2018

AUTONOMOUS POTENTIAL:

COMPLETE STREETS IN AN AUTONOMOUS VEHICLE FUTURE

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PROFESSIONAL PROJECT REPORT

We constantly sacrifice all kinds of amenities for automobiles. I think we can wear down their number by sacrificing the roadbed to some of our other needs instead. It's a switch in values.

- Jane Jacobs

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INTRODUCTION

For people engaged in promoting sustainable, safe, and equitable communities, there is hope that autonomous vehicles (AVs) can reduce the number of cars on the road, increase ride sharing, improve public transit service, and reallocate space away from private vehicles and towards uses that benefit everyone. Achieving these outcomes will require significant planning and regulation at all levels of government in order to be realized, and the discussion on how an autonomous future could look is just getting started.

The most tangible impact of autonomous vehicles will be their influence on urban design. As the amount of space vehicles require is reduced and the way they use space changes, areas that are currently designated for cars can be adapted for new and different uses. City streets are one type of public space that will potentially change dramatically in form and function once autonomous vehicles become mainstream. Parking spaces may disappear to be replaced by flex-use curb space.[1] Transit and bicycle infrastructure might dominate the roadway, and pedestrians may be able to cross the street at any location.[2] New imaginings of city streetscapes are beginning to emerge, building off the recently popularized principles of complete streets and next generation street design. How autonomous vehicles will ultimately fit into these principles and the transportation goals of future communities is yet to be seen, but urbanists and transportation planners are starting to propose their visions for this integration.

This report aims to contribute to the discussion by proposing street designs that capitalize on the opportunities of autonomous vehicles to enhance active transportation. Two streets in Eugene, Oregon have been used at case studies, creating designs that focus on an equitable and efficient distribution of public space for all modes while taking into account the new issues of safety and access caused by autonomous vehicles. These designs and the accompanying discussion might be especially useful for smaller cities that generally lack the capacity to create their own designs from scratch and are looking for a starting place for local conversations on the subject of autonomous vehicles and future transportation changes.

QUESTIONS

This report aims to answer four questions regarding autonomous vehicle impacts on street design.

1. What are the key impacts of autonomous vehicles on street design?
2. Will these impacts positively or negatively affect active transportation and complete street principles?
3. How does a complete street that includes autonomous vehicles differ from today's complete street principles?
4. What are the key opportunities for autonomous vehicles to support active transportation?

LITERATURE REVIEW

Transportation Planning Trends

Over the past 25 years, cities have begun to reevaluate the safety, sustainability, and equity of a transportation system oriented around the use of the private automobile. Discussions of high levels of traffic fatalities, increasing pollution, and sprawling development patterns that make car ownership essential to daily life are now commonplace within the transportation profession. To combat these problems, academics and professionals have developed policy solutions in the form of Smart Growth[3] and Vision Zero[4], and design solutions such as Complete Streets[5] or other next generation street design principles that promote walking, biking, and the use of public transit. These ideas have been formalized in design guides that are currently used throughout the country. The National Association of City Transportation Officials has produced a collection of respected guides for promoting active transportation,[6] and a large selection of guides have been created to specifically enhance infrastructure for bicyclists and pedestrians.[7]

Assuming the values of safety, sustainability, and equity will continue to be incorporated into city transportation goals, the use of autonomous vehicles should contribute to their enhancement. Therefore, it is important to consider the opportunities and challenges autonomous vehicles will provide.

Complete Streets Design Principles

Complete Streets is a street design philosophy that creates space for all types of transportation on a roadway. This includes designated space for pedestrians, bicyclists, public transit and cars so that everyone can be safe and comfortable no matter how they choose to move around. Because street design is heavily dependent on context, a wide variety of design guides have been produced that show exceptional infrastructure for active transportation.

Complete Streets Definition
from Smart Growth America

"**Complete Streets are streets for everyone.** They are designed and operated to enable safe access for all users, including pedestrians, bicyclists, motorists and transit riders of all ages and abilities. Complete Streets make it easy to cross the street, walk to shops, and bicycle to work. They allow buses to run on time and make it safe for people to walk to and from train stations."

Designing for Bicycles

Bicycle infrastructure must create a sense of safety for the user in order to be widely utilized. The majority of people can be categorized as "interested but concerned" when it comes to biking,[8] so facilities that feel comfortable to these users will attract the greatest number of cyclists. A comfortable biking experience is dependent on the speed, frequency, and proximity of vehicle traffic along the route, and a large number of design guides have been created that describe appropriate treatments for a wide variety of situations.

- Buffered or physically separated bike lanes or cycle tracks improve cyclists' sense of safety.[9] Buffered lanes provide additional space for passing without the need to enter the vehicle lane.[10] Separated cycle tracks have a physical barrier between bikes and vehicles and are most attractive to users of all comfort levels.[11]
- Painted bike boxes at intersections increase visibility of cyclists for drivers.[12]

- Painted bike lanes are easy to implement and require the least amount of space.[13] These are best for streets with traffic speeds less than 25 mph, and should be at minimum 6 ft. wide with 4 ft. of rideable surface area.[14]
- Contra-flow lanes can be used on one-way streets to increase bicycle connections, they should be separated with yellow painted stripes.[15]
- Left side bike lanes are also good for one way streets or on streets with frequent deliveries or parking turnover.[16]

Designing for Pedestrians

Vehicles operate on most streets at a speed that is dangerous for pedestrians, necessitating physical separation through the use of a sidewalk in most places. Most urban streets include sidewalks, but surrounding land uses can make the walking experience unpleasant if they are not designed for a human scale. People are willing to walk further on streets they find attractive, so creating a pleasant pedestrian environment is important to increase the viability of walking as a transportation mode. Destination proximity is another important factor in creating a walkable environment, but this is determined by land use and zoning, which lies outside the scope of this report. Designing walkable streetscapes is a key component of complete streets, and has been explored in multiple design guides.

