scale, allowing them to use less VMTs to deliver the same amount of goods. Localities could experiment with approaches to enabling the use of these vehicles on certain streets.

- **Creating dedicated space for shared vehicles, public transit, and light mobilities such as bikes and scooters.** The arrival of AVs could make it more feasible to devote space on the street specifically to vehicles that maximize the use of the public right-of-way. Certain street lanes, for example, could be reserved for shared vehicles, such as transit buses or AV vans, to maximize lane throughput in terms of the number of passengers carried through an area (see the right of way management policy sheet for more details on this issue). At the same time, localities may make way for more light mobilities, such as bikes, scooters, and freight-carrying bicycles through dedicated lanes that are protected from the surrounding traffic or off-street entirely, such as those seen on the right side of figure 5.1. This could encourage more people to get out of cars, thus reducing negative environmental impacts that may occur due to AVs.

Figure 5.1 Cycling Infrastructure Types



Source: Freemark et al. (2022).

Which stakeholders are relevant to revising street designs?

Local governments play the most important role in making policy choices related to city street and suburban arterial design. They generally have control over most neighborhood streets and they install sidewalks and bike lanes. Nonetheless, **state departments of transportation** often impose standards related to vehicle lanes and crossings. Moreover, state governments typically control a large share of arterial streets (as well as highways); they manage the design of these facilities directly. States could enable the transformation of streets to support more equitable and environmentally sensitive uses of the public right of way. Local leaders can also utilize the National Association for City Transportation Planning Official's (NACTO) Blueprint for Autonomous Urbanism, which offers recommendations for a comprehensive overhaul of how our streets are designed, allocated, and shared to increase the likelihood that AVs will result in substantive safety, sustainability, and equity gains.[6]

The **federal government** also has an important role to play through the Federal Highway Administration's Manual on Uniform Traffic Control Devices for Streets and Highways. This Manual defines baseline standards for city streets, arterials, and other surface transportation facilities, and was last updated in 2023. However, the Manual does not currently address AVs directly. At the same time, the National Highway Traffic Safety Administration makes policies related to what types of vehicles are considered roadworthy. AV technology could change the design of many of the vehicles now carrying passengers and freight—and, in the process, reduce roadway congestion and pollution—but those designs must meet federal rules to be allowed on the public right of way. Currently, the federal government has limited the number of AV test vehicles allowed nationwide.

How could implementing street design changes differ based on community type?

Communities with less car and truck dependency and higher densities (such as community types 2, 4, and 6) may be most apt for transforming their public rights-of-way. These communities can leverage AV technology to maximize throughput by encouraging shared vehicles and transit and expanding space for pedestrians and bikers. They may also be most ready to create zones where only AVs are allowed to enter the street. This may be most feasible in the communities with high development pressure and where new neighborhoods can be constructed, such as in communities 6 and 10.

At the same time, street design transformations designed to encourage different types of goods delivery may be most effective in relatively dense communities with high car and truck reliance, such as community types 1, 3, and 5. In each of these areas, experimenting with goods delivery by AV robot could be an effective mechanism to encourage reduced traffic.

What can we learn from historical examples related to street design changes?

The creation of bicycle sharing networks in cities around the world has been associated with a number of major changes to the public right of way. Notably, cities have chosen to associate the rollout of this technology with new bike lanes and dedicated space along the sidewalk—sometimes expanded—to store bikes. Bike share systems have helped encourage the reduction of the space taken up by cars on streets. AV technology could follow a similar approach.

What does community engagement look like for street design?

People who live along, businesses located along, and people who frequently travel to or through streets being considered for street redesigns should be directly integrated into discussions about the right types of transportation modes to prioritize and the best ways to ensure that the street can contribute to a community becoming more socially equitable and environmentally sustainable. Nonetheless, decisions about street design should not be limited to those individuals alone, especially since evidence shows that engagement processes are often biased by the disproportionate involvement of homeowners and people with higher incomes. Other users of the street and potential users of the street should also have their views integrated into the process. For more guidance on engagement with historically excluded populations, see the community engagement fact sheet.

Policy: Use of the Curb

Jump to the guide

Curb use obstacles to AV ecosystem equity and environmental sustainability

The choice about who or what has access to a curb reflects a community's priorities. The curb might be set aside for parking by residents or businesses, suggesting that the local goal is to encourage car access for people who live or who shop there. Or, it might be devoted to traffic lanes, so as to speed car movement along the street. It might include ample space to drop off passengers and goods, giving preference to people and things moving in and out of the area. Finally, it might have some mix of all three—plus, perhaps, space for trash receptacles, bike storage, and seating.

Management of curb space will play a major role in the rollout of AVs and could influence whether AVs lead to further automobile dependency or a greater mix of transportation modes. With the recent rise of ride-hailed passenger cars and bike-sharing systems, curb access is already undergoing major changes that may accelerate in the context of AV rollout.

What is the street curb?

Little-mentioned but very important for the function of the street, the curb is the key site of interaction between people moving and people arriving or departing from destinations. The curb is used for a variety of purposes, including vehicular parking; sanitation; loading and unloading of goods; drop offs and pick-ups of passengers; bicycle storage; and sometimes streetside cafes and other extensions of nearby land uses. Because of the wide array of needs, the curb is a contested space that must be managed if it is to contribute to the surrounding community. Managing the curb's limited space requires compromising between various needs.

How could curb use be altered to respond to the AV ecosystem equitably and sustainably?

AVs could lead to substantial growth in demand for curb access, if it is associated with more ride-hailed trips and automated deliveries. However, public policy can influence the trajectory of the AV ecosystem in ways that shift the type of demand for curb access. First, will AVs be associated with greater use of shared vehicles or will they encourage more single-occupancy automobile travel? Second, will automated freight delivery increase congestion and emissions, or enable more efficient movement of goods and reduce VMT? Localities may consider several policy options to encourage greater equity and environmental sustainability in the context of AV rollout:

- **Devote dedicated space to passenger pick-up and drop-off.** The rise of ride-hailing options has substantially increased the number of people being picked up and dropped off along streets in many crowded areas, but those passenger movements often require people to skirt around parked cars and risk traffic crashes. They also make it difficult for people with physical disabilities to use these services. AVs could make ride-hailing options more widely available, but better access is necessary to ensure people can equitably and safely use them. Localities could devote specific pick-up and drop-off zones throughout a community in order to ease access, and work with AV transportation providers to ensure that their vehicles stop there. On blocks with a high density of retail and other businesses, multiple or large zones may be needed.

- **Provide quality access to public transit services.** To encourage environmentally sustainable transit use, bus services could benefit from a portion of the curb specifically devoted to their passengers' needs, a convenience available in some places but not everywhere. This could allow riders easier access onto transit and encourage them to use buses—automated or not—rather than single-occupancy automobiles. This bus-dedicated area could include benches and lighting and be associated with curb bulb-outs to reduce the difficulty getting on the bus (see street design policy sheet for more information).

- **Charge for curb use, prioritizing shared vehicles.** To incentivize the use shared vehicles over single-occupancy and private automobiles, localities could charge for curb use, including for parking, drop-offs and pick-ups. These charges would encourage shared vehicle use by effectively distributing that fee among more passengers. Fees could also vary based on the time of day, day of the week, real-time demand, characteristics of the vehicle (such as lower fees for electric or small cars), or the characteristics of the passenger (such as waiving fees for older residents or people with mobility disabilities).

- **Devote a portion of the curb to freight deliveries.** If AVs substantially reduce shipping costs, delivery orders may increase. Delivery vehicles can create unsafe situations when, lacking alternatives, they stop illegally next to parked cars or on crosswalks, and they can increase congestion due to frequent stops. To prevent this, communities could designate frequent freight loading areas, potentially with dynamic, time-dependent rules. They could also consider ways to enable small-scale robot AVs to operate.

Which stakeholders are relevant to revising curb use?

Local governments typically manage curb use. They often create and enforce policies related to where on-street parking is allowed, whether people must pay to park, who is allowed to park (e.g., residents or the general public), and how drop-offs or deliveries are handled. Their ability to manage dropoffs requires close collaboration with **commercial delivery services**.

In addition, **major developers and landlords**, such as universities and hospitals, often work with local governments to prioritize certain users along streets near their facilities. In some cases, these organizations own private streets where they set policies. **State departments of transportation** may also impose policies about curb use on state roads.

How could implementing curb use changes differ based on community type?

The communities with the highest population and employment densities—community types 1, 2, 3, and 4—will likely have the greatest need to revise curb access regulations because they may have the most competition between users.

Moderate-density communities can also consider changing curb access (types 5, 6, 7, and 8), especially when evaluating how to implement new transit and shared transportation options in the context of AV technology, or how to encourage certain models of AV ownership or use.

What can we learn from historical examples related to curb use?

The rollout of the container freight system introduced standard semi-trailer trucks to streets throughout the world. In many cases, these trucks replaced smaller parcel trucks. Semi-trailers are quite large and without dedicated loading space, often block travel lanes, increasing congestion. These vehicles were not designed to operate effectively in dense urban areas. If the AV rollout is associated with new freight vehicle designs, especially smaller ones, it ease challenges of curb access for freight and improve the ability of trucks to operate in dense areas without snarling traffic, particularly if rolled out in tandem with building design changes.

What does community engagement look like for curb use?

Residents and businesses along streets being considered for changes related to their curb use should be directly engaged in revising curb access regulations. Other users of the street—such as people who bike or ride buses along it—should also have their views integrated into the process. For more guidance on how to conduct engagement with historically excluded populations, see the community engagement factsheet.

Policy: Greenfield Development

Jump to the guide

Greenfield development obstacles to AV ecosystem equity and environmental sustainability

Greenfield development presents both advantages and challenges for advancing environmental sustainability and social equity. On the one hand, it offers the opportunity to design communities from scratch, allowing planners to implement innovative and sustainable solutions that cater to the specific needs of residents. This fresh start enables efficient land use, integration of green spaces, and the establishment of effective and sustainable infrastructure with social equity in mind. On the other hand, greenfield development can contribute to urban sprawl and all the challenges that come with it, including increased car dependency, longer commute times, and environmental degradation due to habitat loss and increased carbon emissions from transportation (Heid 2004).

> What is greenfield development?
>
> Greenfield development takes place on previously undeveloped land. It tends to occur in and around rural areas, highways, or areas of suburban expansion. Greenfield development is not tied or constrained by any preexisting structures or infrastructure (which differentiates it from brownfield development, for example). The new development can be of any land use variety, such as industrial, commercial, residential, or infrastructure. Greenfield development can refer to isolated, small-scale new structures or the development

The introduction and widespread adoption of autonomous vehicle (AV) technology may impact greenfield development in two ways. First, AVs could lead to increased sprawl and the development of new communities on the outskirts of urban areas. The convenience of AVs enabling occupants to engage in other activities during commutes may make users more inclined to endure longer travel times. This could result in the expansion of suburban and exurban areas as people seek lower housing costs and larger properties in the periphery, a prime opportunity for greenfield development. Additionally, the development of AV-related infrastructure could highly rely on greenfield development. This would include the creation of AV parking facilities, charging stations, server farms, and dedicated lanes or routes optimized for AVs. AV-enabled freight could also leverage greenfield development to develop new industrial parks and distribution centers optimized for AVs.

How could greenfield development be managed or regulated to respond to the AV ecosystem equitably and sustainably?

AV technology could trigger an increase in greenfield development by incentivizing sprawl and requiring or facilitating the development of new infrastructure. But only in rare cases can greenfield development provide better outcomes compared to development in vacant or underutilized parcels of land within already established urban areas. Public policies may be able to set guardrails that limit urban sprawl and guide the development of new infrastructure to infill or brownfield options. Localities and states may consider several policy options to encourage development that can enable higher quality of life in the context of AV rollout:

- **Create a new or updated comprehensive plans.** Developing comprehensive plans allows jurisdictions to outline long-term goals and strategies for managing growth and development in greenfield areas. These plans typically include considerations for transportation, environmental conservation, housing affordability, economic development, and community amenities. The plan can set goals or priorities for each of these considerations by making recommendations regarding land use designations and urban growth boundaries. Localities should establish explicit strategies or considerations related to the development of new industrial and freight infrastructure, especially distribution centers (Godschalk and Rouse 2015).

- **Update land use ordinances to limit development in peripheral areas**. Localities may review and revise their zoning or land use codes (see zoning policy sheet for more information) to preemptively establish open space, environmental, or conservation zones in areas susceptible to greenfield development. This could effectively create urban growth boundaries. They may also relax certain land use restrictions in vacant or underutilized parcels within established urban areas to incentivize denser development. Municipalities could also carefully review and revise where they currently use industrial or transportation zones to guide new AV-related infrastructure, including that affecting freight, to areas closer to the urban footprint. These efforts would require extensive planning, so localities can make informed predictions of new development needs, including where these developments would be more likely to be located absent any zoning changes, and where they should be located to maximize societal value. States may get involved in this process through preemption by establishing rules that govern how local governments do zoning.

- **Create environmental regulations for greenfield development.** Implementing environmental regulations and standards could ensure that necessary greenfield development projects adhere to requirements for protecting sensitive ecosystems, wildlife habitats, water resources, and air quality (Forsyth et al 2016). Localities and states have several tools at their disposal to achieve this:

    - **Environmental Impact Assessments (EIAs)**. Localities or states may require developers to conduct EIAs before initiating greenfield development projects to help evaluate potential environmental impacts.

    - **Wetland and Riparian Buffers**: Localities or states may ban development in areas around shorelines, wetlands, or streams to help preserve critical ecosystems, maintain water quality, and prevent erosion.

    - **Stormwater Management Regulations**: Cities or states may require that new projects include the installation of retention ponds, permeable pavement, green roofs, and other stormwater management practices. These measures could control runoff and mitigate the risk of flooding, erosion, and pollution.

    - **Tree Preservation Requirements**: Cities or states may also require new projects to preserve existing trees and vegetation to maintain biodiversity, enhance air quality, and mitigate the urban heat island effect. Regulations may specify tree protection zones and requirements for planting native species.

    - **Erosion and Sediment Control Measures**: Localities or states could require new projects to include erosion control barriers, sediment basins, vegetative stabilization, and construction phasing to minimize disturbance to natural terrain and prevent sediment runoff.

- **Incentives for infill or brownfield development over greenfield.** Local and state governments can offer incentive programs to encourage developers and other stakeholders to adhere to specific planning goals that prioritize infill and brownfield development. Greenfield development has a big appeal in that land in undeveloped areas is relatively more affordable. Localities may need to shift the cost structures of urban development so infill and brownfield developments are better options. Some incentive tools include:

- **Tax incentives:** Governments can offer property tax abatements or exemptions for infill or brownfield projects.

- **Density Bonuses:** Governments may grant density bonuses to developers who choose to build within designated infill or brownfield areas so they can construct additional floors or units beyond what is typically permitted under zoning regulations.

- **Grants and Subsidies:** Governments can provide grants, subsidies, or low-interest loans to offset the costs associated with infill or brownfield development.

- **Fast-Track Permitting and Regulatory Streamlining**: Governments may streamline the permitting process and expedite regulatory approvals for infill or brownfield development projects.

- **Infrastructure Investments**: Governments can invest in infrastructure improvements and public amenities in infill or brownfield areas to catalyze redevelopment and attract private investment.

- **Fee Waivers or Reductions**: Governments may waive or reduce various development fees, impact fees, or permitting costs associated with infill or brownfield projects.

Which stakeholders are relevant to revising greenfield development?

Local governments typically make choices related to greenfield development in incorporated areas. They may regulate this through zoning codes, environmental regulations, and incentive structures. In some cases, **state governments** may also exert some influence over greenfield development across all these policy levers, except for zoning, which is by and large a prerogative of local jurisdictions due to home rule. However, more states are increasingly using preemption power to guide the way local jurisdictions regulate land use and zoning.[7] For unincorporated areas, where there could be several greenfield development opportunities, **county or state governments** may be best positioned to use policies to manage or regulate greenfield development. National parks, wilderness areas, national wildlife refuges, military reservations, and public-domain land are all administered or owned by the **Federal government**.[8] Finally, specific government agencies, at different jurisdiction levels, may have a role in executing or shaping greenfield development: **local or regional planning departments, environmental protection agencies, transportation departments, or public utilities and services providers**.

How could greenfield development pressures differ based on community type?

The communities with the lowest population and employment densities—community types 9, 10, 11, and 12—will tend to be more susceptible to experiencing greenfield development due to AV rollout since there is more availability of undeveloped land. Among these communities, those with high or moderate car and truck reliance—the exurban fringe and the metropolitan edge—may see the highest pressure to allow greenfield development, since AV technology may have a bigger impact and there would be more incentives and need to develop an ecosystem and infrastructure for it. This, in combination with the availability of undeveloped land, makes these communities highly susceptible to greenfield projects. Among these two, the exurban fringe, which is already facing high development pressure due to growth in residents and/or jobs, will face the biggest pressure to build in its undeveloped land stock. It is important that these types of communities take preemptive steps to either prevent or guide future greenfield development to maximize societal gains, promote social equity, and minimize environmental impacts.

What can we learn from historical examples related to greenfield development?

Highways made car travel cheaper and more convenient. They raised people's tolerance for longer commutes, which enabled a process of suburbanization driven by lower housing costs and more space availability. In the same fashion, highways encouraged a shift of the freight transportation system from railways and canals onto trucks. As part of this process, agricultural and natural land was converted into other uses to make room for industrial, housing, and commercial infrastructure. As a result, highways led to reduced biodiversity, mainly because they fragmented habitats and exposed other habitats to impact by humans, and because of direct mortality. The loss of agricultural land had negative environmental consequences, including issues in stormwater management, recharging of water aquifers, open space preservation, and air purification.

What does community engagement look like for greenfield development?

As explained, greenfield development takes place in areas without prior development or infrastructure, so identifying immediately affected communities to engage in decision-making is complex. Most likely, a jurisdiction may interact or engage with environmental groups, some of which may have strong connections to surrounding or nearby communities. Regardless, stakeholders should engage with communities likely to be affected by some proposed development, rural communities, homeowners, potential future residents, and people who may indirectly be affected by new developments, such as visitors, commuters, workers, and people who benefit from the environmental assets of a given location. Workshops and focus groups may facilitate in-depth discussions, fostering a deeper understanding of affected community needs and preferences. Employing visual aids such as maps, diagrams, and simulations can help residents visualize the potential impact of the development. Transparent communication channels, such as newsletters or dedicated hotlines, should be established to address inquiries promptly and keep interested parties informed throughout the process. One option to achieve this is to appoint liaisons or community ambassadors to facilitate ongoing dialogue and build trust. For best practices on how to transfer this power, see the community engagement fact sheet.

Policy: Expansion of the transportation network

Jump to the guide

Transportation network obstacles to AV ecosystem equity and environmental sustainability

The current transportation network in the US incentivizes individual car travel over public transit by investing almost four times more in highways as in mass transit or rail.[9] The proliferation of AVs could exacerbate this situation by making people more willing to travel in cars over longer distances, possibly inducing sprawl that has historically generated an unequal provision of public goods and services, residential segregation, and pockets of poverty (Nechyba and Walsh 2004).

How could the transportation network be expanded to respond to the AV ecosystem equitably and sustainably?

Rethinking the way we manage and invest in our transportation infrastructure will be paramount to ensuring that AVs lead to increased equity and environmental sustainability. This should be closely tied to right-of-way management; as transportation networks are expanded, leaders should consider how they can be planned up front with managed lanes as part of the network. Other recommendations include:

What does it mean to expand the transportation network?

The expansion of a transportation network can encompass various elements depending on the needs, goals, and constraints of the region or area being served. Some common components that might be included are:

- Roads and Highways
- Public Transit
- Cycling and Pedestrian Infrastructure
- Airports and Air Routes
- Ports and Waterways
- Intelligent Transportation Systems (ITS)
- Intermodal Facilities
- Ridesharing and Mobility Services

- **Invest in public and active transit.** Investing in public and active transit could help reduce the likelihood that AVs increase VMT, which would then lower future road maintenance costs. Investments in transit can also encourage more development in infill areas rather than construction on greenfield land in suburban locales. This can have the benefit of reducing impacts on sensitive ecologies and limiting greenhouse gas emissions.

