Envisioning Florida's Future: Transportation and Land Use in an Automated Vehicle World

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16. Abstract

This report summarizes the work of a team of faculty and students from Florida State University's Department of Urban & Regional Planning to envision the impact of automated vehicle (AV) technology on Florida's communities, and to assess how AV technology might impact the built environment in the coming decades. As part of this research effort, the FSU Research Team facilitated a visioning session at the 2015 Florida Automated Vehicles Summit. Planners, engineers, public officials, and AV-industry professionals participated in small-table discussions tasked with thinking about how the built environment might need to adapt to accommodate AVs. Key themes from these discussions included that AVs will require narrower right-of-ways and travel lanes; influence the location, form, and amount of parking; impact the mobility of bicyclists and pedestrians; declutter urban environments through reduced signalization and signage; and provide opportunities for redevelopment on now unnecessary parking lots and excess right-of-ways. In this way, this study affirms that AVs are expected to drastically affect the design and functioning of the built environment and provides a starting point for public and private stakeholders to prepare for these impacts. While further research will be necessary, this study provides preliminary guidance for the policy decisions and infrastructure investments necessary to leverage AV technology to create a transportation system that is safer and more efficient than ever before and an urban environment built upon principles of sustainability and human-centered design.

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EXECUTIVE SUMMARY

Automated vehicle (AV) technology has the potential to transform transportation systems and land use patterns to a level not seen since the mass production of the private automobile roughly a century ago. This rapidly advancing technology offers the promise of increased safety and mobility for users and greater efficiency in systems operation. Beyond these important improvements, AVs have the great potential to impact and alter the built environment, impacting roadways, urban form, and site designs in far-reaching ways.

This report summarizes the work of a research team from Florida State University's Department of Urban & Regional Planning to envision the impact of AV technology on Florida's communities, and to assess how AV technology might impact the built environment in the coming decades. The FSU Research Team facilitated a visioning session at the 2015 Florida Automated Vehicles Summit to think about how the built environment might need to adapt over time to accommodate AVs. Participants brainstormed about the impact of AV technology on right-of-ways (ROW), access management, parking, signage and signalization, bicycle and pedestrian mobility, and opportunities for redevelopment. The feedback received from this group of experts was synthesized with a review of existing literature on the impacts of AVs on the built environment to yield a conceptual vision for the future of a built environment designed around the AV. Based upon this work, the following built environment impacts were identified.

Smaller and More Efficient ROWs: AVs' unique navigation capabilities are expected to enable narrower traffic lanes, reduce the number of lanes needed to accommodate traffic demand, and remove the need for medians.

A Drop-off Revolution: AVs are expected to create demand for drop-off areas that are as close as possible to the entrances of destinations. These drop-off areas will impact site-level design and affect access management in the form, location, and design of curb cuts and drop-off/loading areas.

Signage & Signalization: The future lies not in large numbers of traffic signs and signals, as traffic information can be transmitted to AVs wirelessly in real time, yielding far fewer traffic signs and signals and less cluttered urban spaces

Bicycle & Pedestrian Infrastructure: AVs are expected to improve the safety of bicyclists and pedestrians, but they may also make non-motorized travel more difficult by fragmenting or slowing down bike/pedestrian networks.

Parking: AVs will bring massive changes to the location, form, and amount of parking, as AVs can park themselves or remain in the transportation network while awaiting their next rider.

Redevelopment Opportunities: Reducing parking and narrowed right-of-ways will yield substantial redevelopment opportunities in urban areas dominated by surface parking and wide roadways.

This study affirms that AVs are expected to drastically change the design and functioning of the built environment. To capitalize on AVs' potential to improve the form and function of the built environment, transportation and land use planning agencies need to begin considering the far-reaching implications of AVs on the urban fabric. State and local agencies have a unique opportunity to reshape the urban form of our cities by shaping how the transportation system will adapt to accommodate AVs.

This study provides preliminary guidance for the policy decisions and infrastructure investments necessary to leverage AV technology to create a transportation system that is safer and more efficient, while also producing an urban environment built upon principles of sustainability and human-centered design. In particular, recommended steps for preparing for the rise of AVs include:

- *Incorporating AV considerations into the design of streetscapes and road network*s, including revisiting roadway design manuals and long-range transportation plans;
- *Identifying ways to establish separated AV infrastructure*, such as dedicated AV-lanes, to ensure the efficiencies of AVs can be capitalized on during the early stages of AV adoption;
- *Convening design and development stakeholders to develop design standards for the size and location of drop-off areas* to accommodate the growing demand for drop-offs without backing up traffic;
- *Investigating opportunities to use excess ROWs to promote Complete Streets*, perhaps through protected bicycle and pedestrian infrastructure, active streetscapes, and greenspaces;
- *Addressing the challenges of free-flow intersections* by tasking researchers and engineers with developing innovative, yet affordable ways to enable pedestrians to safely cross these intersections;
- R*ecognizing and planning for changes in parking demand* by identifying long-run opportunities for AV parking structures or large surface lots away from city centers, revising codes for parking requirements, and incorporating parking areas into comprehensive plans and other planning documents.

The central contention of this report is that automated vehicles will be the catalyst for the next great transformation in our transportation systems and the built environment. By providing public and private stakeholders with a starting point for envisioning the impact of AVs on the built environment, this report hopes to offer some preliminary guidance toward preparing for that future and ensuring that this remarkable opportunity is grasped.

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1. INTRODUCTION

Just over a century ago, the mass production and rising affordability of the private automobile contributed to massive changes in transportation networks, individual travel behaviors, and the built environment. The private automobile provided greater mobility, allowing drivers and their passengers to escape dense, complicated, and polluted urban centers. In the following decades federal, state, and local governments supported this increased mobility through massive investments in road networks, state highways, and ultimately a massive interstate system that allows for high-speed travel over long distances.

This increased mobility brought about long-run changes in the built environment as well. At the metropolitan level, reduced travel times and costs contributed to the suburbanization of upper class households in the 1920s, and then middle class households starting in the 1940s. These new suburbanites consumed far-flung single family housing at stunning rates, contributing to America's sustained economic boom in the post-World War I and post-World War II eras. As these wealthier households left the city, retail centers followed. Whereas the early 1900s saw most retail outlets located in downtowns and urban neighborhoods, by the 1960s the suburban shopping mall and strip mall had come to dominate the retail market.

The rise of the automobile brought about changes at the corridor and site levels, as well. Urban and suburban arterials were designed to promote speed and safety for automobiles, and mobility concerns came to dominate roadway design. At the site level, buildings were pushed back to make room for automobile parking, and parking standards for the busiest parking day of the season came to dominate local codes. In a few decades, the American landscape was largely redesigned to ensure that the private automobile could travel at speed, over long distances, and with easy ingress/egress to the vast majority of land uses in the city.

Figure 1.1 - Typical Auto-oriented Commercial Strip Development: The land use impacts of the rise of the automobile are especially evident in today's commercial strip malls and suburban corridors.
Source: http://makecalgary.com/?p=16123

1.1 Automated Vehicles & the Next Great Transportation Transformation

The central contention of this report is that automated vehicles (AVs) will cause the next great transformation in our transportation systems and the built environment. This technology, which is advancing very quickly, offers

the promise of increased safety for users and greater efficiency in systems operation. AVs also allow riders to be productive and/or entertained during their travel times, provide mobility to populations that are unable to drive (children and the elderly), and will almost certainly contribute to changes in vehicle ownership patterns.

Figure 1.2 - The Google Car: Innovative vehicle designs, such as the Google Car, may affect the ROW needed to accommodate AVs. *Source: http://www.automobilemag.com/news/the-arrival-of-autonomous-cars-examined/*

Beyond these very important improvements in safety and mobility, not to mention the potential quality of life benefits for a variety of users, AVs have the great potential to impact and alter the built environment in the coming decades. The impact of AVs on roadway design, urban form, and site level impacts may be of a magnitude similar to those during rise of the private automobile in the early 20th Century. As discussed in this report, there is very strong evidence that AVs will require narrower ROWs and travel lanes, influence the location, form, and amount of parking, impact the mobility of bicyclists and pedestrians, declutter urban environments through reduced signalization and signage, and provide opportunities for redevelopment on now unnecessary parking lots and excess ROW. While many studies have focused upon the revolutionary impact of AVs on transportation systems and safety, far too little analysis has investigated the impact of this technology on the built environment.

This report summarizes the work of a team of faculty and students in the Florida State University Department of Urban & Regional Planning to envision the impact of AVs on Florida's communities, and to assess how AV technology might impact the built environment in the coming decades. As part of this research effort, the FSU Research Team facilitated a visioning session at the Florida Automated Vehicles Summit held in Jacksonville, Florida in December 2015. Planners, engineers, public officials, and professionals from AV-affiliated industries contributed to fourteen separate small-table discussions. These expert groups were tasked with thinking about how specific aspects of the built environment might need to change over time. These discussions centered upon the impacts of AVs on four pre-determined urban

settings that are vital to Florida's economic health and quality of life: a Downtown (Orlando served as the example for this discussion), an Office/Medical/University Complex (USF Health in Tampa), a Transit-Oriented Development (Dadeland Mall in Miami), and an Urban Arterial (US-19 in Pasco County).