- Frequent crossings are important on main streets where there are multiple destinations on both sides of the street.[17]
- Parklets create seating and street activity.[18]
- Sidewalk zones include frontage zone, pedestrian through zone, street furniture/curb zone, and enhancement/buffer zone.[19]
- Curb extensions and pinch points facilitate crossings.[20]

Designing for Transit

In order for transit to be an effective transportation mode, it must be convenient and reliable. Public transit is often the most efficient way to move high volumes of people, but it is often perceived as the opposite. Buses that are infrequent or experience delays hinder the efficiency of the system and reduce people's willingness to use the service. Therefore, streets that prioritize transit and allow for consistent arrival and departure times make public transit more attractive to users. Multiple design options have been developed which create designated transit space on a congested streetscape.

- Bus bulbs with far or near side placement depending on context can aid passenger loading and provide space for shelter and seating.[21] Additionally, bus bulbs can tighten turning radii.[22]
- Dedicated bus lanes can be separated with physical barriers.[23] Can be placed curbside or along the median, the latter is better for high traffic streets as they reduce vehicle conflicts.
- Center median bus lanes have conflicts with left turning vehicles, but this can be solved through restricted turns or staggered signals.[24]
- Bus lanes should be a minimum of 10 ft. wide, with 12 ft. being preferred.[25]

Considerations for Vehicles

Complete streets still include vehicles because they remain the dominant form of transportation for the majority of the population and are often necessary for the delivery of goods. Traditional street design aims to maximize vehicle throughput, whereas complete streets prioritize safety and mode choice. Though complete streets often have trade-offs between vehicles and other transportation modes, the impact on vehicle throughput is generally negligible and at times is improved. Complete streets create a safer, more enjoyable experience for vehicles too. Every complete street guide contains considerations for vehicle traffic.

- Bike lanes narrow the vehicle travel lanes and slow speeds.[26]
- Speed controls such as speed bumps or chicanes can also reduce speeding.[27]
- “Road diets” that change four-lane roads to two-lane roads with bike lanes and a center median has either no effect on congestion or will improve traffic flow.[28]

Integrating Modes

Complete streets are designed to incorporate multiple transportation modes within the right of way. Therefore, complete street designs must address the ways different modes can impact each other and how they can all be integrated seamlessly.

- Cycle tracks pair well with transit corridors.[29] However, they should be routed behind bus stops to reduce conflicts.[30]
- Shared streets possible in locations with many destinations and lots of street activity.[31]
- Buses and bikes frequently have conflicts because they are often placed on the same side of the street and buses need to have access to the curb for passenger boarding. On streets with limited space this often can’t be avoided without a fundamental change in the type of modes allowed on the street.[32]

Additional design guides discuss the street elements listed above with variations based on contextual differences. Chapter X includes a comprehensive table of design options and the guides that describe or reference them.

Potential Autonomous Vehicle Impacts

As details of autonomous vehicle technology continue to be determined, ideas about how they can change the transportation system are being hypothesized. Recently, multiple reports, academic white papers, journal articles, and popular press articles have been released discussing the potential impacts of autonomous vehicles on the ways city streets look and function.

Parking Impacts

- Parking demand could decrease by as much as 80%.[33]
- Parking garages could relocate to the city periphery to make room for higher value urban uses.[34]

Impacts on Lane Capacity

- Vehicles will be able to travel closer together, increasing lane capacity by up to 80%.[35] Increasing lane capacity would allow cities to reduce the number of vehicle lanes without limiting vehicle throughput.[36]

Impacts on Transportation Behavior

- High AV ownership costs are likely to make vehicle sharing more attractive, influencing vehicle use and function.[37]

Interactions with Cyclists and Pedestrians

- Risk-averse technology of autonomous vehicles will give pedestrians greater freedom of movement as cars stop for them automatically regardless of whether they use proper pedestrian facilities (e.g. crosswalks).[38]
- People will feel less secure in the presence of AV traffic and require additional road safety features to feel comfortable walking or biking in the same space as AVs.[39]
- Advocates have raised issues related to interactions between pedestrians, bicycles, and AVs. Concerns include how AVs will detect and communicate with other road users, how right-of-way will be determined, passing and speed, how AV passengers will be dropped off at the curb, challenges during the transition period from traditional to autonomous cars, and the use of data.[40]

Interactions with Transit

- Shared vehicle fleets could integrate with public transit systems, increasing system flexibility and level of service.[41]
- Alternatively, the current trend of reduced transit ridership due to increasing use of ride share services could continue as shared rides become even cheaper.

Design Concepts

Ideas for street designs have begun to emerge through private firms, design competitions, and transportation organizations. Examples include:

- The Blank Space Driverless Future Challenge solicited design ideas for the city of New York.[42]
- Lyft partnership with Nelson/Nygaard and Perkins & Will reimagines Wilshire Boulevard in Los Angeles.[43]
- National Association of City Transportation Officials created a *Blueprint for Autonomous Urbanism,*[44] taking a design-based approach to how road space and mobility options could look in the future.

Summary

Many trends in urban street design have centered on promoting active transportation and increasing street safety, and the advent of autonomous vehicles provides additional opportunities for changing how city streets are designed and how they function. These changes have the potential to solve some of today's inequities in our transportation system by reallocating street space for bikes, pedestrians, and transit and ceasing to prioritize single-occupancy cars. However, the use of shared autonomous vehicles creates new safety challenges for bikers and pedestrians. In creating new street designs to adapt to AVs, new standards for safety will need to be created as well. While it is still too soon for cities to have implemented any new street designs, it is not too soon to begin identifying potential options that will prioritize safe, sustainable, and equitable public streets. This project and proposed design options are meant to stimulate the conversation around the opportunities AVs create for city streets and transportation systems as a whole.