- **Think carefully about the location of highway expansions in suburban and rural areas** so that freight, servers, and AV parking needs are efficiently located and do not disrupt local ecosystems or communities with low incomes or communities of color. Engaging deeply with communities in these areas will be central to this careful planning. Limiting highway expansion also has the benefit of, again, reducing the potential for environmentally destructive urban sprawl.

- **Invest in AV transit.** If more cost-efficient transit services can be provided by switching to automated operations, stakeholders might consider investing in AV transit options to increase access to opportunity for people of color (who disproportionately ride transit) and to increase reduce transportation-related greenhouse gas emissions and air pollutants (Stacy and Fernandez 2024).[10] Cost savings could be used to improve service quality to further reinforce these benefits. If AV transit does not substantially reduce operations costs, communities should consider upping their investment in human-driven transit options.

- **Invest in freight rail.** To mitigate potential adverse effects from autonomous freight delivery, such as increased VMT due to more frequent, smaller deliveries, decision-makers may explore investing in freight rail infrastructure to counterbalance any upsurge in freight VMT. This investment in freight rail could be associated with the construction of freight distribution hubs designed to ensure easy connections between railways and last-mile delivery options.

Which stakeholders are relevant to expanding the transportation network?

The **Federal government** and **state governments** are key decisionmakers when it comes to funding, planning, constructing, and maintaining the nation's transportation network, but **local governments** also have control over the transportation system by using federal and state funds for transportation projects within their jurisdictions. **Metropolitan Planning Organizations** can also be crucial for local transportation network expansion by helping to coordinate transportation planning and investment across multiple jurisdictions within a metropolitan area or larger region.

How could needs related to the expansion of the transportation network differ based on community type?

The expansion of public transit will be most relevant and financially feasible in dense areas, such as community types 2 and 3, but even more so in dense areas that are currently car dependent, such as type 1. Careful planning around transportation infrastructure expansion in suburban and rural areas for freight, parking, and servers will be most relevant for community types 5, 7, 9, and 11.

What can we learn from historical examples related to expanding the transportation network?

The expansion of the interstate highway system revolutionized travel, residential patterns, and land utilization, but also fostered suburbanization and a shifting of freight transport from railways to trucks (Baum-Snow 2007). While urban sprawl may have made some Americans better off than they were prior to the rise of sprawling cities (largely because urban sprawl has created opportunities for significantly higher levels of housing and land consumption for most households), they also led to: 1) unproductive congestion on roads, 2) high levels of metropolitan car pollution, 3) the loss of open space amenities, and 4) unequal provision of public goods and services across sprawling metropolitan suburbs that give rise to residential segregation and pockets of poverty (Nechyba and Walsh 2004). As AVs become more prevalent on the roads, care needs to be taken in the expansion of the transportation network to ensure that these negative effects of sprawl do not worsen.

What does community engagement look like for expanding the transportation network and what are best practices?

Current and future users of transportation networks, as well as residents of areas in which these investments might take place, should all be considered for input. Deep and meaningful community engagement with historically excluded populations such as people of color, people with low incomes, and people with disabilities should be at the core of any transportation expansion decision. This means investing early in trust building with these communities to hear what their preferences are long before proposing solutions. It does not mean going into a community and telling them why they should want whatever expansion has already been decided upon. For more guidance on engagement with historically excluded populations, see our community engagement fact sheet.

Policy: Publicly owned land

Jump to the guide

Public land use obstacles to AV ecosystem equity and environmental sustainability

In the US, about 29 percent of land surface area is owned by the Federal government and 9 percent by state and local governments (Congressional Research Service 2020). Cities, suburbs, and even small towns use land they own for a variety of purposes, such as for public facilities, affordable housing, conservation, parks and recreation, and all sorts of public infrastructure. But some of the land they own is underused. Local governments need to balance competing priorities when deciding on the best use of this valuable and scarce resource at their disposal.

The introduction and widespread adoption of AV technology may impact local governments' use of publicly owned land in two contrasting ways. On one hand, AVs may put pressure on local governments to use their land for the development of AV-supporting infrastructure. This could include the creation of charging stations, dedicated lanes or routes optimized for AVs, and communication centers critical for effective AV navigation. AV-enabled freight could also tap onto local governments and their land for the development of new industrial parks and distribution centers optimized for AVs.

On the other hand, AVs could lead to significant reduction in traditional parking infrastructure needs, freeing up vast amounts of valuable land currently dedicated to parking lots and structures, which, in some cases, are local government property or could become local government property. The efficient operation of AVs may also prompt reevaluations of transportation infrastructure, potentially leading to reduced road widths and expanded pedestrian zones, which may be owned by local governments. Local governments will need to adapt their planning strategies to harness the transformative potential of AVs, ensuring that urban development remains equitable, accessible, and conducive to higher quality of life.

What is publicly owned land?

Publicly owned land refers to land that is owned by a government entity rather than by private individuals or corporations. Examples include land for parks, government buildings, and roads, bridges, airports, and other transportation infrastructure. In the US, the federal government alone owns more than a quarter of all land, much of it devoted to parks and recreational preserves. State and local governments own about an additional 9 percent of the nation's land. Many cities also have high concentrations of public land; in Los Angeles, for example, almost 800,000 properties are owned

How could the use of publicly owned land change to respond to the AV ecosystem equitably and sustainably?

AV technology may put pressure on local governments to dedicate valuable publicly owned land for the benefit of AV use, but it may also free up more space and increase a local government's inventory of land. Since the land is directly owned by government, this is one of the policy options for which the public sector may have the most direct leverage over, making it an effective way to shape the way in which the AV ecosystem may impact land use.[11] Localities and states may consider several options to encourage use of publicly owned land in a way that enables higher quality of life in the context of AV rollout:

- **Update land use ordinances to establish desired uses for publicly owned land.** Localities may incorporate specific land use designations and regulations for the land they own that are tailored to their unique objectives (see zoning policy sheet for more information). Some of these uses or objectives may include affordable housing, public parks, community facilities, public transportation projects, or freight distribution centers. Localities may preemptively reform their land use codes to prevent publicly owned land from being used to advance motorized individual transportation through AVs or otherwise. States may participate in this process by using preemption power to regulate how localities zone their land.

- **Design and issue requests for proposals (RFPs) to develop publicly owned land.** Local and state governments can issue RFPs or requests for qualifications (RFQs) to solicit interest from developers, investors, or nonprofit organizations for projects that fit the objectives of the municipality. By developing this land, local and state governments would effectively prevent it from later on being used for potential AV-supporting infrastructure that would not be in alignment with sustainably improving quality of life.

- **Modify or leverage street design for newly freed up spaces.** If future AV prevalence leads to a more efficient use of road space, local governments could change their rules for street design to achieve different objectives, such as prioritizing pedestrians and better managing different vehicle types (see the street design policy sheet for more information).

- **Establish different mechanisms to retain control over how publicly owned land is used.** Local and state governments may rely on different levers to retain control over the use of land they own and ensure better alignment with their objectives for better quality of life and sustainability. Such mechanisms include creating land disposition authorities, development agreements, long-term lease agreements, or land banks.

Which stakeholders are relevant to managing publicly owned land?

Federal, state, and local governments, as owners of the applicable land, have the ultimate authority over its use. This control may be exercised through specific agencies or authorities, such as departments of transportation or housing authorities. These governments may still need to follow applicable norms or regulations, such as existing land use ordinances. Mayors may also require approval from their respective city councils, while state governments may require state legislative approval. Local and state governments should scrupulously follow established norms, regulations, and processes for the management or disposal of its property and assets when making decisions over publicly owned land.

How could publicly owned land be managed or used differently based on community type?

Communities with high development pressure—community types 1, 2, 5, 6, 9, and 10—are more likely to face pressures from car and AV industries to use valuable land, including publicly owned land, for AV-supporting infrastructure. This pressure may be more critical in communities that also have high or moderate density—community types 1, 2, 3, and 4. In these communities, land is scarcer and, thus, local and state governments should be more scrupulous in terms of how they use their assets in a way that delivers maximum possible social goods, whether that is through transportation-related infrastructure or not.

What can we learn from historical examples related to the use and management of publicly owned land?

Bike sharing, ride hailing, and electric vehicles provide some examples of how new technologies have affected how governments use their proprietary land. Bike sharing increased competition for curb space to incorporate docking stations onto curbs. Similarly, ride hailing services increased the demand for curb access, although examples of cities dedicating curb space to new uses or changing practices for managing access are limited. Ride-hailing services have decreased demand for parking in central urban areas and at locations that typically have large, dedicated parking facilities such as airports and stadiums. In some cases, these facilities may be or include government property.

What does community engagement look like for curb use?

In a context of rising AV use, local and state governments may be subjected to pressure to dedicate publicly owned land for AV-supporting infrastructure. However, it will be important to balance these pressures with input from other stakeholders, including people who live, and businesses located, close to the corresponding land sites, but also historically marginalized communities that could be affected or benefited by the counterfactual use of publicly owned land (for example, potential residents of future affordable housing built on city-owned land that is used instead for an AV parking site). Tenants of publicly owned land or developers may also need to be considered in decisions regarding the use of these properties, either because they may have rights or interests over them. Other stakeholders, such as affordable housing and environmental sustainability advocacy groups and urban planning experts, should also be involved. Governments may host town hall meetings, public forums, and online surveys to gather input from the community to understand their needs, preferences, and concerns regarding the potential uses of publicly owned land, either at the level of specific sites or more generally. Moreover, incorporating participatory planning methods such as charrettes or design workshops can empower residents to actively contribute ideas and collaborate in the decision-making process. For best practices on how to transfer this power, see the community engagement fact sheet.

Policy: Right of Way Management

Jump to the guide

Right of way obstacles to AV ecosystem equity and environmental sustainability

Current right of way management on roads may not be the most efficient for a world in which AVs are prevalent, either with human-driven cars or without. As lane widths become narrower and lane capacities increase in a scenario with high AV adoption, there is a chance to redistribute road space to accommodate other modes or needs, such as extending the sidewalk or implementing alternative transportation options (Infrastructure Victoria 2018).

Right of way management changes will also be needed for curb space management as AVs become more prevalent. The most common way that local governments provide access to curb space for shared mobility, such as car sharing, bike sharing, and loading zones for ride-hailing, is through the public right-of-way. See our Curb Management Fact Sheet for more.

What is right of way management?

Right-of-way management refers to the process of determining and regulating the allocation and usage of space within transportation corridors. This includes roads, highways, railways, waterways, and airspaces. The goal of right-of-way management is to ensure safe and efficient movement of people and goods while minimizing conflicts and maximizing the capacity of the transportation infrastructure. This can include land acquisition, zoning and land use planning, traffic controls and signals, permitting, and easements and

How could right of way management be amended to respond to the AV ecosystem equitably and sustainably?

Below is a list of ways by which leaders can manage the right-of-way to help ensure that AVs benefit equity and environmental sustainability.

- **Create managed lanes for AV busses and other transit and give them the priority in the right of way.** Since AVs **can drive closer together**, allocating freeway lanes exclusively to AVs may have benefits. While managed lanes that only allow AVs may reduce conflicts with human-driven vehicles and provide a controlled environment for AV testing and deployment, they may have equity implications given that AVs will likely be too expensive in the short to medium term for people with low incomes (Hussain, Ghiasi, and Li 2016). These managed lanes may also crowd out bus rapid transit lanes, which have the benefit of leading to fewer emissions and increasing equity, compared with private or ride-hailed AVs. Managed lanes and right-of-way preferences for AV busses and other transit may be the best option for deploying AVs in a way that is safe, equitable, and sustainable.
- **Consider congestion pricing and reinvest revenues into transit.** Congestion pricing—charging more for road use at certain times of day and in certain locations—can help mitigate the traffic that AVs are likely to cause. Congestion pricing may be most effective when leaders reinvest the profits gained into local public transit systems and other equitable means of travelling so that riders are more likely to shift from cars to transit rather than to just a different time of day. Congestion pricing can raise equity concerns, though, so leaders should consider implementing discounts or exemptions from this pricing for people with low incomes and people with disabilities (National Association of City Transportation Officials, 2019).
- **Carefully design geofences.** Geofences are virtual boundaries that restrict where AVs can travel. AVs at Level 4 or higher often need to be restricted to areas already mapped in detail using LIDAR

and other sensing techniques.[12] Level 5 AVs will involve removing these fences, but this will may artificial intelligence that can make abstractions and inferences and become smarter as they are being used. Until then, geofences can help lower response times, reduce systemwide VMT across all modes, and ensure uniform access to shared AVs. When defining geofences, leaders should consider both the efficiency and VMT implications of the geofence location, as well as the equity in access to shared AVs for people of color and people with low incomes.

- **Open up new land for pedestrians and bicycles.** AVs are likely to require less road space compared to conventional vehicles, creating additional room within the public right-of-way for pedestrian and bicycle pathways. Local leaders could help to reduce VMT and improve health outcomes by using some of this newly opened land for pedestrian and bicycle paths and giving additional right-of-way preferences to these active modes of transit.
- **Integrate with the transit system.** Leaders can consider integrating AVs with existing public transit systems to provide first-mile/last-mile connectivity to improve overall mobility options. This could include designated pick-up and drop-off zones for AVs at transit hubs or coordinating AV services with public transit schedules to enhance accessibility and convenience for passengers.
- **Use carrots and sticks to discourage empty VMTs.** Leaders might consider regulating right of ways by imposing fines or fees on empty cars in city centers to minimize empty VMT, and/or by using subsidies for ride pooling to offset some of the VMT that is likely to occur as AVs become more prevalent. However, leaders should balance these tools to ensure that they do not offset the benefits of reduced parking in central cities; i.e., if these taxes are too high, they could discourage cars from parking in less dense inner suburbs and maintain the need for parking in central cities. One way to do so might be to tax empty VMT and parking, which should encourage shared uses. Leaders will need to carefully balance the tradeoffs between the need for less parking and increased VMT as AVs continue to grow in popularity on our roads.

Which stakeholders are relevant to right-of-way management?

Right-of-way management will likely require the development of new regulatory frameworks to govern the operation of AVs within transportation corridors. This may involve establishing rules and standards for AV behavior, safety certification requirements, and liability considerations. Additionally, regulations may need to address issues such as data privacy, cybersecurity, and ethical decision-making algorithms for AVs. A uniform set of regulations would be ideal, but **states**, **localities**, and **metropolitan planning organizations** will also likely need to generate rules that are specific to their regions.

How could needs related right of way management differ based on community type?

Right-of-way management will be most relevant in dense areas with high traffic volume, such as community types 2 and 3, but even more so in dense areas that are currently car dependent such as type 1. Because rural roads can be the most dangerous, however, right-of-way management is also important for less dense communities such as types 9, 10, 11, and12.

What can we learn from historical examples related to right of way management?

The historical example of streetcars offers insights into the transformative impact of transportation technologies on the management of right-of-way. Similar to AVs, streetcars operated within the public roadway right-of-way, utilizing dedicated metal railways powered by electricity. Streetcars revolutionized urban transportation from the late 1800s to the mid-1900s, fundamentally altering the size and layout of cities. Before streetcars, city expansion was limited by walking distances. However, the introduction of streetcars extended the reach of urban areas, facilitating the emergence of "streetcar suburbs." These suburbs provided housing in less densely populated settings within commuting distance of urban jobs, leading to the expansion of urban land areas.

In a contemporary context, this historical parallel underscores the importance of managing right-of-way to accommodate emerging transportation technologies like AVs. Just as streetcars influenced urban development patterns, AVs have the potential to reshape transportation networks and urban landscapes. Proper management of right-of-way is essential for optimizing space utilization, facilitating efficient and equitable transportation access, and promoting sustainable urban growth in the era of autonomous vehicles.

What does community engagement look like for right of way management and what are best practices?

Community engagement plays a crucial role in right-of-way management, particularly concerning the integration of AVs into urban environments. Community engagement with historically excluded and marginalized populations is essential for ensuring that right-of-way management strategies related to autonomous vehicles are inclusive, responsive, and aligned with the needs and aspirations of the communities they serve. By fostering dialogue, building trust, and promoting collaboration, effective community engagement can lead to more equitable, sustainable, and resilient urban transportation systems. For more tips on how to ensure that engagement is with historically excluded populations, see the community engagement fact sheet.

6. Use metrics to assess AV rollout and land use change

A varied and well-rounded set of measures is essential because of the uncertainties inherent in the rollout of the AV ecosystem. For example, since we do not know how quickly, and to what degree, autonomous freight and passenger services will become available, it will be up to future users of the toolbox to self-diagnose and identify mechanisms to address their needs. Our focus when it comes to metrics is on increasing social equity and environmental sustainability.

Overall, these metrics are designed to:

1) Help practitioners and other stakeholders develop public policies, regulations, and plans related both to the AV ecosystem and land use tailored to the characteristics of their communities, and

2) Provide practitioners and other stakeholders the means to monitor for negative and positive impacts accruing to their communities of interest as the AV ecosystem is deployed.

We recommend that policymakers and community members interested in planning for AV rollout begin identifying how they could begin data collection on each of the metrics we define below, so that they are ready for roll out as it occurs. We developed these metrics based on other work. Our review of the scholarship informed our understanding of what issues policymakers and others should be looking for when identifying how AVs could affect land uses (e.g., previous research has demonstrated that AVs could substantially reduce demand for parking). And our analysis of five historical case studies of transformative transportation technology informed our identification of steps practitioners should take to track changes over time (e.g., if, as with the development of highways, AVs result in substantially higher levels of VMT, planners should be concerned about the role of the AV ecosystem in leading to environmentally destructive patterns of sprawl).

The metrics we have developed are designed to apply to multiple geographical levels, such as states, metropolitan areas, counties, cities, neighborhoods, and even districts, such as the areas surrounding hospitals. Because the AV ecosystem will have land use impacts, we point to strategies to ensure coordination between transportation and land use planning agencies, since both have to be involved to ultimately achieve outcomes that meet our overall goals of increased equity and environmental sustainability.

Box 6.1 About the Term “Metric”

While there is no consensus on the difference between the terms *metrics* and *indicators*, in most cases, *metrics* are defined as quantitative, raw measures, while indicators tend to be used in the context of a specific program or activity to assess their performance.[13] Because our toolbox is not evaluating any specific program or activity, but rather a large array of conditions and policy approaches and options, we believe the former definition better fits the needs of this document. Moreover, to avoid confusion for toolbox users whose primary goal should be to leverage the toolbox, not get caught up in semantics, we use only the term *metrics* moving forward.

Tracking the AV rollout

As communities navigate the proliferation of AVs, it is crucial to establish comprehensive metrics and tracking mechanisms so communities and decisionmakers can monitor changes and impacts, while making appropriate revisions to their strategies, including to redress emerging disparities ensure equity.

We propose the following metrics.

1) **Total Number of AVs Registered:** The absolute number of AVs registered within a community, providing a baseline for tracking growth over time. The source of this type of information will vary by area. In some cases, this data could be collected and managed by state or city departments of motor vehicles, departments of transportation, traffic police or law enforcement agencies, or other transportation authorities. Some jurisdictions may first need to make decisions on how information on fleet sizes is collected and managed, and by whom.

2) **Frequency, Duration, and Origin-Destination of AV-Based Trips:** This set of metrics offer insights into usage patterns and trends. For example, times of the day or days of the week during which AVs are used more often, geographic areas or roads most used by AVs, and types of trips (e.g., for commuting or recreation). These insights could inform better land use planning decisions by tackling policy areas more likely to be impacted by AVs. This type of information would need to be collected by AV technology providers and jurisdictions and authorities would need to reach agreements with these private entities to ensure access to these data for policymaking purposes. Such agreements could be made when negotiating operation licenses for these companies.