Participants were assigned an urban setting and a set of assumptions regarding some baseline conditions in the year 2040 or 2060 (summarized in Table 1).

Table 1: AV Assumptions Guiding the Visioning Session Discussions

2040	2060

• 50% Fully Automated Vehicles
  • 90% Privately Owned
  • 10% Share Ownership
• 50% Human-Driven Vehicles
	• 100% Fully Automated Vehicles
	  • 70% Privately Owned
	  • 30% Shared Ownership
	• 0% Human-Driven Vehicles

Figure 1.3 - 2015 Florida Automated Vehicles Summit Visioning Session: One hundred participants gathered to envision the future of the built environment.

Participants utilized these assumptions to brainstorm about the impacts of AV technology in a partial-AV scenario (2040, where 50% of vehicles are automated) and a full-AV scenario (2060, where 100% of the fleet is automated). Participants were then engaged in an "Urban Immersion Experience" that asked participants to proceed through a typical journey for four different actors, each using a different transportation mode, in their group's urban setting.

Participants were asked to think about the impact of AV technology on:

Right-of-Ways: AVs are expected to be smaller in size, require less physical space, and drive with greater precision than existing vehicles. How will the coming of AVs affect the form, design, and functioning of the highways, arterials, and local streets in the transportation system?

Intersections: One of the technology's most exciting advances revolves around continuous flow intersections, ones where vehicles no longer need to stop at red lights or stop signs. As AVs come to dominate the fleet, how might intersections need to change to accommodate AVs?

Access Management: AVs will bring a drop-off revolution to transportation, with users desiring to be picked up and dropped off very close to their origins and destinations, yielding even more complications for system access management. How might AVs impact the form, location, and design of curb cuts and drop-off/loading areas in urban environments?

Parking: AV technology promises vehicles that can drop riders off and park themselves, making the need for nearby parking much less important for a large number of land uses. What impacts can AVs have on the form, location, and number of parking lots/spaces in urban settings?

Signage and Signalization: As AVs come to dominate the vehicle fleet, the need for signage and signalization will decrease substantially because AVs obtain information on destinations, turn lanes, and intersections wirelessly in real-time. How will signage and signalization need to evolve with the coming of AVs?

Bicycle and Pedestrian Mobility: AVs have the potential to improve the quality and productivity of riders, but the increasing numbers of drop-off/loading areas and free flow intersections could hinder pedestrian and bicycle travel. What are the potential positive and negative impacts of AVs on bike/ped mobility?

Redevelopment Opportunities: Given these many changes to the urban environment, there is potential for redevelopment opportunities in these urban settings. What are the opportunities for redevelopment in these urban settings, especially on surplus surface parking lots and along excess system ROWs?

In the sections that follow, this report summarizes key themes that emerged from these facilitated discussions and a review of the rather modest literature on the impacts of AVs on the built environment. These findings should be seen as impressionistic, pointing to some of the built environment chal-

lenges and opportunities that may arise with the transition to an AV fleet in the coming decades. These impressions are intended to spur further research and discussion about the impacts of AVs on the built environment. To date, substantial thought has gone into transportation benefits/challenges of the technology. In contrast, the built environment professions of planning, architecture, and real estate have largely remained disengaged from thinking about and anticipating the impacts of AVs on cities, employment centers, retail hubs, and suburban strips. The goal of this report is to provide public and private stakeholders a starting point for envisioning the impact of AVs on the built environment, yielding urban settings that rest upon the principles of sustainability and human-centered design. AVs have the potential to promote these attributes in urban settings, but only if care is taken to design and invest in a built environment that serves humans first and AVs second.

2. AVS & THE BUILT ENVIRONMENT

It is clear that automated vehicles are poised to revolutionize the way people travel, and they will also have a profound impact on the built environment. While the exact form of these effects is difficult to predict and will likely be place-specific, there are numerous effects that should impact the way we prepare for a future transportation system highly influenced by automated vehicles in almost all urban settings. These effects include smaller, more efficient right-of-ways, access management changes, signage and signalization changes, pedestrian and bicycle interface effects as well as parking reduction and location changes. These changes will also present significant redevelopment opportunities. Each of these effects are explored in detail in the following sections.

Figure 2.1 - Congested Highway System: Traffic congestion will likely be reduced with the improved efficiency of AVs.
Source: http://bmcuk.org/Blog/4/Congestion-in-Dubai-overtakes-Cairo

2.1 Smaller and More Efficient Right-of-Ways

Because AVs have the capability to travel more precisely than human-operated vehicles and in harmony with other AVs, AV technology opens the possibility for smaller and more efficient ROWs. By reducing the width required for vehicle lanes and potentially reducing the number of lanes needed to accommodate traffic flow, the adoption of AVs will have several key implications for how streetscapes are planned and designed.

Reduced Lane Widths

Humans are relatively imprecise drivers. Even when drivers are trying their best to keep their vehicle in the center of the lane they inevitably will move back and forth within the lane. Consequently, roadways today are designed to provide drivers with a margin of error. They are designed to give drivers space to move side-to-side without crossing into an adjacent lane and putting other vehicles at risk of a collision.

"Reduced lane widths for AVs... could be used for better pedestrian or bicycle facilities"

-USF 2040 Participant

AVs are expected to remove the need to design roads and lanes to account for human-error. AVs' ability to move more precisely than human-operated vehicles will enable roads to be designed with narrower lanes. Lanes will only need to be as wide as the vehicles driving on them. While exactly how much this will reduce lane-widths depends on how AVs will be designed (i.e., how wide AVs are), assuming vehicles stay roughly the same size, lanes could be reduced by as much as 20%. However, this may be a low estimate since many believe that the industry will move towards AVs that are smaller than cars today. At first, narrower traffic lanes may only be possible in dedicated AV lanes similar to HOV lanes. But as AVs are adopted, all roadways may be designed with narrower lanes, which will create more space for bicycle and pedestrian facilities, active streetscapes, or greenspaces.

Fewer Traffic Lanes/Reduced Lane Expansion

Beyond allowing for narrower lanes, AVs are expected to increase the capacity and efficiency of existing roadways. Since AVs will likely be smaller, have significantly faster reaction time, and can communicate with other vehicles, AVs will be able to safely travel closer together than human-operated vehicles. This will significantly increase the throughput of each vehicle lane. In addition, AVs will not be involved in as many car crashes. Since 25% of congestion is caused by traffic incidents, the added safety of AVs could drastically improve the efficiency of existing roadways. Finally, as will be discussed in a later section, automated and connected vehicles are expected to improve traffic flow through intersections. The combination of these factors will significantly improve the efficiency and throughput of existing ROWs. At the very least, this may reduce the need for lane expansions. However, it is possible that the AV revolution will even enable road diets that accommodate the same amount of traffic with fewer lanes.

Smaller Medians

The final way AVs may impact how ROWs are designed is by reducing the need for medians. The primary purpose of medians today is to provide a safety buffer between two lanes of traffic heading in opposite directions. Since AVs never get distracted and never fall asleep at the wheel, medians can be narrowed or eliminated altogether. Some medians may be kept in place for aesthetic value, but in most cases, medians will become unnecessary.

In the coming decades AVs will reshape the streetscape by allowing for significantly smaller, yet more efficient ROWs. The extra space no longer needed to move automobile traffic can then be used to provide wider sidewalks, bike lanes, and more greenspace without requiring more ROW. In this way, AVs open the possibility of safer and more inviting urban spaces with more space for bicyclists, pedestrians, and other creative uses such as drop-off infrastructure.

Figure 2.2 - Example of a Common Auto-centric ROW in 2016: Today most urban roadways have wide lanes and medians, narrow sidewalks and on-street parking.