METHODS

SWOT Analysis

A strengths, weaknesses, opportunities, and threats (SWOT) analysis was conducted on complete streets principles using potential autonomous vehicle impacts as an evaluation lens. A collection of design guides were used to create a comprehensive list of design elements that support public transit, bicyclists, and pedestrians on city streets. Since the impacts of autonomous vehicles remain largely theoretical, potential impacts were gathered from reports, academic white papers, journal articles, and popular press articles. Each element of complete street designs was analyzed for potential changes due to the full array of potential AV impacts.

Each design element was classified as being positively or negatively impacted by autonomous vehicles.

- Positive impact – Transportation system changes due to autonomous vehicles create more space for a design element on the street or changes in vehicle movement reduce limitations for a design element on certain types of streets.
- Negative impacts - The operation of autonomous vehicles creates new safety risks or conflict points with conventional active transportation infrastructure.
- Neutral impacts – Vehicle operation and the overall transportation system does not differ significantly from today's system of human operated vehicles so new opportunities or challenges are not created for active transportation.

During the SWOT analysis, all potential autonomous vehicle outcomes were considered. Because theorized impacts are scenario dependent, some design elements were classified as being both positively and negatively impacted by autonomous vehicles based on differences in future scenarios. By examining all potential outcomes, this report is able to determine which autonomous vehicle scenario results in the greatest benefit for active transportation. Cities will find this information useful as they begin creating legislation for autonomous vehicle operation within their jurisdiction.

Street Design Case Studies

Because autonomous vehicles are still an uncertain reality for most cities, ideas for future AV street designs are limited. Design examples that have been proposed were created for streets in two of America's largest cities; New York[45] and Los Angeles.[46] The most generalized design ideas, shown in NACTO'S Blueprint for Autonomous Urbanism,[47] also feel tailored to the context of high density neighborhoods more commonly found in large cities.

In order to provide design concepts that are applicable to cities of all sizes, two streets in Eugene Oregon were used for design case studies. Both street types are commonly seen across the country.

- Coburg Road – High capacity street surrounded by commercial strip development. There are four lanes of traffic and a central turn lane. The speed limit is 35 mph.
- Monroe Street - Single family residential neighborhood street with low traffic volumes. There are no street markings to designate lanes or parking spaces, but there is enough room for two way vehicle traffic and parking on both sides of the street. The speed limit is 25 mph.

These two streets represent typologies commonly seen in cities and towns across the United States.

Each street was first redesigned using current complete streets principles and existing street design codes to create spaces that support active transportation within the context of today's transportation system. The streets were then redesigned again with the assumption that all vehicles were autonomous and would primarily be operated in shared fleets as this scenario creates the most positive impacts for active transportation based on the SWOT analysis.

Differences between the two designs were identified and classified as political opportunities or design opportunities.

- Political opportunities – Changes in transportation behavior cause reductions in political opposition to the reallocation of public road space away from private cars and towards active transportation modes.
- Design opportunities – Changes to vehicle design and operation allow for street designs that not currently possible due to safety concerns or regulations.

Policy Impacts

Cities are currently in the unique position of being able to shape the impacts of impending technology changes rather than adapting to changes after they have taken place. However, few cities have the resources to evaluate all of the potential autonomous vehicles scenarios and their resulting outcomes. This report aims to assist cities in creating a robust active transportation system in the face of increasing automation and technological advancement. Using the results of the SWOT analysis and the street design case studies, the key impacts of autonomous vehicles on active transportation modes were identified. A variety of policy options that promote the most beneficial future scenario were collected from existing autonomous vehicle literature and are summarized in this report. Additionally, street design code changes that would allow cities to take advantage of the unique design opportunities of autonomous vehicles are also discussed.

FINDINGS

SUMMARY OF ACTIVE TRANSPORTATION DESIGN GUIDES

A wide variety of design guides have been released by transportation organizations and agencies describing various complete streets infrastructure options. All of the guides evaluated for this report demonstrate designs that can be implemented under current United States transportation regulations. Upon evaluation, a comprehensive list of complete street design options and considerations was generated.

Complete Street Design Options and Considerations

Bike lanes: On-street space for cyclists designated by a single strip of white paint. Additional painted symbols or color can be used within the lanes to indicate that the space is meant for cyclists.

Buffered bike lanes: On-street space for cyclists separated from vehicle lanes by a striped painted area, providing more special separation between vehicles and bikes than a standard bike lane.

Protected or separated bike lanes: Protected bike lanes have a physical barrier between vehicle lanes and bike lanes. Separated bike lanes are off-street bike facilities such as a path or trail.

Bicycle boulevards and sharrows: Bike boulevards are streets with design elements that slow vehicle speeds so they can safely share the road with cyclists. Painted markings known as sharrows, are sometimes used on bike boulevards to indicate to drivers that they are expected to share the space with cyclists.

Network connectivity: Multiple bicycle or pedestrian facilities create a network. The network is most effective when segments are connected and users can reach destinations without experiencing streets that lack appropriate infrastructure for their travel mode.

Curb cuts or turning conflicts: Spaces where vehicles cross bike lanes or sidewalks are known as curb cuts, and are often used to access driveways or parking lots. They create conflict points between vehicles and other road users. Turn lanes can create similar conflict points when they cross bike lanes. Any space where two modes could occupy the same location is a potential collision site, primarily due to human error.

Wide sidewalks: Sidewalks should have a minimum width of 6 ft. Wider sidewalks encourage walking. Parklets: Parklets are small areas of green space, seating, or public activity. They can be temporary or permanent and are often placed in underutilized parking spaces.

Frequent crossings: Frequently spaced pedestrian crossings increase pedestrian safety and encourage walking.

Bus bulbs or in-lane stopping: Bus bulbs are raised, paved areas that extend into the street to create additional space for passenger loading at bus stops. They facilitate in-lane bus stopping, where buses remain in the travel lane at the stop.

Bus merging into/out of traffic: At stops where buses move out of the travel lane, efficiency can be reduced if the bus must wait to re-enter the travel lane due to congestion.