3) **Share of Commuters Using AV Services:** This metric indicates the degree of reliance on autonomous transportation for daily commuting. This metric could be approximated by observing patterns in the previous metric. For example, whether a great share of all trips happens from Monday to Friday, during peak hours, and between common residential and labor centers within a city. Otherwise, the data for this metric could be collected via household surveys.

4) **Share of Overall Travel Conducted Using AVs:** The percent of all passenger miles traveled that take place in an AV is the key metric to understand the intensity of AV rollout and how common or even essential this technology becomes in a given community. Means of transportation are more commonly collected via surveys. However, this information may be complemented by administrative data from different government entities, such as transit and transportation authorities.

5) **Descriptive Data on AV Ride-Hailing Companies:** AVs will most likely be operated by private companies, which will provide the communication and technology services that enable these vehicles to function, even if individually owned. As such, it is important for communities and stakeholders to understand how these firms operate, including by collecting information about business models, governance rules, staff structure, fleet size and types, among others. This descriptive data could provide insights for more effective land use planning.

6) **Share of Local Freight Deliveries by AV Freight Vehicles:** This metric will help assess the penetration of autonomous technology in the logistics and goods movement sector for more effective land use planning, particularly around the use of the curb for the pickup and delivery of goods, the management of rail for freight, and the development of distribution centers. This type of information would most likely be collected through surveys of businesses.

7) **Survey-Based Public Opinions:** Conducting surveys to gauge public opinions and perceptions related to AVs offers valuable insights into community acceptance, use, concerns, and preferences regarding autonomous transportation. This information will also be critical to identify potential equity issues in the deployment and impacts of this technology. This survey could be combined with the household survey mentioned in metric 3.

8) **Readiness of Streets and Public Infrastructure:** Communities could monitor changes in public infrastructure aimed at accommodating AVs. Changes in street and lane management (including the full right-of-way), parking garages, traffic cameras and other on-street tech equipment, and curb design, could not only signal an intensified adoption of AVs but also its impact on the built environment. This assessment could be conducted by on-the-ground visual surveys.

9) **Change in Jobs and Economic Dependency:** Monitoring changes in the number of jobs in freight, warehousing, and transportation sectors, as well as assessing economic dependency on these sectors relative to the overall economy, helps assess potential workforce disruptions and economic shifts, revealing significant levels of AV adoption. Public administrative data could be used for this purpose, such as that from the Bureau of Labor Statistics and the Current Population Survey.

By systematically tracking these metrics, cities and states can effectively monitor the progression of AV deployment, identify emerging trends and challenges, and proactively adapt policies and strategies to maximize the benefits of AV technology in relation to land use, while addressing potential risks and concerns.

Outcome metrics

As communities and their stakeholders navigate AV rollout, it is key to establish clear outcome metrics to assess the effectiveness and impact of related land use policies. The purpose of this toolbox is to help communities achieve improvements in the quality of life of their communities in an equitable and environmentally sustainable manner. Outcome metrics provide the necessary framework for policymakers and other stakeholders to measure progress on this goal and identify areas for improvement. Without robust metrics in place, we risk implementing policies that fall short of their intended outcomes or inadvertently exacerbate existing challenges. Below, we provide measurable outcome metrics related to expanding quality of life, social equity, and environmental sustainability. For each metric, we describe what outcome communities should consider aiming for.

It is important to note that different communities have different priorities or even interpretations of what *quality of life* means*.* The set of metrics we propose are neutral in nature, and each toolbox user and other related stakeholders will need to determine which metrics are relevant for their specific priorities and contexts. Communities will also need to set their own targets for each of these metrics based on these priorities and contexts.

We outline potential key outcome metrics to track the impacts of recommended actions related to land use planning in the context of a future with AV prevalence. While we separate metrics that could be used exclusively for the purpose of assessing social equity outcomes, all other outcome metrics related to quality of life and environmental sustainability should be collected and analyzed in a way that makes it possible to disaggregate information by demographic characteristics such as age, gender, race/ethnicity, income, and disability. This allows stakeholders to conduct equity assessments across all metrics and dimensions.

Quality of life

1) **Road Injuries and Fatalities.** This metric tracks the number of injuries and fatalities resulting from all traffic accidents, including those involving AVs. Monitoring these incidents will not only allow policymakers and regulators to assess the effectiveness of AV safety measures and regulations, but also how these may interact with certain types of street design or land use features. One example is related to curb management and lane widths. This information can be collected through existing traffic incident reporting systems, emergency services dispatch, or traffic cameras. Incidents involving AVs should be reported by the companies to the applicable agencies. **Outcome to aim for: Reduced road injuries and fatalities over time.**

2) **Commuting and Travel Times.** This metric measures the time it takes for individuals to commute or travel using AVs compared to traditional modes of transportation. This matters because reducing travel times enhances productivity, improves quality of life, and reduces congestion and environmental impacts. By tracking commute and travel times, policymakers can evaluate the

efficiency of AV networks, identify bottlenecks or inefficiencies in transportation systems, and prioritize investments in infrastructure or service improvements. This information can be collected from transit authorities, AV firms, and household surveys. **Outcome to aim for: Reduced travel time over time.**

3) **Spatial Mismatch.** This metric assesses the gap between where jobs are located and where job seekers live in terms of distance and accessibility. Large gaps can harm both employers and potential workers. Employers may have positions that go unfilled, and potential workers may be discouraged from seeking available jobs by commuting costs that outweigh take-home pay.[14] This metric can reveal the extent to which land use initiatives or changes in interaction with AVs may mitigate or exacerbate spatial mismatch and access to opportunities. Data on the location of job openings can be obtained from third-party data providers, and these locations may be compared to specific areas in a community, such as public housing sites, housing voucher holders, or low-income tracts. **Outcome to aim for: More employment opportunities available for workers over time.**

4) **Accessibility of AV services at transit stations.** This metric assesses the ease with which individuals can access AV services from transit stations, considering factors such as proximity, affordability, and service frequency. Integrating AV services with public transit hubs can enhance first- and last-mile connectivity, particularly for underserved communities, older adults, and people with disabilities. Information to build this metric could be sourced directly from AV companies or transit authorities. **Outcome to aim for: Increasing share of transit stations with easy access to integrated AV services over time.**

5) **Housing Costs.** Housing affordability is vital for quality of life as it directly impacts individuals' well-being and socio-economic stability. Affordable housing ensures that individuals and families can allocate their resources effectively, allowing them to meet other essential needs. **Outcome to aim for: Reduced housing costs over time.**

   There are several ways in which a community may assess the affordability of housing within a community, usually relative to income levels. We provide a list of more specific options below:

   a) **Median Rent:** The median rental price in market-rate housing.

   b) **Rent-to-Income Ratio:** This ratio compares median rent to median household income, indicating the percentage of income spent on rent. A lower ratio suggests greater affordability.

   c) **Housing Wage:** The hourly wage a household must earn to afford a typical rental unit without spending more than 30 percent of income on housing, as recommended by the US Department of Housing and Urban Development.

   d) **HUD's Rental Affordability Index:** An index that considers rent prices, household income, and other factors to provide an overall measure of rental affordability in a market.

   e) **Median Home Price:** The median price of homes sold in the market.

   f) **Median Monthly Housing Payments:** The monthly housing payments a family incurs to cover mortgage repayment, maintenance costs, fees, prorated insurance, and tax payments.

   g) **Home Price-to-Income Ratio:** This ratio compares median home prices to median household income, indicating the affordability of purchasing a home. A lower ratio suggests greater affordability.

h) **NAR's Housing Affordability Index:** The National Association of Realtors (NAR) develops an index that measures whether a typical family earns enough income to qualify for a mortgage loan.

i) **Foreclosure Rate:** A lower foreclosure rate suggests greater stability in the housing market and may indicate more affordable homeownership options.

Social equity

1) **Affordability of AV Ride-Hail or Transit Services.** This metric assesses the financial accessibility of AV transportation options for residents within a community. Affordability ensures that AV services are inclusive and not limited to only those with higher incomes, thereby reducing disparities in mobility and the opportunities to which effective mobility gives access. Monitoring this metric would allow policymakers to identify any affordability barriers and implement measures to address them, such as subsidies, fare capping, or boost supply in a way that brings down prices. It is important to monitor changes in AV service prices compared to inflation and wages. Policymakers and stakeholders can track these prices through market studies. **Outcome to aim for: Lower inflation- and income-adjusted costs to use shared transportation services over time.**

2) **Availability of AV Services in Equity Zones.** Equity zones are designated neighborhoods or areas of historical disinvestment where policymakers have implemented intentional efforts to improve equity by encouraging investment. Equitable access to transportation is crucial for promoting social inclusion and economic opportunity, so ensuring the availability of AV services in these zones can help address transportation-related disparities by providing residents with convenient and reliable mobility options. Policymakers and stakeholders can collect this information through market studies about the areas serviced by AV companies and public agencies. **Outcome to aim for: Higher levels of transportation services offered in historically underinvested communities over time.**

3) **Demographic Characteristics of AV Users Versus General Population.** Understanding the demographic makeup of AV users helps policymakers assess the technology's adoption patterns and its impact on different segments of the population. By examining factors such as age, income, gender, race/ethnicity, and residential location, policymakers can identify disparities in AV adoption and tailor outreach efforts or service provision to better meet the needs of diverse communities. At the individual level, this kind of data is highly sensitive. Policymakers and stakeholders need to reach carefully crafted data sharing agreements with AV companies to obtain this type of data, most likely in an aggregate format. Another option to obtain this information is by conducting household surveys that ask about AV use (similar to those mentioned in the previous section) and demographic characteristics. **Outcome to aim for: AV use that is increasingly representative of the population overall over time.**

4) **Share of Local AVs that are ADA-Compliant.** This metric measures the proportion of AVs within a community that meets the accessibility standards outlined in the Americans with Disabilities Act (ADA). Ensuring that AVs are accessible to individuals with disabilities is essential for promoting equitable mobility and social inclusion. This metric enables policymakers to better understand gaps in inclusive transportation, which they may address through a diversity of policies or initiatives, possibly related to land use. Reporting on ADA-compliance should be mandated for AV companies and other entities using AVs. **Outcome to aim for: An increasing share of AV passenger vehicles that is fully ADA-compliant over time.**

Environmental Sustainability

1) **Share of Local AVs that are Electrically Powered.** Electric AVs can significantly reduce greenhouse gas emissions and local air pollution compared to conventional fuel vehicles, and in so doing, contribute to improving environmental sustainability and public health. This metric could be affected by specific land use-related practices or initiatives, such as those related to the availability and location of charging stations. That said, more electric vehicles, whether autonomous or not, result in better environmental outcomes only if compared to a counterfactual of the same number of fossil fuel-powered vehicles. Information to build this metric should be reported by AV service providers and other entities using AVs. **Outcome to aim for: An increasing share of AV passenger and freight vehicles that is electrifically powered.**

2) **Vehicle Miles Traveled by Type of Vehicle.** This metric assesses the distribution of vehicle usage across different modes of transportation and vehicle types. A higher share of individual car use, compared to passengers using transit and ride hailing, means a higher environmental impact in the form of carbon emissions and exhaust from tires and brakes. For AVs, the data to calculate VMT could be sourced directly from the entities managing them: e.g., AV suppliers, ride hailing platforms, or transit authorities. For all other vehicles, VMT is usually estimated using traffic counters, which are electric sensors placed on a sample of roads to count how many vehicles pass them. The technology used for this purpose would need to be able to identify the type of vehicle it registers (e.g., individual passenger vehicles, taxis, freight trucks, buses, etc.). **Outcome to aim for: Reduced VMT per capita in single-occupancy vehicles over time.**

3) **Share of new development occurring on infill versus greenfield land.** This metric compares the proportion of new development projects located on infill sites—urban areas that already have infrastructure and development—versus greenfield sites—undeveloped land in suburban or rural areas. Prioritizing infill development promotes efficient land use, reduces urban sprawl, preserves natural habitats, and maximizes existing infrastructure investments. Information for this metric can be collected by local, regional, and state authorities that regulate any new development in the applicable community. **Outcome to aim for: An increasing share of new development on infill land over time.**

4) **Density of new development for residential and non-residential uses.** This metric measures the intensity of new land development, expressed as the number of housing units or commercial spaces per acre or square kilometer. Higher development density reduces the need for expansive land development, thereby preserving natural habitats and agricultural land. Additionally, it promotes more efficient transportation systems and encourages walking and public transit use, leading to lower greenhouse gas emissions and mitigated environmental impact. Information for this metric can be collected by municipal authorities that regulate any new development in the applicable community. **Outcome to aim for: Higher densities of new development over time.**

5) **Number of parking spaces (both private and on-street).** Excessive parking infrastructure can have adverse environmental impacts by inducing car dependency, consuming valuable land, increasing impervious surfaces, and contributing to traffic congestion and urban heat island effects. A community may utilize satellite imagery and geospatial technology to systematically analyze and map parking areas across the city, including both on-street parking and private parking lots, while complementing the data with ground surveys for accuracy validation. **Outcome to aim for: Reduced number of parking spaces per capita over time.**

6) **Rate of underutilized land conversion.** This metric evaluates the pace at which underutilized or vacant land, including parking lots, is repurposed for productive uses facilitated by AV adoption and use. Using land use to leverage AV technology presents opportunities to reclaim valuable urban space for housing, parks, commercial activities, and green infrastructure. This information could be

collected by the applicable municipal authorities that regulate and approve new developments and changes to the build environment, such as sidewalks. **Outcome to aim for: Increased development on underutilized land over time.**

7) **Carbon emissions per capita.** This metric calculates the amount of carbon dioxide and other greenhouse gas emissions generated within a community or region. Reducing carbon emissions is essential for achieving sustainability and climate resilience goals. For this purpose, we recommend following the World Resources Institute, C40 Cities, and the ICLEI.[15] Policymakers and communities should track emissions from transportation-related sources to better understand the potential impact of AVs in this area. **Outcome to aim for: Reduced per-capita carbon emissions over time.**

7. Implementing the toolbox: Examples for how this toolbox could be used

This toolbox is designed to be used by a variety of stakeholders in the fashion that best meets their needs. In this section, we provide five examples of how users could leverage information from the toolbox to support the goals of achieving greater equity and environmental sustainability. The five examples are linked below:

- A state department of transportation
- A city department of housing and urban planning
- A metropolitan planning organization
- A university
- A neighborhood association

Each use case is a prototypical example with invented organizations, place names, and projects, to help people to imagine how the AV ecosystem may rollout, and what policies they can undertake to address its potential land use implications.

Users should feel free to deviate from the exact uses described here to best meet their needs and goals.

Use case 1: State Department of Transportation

Context

Cascadia, the recently created 51st state, has established one of the most ambitious policies to reduce harmful global and local pollutants from its transportation sector. Through a long consultation process, Cascadia's Department of Transportation (CSDOT) established statewide CO_2 emission targets for the sector that are aligned with the United States' international climate commitments and which are designed to eventually achieve a complete decarbonization of the sector by 2050. As part of its proposed strategies to achieve this goal, CSDOT has identified land-use planning as a key element to reduce emissions, by making modes such as walking and cycling feasible throughout all communities in the state. However, it has not created any guidance or concrete plans to support local government agencies in aligning their transportation and land-use planning and investment.

SwiftDrive, the new AV ride-hailing company that has thus far only been operating in its native California, has been making plans to enter the Cascadian market. As part of its plans, SwiftDrive met with CSDOT to share its intended timeline of starting a pilot program in the coastal city of Havenfield as soon as next year, but with plans to expand to all major cities in Cascadia in the next five years. CSDOT is responsible for permitting AV operations in the state, but due to the novelty of this technology, CSDOT has not yet had the opportunity to consider how the rollout of an AV service would affect its CO_2 emission targets and is especially concerned about the impact that a cheap AV ride-hailing service might have on planning decisions made by local authorities.

For this use case, table 7.1 lists major stakeholders with a meaningful role to play in affecting the rollout of the AV ecosystem in the context of land use policy.

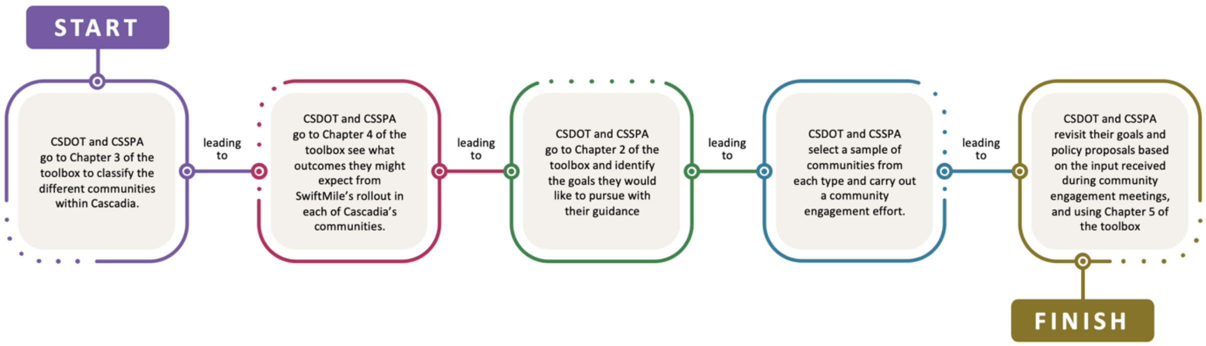
Table 7.1 Stakeholders

Name	*Role*
CSDOT	***Responsible for transportation strategy in the state and permitting for AV services***
Cascadia's State Planning Agency (CSSPA)	***Responsible for land use strategy in the state, but with limited power of enforcement. Mainly works as a technical partner to local authorities***
Local authorities (e.g., cities and counties)	***Ultimately responsible for land use plans for their jurisdictions. Will take guidance from CSSPA, but they are not necessarily bound by CSSPA's decisions***
Local advocacy organizations	***Representing diverse causes***
Residents	***Facing day-to-day challenges of the existing mobility system***
SwiftDrive	***AV ride-hailing company, interested in receiving an operating permit from CSDOT to expand their market in Cascadia***

Using the toolbox to link land use and the AV ecosystem

After the meeting with SwiftDrive, CSDOT decides to use this toolbox to plan next steps as it prepares for SwiftDrive's arrival. With its CO_2 targets, CSDOT has a clear goal of reducing emissions from the transportation sector, but it understands that a one-size-fits-all solution is difficult given the different types of communities within the state (from dense and urban Havenfield to the sprawling agglomeration of small, rural towns in its wine country). CSDOT therefore works with CSSPA to use the toolbox to develop plans for the future. The organizations follow the steps summarized in figure 7.1.

Figure 7.1 How a state government could leverage the toolbox to plan for the AV ecosystem



Below, we detail the steps that are described in figure 7.1.

1. CSDOT staff, in conjunction with CSSPA, go to Chapter 3 of the toolbox to classify the different types of communities in the state for which it will build development plan guidelines that align with its CO_2 targets. After conducting a classification exercise based on density, development pressure, and the current car and truck reliance of its communities, it notices that most of its communities fall within four categories:
    a. The car-heavy urban core
    b. The sprawling suburb
    c. The rural center
    d. The rural town
2. With this understanding, CSDOT and CSSPA staff go to Chapter 4 of the toolbox to learn more about the expected interactions between a potential AV rollout and land use outcomes in each of the community types. They notice that the potential impacts of an AV rollout in each community can be markedly different, which will require different guidance for each type of community. The state agencies learn that, absent the proper land-use levers, it could see the following impacts in its different communities:
    a. The car-heavy urban core could see an increase in car use due to the higher number of AVs that will coexist with the current privately owned car stock. Given existing infrastructure, it could risk sprawling due to higher tolerance for longer commutes.
    b. The sprawling suburb's car usage will likely increase due to the fact that the shared use of AVs will likely not be effective for most trips, meaning that most people are likely to travel alone, even if they are not doing so to get to the office.
    c. The rural centers could see an increase in travel because shared-use services are unlikely to be effective for most trips; most people are likely to travel alone.
    d. The rural towns could see an expansion of trucking, combined with warehouse and distribution facilities. This may expand congestion on the highway system and increase the transformation of land to fill the needs of the freight system.
3. Having noted these potential impacts, CSDOT staff go to Chapter 2 of the toolbox to learn about the past and select what goals, in addition to the goal of CO_2 reduction, the agency wants to pursue with the guidance it will prepare for each different community type. Agency staff decide that ensuring that AVs support the access to the necessities of residents is a key goal. Specifically, staff want to support residents living in:
    a. The quickly expanding suburb communities who are heavily reliant on their private vehicles and might need alternatives to their cars to conduct their daily activities, and

    b. Those living in the quiet, clustered rural town who are aging and are having difficulties with accessing healthcare.