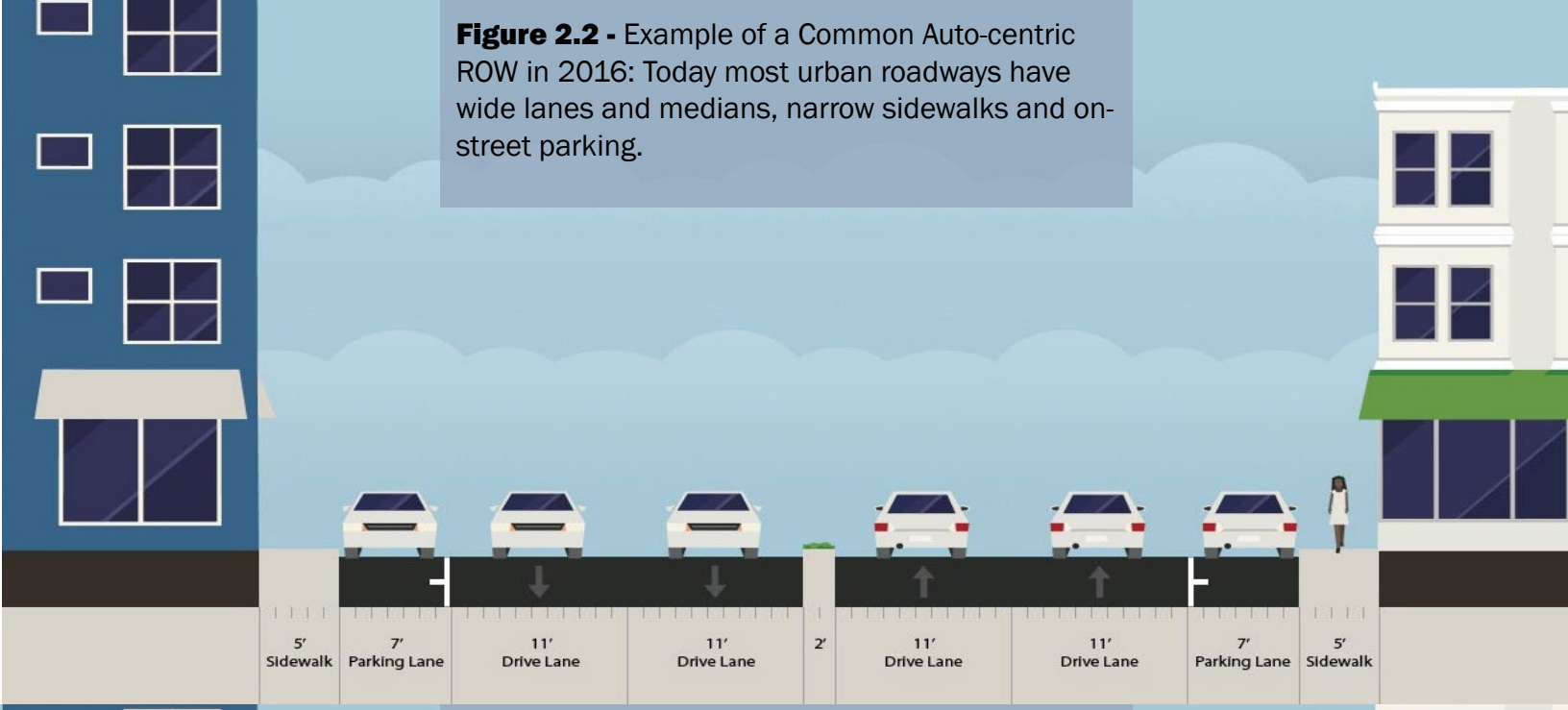


Figure 2.3 - Example of an AV ROW - Moving Toward Complete Streets: Because AVs do not need wide lanes or medians to travel safely, this space can be freed up for more pedestrian and bicycle infrastructure

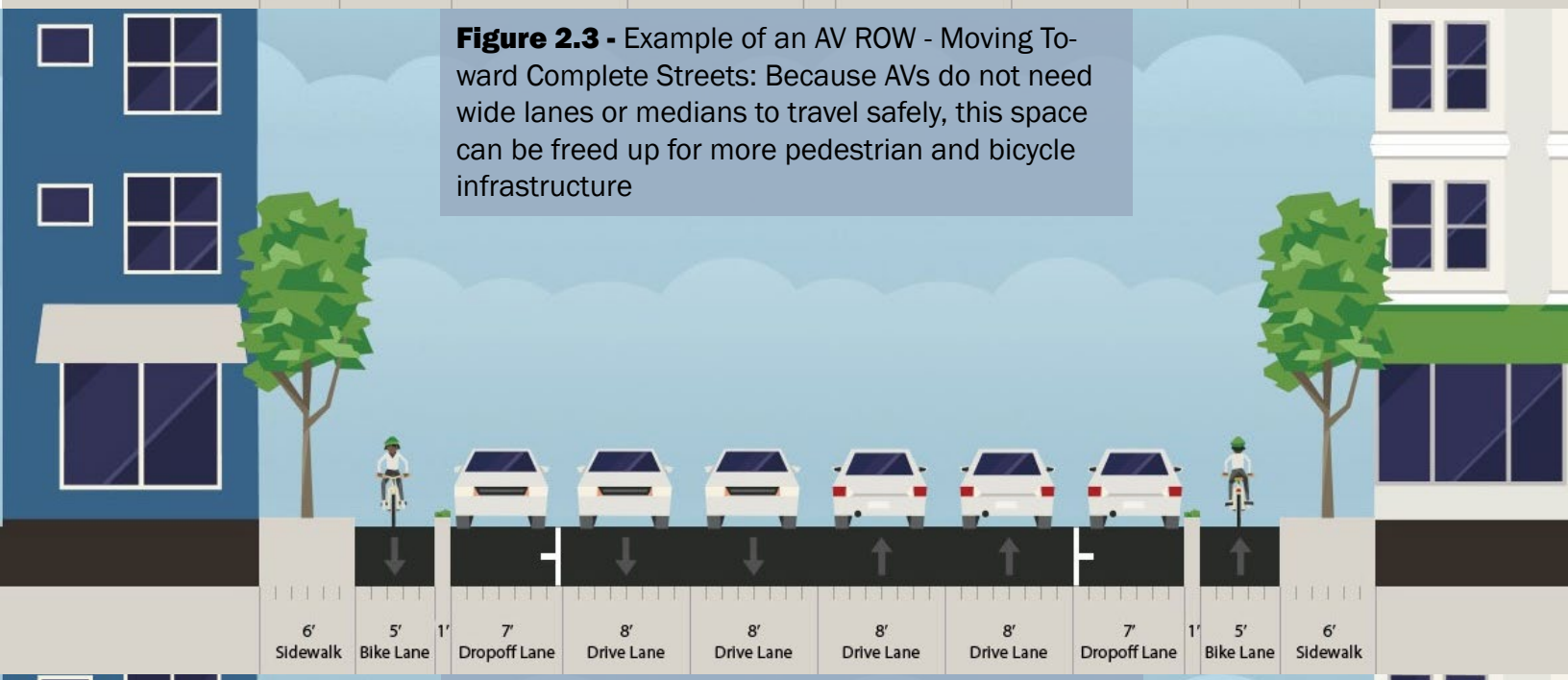
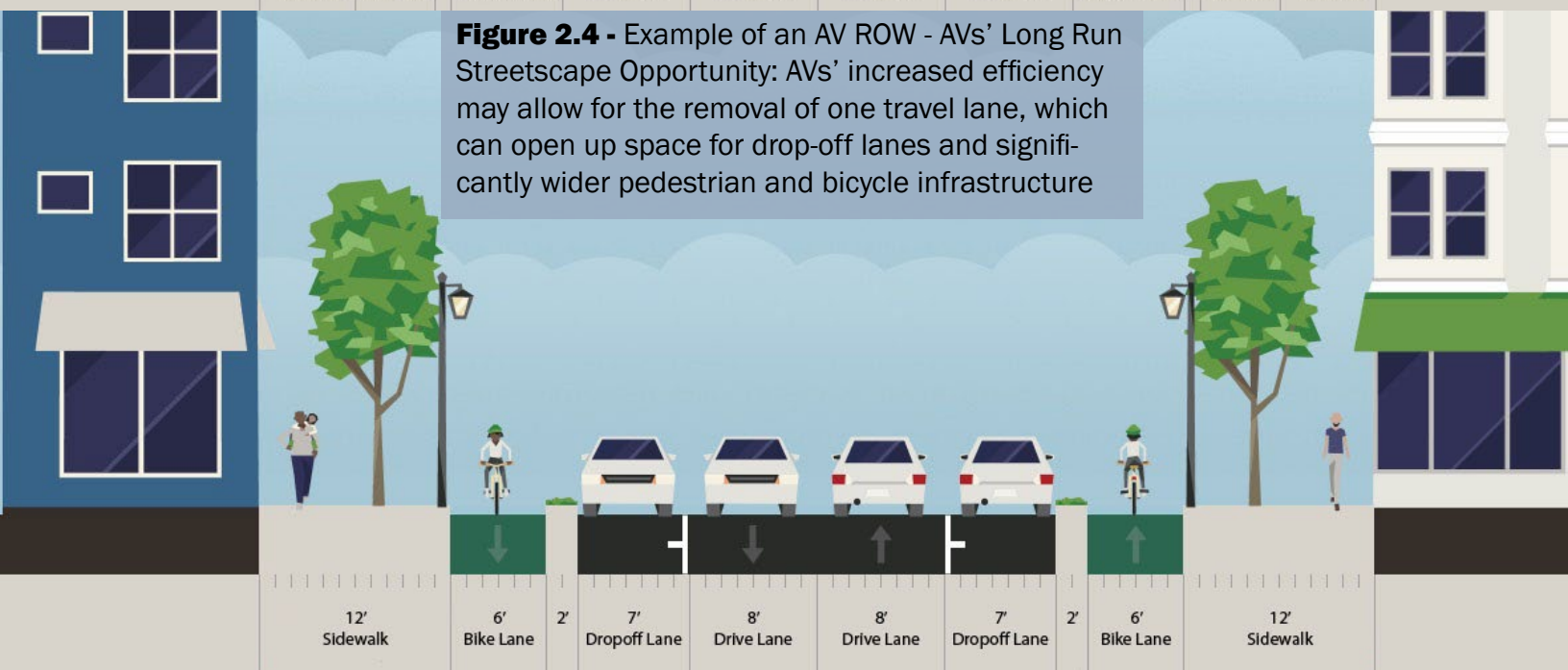