Dedicated transit lanes: Transit-only lanes allow for frequent service on a reliable schedule as transit vehicles aren't impacted by congestion on the rest of the street.

Transit frequency: More frequent transit service increases the attractiveness of transit as riders have more flexibility in their use of the system.

Shared or curbless streets: Shared streets allow for all modes to mix within the street space. They require slow vehicle speeds and low traffic volumes to be effective. Curbless streets are a type of shared street that doesn't have a raised sidewalk.

Road diets: A road diet is when four travel lanes are converted to two travel lanes with a central turn lane and bike lanes on each side of the street.

Traffic calming or designed speed: Any street element which encourages reduced vehicle speeds is known as traffic calming. Such elements are useful for creating the designed speed for a street, the speed most vehicles will operate due to the way the street is designed rather than the speed which is posted.

Each guide discussed a different collection of design options and considerations from this list. The majority of options were covered in more than one guide, yet each guide described the options through a unique lens and context. The majority of guides discussed bicycle and pedestrian infrastructure since these modes are most commonly classified as active transportation. Transit infrastructure was primarily addressed through the lens of its interaction with cyclists and pedestrians, but some guides specifically described transit infrastructure design. Some transit considerations are primarily determined by how the transit system is operated, but they are still influenced by street design and therefor were included in the list of design options.

Table 1: Summary of Active Transportation Design Guides

Document Title	Agency	Bike lanes	Buffered bike lanes	Protected or separated bike lanes	Bicycle boulevards & sharrows	Network connectivity	Curb cuts or turning conflicts	Wide sidewalks	Parklets	Frequent crossings	Bus-bulbs or in-lane stopping	Bus merging into/out of traffic	Dedicated transit lanes	Transit frequency	Shared or curbless streets	Road diets	Traffic calming & designed speed
Urban Street Design Guide[48]	NACTO	X	X	X	X		X	X	X	X	X	X	X			X	X
Urban Bikeway Design Guide[49]	NACTO	X	X	X	X	X	X										
Transit Street Design Guide[50]	NACTO			X			X	X			X	X	X	X	X		
Rethinking Streets[51]	SCI	X	X	X	X	X	X	X	X	X	X	X			X	X	X
Achieving Multimodal Networks[52]	FHWA	X	X	X						X	X				X	X	X
Accessible Shared Streets[53]	FHWA								X	X					X		X
Bicycle Network Planning & Facility Design Approaches in the Netherlands and the United States[54]	FHWA	X	X	X		X											X
Case Studies in Delivering Safe, Comfortable, and Connected Pedestrian and Bicycle Networks[55]	FHWA	X	X	X	X	X	X	X		X							
Incorporating On-Road Bicycle Networks into Resurfacing Projects[56]	FHWA	X	X		X	X										X	X
Separated Bike Lane Planning and Design Guide[57]	FHWA			X			X			X	X						X
Small Town and Rural Multimodal Networks[58]	FHWA	X	X	X	X	X									X	X	
Manual on Pedestrian and Bicycle Connections to Transit[59]	FTA	X	X	X	X	X	X	X	X	X	X						

AUTONOMOUS VEHICLE IMPACTS ON ACTIVE TRANSPORTATION INFRASTRUCTURE

Based on current literature on autonomous vehicle operation and preliminary studies on potential AV impacts, there are three key impacts on street design.

1. Reduction in parking demand – up to 80% less parking will be needed with shared autonomous vehicles.[60]
2. More efficient vehicle movement – sensors and vehicle communication will allow for reduced lane widths and could eliminate the need for some turn lanes and travel lanes.
3. Curbside management – shared fleet vehicles will frequently drop off passengers at the curb, creating conflicts with buses and bike lanes.

These impacts are dependent on whether today's vehicle ownership patterns extend to autonomous vehicles or whether conventions change and the majority of vehicles are operated in shared fleets under a "mobility as a service" model.

How Each Ownership Model Could Impact Active Transportation

Bike lanes: Vehicle sharing is likely to reduce parking demand allowing current on-street parking to be converted into bike lanes. However, pedestrian drop off zones need to be carefully designed and located to reduce conflicts between cyclists and cars pulling up to the curb. Private AV ownership is unlikely to reduce parking demand significantly, so space will not become available for bike lanes.

Buffered bike lanes: Reductions in lane widths create space to add buffers to existing bike lanes. The buffer can serve as a passenger unloading zone which removes the potential conflicts between cyclists and AV passengers. If vehicles are shared, reductions in parking demand create opportunities for new bike lanes, but if vehicles are privately owned this benefit is less likely.

Protected or separated bike lanes: Similar to standard and buffered bike lanes, vehicle sharing and corresponding reductions in parking create space for protected or separated bike lanes. Private AV ownership is unlikely to reduce parking demand significantly, so space will not become available for protected or separated bike lanes. Reductions in lane widths will still allow for physical protections to be added to existing bike lanes.

Bicycle boulevards and sharrows: Autonomous vehicles will be able to sense cyclists in the road and can automatically adjust their speed to drive at a safe distance behind them.

Network connectivity: Adding or upgrading bike infrastructure improves network connectivity and comfort.

Curb cuts or turning conflicts: Autonomous vehicles will be able to sense pedestrians and cyclists while making turns. If vehicles are shared reductions in parking demand will reduce the number of needed curb cuts. If vehicles are privately owned the number of curb cuts is less likely to be reduced due to status-quo parking demand.

Wide sidewalks: Reductions in parking and lane widths allow for wider sidewalks.

Parklets: If vehicles are shared reductions in parking create space for parklets. Private AV ownership is unlikely to reduce parking demand significantly, so parklet space will be less likely to change.

Frequent crossings: Autonomous vehicles will be able to stop for pedestrians more quickly, making mid-block crossings safer and more viable. However, if empty cars are allowed to drive on the road, congestion will likely increase and reduce the number of gaps pedestrians can use to initiate their crossing.