4. Armed with all of this information, CSDOT and CSSPA staff start a community engagement process, in conjunction with local transit agencies and other local government entities in a few communities representative of each community type. Agency staff use the community typology factsheets to prepare a presentation showing how the rollout of SwiftDrive might impact each community they are engaging with and the historical examples from the appendix (available on the Transportation Research Board website) to hypothesize what could go wrong with the deployment of new technologies. They also include their goals of access and CO_2 emissions reductions in their presentation. In the communities they have selected for engagement, they conduct a shared-planning exercise with the local transit agency, community members, and local advocacy organizations. They realize two things:
    a. That their assumptions of residents from the quiet, clustered rural town were true; the quickly ageing population is having difficulty in accessing specialized healthcare centers.
    b. That, while their assumption about reliance on private vehicles of the quickly expanding suburban communities is true, residents there do not feel that AVs will solve their problems since they see rush hour traffic on the main commuting highway, I-104, as something the state should solve.
5. With this new information, CSDOT and CSSPA staff go to Chapter 5 of the toolbox to identify the policies that would support their revisited goals. CSDOT staff find some useful guidance that will help create an AV permitting process that prioritizes its revised goals. Since CSSPA is not implementing any policies but simply providing guidance to local authorities, they use the policy factsheets to create a tailored guidance document for each of their community types knowing that ridesharing could be the tipping point for AV services being deployed in the state and that some of their communities are especially vulnerable to changes to freight distribution brought about by AVs. Specifically, Cascadia's agencies recommend local jurisdictions implement the following actions and policies:
    a. Havenfield, its car-heavy urban core, should consider the possibility of redesigning its roads to dedicate more space to pedestrians, cyclists, and transit, considering that AVs make a more efficient use of road space.
    b. The state's sprawling suburbs could create a distribution center for freight from a variety of companies at the edge of each community, use land-use policy to encourage the creation of mixed-use community centers, with multiple types of housing and access to retail, link community centers with a variety of non-motorized travel options, and encourage an increase in housing density.
    c. The rural centers of the state could encourage the transformation of strip malls and business parks into mixed-use walkable urban centers, pilot small-scale freight delivery options in certain parts of the community, identify key corridors for the implementation of AV transit services, and eliminate parking requirements to support neighborhood redevelopment.
    d. The rural towns could develop cooperative arrangements between shippers to coordinate facilities, encourage intermodal shipping with a focus on moving goods by freight rail if possible, limit competition for new businesses between individual jurisdictions by preventing the use of economic development subsidies for freight-related uses, and consider implementing a greenbelt policy to ensure the continued survival of agriculture and the preservation of key natural spaces on the region's edge.
6. CSDOT and CSSPA then refer to Chapter 6. Use metrics to assess AV rollout and land use change to develop metrics that would enable them to track the success of their policies and plans, and

make adjustments if needed. For example, for Havenfield, they decide to track road injuries and fatalities, to see if the roads that were redesigned to dedicate more space to pedestrians, cyclists, and transit riders are creating safer conditions for those vulnerable road users. They look for the source of this data and find that it is collected by the CSDOT's Office of Traffic Safety. They then add a Monitoring and Evaluation section to their plan that suggests requesting this data every year. If injuries and fatalities are stable or rising, their plan calls for conducting a road safety inspection in cooperation with owners' of the dangerous roads, to determine how to more safely integrate AVs with other road users. For the other community types, CSDOT and CSSPA conduct a similar process of identifying relevant metrics and their associated data sources, creating a plan for data collection and analysis, and indicating the stakeholders to coordinate with and the actions to take if the metrics indicate that their policies and actions are not having the desired impact.

Outcomes

After creating its guidance document, CSDOT and CSSPA hope that it will serve as a foundation for additional services that might wish to operate in Cascadia. Their main goals remain the same: achieving CO_2 emission reductions and improving access to necessities of the population. But they are realistic about the expectation that the policy guidance they provided might take years to implement. They still believe that their goals will be achieved by encouraging Havenfield to prevent additional sprawl, and by encouraging some modal shift towards non-motorized modes of transportation and shared modes such as SwiftMile's services.

Anecdotally, they have heard that older adult residents of the quiet, clustered rural towns are really enjoying SwiftMile's service, and that it has helped them to access both healthcare, and other opportunities such as some of the wineries and other entertainment venues which were previously hard to reach without a car.

Use case 2: City Department of Housing and Urban Planning

Context

Starling City is an American city that experienced rapid growth in its service and financial sectors in the 1970s through 1990s. This led to high population and employment densities. But recently, it has had low levels of population change and development pressure, combined with a persistently high reliance on cars and trucks. Its downtown features large modernist office towers, many of them surrounded by parking lots and parking garages. Both buildings and parking are surrounded by wide streets that are designed to move thousands of cars every hour. The road construction boom of the last few decades tore over historic neighborhoods and resulted in the segregation of communities by urban highways. While public transportation options exist, these have not been prioritized by Starling City Transportation Department (SCTD), and most bus routes thus have low frequencies. Residents have therefore had to rely on their private vehicles to access job opportunities, which creates a negative pressure on household finances, since they have to spend large portions of their incomes on owning, insuring, and maintaining their cars. In addition to this, most families that were able to afford suburban houses left the city core over the past few decades, but many kept their jobs within city limits. This has led to increasing congestion during rush hours from suburban commuters that has made public transit an even slower option.

The mayor of Starling City made a campaign promise that she would work to cut commuting times of Starling City residents by one third. Leadership from SCTD and Starling City's Department of Housing and Urban Planning (SCDHUP) have therefore been considering ways in which they can reduce commuting times for residents to fulfil the mayor's campaign's promise.

Knowing their goals, WayGo, the autonomous shuttle company that has been carrying out testing in a warehouse just outside of Starling City, has just approached the mayor to offer to implement an autonomous shuttle route that would connect residents from the wealthy neighborhood of Golden Oaks to downtown, where office space predominates. The mayor tasked staff from SCTD and SCDHUP to evaluate the proposal and decide on a path forward.

For this use case, table 7.2 lists major stakeholders with a meaningful role to play in affecting the rollout of the AV ecosystem in the context of land use policy.

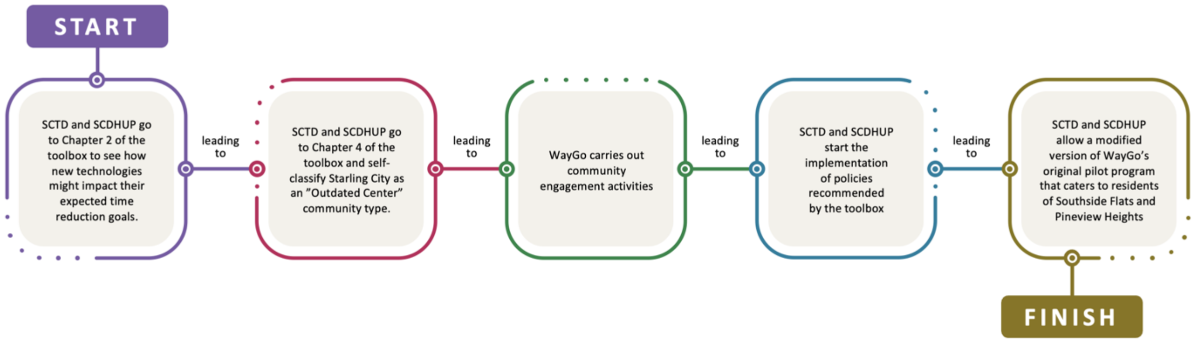
Table 7.2 Stakeholders

Name	*Role*
SCTD	***Responsible for transportation strategy in Starling City and permitting for AV services***
SCDHUP	***Responsible for land use strategy and zoning in Starling City***
Local advocacy organizations and neighborhood groups	***Representing diverse causes, including racial equity, pro-status quo (NIMBYs), and environmental groups***
Residents	***Facing day-to-day challenges of the existing mobility system***
WayGo	***AV shuttle company wishing to try its technology in the real world***

Using the toolbox to link land use and the AV ecosystem

SCTD and SCDHUP staff decide to use the AV Toolbox to plan next steps as they prepare to decide on WayGo's proposal. The steps they undertake to do this are summarized in figure 7.2.

Figure 7.2 How city government stakeholders could leverage the toolbox to plan for the AV ecosystem



Below, we detail the steps that are described in figure 7.2.

1. SCTD and SCDHUP staff go to Chapter 2 of the toolbox, as well as the online appendix, to identify how new technologies might impact their travel time reduction goals. They confirm their knowledge of the impacts that Black residents endured due to the expansion of urban highways in the recent past and realized that while reducing commuting times for everyone in Starling City is a good goal, they would like to improve the lives of those residents who were segregated by urban highways first. They therefore go to Chapter 6 of the toolbox and identify metrics that specifically target an equitable rollout of AVs.
2. Staff from these entities then go to Chapter 3 of the toolbox, and using the suggested metrics, self-classify Starling City as an Established Hub community type. Looking through the established hub factsheet, SCTD and SCDHUP staff realize that WayGo's proposal could reduce the need for parking in the downtown area, as residents might decide to use the shuttle service instead of using their private cars.
3. With this information, SCTD and SCDHUP staff task WayGo to start a community engagement process with residents of those communities that have been disrupted by highway construction (including the neighborhoods of Southside Flats and Pineview Heights) to take into account their thoughts on WayGo's proposal. They learn from the community engagement factsheet to do so. After some negotiation, WayGo agrees to do a broader engagement process that includes both residents of these neighborhoods and from Golden Oaks.
4. During the community engagement process, WayGo and city officials realized that it would be very unlikely that Golden Oaks residents would forego their cars to use the shuttle service. However, residents from Southside Flats and Pineview Heights do see the service as a possible commuting option, though they are concerned about the service's cost and are skeptical about how it would be better than the existing bus network, which has long wait times.
5. With this new information, SCTD and SCDHUP staff go to Chapter 5 of the toolbox to identify the policies that would support their new goals and that would cater to the concerns of Southside Flats and Pineview Heights residents. In preparation for a potential project launch, SCTD and SCDHUP decide to implement the following changes:
    a. They redesign streets connecting Southside Flats and Pineview Heights to the downtown area to incorporate bus-only lanes that would be used by the AV shuttles.
    b. They start the process to create a policy to charge single-occupancy vehicles for the use of streets and parking in the core downtown area.

c. Knowing that parking needs will be reduced, they support the redevelopment of parking lots and parking garages into a broad mix of uses by changing zoning in the downtown area.

6. Once the redesign of the streets is completed, they allow WayGo to operate multiple AV shuttle routes from Southside Flats and Pineview Heights to Downtown Starling City. To incentivize them to operate these routes, and to help residents of these neighborhoods with the cost of commuting, the city decides to subsidize these routes and make them free to use for all users for a trial period of one year. They consult Chapter 6. Use metrics to assess AV rollout and land use change to explore metrics they could use to assess the impact of WayGo's service during the trial period, and settle on "Commuting and Travel Times," commuting costs ("Affordability of AV Ride-Hail or Transit Services"), and mode shift from private cars to the shared shuttle ("Vehicle Miles Traveled by Type of Vehicle").

Outcomes

After the routes had been operating for one year, SCTD conducted a survey with riders to analyze the outcomes of the pilot project. Residents from Southside Flats and Pineview Heights reported improvement in their commute times, as well as lower transportation costs resulting from the lower fuel and maintenance costs of using the cars less frequently. Residents are still hesitant to rely entirely on the AV shuttle and give up their private vehicles, but some of them reported that they were considering reducing the number of cars in their household.

While the changes in zoning regulations and charges for single occupancy vehicles have not been yet implemented, SCTD expects that car commuting will go down, leading to reduce carbon and local pollutant emissions.

Use case 3: Metropolitan Planning Organization

Context

Sunrise Transportation Planning Board (STPB) is the designated Metropolitan Planning Organization for the Veridian Bay Metropolitan Area. The area encompasses multiple urbanized areas and is home to 6 million people. This number has been steadily growing over the past decade and is expected to reach 7.5 million by 2050. The largest urban center within Veridian Bay is Marina Vista, which is home to 1.5 million residents. As population increases, the number of trips taken by residents is expected to increase from 19 million daily trips today to 24 million by 2050.

As part of its federally mandated activities, STPB is currently planning the latest update to its Long-Range Transportation Plan (LRTP) which will guide the region's transportation investments and policy during the 2030-2050 period. Members of STPB have agreed on three main objectives for the LRTP: 1. Expand economic opportunities for the area's increasing population, 2. Achieve the area's "Vision Zero" objectives (meaning eliminating roadway fatalities), and 3. Protect the environment from harms caused by the transportation system.

To achieve these objectives, STPB is planning to work with the area's local transit agencies to increase investments in regional rail, expand its regional bus-rapid transit network, and complete the regional network of interconnected cycling paths. Through these investments, STPB is also hoping to leverage land-use policies to create Transit Oriented Development projects where new rail, BRT, and cycling nodes are going to be developed. STPB has also been following very closely the latest technological developments coming out of the West Coast, where multiple companies seem to be on the verge of deploying autonomous freight trucks, a technology that would need to be integrated into STPB's LRTP to ensure it does not end up clashing with its three objectives.

For this use case, table 7.3 lists major stakeholders with a meaningful role to play in affecting the rollout of the AV ecosystem in the context of land use policy.

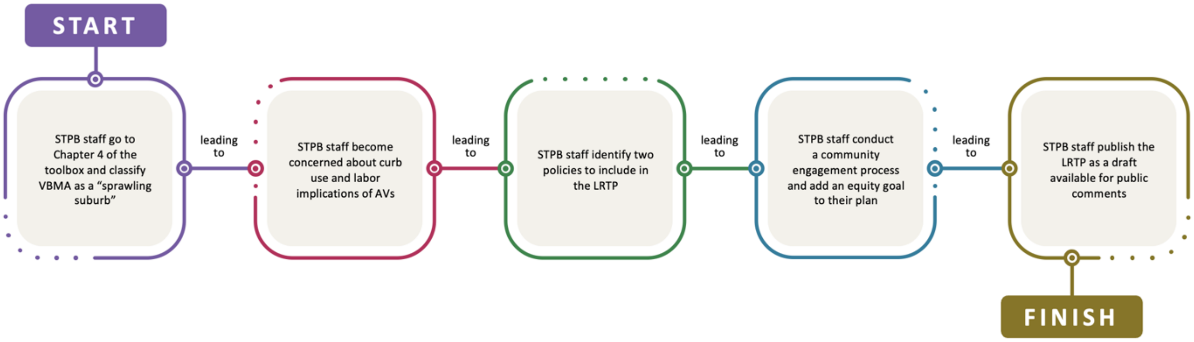
Table 7.3 Stakeholders

Name	*Role*
STPB	***Designated Metropolitan Planning Organization for the Veridian Bay Metropolitan Area and in charge of developing the Long-Range Transportation Plan***
Veridian Bay advocacy organizations and neighborhood groups	***Representing diverse causes, including neighborhood associations, racial equity organizations, transit advocates, business owners and chambers of commerce, and environmental groups***
Transit agencies and operator(s)	***Plan and operate transportation services in the municipalities that comprise the Veridian Bay Metropolitan Area, manage and maintain roadways***
Local/municipal governments	***Oversee local governance, economic activity and land use planning and management in the various municipalities that comprise the Veridian Bay Metropolitan Area***

Using the toolbox to link land use and the AV ecosystem

STPB staff decide to use the AV Toolbox to create policy guidance that will ensure the integration of future AV trucking services into the LRTP. The steps they undertake to do this are summarized in figure 7.3.

Figure 7.3 How a metropolitan planning organization could leverage the toolbox to plan for the AV ecosystem



Below, we detail the steps that are described in figure 7.3.

1. STPB staff go to Chapter 3 of the toolbox to classify the Veridian Bay Metropolitan Area into one of the community typologies. When doing so, they realize that since the area is comprised of multiple urban centers, there are potentially different typologies under which it can be classified. Marina Vista, for example, could be classified as a dense multi-modal community, with low levels of car ownership and high population and employment densities. However, most of the other urban centers that form part of the metropolitan area can be better classified as sprawling suburbs that have much higher reliance on cars and trucks, yet still have moderate population and employment densities. STPB staff therefore decide to use these two community types as potential blueprints for their AV policy recommendations.
2. When reviewing Chapter 4 of the toolbox, STPB staff note the potential for AV freight services to increase traffic throughout the region, especially as population increases and more people rely on delivery services which could become cheaper if done by AVs. This also raises a concern regarding access to curb space, especially in Marina Vista, which is already crowded with existing delivery and ridehailing services. Cheaper last-mile delivery services will likely increase the pressure on this already scarce resource. Finally, the staff note a concern about the potential impact on current delivery workers, who would lose income if these services become automated.
3. With this information, STPB staff go to Chapter 5 of the toolbox and identify a policy and a development project that can be included in the LRTP and that would support their goals:
    a. Curb use policies, specifically for Marina Vista.
    b. Multiple freight distribution centers in some of the secondary urban centers.
4. With these initial ideas, STPB staff start their community outreach process. This includes a statistically representative survey of residents throughout Veridian Bay and five focus groups with different interest groups including neighborhood associations, racial equity organizations, transit advocates, business owners and chambers of commerce, and environmental groups.
5. After the community outreach process, STPB tweaked their initial goals to also include a goal on equitable distribution of benefits and transportation opportunities. They agree to monitor progress towards these goals with the following indicators from Chapter 6. Use metrics to assess AV rollout and land use change: Availability of AV Services in Equity Zones, Affordability of AV Ride-Hail or Transit Services, Demographic Characteristics of AV Users

Versus General Population, Share of Local AVs that are ADA-Compliant, and Total Employment in Delivery-and Freight-related Jobs.

6. Finally, STPB staff propose to include in the LRTP the development of a curb use policy for Marina Vista that includes the digitization of existing curb uses, the development of a real-time curb-use system that would dynamically alter the allowable uses and prices of curb space by time of day depending on demand, and the trial of small robot AV services that would replace delivery by vans. They allocate resources to train staff of local transit agencies on how the policy would work and the tools they will use to implement and enforce it. STPB staff also propose the creation of six distribution centers throughout the region.

Outcomes

While the draft of the LRTP is currently available for public comment, STPB staff expect its proposals for dealing with AV freight services will lead to a more organized rollout of these services that will have a lower impact on overall traffic in the Metropolitan Area. This in turn, should reduce the environmental impact, and improve the overall safety of the entire transportation system. Furthermore, the creation of the six distribution centers will create new jobs that can absorb some of the jobs lost as delivery services become automated. This will therefore support STPB's goals of increasing economic opportunities and equitable distribution of opportunities.

Use case 4: University

Context

Harborview College is one of the oldest post-secondary academic institutions in the city of Pinecrest Harbor. The modern Pinecrest Harbor has grown around the college to become a bustling city of 800,000 inhabitants. The original college campus predates the modern city, and as both the city and university have grown, the campus has expanded to now include buildings both in Downtown Pinecrest Harbor, but also in the suburbs of Cedarwood Hills and Sunset Ridge.