Figure 2.4 - Example of an AV ROW - AVs' Long Run Streetscape Opportunity: AVs' increased efficiency may allow for the removal of one travel lane, which can open up space for drop-off lanes and significantly wider pedestrian and bicycle infrastructure



2.2 Access Management

The ability of AVs to drop-off passengers before going to park themselves or to pick-up another passenger is expected to bring a drop-off revolution to the transportation system. Space previously used for on-site parking is expected to be transformed into drop-off areas, and businesses will likely explore new site designs to allow for quick and easy ingress/egress onto adjacent roadways. Consequently, the transition from parking to drop-off areas will have far-reaching implications for access management including the form, location, and design of curb cuts and drop-off/loading areas.

The Emergence of Drop-off and Pick-Up Areas

AVs remove the need for passengers to be with the vehicle when it parks, enabling passengers to be dropped off, instead of having to exit the vehicle wherever parking is available. Users will likely want to be dropped off and picked up as close to their destinations as possible. In this way, AVs will shift the priority at the site level from parking to drop-off areas. Drop-off areas will no longer be relegated to airports and bus stops, instead they are expected to become a staple in the design of urban spaces.

Figure 2.5 - Example of Existing Drop-off Areas: Drop-off and pick-up zones are certain to be an important feature in tomorrow's transportation system. *Source: National Rail http://www.nationalrail.co.uk/SME/html/NRE_CLJ/images/photos/800/o1504-0001321.jpg*

"Since travelers would not be parking in a surface lot... there would be more demand for drop-offs."

-Dadeland 2060 Participant

Drop-off areas can take many different shapes and sizes and can be incorporated into the design of various urban settings in a lot different ways. In many cases, the form of the drop-off areas may be influenced by the existing built environment. In fact, there are several features of today's built environment that could easily be retrofitted into drop-off areas including bus stops, turn lanes, frontage roads, and service roads. Since space will be at a premium in downtowns, there will likely be less space available for downtown

Figure 2.6 - Typical Suburban Strip Mall Site Design in 2016

Figure 2.7 - Conceptual Site Design for AV-Oriented Commercial Redevelopment in 2060

drop-offs, particularly separated drop-offs. However, if AVs shift the priority from parking to drop-offs, on-street parking spaces may be retrofitted to be into drop-off lanes.

Although retrofitting existing infrastructure may provide drop-off solutions during the transition to AVs, once AVs are the predominant mode of transportation drop-off/pick areas will likely be fully integrated into the design of almost all urban spaces. Figures 2.6 and 2.7 provide an example of how drop-off areas could be incorporated the design of commercial strip development in a suburban setting. Drop-offs may take several different forms including pull-offs, cul-de-sacs, and frontage roads, but in all cases drop-off areas need to be separated from traffic lanes to ensure the safety of those entering and exiting the vehicles. In high-traffic areas like downtowns, it may also be important to separate drop-off areas from pick-up areas to make the arrival and departure process is as efficient as possible and to ensure drop-offs areas do not impede the flow of traffic.

Regardless of the setting or the design of drop-off/pick-up areas, another vital feature of pick-up areas in particular will be passenger waiting areas. Riders will need safe and comfortable spaces to wait for their vehicles. The design of these areas could borrow design cues from existing best practices of bus stop design including the need for shaded and covered places to sit.

Though drop-offs and pick-ups are a minor feature in today's transportation system, they are expected to be one of the most important design elements in a world dominated by automated vehicles. Transportation engineers and planners will need to conceive of creative ways to reuse existing infrastructure and to develop completely new features to enable people to arrive at and depart from their destinations safely and efficiently.

2.3 Signage & Signalization

Traffic signs and signals are among the most important features of today's transportation system. They provide drivers with all the information they need to keep the transportation system running smoothly and efficiently. Signs and signals inform drivers when, where, and how fast they may go, and ensure traffic keeps moving safely and efficiently through intersections. In short, traffic signs and signals are necessary to prevent the transportation system from devolving into chaos. However, the emergence of Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) technology is poised to revolutionize how information is transmitted to drivers and how traffic moves through intersections. This may significantly improve traffic-flow and reduce congestion, but it will also have notable effects on the built environment. Most notably, automated and connected vehicles will declutter roadways by removing the need for the vast majority of traffic signs and signals.

The Decline of Street Signs

In the coming decades information previously given to drivers through traffic signs (speed limit, road signs, stop signs etc.), can be transmitted to the vehicle through V2I sensors embedded in the infrastructure. AVs can then adjust their speed, direction, or route according to the information provided by the V2I "signs."When AVs are first adopted and they share the road with human-operated vehicles, more signs and signals may be necessary to accommodate human drivers and to delineate where automated and human-operated vehicles are and are not allowed to drive. However, once AVs make up most or all of the vehicle fleet, physical signs and signals are not expected to be necessary. Even lane striping could be phased out once vehicles can sense where other vehicles are on the road. While some AVs currently rely on road lines to help their navigation systems, the primary function of lane stripping is to guide human eyes. More sophisticated systems may not need them, and they could be replaced by virtual lane systems embedded in the infrastructure.

Figure 2.8 - Flexible-Lane Signalization Infrastructure: Despite their efficiency, flexible lane systems today require cumbersome infrastructure to keep roadways safe. AV systems will allow for the benefits of directionally flexible roads without the expensive and unsightly infrastructure investments.
Source: http://www.deseretnews.com/article/865566239/Utahs-first-flex-lanes-system-opens-on-5400-South-in-Taylorsville.html?pg=all

V2I technology could provide vehicles with real time information on traffic delays and road work. AVs could then use this information to find the fastest and most efficient routes to their destination. In this way, the transition from street signs to V2I technology could serve to reduce traffic congestion and shorten travel times.

The Decline of Traffic Signals

V2I and V2V technology will also contribute to the replacement of traffic signals. Just like traffic signs, traffic signals will no longer need to be visible; instead sensors embedded in the road or placed in traffic towers can communicate traffic information to vehicles on the road. At the very least, this means that physical traffic signals could be removed from intersections. However, the combination of automated and connected vehicle technology may completely revolutionize how intersections function by removing the need for traffic to to stop at intersections. Instead, AVs able to sense and

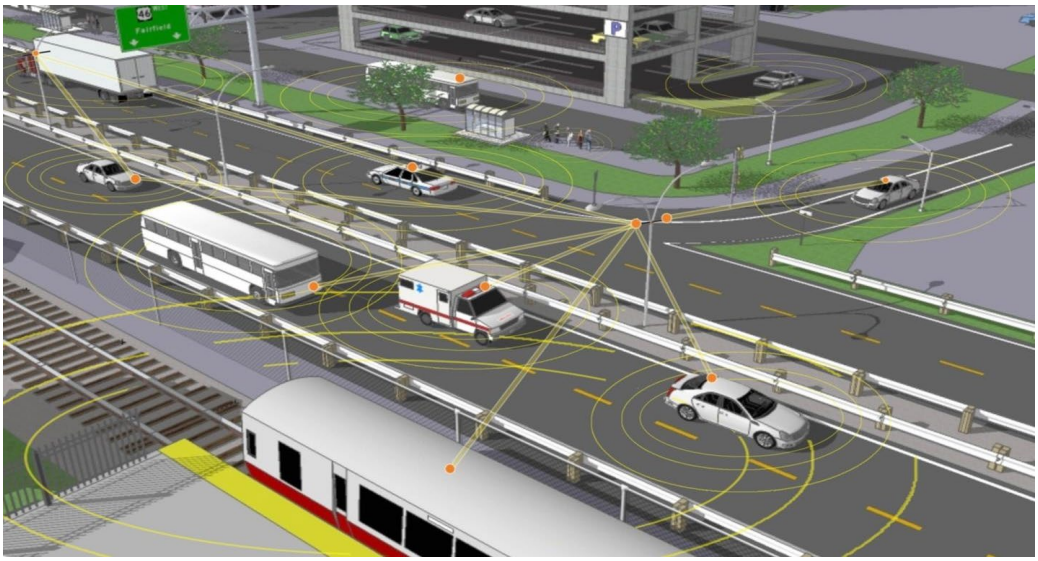


Figure 2.9 - Conceptual Example of V2I Communication: V2V and V2I technology makes it possible to communicate with AVs without any physical signage or signalization. *Source: NHTSA*

communicate with other vehicles will be able to flow freely through intersections. Each vehicle will simply react to other vehicles and cross traffic when an opening is available. While an overhaul of how intersections function (from a start -stop system to a free-flowing system) will likely not be possible until most or all vehicles on the road are automated, these ideas promise to significantly improve traffic flow and reduce congestion.