Bus bulbs or in-lane stopping: Reductions in parking and lane widths create more space for bus bulbs. Autonomous vehicles will be able to more easily accommodate in-lane bus stops as well.

Bus merging into/out of traffic: Autonomous vehicles will be able to sense and adapt to buses merging in and out of the travel lane, making movement more efficient for all vehicles. However, if AV passenger drop-off zones are not appropriately designated, vehicles may try to drop off passengers at bus stops.

Dedicated transit lanes: If vehicles are shared a reduction in vehicle numbers allows for general travel lanes to be converted into dedicated transit lanes. Private autonomous vehicles will likely maintain the status-quo in terms of vehicle numbers and could potentially increase congestion making the conversion of general lanes to dedicated transit lanes unlikely.

Transit frequency: Transit can be operated with autonomous technology, reducing operating costs and therefore allowing for increased frequency.

Shared or curbless streets: Autonomous vehicles will be able to sense other road users and operate safely among them with less chance of error.

Road diets: Vehicle communication will allow current road diet designs to operate even more efficiently, and may even be able to remove the center turn lane. Additionally, if vehicles are shared reductions in vehicle numbers will reduce demand for multiple travel lanes.

Traffic calming or designed speed: Autonomous vehicles will automatically drive the speed limit, so traffic calming devices will no longer be necessary.

Table 2: Potential Autonomous Vehicle Impacts

Complete Street Design Option	Privately Owned	Shared Fleets
Bike lanes	-	+/-
Buffered bike lanes	O	+
Protected or separated bike lanes	O	+
Bicycle boulevards and sharrows	+	+
Network connectivity	+	+
Curb cuts or turning conflicts	+	+
Wide sidewalks	+	+
Parklets	O	+
Frequent crossings	+/-	+/-
Bus bulbs or in-lane stopping	+	+
Bus merging into/out of traffic	+/-	+/-
Dedicated transit lanes	O	+
Transit frequency	+	+
Shared or curbless streets	+	+
Road diets	+	+
Traffic calming or designed speed	+	+

Key:
+ Positive Impact
- Negative Impact
O Neutral Impact

What Is the Ideal AV Future?

If active transportation is going to become a greater component of our transportation system, the preferred outcomes of autonomous vehicles are those that create opportunities for improving active transportation infrastructure. Based on the SWOT analysis**, there is the potential for more positive outcomes if the majority of vehicles are operated in a shared fleet capacity**. Through appropriate regulation, the potential negative impacts of autonomous vehicles can be mitigated. If the majority of vehicles continue to be privately owned, active transportation is likely to experience limited improvements with the potential for significant negative impacts due to autonomous vehicles.

Governments have the ability to shape the autonomous vehicle future so that it supports existing goals and creates societal benefits. The actions governments can take to incentivize shared fleet vehicles and a system that creates new opportunities for active transportation are discussed further in the following chapter.

DESIGN CASE STUDIES

New opportunities for active transportation have been identified for a future where most vehicles are operated in shared autonomous fleets. However, there has so far been little discussion about whether autonomous vehicles are necessary to capitalize on these opportunities or if the infrastructure changes could be implemented today.

The opportunities for active transportation can be classified into two categories: political opportunities and functional opportunities. Political opportunities are those that could result from shifts in public opinion due to changes in vehicle ownership. Street design options that can legally be implemented today but are unlikely because they are politically unpopular fall into this category. Functional opportunities are those that are due to changes in how AVs operate on the street. Design options that can't be implemented today due to the behavior of human drivers fall into this category. The following design case studies were used to identify which category certain opportunities fall into.

For the purposes of this case study, it was assumed that all vehicles are autonomous and the majority of vehicles are operated in shared fleets.

STREET CONTEXT

Street designs are context-dependent, necessitating a discussion of the context for the design case studies. However, these two streets were strategically chosen to represent common street typologies so that the lessons can be adapted to other streets and cities.

Coburg Road

Coburg Road is a high-volume street that connects north and south Eugene as one of the few crossing points on the Willamette River. This section passes a large shopping center, several grocery stores, and a collection of businesses and restaurants built in a strip development fashion.