Many students manage busy schedules that take them from the main downtown campus to one of the other campuses in a single day for classes. While Pinecrest Harbor is a dense city, commuting to either of the campuses takes almost an hour. Furthermore, public transportation options between the downtown campus and the other campuses are very limited, plus require multiple rail and bus connections. This has led most students to drive when taking classes on one of the suburban campuses.

DriveSense Technologies, a startup that came out of Harborview College's incubator (the StartUp Nexus), approached the college president to propose an on-demand AV shuttle service that would connect all three campuses. While DriveSense's shuttle services would prioritize students and college staff, and have fixed starting and ending points at the college's campuses, they are proposing that the service would be open to the public. The president is intrigued about the proposal, but also concerned about how the system would affect its existing parking contract, interact with the public transit system, and how the mayors of the three cities might perceive it.

For this use case, table 7.4 lists major stakeholders with a meaningful role to play in affecting the rollout of the AV ecosystem in the context of land use policy.

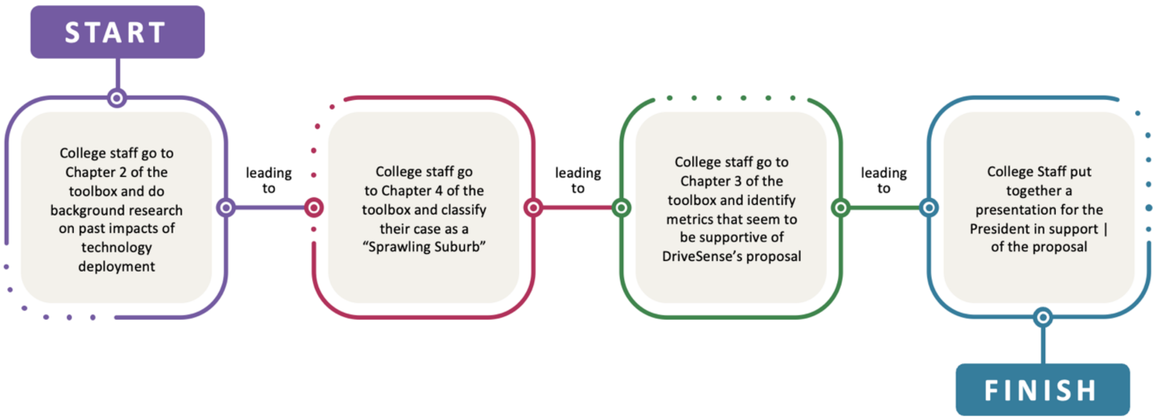
Table 7.4 Stakeholders

Name	*Role*
President of Harborview College	***Ultimate decisionmaker for DriveSense's proposal. Needs to maintain good relationships with the mayors of all three towns where the College has buildings***
Facilities and Contracting Directors for Harborview College	***Tasked with evaluating DriveSense's proposal and follow the directions from the President***
Mayors of Pinecrest Harbor, Cedarwood Hills, and Sunset Ridge	***Interested in creating stronger economic links between the three towns. Would prefer that a private company runs their transit system***
DriveSense Technologies	***Eager to rollout their newly developed technology***
Students and staff of Harborview College, as well as neighboring residents	***Potential users of the AV shuttle, facing day-to-day challenges of the existing mobility system***

Using the toolbox to link land use and the AV ecosystem

Harborview College's president has tasked its facilities and contracting directors to analyze the proposal and suggest next steps. The steps they undertake to do this are summarized in figure 7.4.

Figure 7.4 How a university could leverage the toolbox to plan for the AV ecosystem



Below, we detail the steps that are described in figure 7.4.

1. College staff go to Chapter 2 of the toolbox to start doing some background research on how technologies in the past have shaped urban form. They take note of some of the potential impacts, especially about how new technologies have displaced other services and the impact that this might have on the college's existing infrastructure, in particular their new parking buildings that were just completed three years ago.
2. College staff then go to Chapter 3. They notice that, even though their main campus is in Pinecrest Harbor, which would be considered a dense multi-modal community, the college as a whole is more reminiscent of a sprawling suburb, with high reliance on cars for travel between campuses.
3. Staff then go to Chapter 6 to identify some potential metrics which they could use to analyze DriveSense's proposal. They acknowledge that DriveSense's proposal, particularly because of its on-demand component, would be well suited to the college's needs, and help with reducing students' reliance on cars. This reduced car dependence could lead to lower costs and productivity gains, as they can use the commute time to do schoolwork.
4. What really excited the college staff was learning about the potential reduced need for parking. They were developing plans to build even more parking structures, but the shuttle might allow them to allocate that land to other uses like student accommodation and commercial activities (e.g., grocery stores, restaurants, and recreation centers). This will not only generate additional revenues for the college, but also further reduce the need for students to travel by car.
5. With this information, college staff assemble a presentation for the college president, with plans to then reach out to local mayors and transit agencies. They highlight the opportunities for both the college and all three towns to use this proposal as a way to explore how low-cost, on-demand AV shuttles could expand their transit services. Their presentation includes proposals of key metrics to evaluate the success of the AV shuttle: number of trips, average travel times between campuses, and the share of riders that are college students or staff versus local residents.

Outcomes

After the routes had been operating for one year, Harborview College's school of transportation conducted a series of rider surveys and analyzed usage data provided by DriveSense to track their selected metrics. The survey respondents were overwhelmingly positive about the shuttle, with most student riders using the shuttles to replace previous car trips. However, ridership by non-students is still limited, potentially since the new infill developments with housing and commercial spaces at the three campuses are just breaking ground. City and college staff are expecting a new exchange of residents between the three towns as the new commercial spaces are set to open in the next four years.

Use case 5: Neighborhood association

Context

Silverleaf Heights Neighborhood Association (SHNA) represents the interests of some residents of the Silverleaf Heights neighborhood in the city of Oakridge Meadows. In the 1980s, SHNA advocated against the construction of a rail station that would connect the neighborhood with the rest of the city. This has led to the neighborhood retaining a small-town character. Its residents, many of whom have lived in their homes for over forty years, are starting to see an influx of young neighbors, primarily first-time homebuyers who see the neighborhood as a place to live within city limits, but without the hustle and bustle of more central neighborhoods in Oakridge Meadows. Household incomes in the neighborhood are amongst the highest in the city, and many residents hold considerable sway with local politicians.

Most of the incoming residents consider themselves liberal and care deeply about the environment. Additionally, these new residents are open to exploring forms of transportation other than their private cars, such as transit and cycling. However, they mostly agree with SHNA's decision to oppose the construction of a transit station in the neighborhood in the 1980s, as this would have likely changed the quaint atmosphere that drew them to Silverleaf Heights.

Oakridge Meadows' city government, through its Department of Transportation (OMDOT), has been developing a plan to welcome the newly developed AV ecosystem into the city; they are calling this plan their AV Playbook. The playbook will include policies that are supportive of different services, including AV buses, AV ridehailing, and AV deliveries. The city is keen on demonstrating leadership in the tech space, as it is competing to become a second Silicon Valley, and its policies have been very favorable to testing new technologies with its residents.

SHNA conducted a meeting with its members, during which it became clear that the goals of old and new residents did not align. The Association therefore created a standing committee to analyze Oakridge Meadows' AV Playbook and develop a stance for the SHNA that will be submitted for voting in the next meeting in two months.

For this use case, table 7.5 lists major stakeholders with a meaningful role to play in affecting the rollout of the AV ecosystem in the context of land use policy.

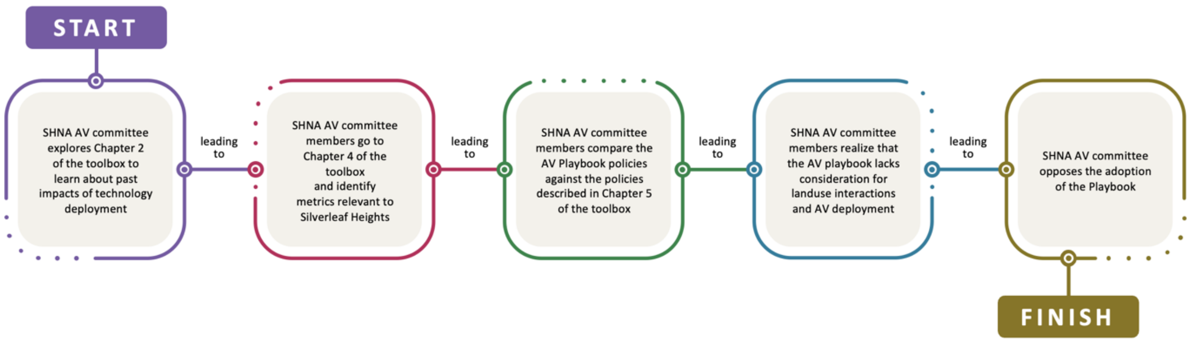
Table 7.5 Stakeholders

Name	*Role*
SHNA	***Represents the interests of the Silverleaf Heights Neighborhood***
SHNA AV committee	***Tasked by SHNA to evaluate the city's AV Playbook in the light of the interests of Silverleaf Heights' neighbors***
OMDOT	***Author of the playbook. Interested in being welcoming of new AV services in line with the mayor's plans to become a second Silicon Valley***
Mayor	***Ultimate decisionmaker for the playbook. Can be swayed by powerful residents from Silverleaf Heights***

Using the toolbox to link land use and the AV ecosystem

Members of SHNA AV committee turn to the playbook to analyze the potential impacts that the AV playbook's suggested policies would mean for their neighborhood, and better inform their own position as they prepare to either support or oppose it. The steps they undertake to do this are summarized in figure 7.5.

Figure 7.5 How a neighborhood association could leverage the toolbox to plan for the AV ecosystem



Below, we detail the steps that are described in figure 7.5.

1. SHNA AV committee members start exploring Chapter 2; they were surprised by the many ways past technologies had influenced their current neighborhood character. They realized, for example, that investments in highways that crisscrossed Oakridge Meadows had segregated their community from the historical Black neighborhoods just south of Silverleaf Heights and that a long-gone streetcar line had initially spurred the development of the neighborhood.
2. Another thing that catches their attention from Chapter 2 is how public sector support through policies and investments in the past has led to an increase in car reliance. One of the things that most members of SHNA agree on is that they would like to see fewer cars speeding across the neighborhood. They wonder if the AV Playbook's support for testing AV technologies could lead to a swarm of AVs in their neighborhood.
3. After exploring the historic examples, SHNA AV committee members go to Chapter 6 to explore suggested metrics. They are interested in metrics that describe overall travel conducted in AVs, road injuries and fatalities, and the share of AVs that are electric. They feel these metrics capture most of the concerns they heard in the SHNA meeting, and therefore will be useful when engaging with OMDOT staff to ensure they have thought through these impacts in Silverleaf Heights.
4. SHNA AV committee members now go to Chapter 5 to see how the policies proposed in the AV playbook compare. They notice that most policies in the playbook are focused on supporting AV deployment, but do not discuss other implications such as right-of-way considerations, changes in street design, and curb use that are mentioned in this toolbox. All these considerations are relevant for Silverleaf Heights.
5. With this information, the SHNA AV committee prepares a report and presentation for the full SHNA. They recommend that SHNA cannot be supportive of the AV playbook unless OMDOT staff conducts a detailed evaluation of the possible impacts that their suggested policies would have in Silverleaf Heights with respect to traffic and road injuries and fatalities. Furthermore, they are weary of the apparent blank check that OMDOT would be giving AV companies, so they suggest that OMDOT should ensure that the infrastructure in Silverleaf Heights would be amenable to AVs; this means that a traffic study would be needed to see if an increase in AVs would impact street parking, traffic, and curb use.

Outcomes

With the lack of support from SHNA, OMDOT staff see the political support for their AV Playbook dwindle. The mayor cancels the project. AV companies still deploy their vehicles in the city, but without any guiding policy documents, OMDOT staff scramble to come up with reactive policies to control the number of AVs deployed. This leads to a piecemeal of policies without a clear direction. Silverleaf Heights sees a large influx of small AV delivery robots, since most residents rely on delivery services for takeout and shopping.

8. Conclusion

This toolbox is designed to assist policymakers and other stakeholders across the United States think about how they can plan for the rollout of the AV ecosystem. Though we may have to wait many more years for this technology to be widely available for passenger and freight use, planning in advance can help ensure that AVs contribute to achieving greater equity and environmental sustainability in our communities. We think there is plenty of opportunity for communities to use AV technology for the better.

We have made evident, however, that previous transformative transportation technologies have not always produced outcomes that advance equity for all, or that ensure environmental sustainability. The creation of streetcar networks improved accessibility for many, but it also made commuting more expensive for people who had previously been able to get to work for free. Highway infrastructure made it possible to travel from one end of a metropolitan area to the other, but it also created air and noise pollution, while contributing to suburbanization and racial inequities in access to opportunity. AV technology, too, could improve mobility for many—but its services may not benefit everyone if it is too expensive to use. And it may encourage the destruction of natural ecologies if it is associated with less difficult travel to exurban locales.

We therefore encourage communities nationwide to think about their goals and use this toolbox to plan for the AV ecosystem and land use. Acting proactively can help identify potential problems before AV service becomes commonplace. And it can ensure that the effects of AVs are not purely a product of technological determinism, but also reflect public policy.

We hope this toolbox helps communities identify the issues they are likely to face, while giving them some tools to advance their work. It can be the start of years' worth of planning to ensure the technology has positive impacts.

References

"In Win for Uber and Lyft, Judge Strikes down New York City's Cruising Cap." 2019. CNBC. December 23, 2019. https://www.cnbc.com/2019/12/23/in-win-for-uber-judge-strikes-down-new-york-citys-cruising-cap.html.

"The Future of Mobility in 2035." 2023. McKinsey. April 19, 2023. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-future-of-mobility-mobility-evolves.

"Twin Cities by Trolley." n.d. Book. University of Minnesota Press. Accessed April 5, 2023. https://www.upress.umn.edu/book-division/books/twin-cities-by-trolley.

"Uber Pickup Spots." n.d. Uber. Accessed May 1, 2023. https://www.uber.com/us/en/ride/how-it-works/pickup-spots/.

Abrams, Rachel. 2017. "A Street Fight Among Grocers to Deliver Your Milk, Eggs, Bananas." *The New York Times*, June 24, 2017, sec. Business. https://www.nytimes.com/2017/06/24/business/a-street-fight-among-grocers-to-deliver-your-milk-eggs-bananas.html.

Acemoglu, Daron, and Pascual Restrepo. 2019. Automation and New Tasks: How Technology Displaces and Reinstates Labor. *Journal of Economic Perspectives* 33(2): 3–30.

Alvarez-Palau, Eduard, Dan Bogart, Oliver Dunn, Max Satchell, and Leigh Shaw Taylor. 2020. "Transport and urban growth in the first industrial revolution." Unpublished draft. Yale: https://economics.yale.edu/sites/default/files/marketaccessgrowth_presteam_sept272020.pdf

Anderson, Curtis D., and Judy Anderson. 2010. *Electric and Hybrid Cars: A History*. 2nd ed. Jefferson, N.C: McFarland.

Anderson, James M., Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras, and Oluwatobi A. Oluwatola. 2016. *Autonomous Vehicle Technology: A Guide for Policymakers*. Santa Monica, CA: RAND Corporation.

Anderson, Marco, and Nico Larco. 2017. *Land Use and Transportation Policies*. Policy Brief. Davis, CA: UC Davis Institute of Transportation Studies.

Andersson, Fredrik, John Haltiwanger, Mark Kutzbach, Henry Pollakowski & Daniel Weinberg2018. "Job Displacement and the Duration of Joblessness: The Role of Spatial Mismatch." *Review of Economics and Statistics* 98 (2): 209–225.

Archer, Deborah. 2020. "White Men's Roads through Black Men's Homes: Advancing Racial Equity through Highway Reconstruction." *Vanderbilt Law Review* 73 (5): 1259-1330.

Atiyeh, Clifford. 2012. Predicting Traffic Patterns, One Honda at a Time. *MSN Auto*. June 25.

Austin (city of). 2017. Smart Mobility Roadmap. Austin, TX: City of Austin.

Bachand-Marleau, Julie, Brian H. Y. Lee, and Ahmed M. El-Geneidy. 2012. Better Understanding of Factors Influencing Likelihood of Using Shared Bicycle Systems and Frequency of Use. *Transportation Research Record* 2314(1): 66–71.

Ball, Michael, Melec Cigdem, McKenzie Elizabeth Taylor, and Gavin Wood. 2018. "Urban Growth Boundaries and their Impact on Land Prices." Real Estate and Planning. Henley University of Reading. https://centaur.reading.ac.uk/30142/1/wp0812.pdf

Banza, Célestin Lubaba Nkulu, Tim S. Nawrot, Vincent Haufroid, Sophie Decrée, Thierry De Putter, Erik Smolders, Benjamin Ilunga Kabyla, et al. 2009. "High Human Exposure to Cobalt and Other Metals in Katanga, a Mining Area of the Democratic Republic of Congo." *Environmental Research* 109 (6): 745–52. https://doi.org/10.1016/j.envres.2009.04.012.

Basker, Emek, Shawn Klimek, and Pham Hoang Van. 2012. "Supersize It: The Growth of Retail Chains and the Rise of the "Big-Box" Store." *Journal of Economics and Management Strategy* 21(3): 541–582.

Bassok, Alon, Chris Johnson, Matthew Kitchen. Rebecca Maskin, Kris Overyby, Daniel Carlson, Anne Goodchild, Edward McCormack, and Erica Wygonic. 2013. Smart Growth and Urban Goods Movement. Washington, DC: National Academies of Sciences, Engineering, and Medicine.

Bates, Jason L. 2016. "Consolidating Support for a Law 'Incapable of Enforcement': Segregation on Tennessee Streetcars, 1900-1930." *The Journal of Southern History* 82(1): 97–126.

Baum-Snow, Nathaniel, J. Vernon Henderson, Matthew A. Turner, Qinghua Zhang, and Loren Brandt. 2020. Does investment in national highways help or hurt hinterland city growth? *Journal of Urban Economics* 115: 103124.

Baum-Snow, Nathaniel. 2007. Did Highways Cause Suburbanization? The Quarterly Journal of Economics 122(3): 775–805.

Baum-Snow, Nathaniel. 2020. Urban Transport Expansions and Changes in the Spatial Structure of U.S. Cities: Implications for Productivity and Welfare. *The Review of Economics and Statistics* 102(5): 929–945.

BBC News. 2022. "Uber Granted Two-and-a-Half Year Licence to Operate in London," March 26, 2022, sec. London. https://www.bbc.com/news/uk-england-london-60885937.

Bellinger, Matthew, Ryan Calo, Brooks Lindsay, Emily McReynolds, and Mackenzie Olson. 2017. *Driverless Seattle: How Cities Can Plan for Automated Vehicles*. Seattle, WA: University of Washington Tech Policy Lab.

Bertolini, Luca. 2012. Integrating Mobility and Urban Development Agendas: A Manifesto. *disP – The Planning Review* 48(1): 16–26.

Bhuyan, Istiak A., Celeste Chavis, Amirreza Nickkar, and Philip Barnes. 2019. "GIS-Based Equity Gap Analysis: Case Study of Baltimore Bike Share Program." *Urban Science* 3(2): 42.

Block-Schachter, David, and Jinhua Zhao. 2015. Hysteresis & Urban Rail. *European Journal of Transport and Infrastructure Research* 15(1): 78–91.

Bloom, Nicholas Dagen. 2023. T*he Great American Transit Disaster: A Century of Austerity, Auto-Centric Planning, and White Flight*. Chicago, IL: University of Chicago Press.

Bloomberg.Com. 2021. "Cities Need Housing. Parking Requirements Make It Harder.," April 26, 2021. https://www.bloomberg.com/news/articles/2021-04-26/to-save-the-planet-kill-minimum-parking-mandates.