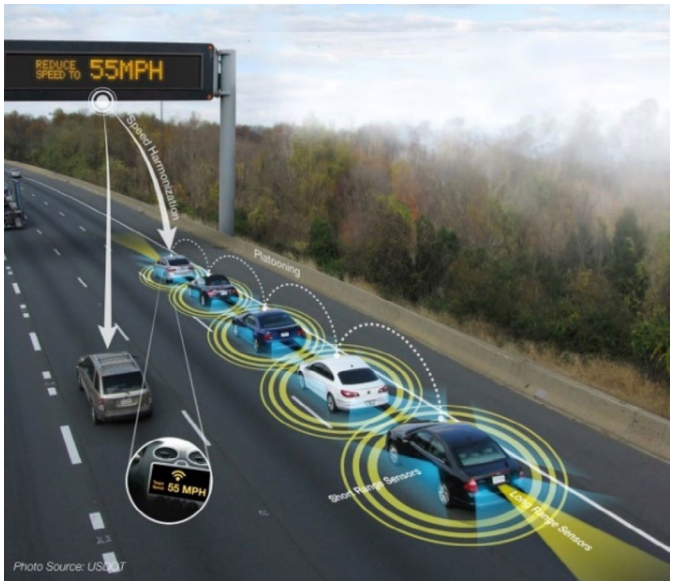


Figure 2.10 - Conceptual Example of V2V Communication: V2V technology will allow AVs to communicate and travel more closely together; V2I technology will communicate road sign data to cars. *Source: USDOT*

"Signals for pedestrians will always be needed."

-USF 2060 Participant

The Reorientation of Signage and Signalization

The only road signs and signals needed in an AV world are for pedestrians and bicyclists. AVs can be expected to cause a reorientation of street signs and traffic signals from automobiles to pedestrians. Removing or redesign-

ing the majority of street signs and signals could also allow for streets and spaces that are more inviting to pedestrians and other modes of transportation. Street signs could be replaced by creative pedestrian way-finding or other features that make streetscapes more appealing and attractive to pedestrians. In this way, AVs could make Complete Streets easier to implement, and could help create more attractive urban spaces and communities.

2.4 AVs and Bicycle/Pedestrian Interface

The coming AV revolution offers substantial benefits for the efficiency and safety of vehicular travel. Less clear, however, is the impact of AVs upon travel by bicyclists and pedestrians. While AVs have the potential to improve the functioning of vehicular systems, one view is that AVs have the potential to make bike and pedestrian travel within urban settings far more complicated and less easily achieved. Alternatively, because AVs will require less urban space than traditional vehicles the technology offers some promise for the development of quality, attractive separated bike/pedestrian infrastructure.

How AVs Might Hamper Bike/Pedestrian Travel

As AVs come to dominate roadways, travel by non-vehicular modes may be hampered by two key factors. First, AVs require no signalization and signage to regulate traffic flow. As a consequence red lights and stop signs that provide for safe intersection crossings may become a thing of the past. Pedestrians and bicyclists attempting to travel in dense urban settings where traffic never stops can be left waiting for long periods for a break in traffic, slowing their travel.

Figure 2.11 - Complete Street Streetscape Design: Narrower and more efficient ROWs made possible by AVs could make Complete Streets possible in more areas, providing safe and enjoyable spaces for pedestrians and bicyclists to travel. *Source: http://www.ca-city.com/complete_streets/fundamentals.html*

Second, AVs will likely require regular drop-off and pick-up zones along most corridors. These zones allow riders in AVs to access their final destinations easily, as well as allow riderless vehicles the ability to pick up passengers to whisk them off to their next destination. These zones require space for

the AVs to access individual sites and space for AVs waiting to pick up their riders. Depending upon their design and location, these (un)loading zones can fragment bike/pedestrian networks and make travel via these modes more cumbersome. Poorly designed urban streetscapes that are dominated by AV drop-off and idling zones can have the effect of depressing bike and pedestrian travel.

How AVs Might Support Bike/Pedestrian Travel

While free flow traffic conditions and drop-off zones may complicate bicyclist and pedestrian travel in urban areas, the AV revolution also holds some promise for urban settings that serve humans first rather than second behind vehicles. AVs are expected to require far less space within urban settings; lane widths will become more narrow, fewer vehicles on the road will contribute to road diets, and the need to provide parking at every destination will evaporate. Urban environments will also be less cluttered by traffic signalization and signage, offering opportunities for more attractive and bike/ped friendly corridors.

Taken together, these trends suggest that roadways and urban environments can be redesigned in ways that will yield more enjoyable travel for bicyclists and pedestrians. Many more urban corridors can become Complete Streets, with separate ROWs for AVs, bicyclists and pedestrians. Reduced signage can open up opportunities for signage and advertising aimed at bicyclists and pedestrians rather than drivers and riders in vehicles. Surface parking and monolithic parking garages will become surplus, ultimately replaced with more residential and non-residential development, or parks and plazas that serve as social spaces and places for physical activity.

2.5 Parking

Figure 2.12 - Futuristic Parking Facility: Because AVs will not need to be as accessible to owners, especially with a shared system, car parking and storage will become more creative and efficient.
Source: http://www.arch2o.com/autostadt-volkswagen-theme-park/

Without the need for a human driver to park the vehicle, the adoption of AVs will likely lead to a significant change in the design of parking in urbanized areas. As parking currently constitutes a significant percentage of the developed land in urbanized areas, the impact of AVs on

parking location, amount and design may be amongst the most significant changes to the built form of cities. Ultimately, the need for human-centered and scaled design for parking areas will be significantly reduced or eliminated once AVs become the dominant mode of transportation.

Parking Location

AVs are expected to significantly impact the location of parking facilities in urbanized areas. As AVs can drop passengers off at a destination and drive elsewhere to park, parking will not necessarily need to be provided on-site, at every business, office, or residence. As a result, it is possible that parking in urban areas can ultimately be consolidated outside of the city center. Larger-scale, AV-only parking garages or lots could be located on the periphery of urban centers where land values are not at a premium and development pressures are less intense. This relocation of parking facilities away from the urban core will likely open up significant infill redevelopment opportunities. Additionally, it is probable that on-street parking will not be needed for AVs as human passengers will no longer require parking at or near their destination. The space once utilized for on-street parking could ultimately be repurposed to accommodate drop-off lanes or other ROW features, such as bike lanes or sidewalks.

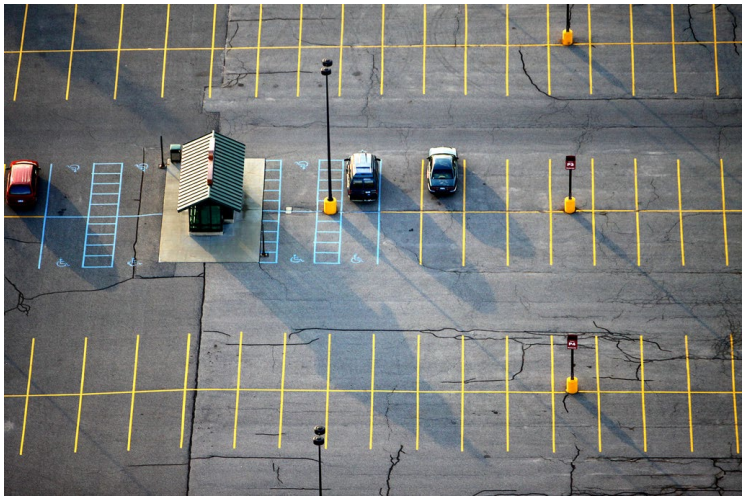


Figure 2.13 - Parking Redevelopment Opportunities: With less demand for parking, surface lots represent a significant opportunity for urban infill and redevelopment.
Source: http://www.strongtowns.org/journal/2015/10/16/fayetteville-eliminates-minimum-parking-requirements

Reduction in Amount of Parking and Parking Facility Design Considerations

The shift from on-site to remote parking facilities will not occur all at once, as human-driven vehicles will need to be accommodated on-site or nearby until the entire vehicle fleet is automated. It is probable that during this transition, automated and human-driven vehicles may need separated parking facilities to ensure AV efficiencies can be realized. For example, AVs are expected to be able to park much closer together, as vehicle doors will not need to be opened after the car parked itself. As a result, AVs can provide significant parking efficiencies in terms of the size and number of parking spaces accommodated within a particular building footprint. However, during the transition, human-driven vehicles will still require parking designed for humans, thereby limiting the space efficiencies of AV parking. Consequently,

separate parking facilities for automated and human-driven vehicles could capitalize on the efficiencies of AVs while still meeting the parking needs of human-driven vehicles. As a result, the most efficient parking paradigm to guide the transition to AVs would include on-site parking facilities designed for human-driven vehicles and off-site parking facilities for AVs. Over time, the on-site facilities would gradually shrink to accommodate the decreasing number of human-driven vehicles on the road, while off-site AV parking facilities grow to take their place.