Image 1: Coburg Road Case Study Location

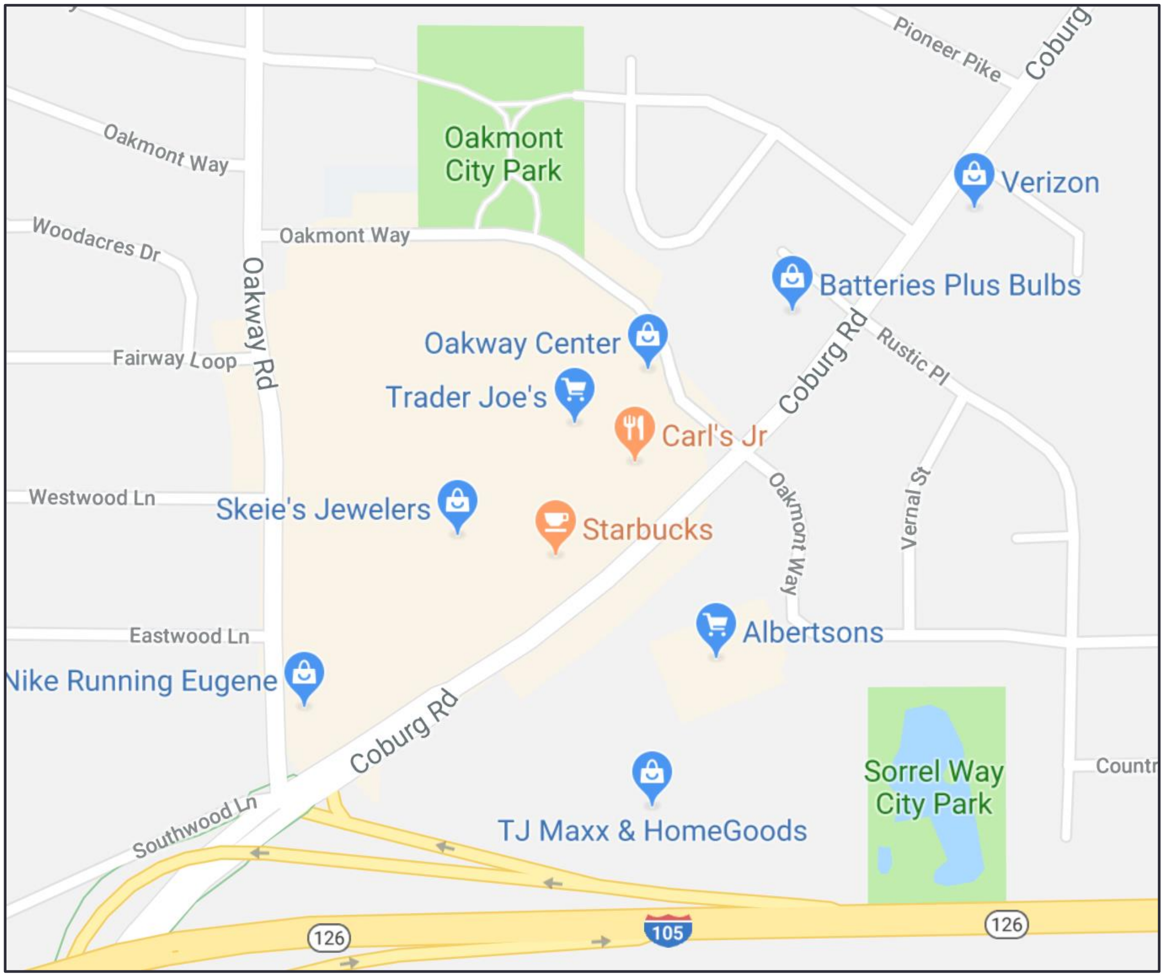


Image 2: Coburg Road Current Conditions

Current Conditions:

- For lanes of two-directional traffic with center turn lane
- 35 mph speed limit
- Simple curbside bike lanes without a buffer
- Multiple bus lines and bus stops
- Infrequent lights and pedestrian crossings
- Multiple curb cuts providing access to parking lots and businesses

Planned Future Conditions:

- Expansion of EmX BRT line with dedicated bus lanes

Bus lines currently have headways of 30 minutes on average. Biking on Coburg is uncomfortable due to high traffic speeds, frequent curb cuts, and a lack of separation from traffic. Strip development and large street-fronting parking lots make for a poor pedestrian environment as well. Overall, Coburg Road is a car-oriented street.

Monroe Street

Monroe Street is a typical low density residential street. It doesn't contain lane markings or parking spot designations, but it is wide enough to allow for curbside parking on both sides of the street and two-way vehicle traffic. Monroe Street is designated as a bike route by the City of Eugene, though this section of the street does not have any bicycle facilities except for the occasional faded sharrow. Monroe Street also runs along the east edge of Monroe Park, making it a key route for accessing this neighborhood amenity.

Image 3: Monroe Street Case Study Location

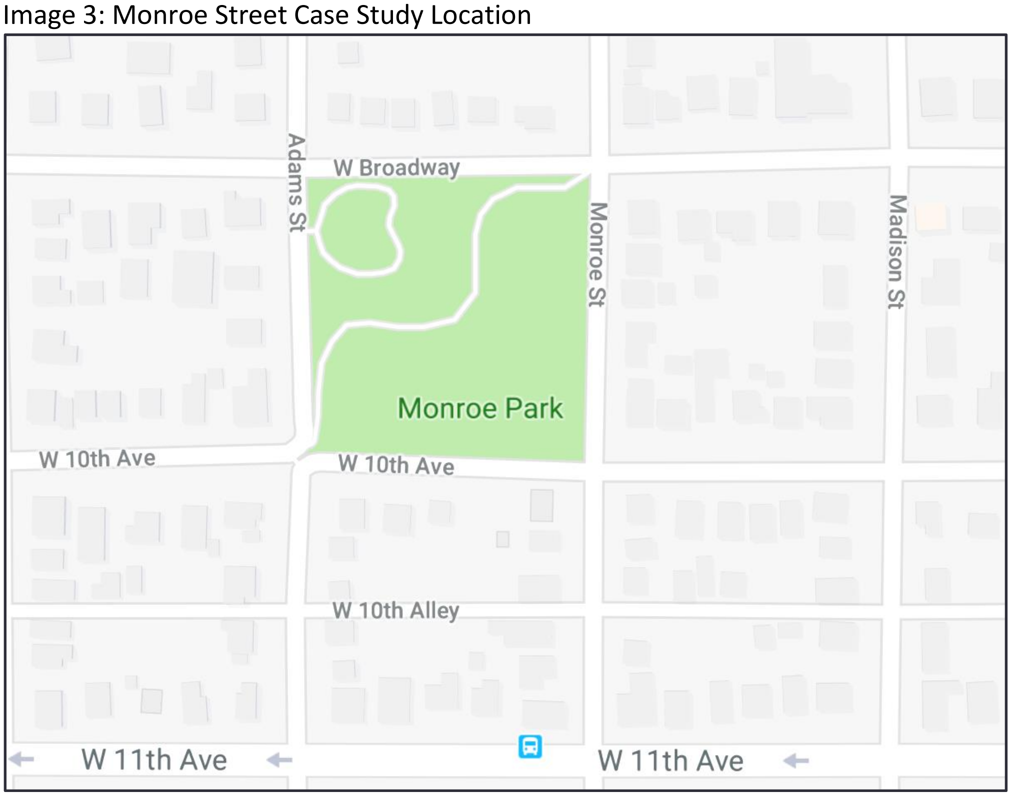


Image 4: Monroe Street Current Conditions

Current Conditions:

- Two-directional traffic
- Free on-street parking
- Faded bike sharrow markings
- 25 mph speed limit

Monroe Street is a pleasant walking environment, and while biking isn't necessarily uncomfortable, it also isn't prioritized. There is a lack of dedicated pedestrian and bicycle connections to the park and an oversupply of parking on the street.