Boustan, Leah Platt, 2007, "Was Postwar Suburbanization "White Flight"? Evidence From the Black Migration." Working Paper 13543. Cambridge, MA: National Bureau of Economic Research.

Bowen, John T. 2008. "Moving places: the geography of warehousing in the US." *Journal of Transport Geography* 16: 379–387.

Brown, Anne, Vinit Mukhija, and Donald Shoup. 2020. "Converting Garages into Housing." *Journal of Planning Education and Research* 40 (1): 56–68.

Buck, Darren and Ralph Buehler. 2012. *Bike Lanes and Other Determinants of Capital Bikeshare Trips*. Paper presented at the Transportation Research Board Annual Meeting 2012, Washington, DC.

Buck, Darren, Ralph Buehler, Patricia Happ, Bradley Rawls, Payton Chung, and Natalie Borecki. 2013. "Are Bikeshare Users Different from Regular Cyclists?: A First Look at Short-Term Users, Annual Members, and Area Cyclists in the Washington, D.C., Region." *Transportation Research Record: Journal of the Transportation Research Board* 2387(1): 112–119.

Buehler, Ralph and Andrea Hamre. 2014. *Economic Benefits of Capital Bikeshare: A Focus on Users and Businesses*. USDOT Report No. VT-2013-06.

Bureau of Transportation Statistics. 2017. “National Household Travel Survey Daily Travel Quick Facts.” 2017. https://www.bts.gov/statistical-products/surveys/national-household-travel-survey-daily-travel-quick-facts.

Burns, Lawrence D., William C. Jordan, Bonnie A. Scarborough. 2012. Transforming Personal Mobility. New York, NY: The Earth Institute - Columbia University.

California Public Utilities Commission. 2020. Order Instituting Rulemaking on Regulations Relating to Passenger Carriers, Ridesharing, and New Online-Enabled Transportation Services. San Francisco, CA.

Carlton, Gregory J., and Selima Sultana. 2022. “Electric Vehicle Charging Station Accessibility and Land Use Clustering: A Case Study of the Chicago Region.” *Journal of Urban Mobility* 2 (December): 100019. https://doi.org/10.1016/j.urbmob.2022.100019.

Castillo-Manzano, José I., Lourdes López-Valpuesta, and Antonio Sánchez-Braza. 2016. “Going a long way? On your bike! Comparing the distances for which public bicycle sharing system and private bicycles are used.” *Applied Geography* 71: 95-106.

Catapult Transport Systems. 2017. Future Proofing Infrastructure for Connected and Automated Vehicles. Technical Report.

Cervero, Robert. 1998. *The Transit Metropolis: A Global Inquiry*. Washington, DC: Island Press.

Cidell, Julie. 2010. “Concentration and decentralization: the new geography of freight distribution in US metropolitan areas.” *Journal of Transport Geography* 18: 363–371.

City of Chicago. 2023. Chicago Transportation Network Providers (Ride-Hail Companies). n.d. Accessed March 29, 2023. https://www.chicago.gov/content/city/en/depts/bacp/provdrs/vehic/svcs/tnp.html.

Clewlow, Regina R., and Gouri S. Mishra. 2017. *Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States*. Research Report UCD-ITS-RR-17-07. Davis, CA: Institute of Transportation Studies, University of California, Davis.

Cohen, Scott, and Debbie Hopkins. 2019. Autonomous vehicles and the future of urban tourism. *Annals of Tourism Research* 74: 33–42.

Combs, Tabitha S., Noreen C. McDonald, and William Leimenstoll. 2020. “Evolution in Local Traffic Impact Assessment Practices.” Journal of Planning, Education, and Research. Vol. 42(4) 815-828.

Compass Transportation and Technology. 2018. The Economic and Social Value of Autonomous Vehicles: Implications from Past Network-Scale Investments. Prepared for: Securing America’s Future Energy (SAFE).

Congressional Research Service. 2020. Federal Land Ownership: Overview and Data. Washington DC: Congressional Research Service.

Conn, W. Clark. 1984. “Waverly Place: The Study of a Nashville Streetcar Suburb Along the Franklin Pike.” *Tennessee Historical Quarterly* 43(1): 3–24.

Constine, Josh. 2015. “Uber Is Now Testing ‘Suggested Pickup Points.’” *TechCrunch* (blog). July 8, 2015. https://techcrunch.com/2015/07/08/uber-suggested-pickup-points/.

Crunchbase. n.d. Crunchbase. Accessed April 4, 2023. https://www.crunchbase.com.

Crute, Jeremy, William Riggs, Timothy S. Chapin, and Lindsay Stevens. 2018. *Planning for Autonomous Mobility*. Chicago, IL: American Planning Association.

Cruz-Daraviña, Paola Andrea, and Juan Pablo Bocarejo Suescún. 2021. Freight operations in city centers: A land use conflict in urban planning. *Land Use Policy* 108: 105575.

Csiszár, Csaba, Bálint Csonka, Dávid Földes, Ervin Wirth, and Tamás Lovas. 2019. "Urban Public Charging Station Locating Method for Electric Vehicles Based on Land Use Approach." *Journal of Transport Geography* 74: 173–80.

Dablanc, Laetitia, and Catherine Ross. 2012. "Atlanta: a mega logistics center in the Piedmont Atlantic Megaregion (PAM)." *Journal of Transport Geography* 24: 432–442.

Dablanc, Laetitia, and Dina Rakotonarivo. 2010. "The impacts of logistic sprawl: How does the location of parcel transport terminals affect the energy efficiency of goods' movements in Paris and what can we do about it?" *Procedia Social and Behavioral Sciences* 2: 6087–6096.

Dablanc, Laetitia, Scott Ogilvie, and Anne Goodchild. 2014. "Logistics Sprawl: Differentiating Warehousing Development Patterns in Los Angeles, California, and Seattle, Washington." *Transportation Research Record* 2410(1): 105–112.

Dean, Matthew D., and Kara M. Kockelman. 2021. "Spatial Variation in Shared Ride-Hail Trip Demand and Factors Contributing to Sharing: Lessons from Chicago." *Journal of Transport Geography* 91 (February): 102944.

DeMaio, Paul. 2009. Bike-sharing: History, Impacts, Models of Provision, and Future. *Journal of Public Transportation* 12(4): 41–56.

Ding, Hongliang, N.N. Sze, Haojie Li, and Yanyong Guo. 2020. "Roles of infrastructure and land use in bicycle crash exposure and frequency: A case study using Greater London bike sharing data." *Accident Analysis & Prevention* 144: 105652.

Divall, Colin, and Winstan Bond. 2017. *Suburbanizing the Masses: Public Transport and Urban Development in Historical Perspective*. Routledge.

Duarte, Fabio and Carlo Ratti. 2018. The Impact of Autonomous Vehicles on Cities: A Review. *Journal of Urban Technology* 25(4): 3–18.

Einstein, Katherine Levine, David M. Glick, and Maxwell Palmer. 2020. "Neighborhood Defenders: Participatory Politics and America's Housing Crisis." Cambridge University Press.

Einstein, Katherine Levine, Maxwell Palmer, and David Glick. 2018. "Racial Disparities in Housing Politics: Evidence from Administrative Data." Boston University Initiative on Cities. https://www.dropbox.com/s/gsn2vzdi7djtmsp/ZoningParticipation_race.pdf?dl=0%5C

Einstein, Katherine Levine, Maxwell Palmer, David M Glick. 2018. "Who Participates in Local Government? Evidence from Meeting Minutes." Perspectives on Politics, pp. 1 - 19. https://doi.org/10.1017/s153759271800213x

El-Assi, Wafic, Mohamed Salah Mahmoud, and Khandker Nurul Habib. 2017. "Effects of built environment and weather on bike sharing demand: A station level analysis of commercial bike sharing in Toronto." *Transportation* 44(3): 589–613.

Eren, Ezgi, and Volkan Emre Uz. 2020. A review on bike-sharing: The factors affecting bike-sharing demand. *Sustainable Cities and Society* 54: 101882.

Ewing, Reid, Rolf Pendall, and Don Chen. 2003. Measuring Sprawl and Its Transportation Impacts. *Transportation Research Record* 1831: 175–183.

Faghih-Imani, Ahmadreza, Naveen Eluru, Ahmed M. El-Geneidy, Michael Rabbat, and Usama Haq. 2014. How land-use and urban form impact bicycle flows: evidence from the bicycle-sharing system (BIXI) in Montreal. *Journal of Transport Geography* 41: 306–314.

Fagnant, Daniel, and Kara Kockelman. 2014. The travel and environmental implication of shared autonomous vehicles using agent-based model scenarios. *Transportation Research Part C: Emerging Technologies* 40: 1–13.

Ferenchak, Nicholas N., and Wesley E. Marshall. 2021. "Bicycling Facility Inequalities and the Causality Dilemma with Socioeconomic/Sociodemographic Change." *Transportation Research Part D* 97: 102920.

Fernandez, Emma, Katie Fallon, Brendan Chen, and Samantha Batko. 2023. *The Ghosts of Housing Discrimination Reach Beyond Redlining*. Washington DC: Urban Institute.

Fischer-Kowalski, Marina, Fridolin Krausmann, and Barbara Smetschka. 2004. Modeling scenarios of transport across history from a socio-metabolic perspective. *Review*: 307–342.

Fishman, Elliot and Vaughan Allan. 2019. "Bike Share." In *Advances in Transport Policy and Planning* 4: 122-149.

Fishman, Elliot, Simon Washington, and Narelle Haworth. 2013. "Bike Share: A Synthesis of the Literature." *Transport Reviews* 33(2): 148-165.

Fishman, Robert. 1990. "America's new city." *The Wilson Quarterly* 14(1): 24-55.

Forsyth, Ann, Charles Brennan, Nélida Escobedo Ruiz, and Margaret Scott. 2016. Revitalizing Places: Improving Housing and Neighborhoods from Block to Metropolis. Cambridge, MA: Harvard University Graduate School of Design.

Fowler, Stephanie L., David Berrigan, and Keshia M. Pollack. 2017. "Perceived barriers to bicycling in an urban U.S. environment." *Journal of Transport & Health* 6: 474-480.

Freemark, Yonah, Anne Hudson, and Jinhua Zhao. 2019. Are Cities Prepared for Autonomous Vehicles? Planning for Technological Change by U.S. Local Governments. *Journal of the American Planning Association* 85(2): 133–151.

Freemark, Yonah, Anne Hudson, and Jinhua Zhao. 2020. Policies for Autonomy: How American Cities Envision Regulating Automated Vehicles. *Urban Science* 4: 55.

Freemark, Yonah, Christina Stacy, Olivia Fiol, and Jorge Morales-Burnett. 2022. *Regulations to Respond to the Potential Benefits and Perils of Self-Driving Cars: Analysis and Recommendations for Advancing Equity and Environmental Sustainability*. Washington, DC: Urban Institute.

Freemark, Yonah, Lydia Lo, Eleanor Noble, and Ananya Hariharan. 2022. *Cracking the Zoning Code: Understanding local land-use regulations and how they can advance affordability and equity*. Washington, DC: Urban Institute.

Freemark, Yonah, Yipeng Su, Wilton Oliver, and Olivia Fiol. 2021. *Making the Case for Improved Bicycling Infrastructure: An Analysis of the Final Mile Bicycle Infrastructure Program*. Washington, DC: Urban Institute.

Friedrich, Bernhard. 2016. The Effect of Autonomous Vehicles on Traffic. *Autonomous Driving*: 317–334.

Fukushige, Tatsuya, Dillon T. Fitch, and Susan Handy. 2021. "Factors influencing dock-less E-bikeshare mode substitution: Evidence from Sacramento, California." *Transportation Research Part D: Transport and Environment* 99: 102990.

Fuller, Daniel, Lise Gauvin, Yan Kestens, Mark Daniel, Michel Fournier, Patrick Morency, and Louis Drouin. 2012. "Impact Evaluation of a Public Bicycle Share Program on Cycling: A Case Example of BIXI in Montreal, Quebec." *American Journal of Public Health* 103(3): 85-92.

Fuller, Glen, Gordon R. Waitt, and Ian M. Buchanan. 2018. "The problem isn't dockless share bikes. It's the lack of bike parking." *The Conversation*.

Gebhart, Kyle and Robert B. Noland. 2014. “The impact of weather conditions on bikeshare trips in Washington, DC.” *Transportation* 41(6): 1205–1225.

Gelauff, George, Ioulia Ossokina, and Coen Teulings. 2017. *Spatial effects of automated driving: Dispersion, concentration or both*. The Hague: KIM – Netherlands Institute for Transport Policy Analysis.

Ghosh, Sudeshna, and Carla Chifos. 2017. “The 1985 Siting of a Toyota Manufacturing Plant in Rural Kentucky, USA: The Ensuing Land Use Change and Implications for Planning.” *Landscape and Urban Planning* 167 (November): 288–301. https://doi.org/10.1016/j.landurbplan.2017.07.006.

Gillingham, Kenneth, and James H. Stock. 2018. “The Cost of Reducing Greenhouse Gas Emissions.” *Journal of Economic Perspectives* 32 (4): 53–72. https://doi.org/10.1257/jep.32.4.53.

Glock, Earl. 2009. “The Rise of Modern Richmond And The Fall Of Electric Transit.” https://doi.org/10.21220/S2-AN1Y-B029.

Godschalk, David, and David Rouse. 2015. Sustaining Places: Best Practices for Comprehensive Plans. Chicago, Illinois: American Planning Association.

Godsmark, Paul, Barrie Kirk, and Brian Flemming. 2015. *Automated Vehicles: The Coming of the Next Disruptive Technology*. Ottawa, ON: The Conference Board of Canada.

Golden, Sean, Noel Jeutang, Ratikanta Pattaik, David Rosenbaum, and Eric Thompson. 2006. *Big Box Stores: Their Impacts on the Economy and Tips for Competing*. Lincoln, NE: University of Nebraska.

Goldman Sachs. 2019. “The Future of Mobility Ride-Hailing and New Businesses to Fuel $7tn+ Global Mobility Market.”

González-Gallina, Alberto, Griselda Benítez-Badillo, Mircea G. Hidalgo-Mihart, Miguel Equihua and Octavio R. Rojas-Soto. 2016. “Roadkills as a complementary information source for biological surveys using rodents as a model.” *Journal of Mammalogy* 97: 145 - 154.

Graffy, Elisabeth, and Steven Kihm. 2014. “Does Disruptive Competition Mean a Death Spiral for Electric Utilities?” *Energy Law Journal* 35(1): 1–44.

Grasso, Susan Hull, Philip Barnes, and Celeste Chavis. 2018. “Bike Share Equity for Underrepresented Groups: Analyzing Barriers to System Usage in Baltimore, Maryland.” *Sustainability* 12(18): 7600.

Greenaway-McGrevy, Ryan and James Allan Jones. 2023. “Can zoning reform change urban development patterns? Evidence from Auckland.” University of Auckland Business School. Economic Policy Centre. Working Paper No. 012.

Grush, Bern, and John Niles. 2018. The end of driving: Transportation systems and public policy planning for autonomous vehicles. Amsterdam, NL: Elsevier.

Guerra, Erick. 2016. Planning for cars that drive themselves: Metropolitan planning organizations, regional transportation plans, and autonomous vehicles. *Journal of Planning Education and Research* 36(2): 210–224.

Head, Brian W. (2007) Community Engagement: Participation on Whose Terms?, Australian Journal of Political Science, 42:3, 441-454, DOI: 10.1080/10361140701513570

Heid, Jim. 2004. Greenfield Development Without Sprawl: The Role of Planned Communities. Washington DC: Urban Land Institute.

Henaghan, Jennifer. 2018. *Preparing Communities for Autonomous Vehicles*. Chicago, IL: American Planning Association.

Henao, Alejandro, and Wesley E. Marshall. 2019. “The Impact of Ride Hailing on Parking (and Vice Versa).” *Journal of Transport and Land Use* 12 (1): 127–47.

Henry, Allison, Richard E. Barone, Alyssa Pichardo, Emily Roach, Tyler Keegan, Dani Simons, Emily Thenhaus, and Ben Oldenburg. 2017. *New Mobility: Autonomous Vehicles and the Region*. New York, NY: Regional Plan Association.

Hesse, Markus. 2008. *The City as a Terminal: The Urban Context of Logistics and Freight Transport*. Farnham, UK: Ashgate.

Hilton, George Woodman, and John Fitzgerald Due. 1964. *The Electric Interurban Railways in America.* Stanford University Press.

Hinners, Sarah Jack, Arthur C. Nelson, and Martin Buchert. 2018. "Streetcars and Economic Development: Do Streetcars Stimulate Employment Growth?" *Transportation Research Record* 2672(8): 339–350.

Hoffmann, Melody L. 2016. *Bike Lanes are White Lanes: Bicycle Advocacy and Urban Planning.* Lincoln: University of Nebraska Press.

Holguin-Veras, Jose, Diana Ramirez-Rios, Juvena Ng, Jeffrey Wojtowicz, Daniel Haake, Catherine T. Lawson, Oriana Calderón, Benjamin Caron, and Cara Wang. 2021. Freight-Efficient Land Uses: Methodology, Strategies, and Tools. *Sustainability* 13(6): 3059.

Holzer, Harry J. 2022. *Understanding the impact of automation on workers, jobs, and wages*. Washington, DC: Brookings Institution.

Høyer, Karl Georg. 2008. "The History of Alternative Fuels in Transportation: The Case of Electric and Hybrid Cars." *Utilities Policy* 16 (2): 63–71. https://doi.org/10.1016/j.jup.2007.11.001.

Hughes, Ryan, and Don MacKenzie. 2016. Transportation network company wait times in Greater Seattle, and relationship to socioeconomic indicators. *Journal of Transport Geography* 56: 36–44.

Hussain, Omar, Amir Ghiasi, and Xiaopeng Li. 2016. "Freeway Lane Management Approach in Mixed Traffic Environment with Connected Autonomous Vehicles." Computer Science. https://arxiv.org/abs/1609.02946

Hymel, Kent, Kenneth Small, and Kurt Van Dender. 2010. "Induced demand and rebound effects in road transport." *Transportation Research Part B: Methodological* 44 (10): 1220-1241.

Hymel, Kent. 2019. "If you build it, they will drive: Measuring induced demand for vehicle travel in urban areas." *Transport Policy* 76: 57-66.

IEA. 2022. "World Energy Outlook 2022." IEA, Paris, France.

Infrastructure Victoria. (2018). Advice on automated and zero emissions vehicles infrastructure. Infrastructure Victoria. https://www.infrastructurevictoria.com.au/project/automated-andzero-emission-vehicle-infrastructure.

Institute for Transportation and Development Policy (ITDP). 2013. *The Bike Share Planning Guide.* New York: ITDP.

International Code Council, 2021 International Building Code (IBC), https://codes.iccsafe.org/content/IBC2021P2; Seattle Department of Construction & Inspections, Building Code, https://www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/building-code; Washington State Building Code Council, https://www.sbcc.wa.gov/

International Transport Forum. 2015. Urban Mobility System Upgrade - How shared self-driving cars could change city traffic. Paris, FR: International Transport Forum.

Jaeger, Joel, Ginette Walls, Ella Clarke, Juan-Carlos Altamirano, Arya Harsono, Helen Mountford, Sharan Burrow, Samantha Smith, and Alison Tate. 2021. "The Green Jobs Advantage: How Climate-Friendly Investments Are Better Job Creators." World Resources Institute: Working Paper October.

Jamal, Shaila, and Muhammad Ahsanul Habib. 2020. Smartphone and daily travel: How the use of smartphone applications affect travel decisions. *Sustainable Cities and Society* 53: 101939.

Jenn, Alan, Katalin Springel, and Anand R. Gopal. 2018. "Effectiveness of Electric Vehicle Incentives in the United States." *Energy Policy* 119 (August): 349–56. https://doi.org/10.1016/j.enpol.2018.04.065.