"Eventually less parking may be needed and AV lots could be placed remotely."
-USF 2040 Participant

Ultimately, parking structures for AVs will likely not need to take humans into consideration in the design and location of the facilities. Therefore, structured parking for AVs would not need to include human-friendly design and safety features such as lighting, elevators, and other amenities. Rather, AV structured parking could be located underground or in other underutilized or out of the way locations, with relatively little lighting or climate control. In this scenario, only limited access for humans would need to be provided, such as maintenance stairways and other limited facilities to allow for human access.

In addition to the massive changes in where parking is located and how it is designed, AVs are also expected to significantly reduce the amount of parking required to meet the demand for parking. AVs promise to do this in two ways: making more efficient use of existing parking and reducing the demand for parking. V2I communication could enable a more efficient use of the parking supply by notifying AVs where the nearest available parking spots are. Previously underutilized parking would become an important part of the parking supply. More importantly, if AVs are owned under a shared model, some vehicles may not need to park after dropping off a passenger, rather the shared AV would move on to the next human user. It is also possible that a privately-owned AV will not be required to park in a public space, but could return to the owners' residence, travel to a remote staging area for maintenance and fuel, or circle the block instead of parking. All of these potential factors would result in the reduction in the amount of needed parking.

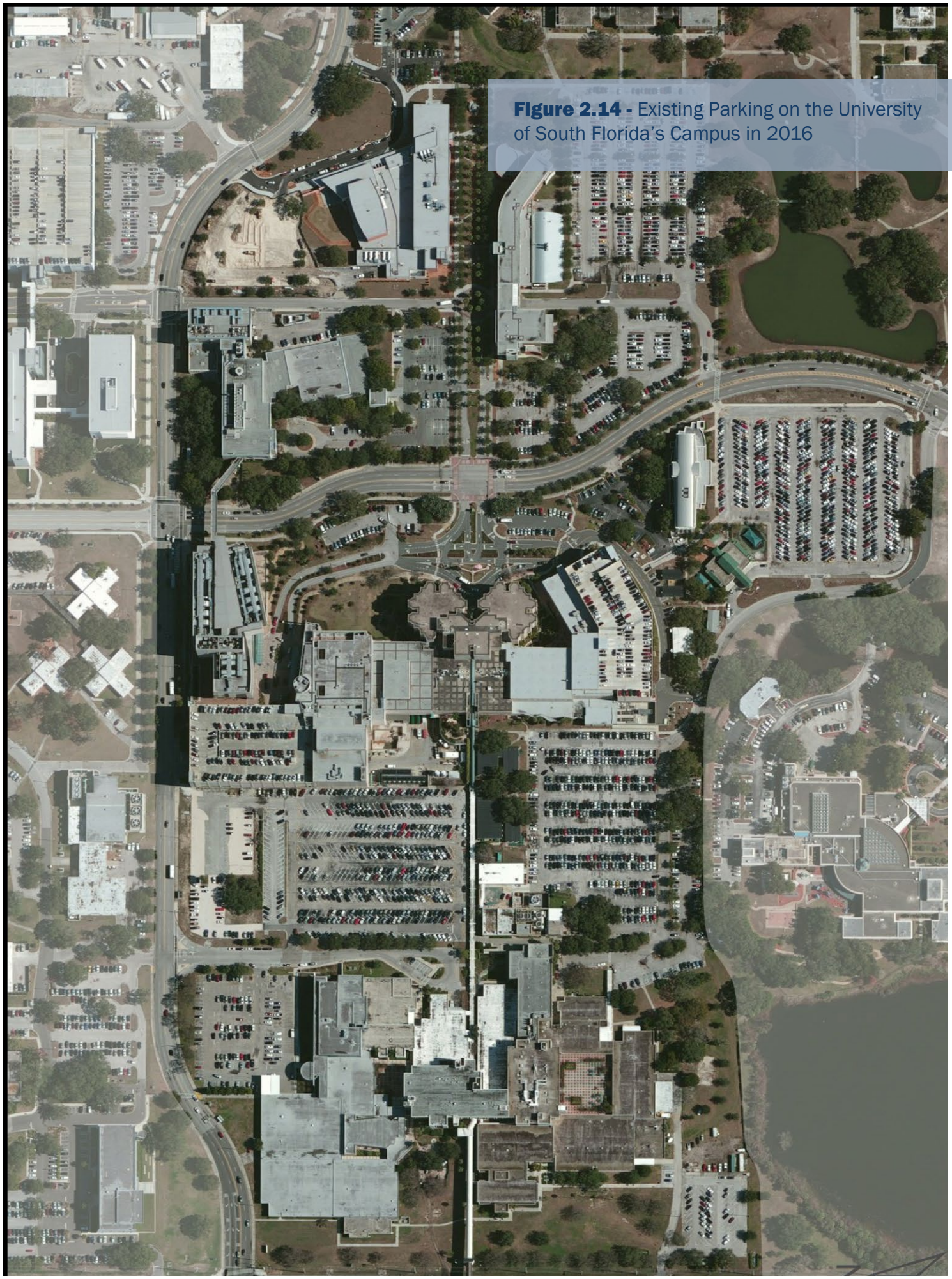


Figure 2.14 - Existing Parking on the University of South Florida's Campus in 2016

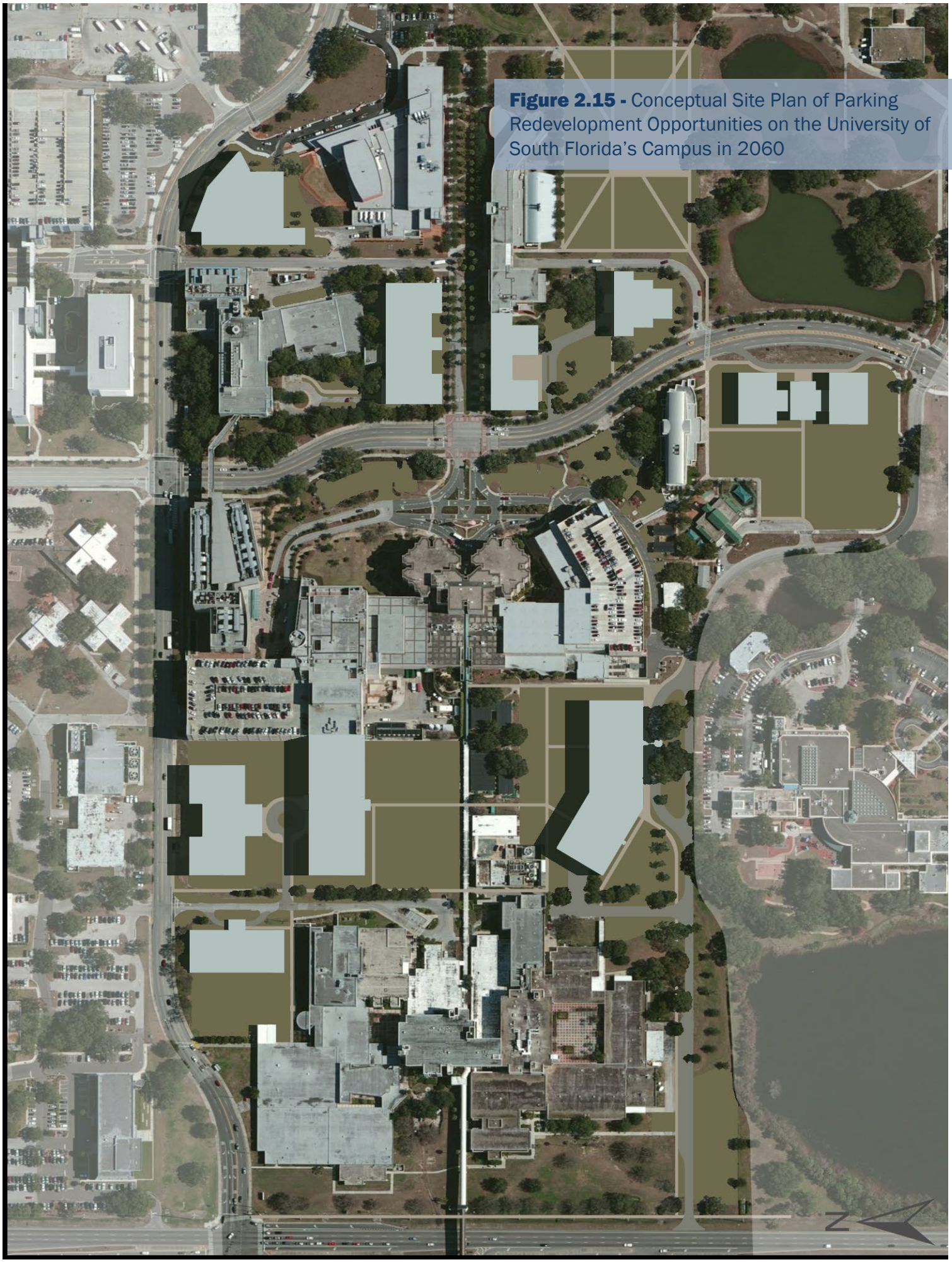


Figure 2.15 - Conceptual Site Plan of Parking Redevelopment Opportunities on the University of South Florida's Campus in 2060

2.6 Redevelopment Opportunities

By reducing the amount of needed parking and relocating parking away from city centers, the wide-scale adoption of AV technology will create significant urban redevelopment opportunities. In particular, as seen in Figures 2.14 and 2.15, the reductions and relocation of parking will allow the transformation of urbanized areas; potential site design norms may be revolutionized with the ultimate adoption of a fully automated vehicular fleet.