STREET REDESIGNS

Coburg Road

Image 5: Coburg Road, Current Conditions

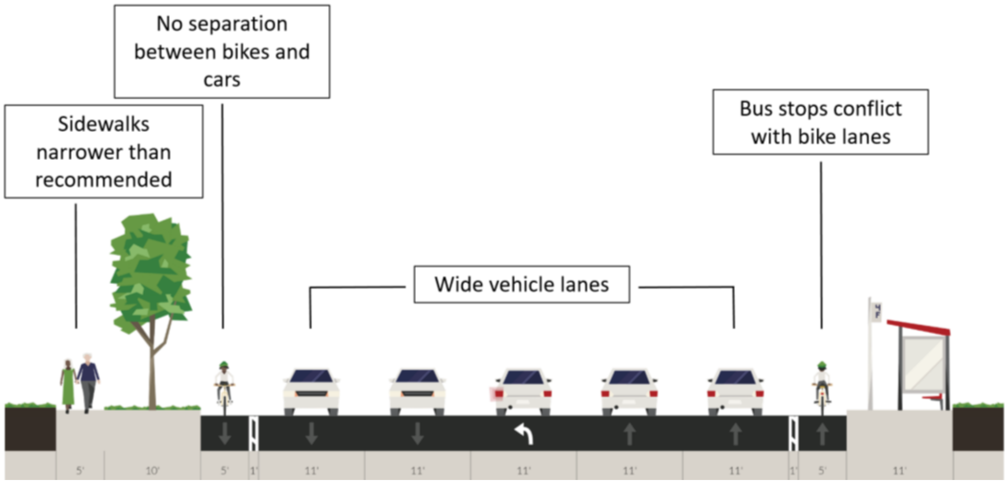


Image 6: Coburg Road, Complete Street

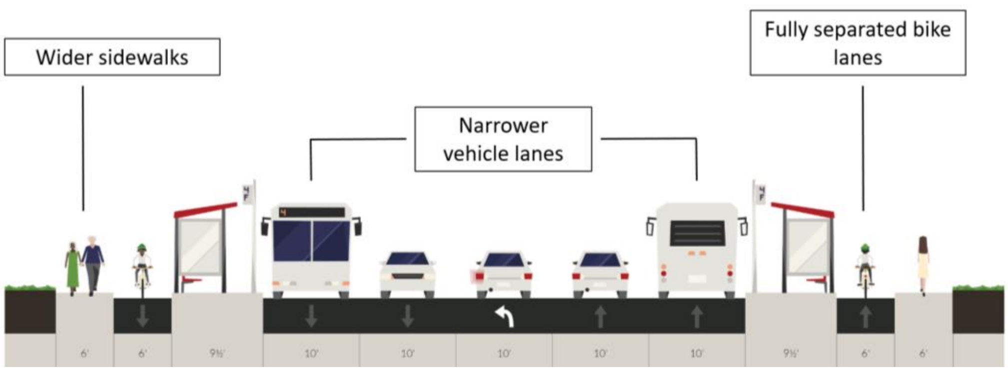
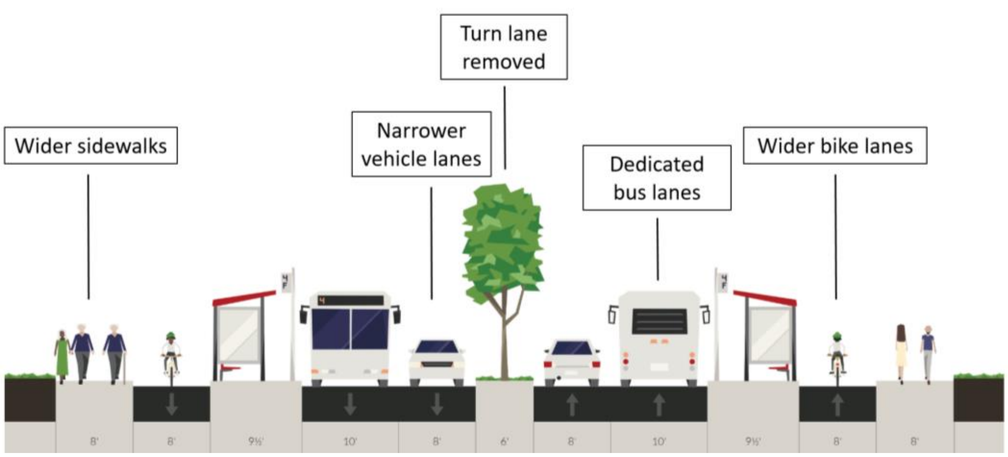