Jiang, Jingjing. 2019. "More Americans Are Using Ride-Hailing Apps." *Pew Research Center* (blog). January 4, 2019. https://www.pewresearch.org/fact-tank/2019/01/04/more-americans-are-using-ride-hailing-apps/.

Jones, Ben, Robert J.R. Elliott, and Viet Nguyen-Tien. 2020. "The EV Revolution: The Road Ahead for Critical Raw Materials Demand." *Applied Energy* 280 (December): 115072. https://doi.org/10.1016/j.apenergy.2020.115072.

Jones, Michael G., Sherry Ryan, Jennifer Donlon, Lauren Ledbetter, David R. Ragland, and Lindsay S. Arnold. 2010. Seamless Travel: Measuring Bicycle and Pedestrian Activity in San Diego County and Its Relationship to Land Use, Transportation, Safety, and Facility Type. Berkeley, CA: University of California, Berkeley.

Jucha, Robert J. 1979. "The Anatomy of a Streetcar Suburb: A Development History of Shadyside, 1852-1916." *Western Pennsylvania History: 1918-2020*, 301–19.

Karas, David. 2015. "Highway to Inequity: The Disparate Impact of the Interstate Highway System on Poor and Minority Communities in American Cities." *New Visions for Public Affairs* 7: 9-21.

Karolemeas, Christos, Stefanos Tsigdinos, Panagiotis G. Tzouras, Alexandros Nikitas, and Efthimios Bakogiannis. 2021. "Determining Electric Vehicle Charging Station Location Suitability: A Qualitative Study of Greek Stakeholders Employing Thematic Analysis and Analytical Hierarchy Process." *Sustainability* 13 (4): 2298.

Kim, Kyung-Hwan, Dong-Hyung Yook, Yong-Seok Ko, and Dong-Han Kim. 2015. *An analysis of expected effects of the autonomous vehicles on transport and land use in Korea*. New York, NY: New York University, Marron Institute of Urban Management.

King, David A., and Lauren Ames Fischer. 2016. "Streetcar Projects as Spatial Planning: A Shift in Transport Planning in the United States." *Journal of Transport Geography* 54 (June): 383–90.

Knowles, Richard D. 2006. Transport shaping space: Differential collapse in time-scape. *Journal of Transport Geography* 14: 407–425.

Knowles, Richard D., Fiona Ferbrache, and Alexandros Nikitas. 2020. Transport's historical, contemporary, and future role in shaping urban development: Re-evaluating transit oriented development. *Cities* 99: 102607.

Kondor, Dániel, Paolo Santi, Diem-Trinh Le, Xiaohu Zhang, Adam Millard-Ball, and Carlo Ratti. 2020. "Addressing the 'Minimum Parking' Problem for on-Demand Mobility." *Scientific Reports* 10 (1): 15885. https://doi.org/10.1038/s41598-020-71867-1.

Kothari, Vishant, and Emmett Werthmann. 2021. "Pole-Mounted Electric Vehicle Charging: Preliminary Guidance for a Low-Cost and More Accessible Public Charging Solution for US Cities."

KPMG. 2012. Self-driving Cars: the Next Revolution.

Kuciemba, Steve, Katie McLaughlin, Chica Morrow, Eric Paul Dennis, Naseeb Souweidane, and Brett Smith. 2023. *Realistic Timing Estimates for Automated Vehicle Implementation*. Washington, DC: The National Academies of Sciences, Engineering, and Medicine.

Kukura, Joe. 2017. "Uber And Lyft Responsible For Two-Thirds Of Downtown Traffic Violations : SFist." SFist. September 26, 2017. https://sfist.com/2017/09/26/uber_and_lyft_responsible_for_two-t/.

Kutela, Boniphace and Huliang Teng. 2019. "The influence of campus characteristics, temporal factors, and weather events on campuses-related daily bike-share trips." *Journal of Transport Geography* 78: 160–169.

Lang, Robert, Jennifer LeFurgy, and Arthur C. Nelson. 2006. "The Six Suburban Eras of the United States Research Note." *Opolis* 2(1).

Lavingo, Bethany, Jeffrey Dorfman, Barry Barnett, and John Bergstrom. 2004. *Farmland preservation in Georgia: three possible roads to success*. Athens GA: The University of Georgia.

Lazer, Leah, Sadanand Wachche, Ryan Sclar, and Sarah Cassius. 2021. "Electrifying Ride-Hailing in the United States, Europe, and Canada: How to Enable Ride-Hailing Drivers to Switch to Electric Vehicles," October. https://www.wri.org/research/electrifying-ride-hailing-united-states-europe-canada.

Leonard, Benjamin, Joshua Linn, and Clayton Munnings. 2019. Explaining the Evolution of Passenger Vehicle Miles Traveled in the United States. *The Energy Journal* 40(1): 25–54.

Lewis, Paul, Gregory Rogers, and Stanford Turner. 2017. Beyond Speculation: Automated Vehicles and Public Policy. An Action Plan for Federal, State, and Local Policymakers. Washington, DC: Eno Center for Transportation.

Li, Qiumeng, Franz Fuerst, and Davide Luca. (2022), Do Shared E-Bikes Reduce Urban Carbon Emissions? Available at SSRN: https://ssrn.com/abstract=4233639 or http://dx.doi.org/10.2139/ssrn.4233639

Litman, Todd, 2023. *Parking Management: Strategies, Evaluation and Planning*. Victoria, BC: Victoria Transport Policy Institute.

Litman, Todd. 2023. *Autonomous Vehicle Implementation Predictions Implications for Transport Planning*. Victoria, BC: Victoria Transport Policy Institute.

Liu, Jin-peng, Teng-xi Zhang, Jiang Zhu, and Tian-nan Ma. 2018. "Allocation Optimization of Electric Vehicle Charging Station (EVCS) Considering with Charging Satisfaction and Distributed Renewables Integration." *Energy* 164: 560–74.

Liu, Yuyan, Miles Tight, Quanxin Sun, and Ruiyu Kang. 2019. A systematic review: Road infrastructure requirement for Connected and Autonomous Vehicles (CAVs). *Journal of Physics: Conference Series* 1187(4): 042074.

Lo, Lydia, and Yonah Freemark. 2022. *Influencers, Bias, and Equity in Rezoning Cases: An Evaluation of Developer-Initiated Zoning Changes in Louisville, Kentucky*. Washington, DC: Urban Institute.

Loa, Patrick, Sanjana Hossain, and Khandker Nurul Habib. 2021. "On the Influence of Land Use and Transit Network Attributes on the Generation of, and Relationship between, the Demand for Public Transit and Ride-Hailing Services in Toronto." *Transportation Research Record: Journal of the Transportation Research Board* 2675 (3). https://trid.trb.org/view/1753270.

Los Angeles Department of Transportation. 2018. *Strategic Implementation Plan*. Los Angeles, CA: City of Los Angeles.

Low, Nicholas, and Rachel Astle. 2009. Path dependence in urban transport: An institutional analysis of urban passenger transport in Melbourne, Australia, 1956–2006. *Transport Policy* 16(2): 47–58.

Lowensohn, Josh. n.d. "Uber Launches in Portland, Oregon despite Being Completely Illegal There." *The Verge*. Accessed May 1, 2023. https://www.theverge.com/2014/12/5/7342981/uber-launches-in-portland-oregon-despite-being-completely-illegal-there.

Lusk, Anne C., Walter C. Willett, Vivien Morris, Christopher Byner, and Yanping Li. 2021. "Bicycle Facilities Safest from Crime and Crashes: Perceptions of Residents Familiar with Higher Crime/Lower

Income Neighborhoods in Boston." *International Journal of Environmental Research and Public Health* 16(3): 484.

Lyon, Brendan, Nick Hudson, Michael Twycross, Dennis Finn, Steve Porter, Zoltan Maklary, and S. Travis Waller. 2017. *Automated vehicles: Do we know which road to take?* Sydney, AU: Infrastructure Partnerships Australia.

Ma, Liang and Jennifer Dill. (2015). "Associations between the objective and perceived built environment and bicycling for transportation." *Journal of Transport & Health* 2(2): 248–255.

Mair, Andrew, Richard Florida, and Martin Kenney. 1988. "The New Geography of Automobile Production: Japanese Transplants in North America." *Economic Geography* 64 (4): 352–73. https://doi.org/10.2307/144233.

Mallach, Stanley. 1979. "The Origins of the Decline of Urban Mass Transportation in the United States, 1890-1930." *Urbanism Past & Present*, no. 8: 1–17.

Mansoor, Iqbal. n.d. "Uber Revenue and Usage Statistics (2023)." Business of Apps. Accessed May 1, 2023. https://www.businessofapps.com/data/uber-statistics/.

Marquet, Oriol. 2020. Spatial distribution of ride-hailing trip demand and its association with walkability and neighborhood characteristics. *Cities* 106: 102926.

Marsden, Greg, Iain Docherty, and Robyn Dowling. 2020. Parking futures: Curbside management in the era of 'new mobility' services in British and Australian cities. *Land Use Policy* 91: 104012.

Martens, Karel, Aaron Golub, and Glenn Robinson. 2012. "A justice-theoretic approach to the distribution of transportation benefits: Implications for transportation planning practice in the United States." *Transportation Research Part A: Policy and Practice* 46(4)L 684-695.

Matt, Villano. 2001. "Plug in a Car and Give It Juice."

McCalla, Robert J., Brian Slack, and Claude Comtois. 2001. "Intermodal freight terminals: locality and industrial linkages." *The Canadian Geographer* 45(3): 404–413.

McDonald, John F., and Daniel P. McMillen. 1998. Land Values, Land Use, and the First Chicago Zoning Ordinance. *The Journal of Real Estate Finance and Economics* 16: 135–150.

McFarland, Matt. 2017. "Cities Warm up to Designated Uber, Lyft Pick-up Spots." CNNMoney. November 16, 2017. https://money.cnn.com/2017/11/16/technology/uber-lyft-designated-pickup-spots/index.html.

McKinnon, Alan. 2009. The present and future land requirements of logistical activities. *Land Use Policy* 26(Supplement 1): S293–S301.

McLeod, Sam, Jake H.M. Schapper, Carey Curtis, and Giles Graham. 2019. "Conceptualizing freight generation for transport and land use planning: A review and synthesis of the literature." *Transport Policy* 74: 24-34.

McMahon, Brian, Ella Claney, G. B. Arrington, Robert Cervero, and Jeff Wood. 2015. Linking Transit Agencies and Land Use Decision Making: Guidebook for Transit Agencies. Washington, DC: National Academies of Sciences, Engineering, and Medicine.

McNeil, Nathan, Joseph Broach, and Jennifer Dill. 2018. *Breaking Barriers to Bike Share: Lessons on Bike Share Equity.* Washington, DC: Institute of Transportation Engineers.

Meier, August, and Elliott Rudwick. 1973. "Negro Boycotts of Segregated Streetcars in Virginia, 1904-1907." *The Virginia Magazine of History and Biography* 81(4): 479–87.

Meyer, Jonas, Henrik Becker, Patrick M. Boesch, and Kay W. Axhausen. 2017. Autonomous vehicles: The next jump in accessibilities? *Research in Transportation Economics* 62: 80–91.

Michigan Department of Transportation. 2021. *Connected and Automated Vehicle Strategic Plan*. Lansing, MI: State of Michigan.

Middleton, William D. 1985. "A Century of Cable Cars." *American Heritage* 36(3).

Miller, Conrad. 2018. "When Work Moves: Job Suburbanization and Black Employment." Working Paper 24728. Cambridge, MA: National Bureau of Economic Research.

Ministry of Ecology (France's Ministry of Ecology Transition and Territorial Cohesion). 2023. Trajectoires Vers L'objectif « Zero Artificialization Nette » Éléments De Méthode. Paris, France: Commissariat Général Au Développement Durable.

Minnesota Department of Transportation. 2019. *Connected and Automated Vehicle Strategic Plan*. St. Paul, MN: State of Minnesota.

Moeckel, Rolf. 2017. Working from Home: Modeling the Impact of Telework on Transportation and Land Use. *Transportation Research Procedia* 26: 207–214.

Mooney, Stephen J., Kate Hosford, Bill Howe, An Yan, Meghan Winters, Alon Bassok, and Jana A. Hirsch. 2019. "Freedom from the station: Spatial equity in access to dockless bike share." *Journal of Transport Geography* 74: 91-96.

Moreno, Ana T., Andrzej Michalski, Carlos Llorca, Rolf Moeckel. 2018. Shared Autonomous Vehicles Effect on Vehicle-Km Traveled and Average Trip Duration. *Journal of Advanced Transportation* 2018: 8969353.

Morris, David. 2018. "Yes, Uber Really Is Killing The Parking Business." *Fortune*, February 28, 2018. https://fortune.com/2018/02/24/yes-uber-really-is-killing-the-parking-business/.

Mothorpe, Chris, Andrew Hanson, and Kurt Schnier. 2013. "The Impact of Interstate Highways on Land Use Conversion." *The Annals of Regional Science* 51: 833–870.

Murphy, Enda and Joe Usher. 2015. "The Role of Bicycle-sharing in the City: Analysis of the Irish Experience." *International Journal of Sustainable Transportation* 9(2): 116-125.

Murphy, Sharon Feigon and Colin, Transit Cooperative Research Program, Transportation Research Board, and National Academies of Sciences, Engineering, and Medicine. 2016. *Shared Mobility and the Transformation of Public Transit*. Washington, D.C.: Transportation Research Board. https://doi.org/10.17226/23578.

NACTO (National Association of City Transportation Officials). 2016. *Bike Share Station Siting Guide.* New York: NACTO.

National Academies (Sciences, Engineering, and Medicine). 2005. *Assessing and Managing the Ecological Impacts of Paved Roads*. Washington, DC: The National Academies.

National Association of City Transportation Officials (NACTO). 2019. *Blueprint for Autonomous Urbanism*. Second edition.

National Association of City Transportation Officials. 2019. Blueprint for Autonomous Urbanism. https://nacto.org/publication/bau2/

Nechyba, Thomas J. and Randall P. Walsh. 2004. "Urban Sprawl." Journal of Economic Perspectives. Volume 18, Number 4, Pages 177–200

Nechyba, Thomas J. and Randall P. Walsh. 2004. "Urban Sprawl." Journal of Economic Perspectives. Volume 18, Number 4, Pages 177–200

Nechyba, Thomas, and Randall Walsh. 2004. "Urban Sprawl." *Journal of Economic Perspectives* 18 (4): 177-200.

Nichols, Cheryl Griffith, and Sandra Taylor Smith. n.d. "Hillcrest: The History and Architectural Heritage of Little Rock's Streetcar Suburb."

Norton, Peter D. 2011. *Fighting Traffic: The Dawn of the Motor Age in the American City*. Cambridge, MA: MIT Press.

Norton, Peter. 2021. *Autonorama: The Illusory Promise of High-Tech Driving*. Washington, DC: Island Press.

Novich, Jeff. 2020. "Op-Ed: How Uber Could Get Its Drivers Out of the Bike Lanes." *Streetsblog New York City* (blog). February 24, 2020. https://nyc.streetsblog.org/2020/02/24/op-ed-how-uber-could-get-its-drivers-out-of-the-bike-lanes/.

Oglivie, F and A. Goodman. 2012. "Inequalities in usage of a public bicycle sharing scheme: Socio-demographic predictors of uptake and usage of the London (UK) cycle hire scheme." *Preventive Medicine* 55(1): 40-45.

Oregon Task Force on Autonomous Vehicles. 2019. *Final Report to the Oregon State Legislature*. Eugene, OR: State of Oregon.

Orsi, Francesco. 2021. "On the Sustainability of Electric Vehicles: What about Their Impacts on Land Use?" *Sustainable Cities and Society* 66 (March): 102680. https://doi.org/10.1016/j.scs.2020.102680.

Othman, Kareem. 2022. Exploring the implications of autonomous vehicles: a comprehensive review. *Innovative Infrastructure Solutions* 7: 165.

Park City Museum. 2007. "Introduction: Transportation in America and the Carriage Age." https://parkcityhistory.org/wp-content/uploads/2012/04/Teacher-Background-Information.pdf.

Parsons, Donald Craig. 2005. *Making a Better World: Public Housing, the Red Scare, and the Direction of Modern Los Angeles*. Minneapolis, MN: University of Minnesota Press.

Patnaik, Aneesh, Jiahn Son, Alice Feng, and Crystal Ade. 2020. *Racial Disparities and Climate Change*. Princeton NJ: Princeton Student Climate Initiative.

Peters, Jonathan R., Adam L. Davidson, and Nora T. Santiago. 2015. *Don't Curb Your Enthusiasm for Bike Share: The Economic Impacts of Transferring Curb Space from Car Parking to Bike Share Docks.* New York: The CUNY Social Policy Simulation Center.

Pittsburgh (city of). Pittsburgh's Shared + Autonomous Mobility Principles. Accessed March 6, 2023. https://pittsburghpa.gov/domi/autonomous

Prince, Thomas Eugene. 1979. "Washington, D.C.'s Streetcar Suburbs: A Comparative Analysis of Brookland and Brightwood, 1870-1900." Thesis.

Qin-Liang, Yeo. 2022. "Why Does Big Tech Stay Headquartered In The US?" *E-International Relations* (blog). February 22, 2022. https://www.e-ir.info/2022/02/22/why-does-big-tech-stay-headquartered-in-the-us/.

Raifman, Matthew and Ernani Choma. 2022. "Disparities in Activity and Traffic Fatalities by Race/Ethnicity." *American Journal of Preventive Medicine* 63 (2): 160-167.

Rankle, Felicia and Cassie Barton. 2023. Green Belt. London, UK: House of Commons Library.

Reft, Ryan, Amanda Phillips de Lucas, and Rebecca Retzlaff. 2023. "How can a Highway Be Racist?" in *Justice and the Interstates*, edited by Amanda Phillips de Lucas, Rebecca Retzlaff, Ryan Reft. Washington DC: Island Press.

Regional Plan Association. 2017. New Mobility: Autonomous Vehicles and the Region. https://rpa.org/work/reports/new-mobility

Requia, Weeberb J., Moataz Mohamed, Christopher D. Higgins, Altaf Arain, and Mark Ferguson. 2018. “How Clean Are Electric Vehicles? Evidence-Based Review of the Effects of Electric Mobility on Air Pollutants, Greenhouse Gas Emissions and Human Health.” *Atmospheric Environment* 185 (July): 64–77. https://doi.org/10.1016/j.atmosenv.2018.04.040.

Reuters. 2020. “U.S. Federal Government Awards Transportation Contract to Uber, Lyft,” November 23, 2020, sec. Autos. https://www.reuters.com/article/us-lyft-uber-contract-idUSKBN2831S5.

Ricci, Miriam. 2015. “Bike sharing: A review of evidence on impacts and processes of implementation and operation.” *Research in Transportation Business & Management* 15: 28-38.

Richards, Tim. 2018. “Zoning and the Urban Freight System.” Clarion. https://clarionassociates.com/whats-new/zoning-urban-freight-system/

Riggs, William, Bruce Appleyard & Michael Johnson. 2020. A design framework for livable streets in the era of autonomous vehicles. *Urban, Planning and Transport Research* 8(1): 125-137.

Rodrigue, Jean-Paul, and Brian Slack. 2020. “5.6 – Intermodal Transportation and Containerization.” In Jean-Paul Rodrique (ed.), *The Geography of Transport Systems* (fifth edition). New York, NY: Routledge.

Rosner, David. 2010. “‘Spanish Flu, or Whatever It Is….’: The Paradox of Public Health in a Time of Crisis.” *Public Health Reports* 125(3_suppl): 37–47.

Rothstein, Richard. 2018. *The Color of Law*. New York City, NY: Liveright Publishing Corporation.

Sabouri, Sadegh, Keunhyun Park, Amy Smith, Guang Tian, and Reid Ewing. 2020. “Exploring the Influence of Built Environment on Uber Demand.” *Transportation Research Part D: Transport and Environment* 81 (April): 102296. https://doi.org/10.1016/j.trd.2020.102296.