Transformation of Urban Centers

With the anticipated reduction in the number and size of parking spaces, AVs provide, a great opportunity to rethink, revitalize, and redevelop urban centers. As seen in Figures 2.14 and 2.15, the reduction and relocation of parking could open up significant land area for infill development within urban centers. While market forces will inevitably play a large part in how newly available land is ultimately redeveloped, policy makers will also have a role in determining how publicly-owned land once utilized for larger ROWs and parking lots will be repurposed. One alternative is to utilize available land to enhance placemaking or beautification efforts. Available land could also be utilized for recreational facilities, parks, drainage, or other similar purposes. Of course, market demand may also lead to the redevelopment of newly available land for residential or commercial uses.

A transformation in urban land uses due to AVs will undoubtedly occur gradually over a period of decades. During this transition period, some urban settings where a clearer separation between human drivers and AVs is possible could feature more prominent land use changes. For example, enclosed environments, such as a college campus, where AV-only zones are more plausible, could be among the first places to experience significant land use changes. Land use changes may also be more prominent along highways with dedicated AV-lanes, along AV-only drop-off and pick-up areas, and in the areas surrounding AV-only parking facilities.

Site Design

As on-site parking is reduced, site plans for commercial and residential development will likely change. Local development regulations will likely reduce, or completely eliminate, on-site parking requirements. This will result in an evolution of site plans from those that are focused on meeting parking requirements, to sites that are more efficiently utilized for building envelopes and amenities. Since AVs will likely drop off passengers at their destinations, newly constructed buildings may be located closer to the abutting road frontage and may include drop-off areas that are adjacent or connected to the building. In areas with high traffic volume, multiple drop-off areas could be designed to mitigate competitive spaces. Another alternative is that commercial strip centers alongside major highways could consolidate

entrances and exits, which would serve to increase buildable area on a site-by-site basis, and potentially improve traffic flow. This type of consolidation could also allow for fewer turn lanes and the ability to repurpose existing turn lanes. It is possible that access roads off of the main thoroughfare will also be employed in some circumstances.

2.7 Putting it All Together

None of these land use changes will happen in a vacuum. ROW implications will affect pedestrian and bicycle spaces. Revolutionary changes to intersections and signage will change both the experience of those in vehicles and pedestrians and bicyclists near the roadway. Parking implications will affect demand for drop offs and opportunities for redevelopment. Site Design will change to address this new demand.

Below are three visualizations that show how a typical arterial road might change over the next 50 years (Figures 2.16 - 2.18). The first photograph depicts a roadway in Tallahassee, Florida in 2016. It is characterized by wide lanes, frequent curb-cuts, large traffic signals and significant parking in front of buildings. By 2040, we expect to see some changes including separated AV lanes. These lanes are narrower and allow room for added bicycle lanes. Turn lanes, medians and traffic signals remain.

By 2060, all of the lanes are narrow AV lanes, which has allowed for separated or protected bike lanes and more attractive pedestrian infrastructure. In other areas, drop offs will replace on-street parking or be prioritized over bike lanes. Medians have disappeared, and in some case lane striping itself may be a thing of the past. Traffic signals have been replaced with V2I communication infrastructure. Pedestrian way-finding signage is the only signage needed. Instead of typical strip mall style buildings with parking in front, buildings have moved up to the street. Overall, what was an uninviting arterial whose primary purpose was simply to move traffic as fast as possible has now been turned into an attractive, people-friendly, efficient and safe urban environments that could draw people in and provide more inviting spaces to live, work, and play.

Similarly, Figure 2.19 shows how AVs could transform a typical city block. Before the adoption of AVs, most city blocks needed to include a significant amount of parking to accommodate the block's residents and commercial patrons. This included large surface lots as well as on-street parking. However, in an AV world, on-street parking could easily be retrofitted into a drop-off lane providing easy access to the blocks' destinations. Since passengers could be dropped off instead of parking, surface lots become significant opportunities for urban infill development. Coupling this denser urban environment with AVs' ability to narrow ROWs and enhance bike and pedestrians facilities (as seen in Figures 2.17 and 2.18), AVs promise to provide planners and policy makers with a unique opportunity to revitalize urban centers and create thriving urban spaces.

Figure 2.16 - Example of a Typical 2016 Streetscape: Today's Auto-centric Built Environment

Figure 2.17 - Example of a 2040 Streetscape: The Transition to an AV World

Figure 2.18 - Example of a 2060 Streetscape: A Fully Autonomous City

Figure 2.19 - AVs' Transformation of a City Block: Surface parking lots, traffic lights, and on-street parking, while common today, may disappear in an AV world. In their place we may find drop off lanes, pedestrian and bicycle amenities, in-fill development, and safer, less cluttered intersections.

3. AVS' IMPACT ON TRANSPORTATION AGENCIES

This section will provide transportation planning agencies with some guidance for how best to prepare for the impact of AVs on the built environment, especially in the near-term. This is not intended as a step-by-step guide to navigate the transition to an AV world, but rather a starting point for envisioning AVs' impact on the built environment. Key considerations to incorporate into infrastructure investments and redevelopment decisions moving forward are highlighted.

3.1 Retrofitting Right-of-Ways

Retrofitting existing ROWs to accommodate the efficiencies of AVs may be among the first and most important steps for state and local transportation agencies to prepare for the emergence of AVs. Agencies will need to adjust how streetscapes are designed and engineered, as well as how and where roadways are planned and built. As part of this effort, roadway design manuals will need to be revisited or rewritten to accommodate AVs' ability to create smaller and more efficient ROWs.

Particular attention will need to be given to acceptable lane widths for roadways servicing AVs. These standards may need to be informed by the automobile industry's expectations for how wide AVs will be and by tests determining the precision of AVs movements within the lane. During the transition to AVs, when automated and human-operated vehicles share the road, these new standards could to be applied to dedicated AV lanes. These lanes could provide the throughput efficiencies of platooning in the near-term, while also facilitating a smooth transition to a completely automated vehicle fleet in the longer term.

At the regional and local level, agencies will need to begin considering the impact of AVs on travel demand and throughput as they develop their long range transportation plans. In particular, regional transportation planning bodies will need to reconsider whether future lane-expansion projects will be necessary if AVs reduce congestion and increase the throughput of each lane. To inform this process, continuing research assessing the impact of AVs on throughput and travel demand will be necessary to provide guidance on how many lanes are required and where road diets could be appropriate. More specifically, AVs will need to be incorporated into travel demand modeling standards and practices. Pilot projects and ongoing testing of AVs, particularly AVs in real world settings, will be a vital part of informing the demand modeling process. Once AVs are integrated into modeling methods, they can be an integral part of informing the long-range transportation planning process determining when and where new roads, roadway expansions, and potentially lane-reductions are necessary.

3.2 Strategic Thinking Regarding Separated Lanes

Many of the benefits of AV technology will not be realized on roadways shared by automated and human-driven vehicles. For example, AVs traveling closer together may actually put human-driven vehicles at greater safety risk unless AV traffic is separated from human-driven traffic. In this way, the transition to an AV world that capitalizes on the efficiency of AVs without compromising the safety of human-driven vehicles will likely require separate infrastructure for automated and human-driven vehicles.

Consequently, an important consideration during the early stages of AV adoption will be identifying and prioritizing roadways where dedicated AV lanes can be implemented. State and federal highways may present easier opportunities for dedicated lanes initially because they have simpler traffic patterns, fewer intersections, and fewer points of ingress/egress than local roadways. However, over time many local roads could likely benefit from AV-only lanes. Although dedicated AV lanes present the need for system prioritization, future transportation systems may also benefit from similar triaging for the transition of intersections, parking structures and virtual infrastructure.

3.3 Preparing for a Drop-off Revolution

As AVs grow in popularity, more and more users will likely want to be dropped off near their destination instead of parking farther away and walking. Designated areas for dropping off and picking up AV passengers will likely become a common feature for roadways and site plans. However, if unregulated, these areas could cause congestion problems by backing up traffic into the street.

To accommodate drop-off areas without creating traffic or safety problems, state and local agencies will likely need to create design standards for drop-off areas and drop-off lanes. In particular, specifications for the length, number of drop-off points, or number of lanes required for a site's drop-off area may be necessary. These standards need to be tailored to the size and expected demand of drop-off areas to ensure drop-off demand does not exceed capacity causing a traffic backup. Separate standards for different categories of drop-off areas may even be necessary (i.e., shopping malls would require larger drop-off areas than a small business).

Local governments may also consider making some changes to existing zoning codes to better accommodate drop-off areas including reducing the required number of parking spaces, reducing setbacks, and specifying drop-off design standards. In effect, parking requirements may be replaced by specifications for number of drop-off points required for a site's drop-off area

Figure 3.1 - Redeveloping On-street Parking as Drop-Off Areas: Drop-offs will be integral in freeing parking for reuse and redevelopment. Here they are seen redeveloped from on-street parking. Additional space from narrower ROWs may also be redeveloped into protected bike lanes or other bike/ped facilities

depending on the number of trips the destination was projected to generate.

3.4 Caution Ahead!: Supporting Bike/Pedestrian Travel in an AV World

One key challenge during the AV revolution will be balancing the needs of AVs with the needs of other travel modes. This balance is particularly important for bike and pedestrian travel in urban settings, trips that offer physical, mental and emotional health benefits, as well as environmental benefits due to no energy costs. However, AVs may lead to a predominance of free flow intersections and will require pick-up/drop-off areas at more locations which make travel better for AV riders, but at the cost of bike and pedestrian travel.

If transportation and land use planning agencies are proactive, AVs can be integrated into urban settings in ways that promote rather than hinder travel by bicyclists and pedestrians. To do so requires attention to these non-AV travel modes from the beginning of any AV-related system planning initiatives and infrastructure redesigns. Assessing and then factoring in the needs of bicyclists and pedestrians at the outset promises greater efficiency in the transition and less expense in the long run.

In anticipation of the transformation of streetscapes, transportation planners and engineers need to adapt roadway design guidelines to factor in how AV technology will impact the system. Building upon best practices in the Complete Streets literature offers a path forward, although these guidelines will need to evolve to take into account the different functionalities of AVs. Guidelines will also need to be developed for the frequency, design, and size of AV pick-up and drop-off areas to ensure that these elements do not fragment bike/pedestrian networks.

There are also important system or infrastructure changes required to promote bicyclist and pedestrian mobility in an AV world. Solutions will be needed to allow for safe and regular crossing of free flow intersections in busy urban settings. These solutions can take the form of regularized, dedicated bike/pedestrian crossing periods, to separated systems for crossing busy streets in the form of tunnels or bridges. The overriding issue is the need to ensure that bicyclist and pedestrian mobility is not compromised by the transition to an AV-only system.

The greatest promise for successfully accommodating AVs and bicyclists/pedestrians in urban settings revolves around the extra ROW that will follow from the reductions in overall system VMT and number of vehicles on roadways. These surplus ROWs hold opportunities for dedicated bike lanes and expanded, more active sidewalks, spaces that are no longer as cluttered with signage and signalization aimed at vehicular traffic. Given that these

surplus spaces should be system-wide, there are likely opportunities for transforming existing roadways into dedicated bike boulevards, as found in many European cities.

3.5 Reconceptualizing Parking Location and Form

AV technology is expected to transform the design and location of parking infrastructure in our urban centers. As the need and demand for on-site parking is significantly reduced, and ultimately eliminated, consolidation of parking infrastructure is likely to be located on the city periphery where land is more readily available and affordable. For policy makers, regulatory considerations include issues related to the permitting of consolidated and likely structured parking.

Local jurisdictions should identify appropriate areas to locate AV parking, and determine how peripheral parking structures may impact adjacent land uses. Special consideration may need to be given about whether to locate these parking structures in industrial areas, or whether other areas on the urban fringe are appropriate. These areas should be appropriately designated in comprehensive plans and other planning documents. Also, once specified areas are designated for these parking facilities, transportation agencies will need to consider whether appropriate road infrastructure exists to serve these parking locations or if additional roadway capacity will be necessary. Finally, local governments may consider if and how they might incentivize the redevelopment of existing parking facilities to revitalize urban cores and make better use of largely underutilized parking space.

State, regional, and local agencies must also consider how to revise building and engineering codes to accommodate the design and construction of consolidated AV parking structures. Building codes may need to be revisited to relax requirements for human-centered amenities in parking facilities, such as climate control, passageways, turning radius, elevators, and potentially even lighting. In addition, building and engineering codes may need to fortify the structural composition of AV parking facilities, as well, should the vehicles require additional loading requirements. Finally, local governments may consider if and how they might incentivize the redevelopment of existing parking facilities to revitalize urban cores and make better use of largely underutilized parking space.

Figure 3.2 - Redeveloping Surface Parking into Commercial Infill Development: In a fully AV world, large surface parking lots may be redeveloped into better uses such as commercial space, as shown here, or parks and public space.

4. AV AS THE NEXT MODEL T

Automated vehicle technology promises to reshape the transportation system and the built environment in ways not seen since the introduction of Henry Ford's Model T over a century ago. By revolutionizing the nature of personal mobility and removing the need for passengers to be in the car at all times, AVs have the potential to dramatically impact roadway design and the built environment to yield urban spaces that are safer, more efficient, and attractive.

There is compelling evidence that AVs will require smaller and more efficient ROWs, increase the speed and throughput of roadways, and open up spaces for bicycle/pedestrian facilities, greenspaces, and other urban amenities. The ability of AVs to wirelessly obtain information on destinations, traffic patterns, and intersections promises to declutter urban environments by removing traffic signs and signals. Drop-off and pick up areas are expected to replace the parking lot as the predominant location for passenger entry and exit. As the majority of parking is relocated into consolidated parking facilities away from urban centers, large amounts of previously underutilized space will be made available for redevelopment opportunities.

Figure 4.1 - Automated Vehicles represent the most significant innovation in transportation since the advent of the car in the early 1900s
Source: http://www.huffingtonpost.com/2014/01/21/1914-cars_n_4611555.html

Much like the Model T of the early 1900s, AVs will usher in massive changes in the way people travel, the form and function of our transportation systems, and the look and feel of the environments we live, work, and play. However, unlike the American experience with Model T, it is hoped that this time policy makers recognize and take advantage of this opportunity to reshape our urban areas in ways that promote safe, sustainable, and people-centered environments. AV technology offers an opportunity to balance what have long been seen as conflicting goals of safer and more efficient transportation systems and urban environments founded upon the principles of sustainability and human-centered design possible simultaneously.

The twin goals of efficiency and urbanity can be achieved only through proactive planning and investment by federal, state, regional and local transportation agencies. As introduced in this report, agencies need to look to the following concepts in order to best capitalize on the unique opportunity afforded by AVs to create safe, efficient, and livable places:

- *Work now to incorporate AV considerations into the design of streetscapes and road networks*, including revisiting roadways design manuals and long-range transportation plans;
- *Begin identifying ways to establish separated AV infrastructure*, such as dedicated AV-lanes, to ensure the efficiencies of AVs can be capitalized on during the early stages of AV adoption;
- *Convene design and development stakeholders to develop standards for the size and location of drop-off areas* to accommodate the growing demand for drop-offs without backing up traffic;
- *Investigate opportunities to use excess ROWs to promote Complete Streets,* perhaps through protected bicycle and pedestrian infrastructure, active streetscapes, and greenspaces;
- *Task researchers and engineers with developing innovative, yet affordable ways to enable pedestrians to safely cross free-flowing AV intersections;*
- *Recognize and begin planning for changes in parking demand* by identifying long-run opportunities for AV parking structures or large surface lots away from city centers, revising codes for parking requirements, and incorporating parking areas into comprehensive plans and other planning documents.

Clearly, further research is required to assess how best to integrate AVs into the transportation system and to understand how AVs will reshape the built environment. This report provides a first step toward envisioning the future in an AV world, a future that can yield attractive, people-friendly, efficient and safe urban environments. To achieve that future, transportation and land use planning agencies need to begin preparing for the AV

Figure 4.2 - Automated Vehicles will come in different shapes and sizes. These differences will allow them to interact with the built environment and people in new ways
Source: http://www.gmauto blog.com/section/chrevolet-en-v/

revolution by focusing upon not only the transportation impacts of the technology, but the built environment impacts too. Few understood and foresaw the massive impact of the Model T upon travel behaviors, transportation systems, and the built environment. Automated vehicles will have a similar impact upon our landscapes; it is our hope that this remarkable opportunity is grasped and not squandered.