Sampson. Susan D., 2008. “Category killers and big-box retailing: their historical impact on retailing in the USA.” *International Journal of Retail and Distribution Management* 36(1): 17–31.

Samuels, Gabe, and Yonah Freemark. 2022. *The Polluted Life Near the Highway: A Review of National Scholarship and a Louisville Case Study*. Washington DC: Urban Institute.

Sanchez, Thomas. 2004. “Land Use and Growth Impacts from Highway Capacity Increases.” *Journal of Urban Planning and Development* 130 (2).

Scheller, M., and J. Urry. 2000. The city and the car. *International Journal of Urban and Regional Research* 25(4): 737–757.

Schlossberg, Marc, William Riggs, Adam Millard-Ball, and Elizabeth Shay. 2018. *Rethinking the Street in an Era of Driverless Cars*. Eugene, OR: University of Oregon.

Schwartz, Samuel I. 2015. *Street Smart: The Rise of Cities and the Fall of Cars*. New York, NY: Public Affairs.

Schwartz, Samuel I. 2018. *No One at the Wheel: Driverless Cars and the Road of the Future*. New York, NY: Public Affairs.

Sciara, Gian-Claudia, Kristin Lovejoy, and Susan Handy. 2018. “The Impacts of Big Box Retail on Downtown: A Case Study of Target in Davis (CA).” *Journal of the American Planning Association* 84(1): 45–60.

Seattle (city of). 2017. *New Mobility Playbook*. Seattle, WA.

Shaheen, Susan A., Elliot W. Martin, Adam P. Cohen, and Rachel S. Finson. 2012. *Public bikesharing In North America : early operator and user understanding*. San Jose: Mineta Transportation Institute.

Shaheen, Susan A., Elliot W. Martin, Nelson D. Chan, Adam P. Cohen, and Mike Pogodzinski.. 2014. *Public Bikesharing in North America During a Period of Rapid Expansion: Understanding Business Models, Industry Trends, and User Impacts.* San Jose: Mineta Transportation Institute.

Shaheen, Susan A., Stacey Guzman, and Hua Zhang. 2010. “Bikesharing in Europe, The Americas, and Asia: Past, Present, and Future. *Transportation Research Record* 2143(1): 159-167.

Shared-Use Mobility Center. Share Mobility Principles for Livable Cities. Visited online March 6, 2023. https://www.sharedmobilityprinciples.org/

Shatz, Howard, Karin Kitchens, Sandra Rosenbloom, and Martin Wachs. 2011. “The Effects of Highway Infrastructure on Economic Activity.” In *Highway Infrastructure and the Economy: Implications for Federal Policy*. Santa Monica, CA: 15–42.

Shishir Mathur. 2014. “Impact of Urban Growth Boundary on Housing and Land Prices: Evidence from King County, Washington.” Housing Studies, 29:1, 128-148, DOI: 10.1080/02673037.2013.825695

Shoup, Donald. 2011. *The High Cost of Free Parking*. Milton Park, UK: Routledge.

Shoup, Donald. 2021. “Pricing Curb Parking.” *Transportation Research Part A: Policy and Practice* 154 (December): 399–412. https://doi.org/10.1016/j.tra.2021.04.012.

Siddiqui, Faiz. 2019. “Metro Plan Would Subsidize Uber and Lyft Fares to Fill Late-Night Service Gap.” *Washington Post*, February 14, 2019. https://www.washingtonpost.com/local/trafficandcommuting/metro-would-subsidize-uber-lyft-fares-to-fill-late-night-service-gap-under-plan/2019/02/12/eaea9ff6-2f10-11e9-86ab-5d02109aeb01_story.html.

Slater, Cliff. 1997. “General Motors and the Demise of Streetcars.” *Transportation Quarterly* 51: 45–66.

Smart Growth America. 2022. *Dangerous By Design 2022.* Washington, DC: Smart Growth America.

Smith, C. Scott, Jun-Seok Oh, Cheyenne Lei. 2015. *Exploring the Equity Dimensions of US Bicycle Sharing Systems.* TRCLC 14-01.

Smith, Theresa. 1994. “The Impact of Highway Infrastructure on Economic Performance.” *Public Roads* 57 (4).

Snider, Sarah E. (Sarah Elizabeth). 2009. “The Return of Streetcars to Western American Cities : Reintroducing Streetcars in Denver’s Historic Streetcar Neighborhoods.” Thesis, Massachusetts Institute of Technology.

Somerville, Kyle. 2018. “An Archaeological Study of a Streetcar Suburb: The East Main Streetcar Barns and Hayward-Hobbie Subdivisions, City of Rochester, New York.” *Industrial Archaeology Review* 40(2): 127–36.

Speck, Jeff. 2020. Ten rules for cities about automated vehicles. February 27. Congress for the New Urbanism. https://www.cnu.org/publicsquare/2020/02/27/ten-rules-cities-about-automated-vehicles

St. Clair, David J. 1981. “The Motorization and Decline of Urban Public Transit, 1935–1950.” *The Journal of Economic History* 41(3): 579–600.

Stacy and Fernandez 2024

Stacy, Christina Plerhoples, Davis, C., Freemark, Y. S., Lo, L., MacDonald, G., Zheng, V., & Pendall, R. (2023). Land-use reforms and housing costs: Does allowing for increased density lead to greater affordability? Urban Studies, 60(14), 2919-2940. https://doi.org/10.1177/00420980231159500

Stacy, Christina Plerhoples, Davis, C., Freemark, Y. S., Lo, L., MacDonald, G., Zheng, V., & Pendall, R. (2023). Land-use reforms and housing costs: Does allowing for increased density lead to greater affordability? Urban Studies, 60(14), 2919-2940. https://doi.org/10.1177/00420980231159500

Stacy, Christina Plerhoples, Karolina Ramos, Donovan Harvey, Sonia Torres Rodriguez, Jorge Morales-Burnett, and Sabina Morris. 2022. “Disrupting Structural Racism: Increasing Transportation Equity in South Dallas.” Urban Institute.

Stacy, Christina Plerhoples, Karolina Ramos, Donovan Harvey, Sonia Torres Rodriguez, Jorge Morales-Burnett, and Sabina Morris. 2022. “Disrupting Structural Racism: Increasing Transportation Equity in South Dallas.” Urban Institute.

Stacy, Christina, Karolina Ramos, Donovan Harvey, Sonia Torres Rodríguez, Jorge Morales-Burnett, and Sabina Morris. 2022. “Disrupting Structural Racism.”

Stainback, Kevin, and Emily Ekl. 2017. “The spread of ‘big box’ retail firms and spatial stratification.” *Sociology Compass* 11: e12462.

Staley, Richard A. 1983. “Land use constraints in locating intermodal terminals.” *Transportation Research Record* 907: 1-4.

State Smart Transportation Initiative. 2017. Cities and Airports Look to Develop Best Practices for Rideshare Pick-Ups and Drop-Offs. December 4, 2017. https://ssti.us/2017/12/04/cities-and-airports-look-to-develop-best-practices-for-rideshare-pick-ups-and-drop-offs/.

Steele, Jeanette. 2018. “Ace Parking Says Uber, Lyft Have Cut Parking Business up to 50% in Some Venues.” *San Diego Union-Tribune*, February 22, 2018, sec. Growth & Development. https://www.sandiegouniontribune.com/business/growth-development/sd-fi-ace-parking-uber-lyft-competition-20180222-story.html.

Stein, Gregory M. 2020. The Impact of Autonomous Vehicles on Urban Land Use Patterns. *Florida State University Law Review* 48: 193.

Sudhakar, Soumya, Vivienne Sze and Sertac Karaman. 2023. Data Centers on Wheels: Emissions From Computing Onboard Autonomous Vehicles. *IEEE Micro* 43(1): 29-39.

Sun, Qi, Tao Feng, Astrid Kemperman, and Andreas Spahn. 2020. “Modal shift implications of e-bike use in the Netherlands: Moving towards sustainability?” *Transportation Research Part D: Transport and Environment* 78: 102202.

TCRP (Transit Cooperative Research Program), 2018, “History of Commuter Rail”, in Contracting Commuter Rail Services, Volume 1: Guidebook, Transit Cooperative Research Program

Tessum, Christopher W., David A. Paolella, Sarah E. Chambliss, Joshua S. Apte, Jason D. Hill, and Julian D. Marshall. 2021. “PM2.5 polluters disproportionately and systemically affect people of color in the United States.” *Science Advances* 7(18).

Thakur, Praveen, Robert Kinghorn, and Renan Grace. 2016. Urban form and function in the autonomous era. Australasian transport research forum proceedings.

The Horseless Age Company. 1902. “The Horseless Age,” December 12, 1902, 7–11 edition.

The Meddin Bike-sharing World Map. 2022. The Meddin Bike-sharing World Map Report: 2022 edition.

The Tioga Group, Inc., Fehr & Peers, Hickory Ridge Group, LLC, and World Class Logistics Consulting, Inc. 2023. State and Local Impacts of Automated Freight Transportation Systems. Washington, DC: The National Academies of Sciences, Engineering, and Medicine.

Titze, Sylvia, Willibald J. Stronegger, Susanne Janschitz, and Pekka Oja. (2008). “Association of built-environment, social-environment and personal factors with bicycling as a mode of transportation among Austrian city dwellers.” *Preventive Medicine: An International Journal Devoted to Practice and Theory* 47(3): 252–259.

Trancik, Roger. 1986. *Finding Lost Space: Theories of Urban Design*. New York, NY: Wiley.

Tsekeris, Theodore. 2022. Freight Transport Cost and Urban Sprawl across EU Regions. *Sustainability* 14(9): 5217.

Ueda, Reed. 1984. "The High School and Social Mobility in a Streetcar Suburb: Somerville, Massachusetts, 1870-1910." *The Journal of Interdisciplinary History* 14(4): 751–71.

Union of Concerned Scientists. 2017. *Maximizing the Benefits of Self-Driving Vehicles*. Cambridge, MA: Union of Concerned Scientists.

Urry, John. 2004. "The 'System' of Automobility." *Theory, Culture & Society* 21 (4–5): 25–39.

Ursaki, Julia and Lisa Aultman-Hall. 2015. *Quantifying the Equity of Bikeshare Access in U.S. Cities*. TRC Report 15-011. Uteng, Tanu Priya and Andre Uteng. 2021. "Accessibility Mapping through Linking Land-Use Development Potentials and Planning for Cycling." *Built Environment* 47(4): 515-540.

U.S. Census Bureau. 2021. "American Community Survey (ACS)." https://www.census.gov/programs-surveys/acs

Visser Johan, and Kim Hassall. 2010. "What should be the balance between free markets and a not so 'Invisible Hand' in urban freight regulation and land use: Dutch and Australian experiences." *Procedia Social and Behavioral Sciences* 2: 6065–6075.

Vogels, Emily a. n.d. "56% of Americans Support More Regulation of Major Technology Companies." *Pew Research Center* (blog). Accessed May 1, 2023. https://www.pewresearch.org/short-reads/2021/07/20/56-of-americans-support-more-regulation-of-major-technology-companies/.

Volker, Jamey, Amy E. Lee, and Susan Handy. 2020. "Induced Vehicle Travel in the Environmental Review Process." *Transportation Research Record: Journal of the Transportation Research Board* 2674 (7): 468–479.

Wadud, Zia. 2020. "An Examination of the Effects of Ride-Hailing Services on Airport Parking Demand." *Journal of Air Transport Management* 84 (C).

Wagner, Peter. 2016. Traffic Control and Traffic Management in a Transportation System with Autonomous Vehicles. *Autonomous Driving*: 301–316.

Walmsley, Julie. n.d. "What Does The Future Hold For Ride-Hailing? Here Are 7 Expert Predictions." Forbes. Accessed May 3, 2023. https://www.forbes.com/sites/juliewalmsley/2018/12/09/what-does-the-future-hold-for-ride-hailing-here-are-7-expert-predictions/.

Wang, Jueyu, and Greg Lindsey. 2019. "Neighborhood Socio-demographic Characteristics and Bike Share Member Patterns of Use." *Journal of Transport Geography* 79: 102475.

Wang, Mingshu, and Lan Mu. 2018. Spatial disparities of Uber accessibility: An exploratory analysis in Atlanta, USA. *Computers, Environment and Urban Systems* 67: 169–175.

Wang, Xiaoquan, Chunfu Shao, Chaoying Yin, and Chengxiang Zhuge. 2018. "Exploring the Influence of Built Environment on Car Ownership and Use with a Spatial Multilevel Model: A Case Study of Changchun, China." *International Journal of Environmental Research and Public Health* 15 (9).

Ward, David. 1964. "A Comparative Historical Geography of Streetcar Suburbs in Boston, Massachusetts and Leeds, England: 1850–1920." *Annals of the Association of American Geographers* 54(4): 477–89.

Ward, Jacob W., Jeremy J. Michalek, Constantine Samaras, Inês L. Azevedo, Alejandro Henao, Clement Rames, and Tom Wenzel. 2021. "The Impact of Uber and Lyft on Vehicle Ownership, Fuel Economy, and Transit across U.S. Cities." *IScience* 24 (1): 101933. https://doi.org/10.1016/j.isci.2020.101933.

Warner, Sam Bass. 1978. *Streetcar Suburbs: The Process of Growth in Boston, 1870–1900*. Cambridge, MA: Harvard University Press.

Washington, DC Autonomous Vehicles Working Group. 2020. *DC AV Study Final Report*. Washington, DC: District of Columbia.

Weingroff, Richard. 1996a. "Federal Aid Road Act of 1916: Building the Foundation." *Public Roads* 60 (1).

Weingroff, Richard. 1996b. "Federal-Aid Highway Act of 1956: Creating the Interstate System." *Public Roads* 60 (1).

Wenus, Laura. 2017. "SF Legislator to Uber, Lyft: Get out of the Bike Lane." Mission Local. November 8, 2017. http://missionlocal.org/2017/11/sf-legislator-to-uber-lyft-get-out-of-the-bike-lane/.

West, Darrell M. 2016. Moving forward: Self-driving vehicles in China, Europe, Japan, Korea, and the United States. Washington, DC: Center for Technology Innovation at Brookings.

Wilson, James Q. 1966. *Urban Renewal: The Record and the Controversy*. Cambridge, MA: The MIT Press.

Woudsma, Clarence, and Paul Jakubicek. 2020. Logistics land use patterns in metropolitan Canada. *Journal of Transport Geography* 88: 102381.

Wu, Xinyi, Jason Cao, and Frank Douma. 2021. The impacts of vehicle automation on transport-disadvantaged people. *Transportation Research Interdisciplinary Perspectives* 11: 100447.

Xie, F., and D. Levinson. 2010. "How Streetcars Shaped Suburbanization: A Granger Causality Analysis of Land Use and Transit in the Twin Cities." *Journal of Economic Geography* 10(3): 453–70.

Yang, Hongtai, Jinghai Huo, Renbin Pan, Kun Xie, Wenjia Zhang, and Xinggang Luo. 2022. "Exploring Built Environment Factors That Influence the Market Share of Ridesourcing Service." *Applied Geography* 142 (May): 102699. https://doi.org/10.1016/j.apgeog.2022.102699.

Yang, Liu, Wei Liu, Fangni Zhang, and Vinayak Dixit. 2021. "Autonomous intersection management for connected and automated vehicles: a lane-based method." Intersectionality. https://www.researchgate.net/publication/357047062_Autonomous_intersection_management_for_connected_and_automated_vehicles_a_lane-based_method

Youngs, Jeff. 2024. "EV Home Charging Satisfaction on the Rise." J.D. Power. https://www.jdpower.com/cars/shopping-guides/ev-home-charging-satisfaction-on-the-rise

Zhang, Wenwen. 2017. The interaction between land use and transportation in the era of shared autonomous vehicles: a simulation model. Georgia Tech Theses and Dissertations.

Zhao, Yi, Shangan Ke, Qiaowen Lin, and Yanghang Yu. 2020. "Impact of land use on bicycle usage." *Journal of Transport and Land Use* 13(1): 299-316.

Zipkin, Amy. 2017. "Airports Are Losing Money as Ride-Hailing Services Grow." *The New York Times*, November 12, 2017. https://www.nytimes.com/2017/12/11/business/airports-ride-hailing-services.html.

Zylstra, Geoff D. 2011. "Whiteness, Freedom, and Technology: The Racial Struggle over Philadelphia's Streetcars, 1859—1867." *Technology and Culture* 52(4): 678–702.

Endnotes

[1] Andrea Chin. 2015. AUDI urban future initiative brings automated parking garage for self-driving cars to boston-area. *Designboom*. November 20. Available at: https://www.designboom.com/design/audi-urban-future-initiative-11-20-2015/

[2] See, for example, the US Department of Transportation's Public Involvement Guide (https://www.transportation.gov/public-involvement), or the People's Climate Innovation Center's Community Driven Planning Tool (https://www.climateinnovation.net/resources).

[3] Aleksandra Sandstrom and Becka A. Alper. 2019. "Americans with higher education and income are more likely to be involved in community groups" Pew. https://www.pewresearch.org/short-reads/2019/02/22/americans-with-higher-education-and-income-are-more-likely-to-be-involved-in-community-groups/

[4] Kirk Siegler. "A California town wiped off the map by wildfire is still recovering 5 years on." National Public Radio. November 8, 2023. https://www.npr.org/2023/11/08/1209471739/a-california-town-wiped-off-the-map-by-wildfire-is-still-recovering-five-years-o.

[5] Transit Oriented Development Institute. 2024. "Transit Oriented Development." http://www.tod.org/

[6] NACTO. 2023. "Blueprint for Autonomous Urbanism: Second Edition." https://nacto.org/publication/bau2/

[7] Noah McDaniel and Jorge González-Hermoso. 2023. "Oregon Expanded Its Housing Options. How Can Other States Follow Suit?" Urban Institute. https://www.urban.org/urban-wire/oregon-expanded-its-housing-options-how-can-other-states-follow-suit

[8] Federal Land Manager Environmental Database. 2023. Federal Lands List. https://views.cira.colostate.edu/fed/Pub/FederalLands.aspx

[9] Yonah Freemark. 2024. "Transportation Spending." The Transport Politic. https://www.thetransportpolitic.com/databook/spending.html

[10] American Public Transit Association. 2008. "Public Transportation Reduces Greenhouse Gases and Conserves Energy." https://www.apta.com/wp-content/uploads/Resources/resources/reportsandpublications/Documents/greenhouse_brochure.pdf

[11] Aaron Shroyer. 2019. "How Using Public Land Can Help Address Housing Shortages." Urban Institute Urban Wire. https://housingmatters.urban.org/articles/how-using-public-land-can-help-address-housing-shortages.

12 Matt Hardigree. 2019 "Geofences: The Invisible Walls Surrounding Autonomous Cars." https://www.apex.one/articles/geofences-the-invisible-walls-surrounding-autonomous-cars/

[13] See, e.g., Livia Labate. 2016. "Metrics, Measures and Indicators." *Carebot*. https://thecarebot.github.io/metrics-measures-and-indicators/; Pedro César Tebaldi. 2017. "What are the main differences between metrics and indicators?" *OP Services* https://www.opservices.com/differences-between-metrics-and-indicators/

[14] Christina Plerhoples Stacy, Christopher Davis, Benny Docter, Leiha Edmonds, Jorge González-Hermoso, Ananya Hariharan, Brady Meixell, Alex Peffley, Nancy M. Pindus, Prasanna Rajasekaran, Daniel Teles, Brett Theodos, Mark Treskon. 2020. Spatial Mismatch and Federally Supported Rental Housing. Urban Institute. https://www.urban.org/research/publication/spatial-mismatch-and-federally-supported-rental-housing

[15] Greenhouse Gas Protocol. 2024. "GHG Protocol for Cities." https://ghgprotocol.org/ghg-protocol-cities