Image 7: Coburg Road, Autonomous Vehicle Future



Monroe Street

Image 8: Monroe Street, Current Conditions

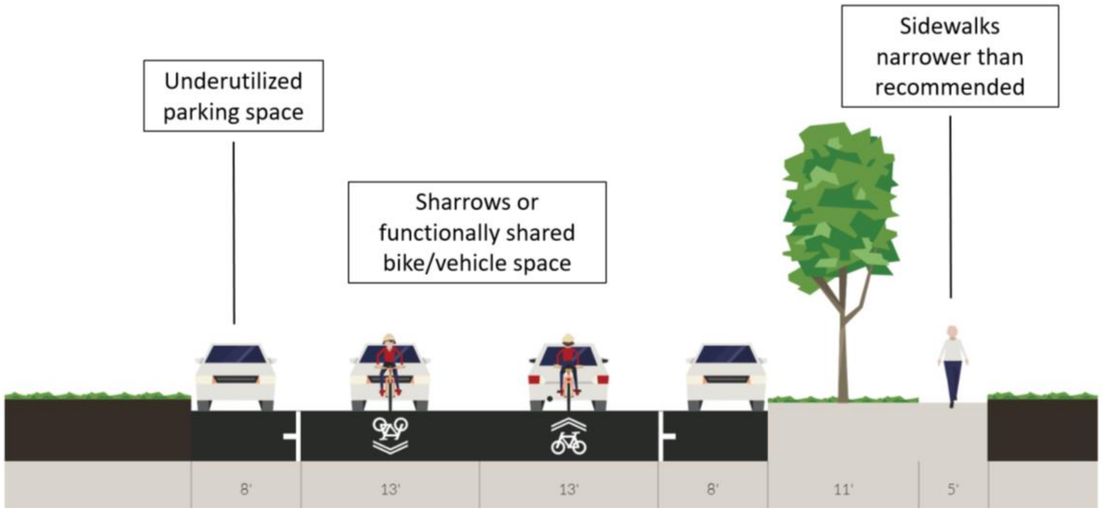


Image 9: Monroe Street, Complete Street

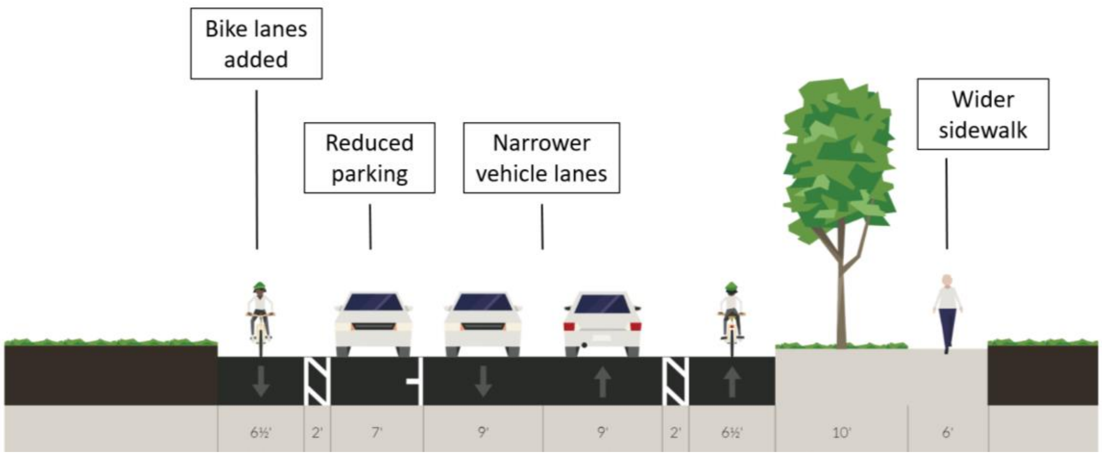
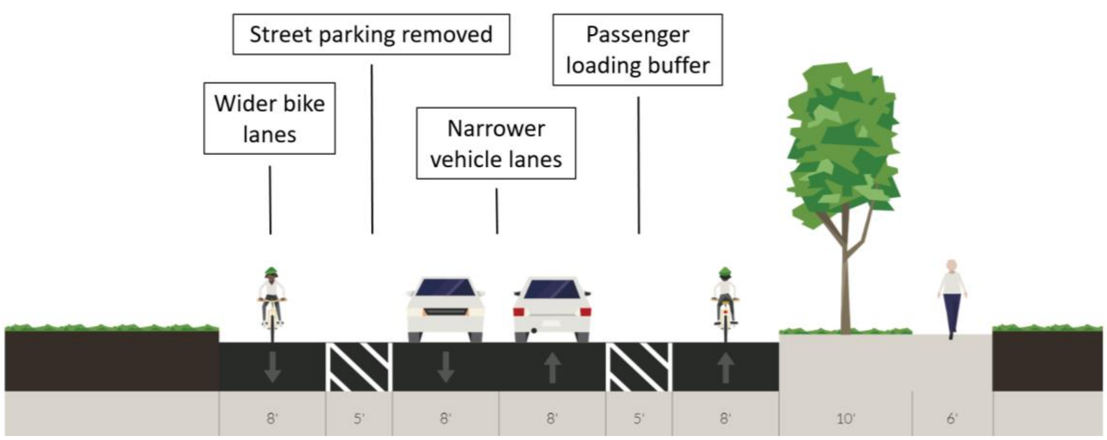


Image 10: Monroe Street, Autonomous Vehicle Future



POLITICAL vs FUNCTIONAL OPPORTUNITIES

The Coburg Road and Monroe Street case studies demonstrated possible design differences between complete streets and streets in an autonomous vehicle future. Five differences were identified for the two street types and were designated as being due to political opportunities or functional opportunities. The results are summarized in Table 4.

Table 3: Opportunity Classification

Opportunity	Political	Functional	Reasoning
Lane width reduction		X	Autonomous vehicles will be able to drive more accurately which will reduce the need for buffer space in vehicle lanes. Travel lanes for passenger vehicles will be able to be able to be thinned, though lanes for larger vehicles such as semis and buses may need to maintain current dimensions due to wheel bed size and turning radiuses.
Elimination of left-turn lanes		X	Interconnected autonomous vehicles can signal upcoming movements to each other. Turning vehicles could signal to oncoming cars about the upcoming turn, allowing the other cars to adjust their speed to create room for a seamless turn. This removes the need for designated turning lanes.
Dedicated bus lane	X		Dedicated bus lanes allow transit vehicles to operate without disrupting or being disrupted by other vehicles. Dedicated bus lanes are currently difficult to implement politically, especially when they would replace a general travel lane due to concerns over congestion. When the vehicle pool is shared, fewer cars need to be on the road at a given time. Additionally, autonomous buses can run more frequently due to reduced operating costs, making transit a more efficient and attractive transportation option. These two factors will likely create the political will to create designated transit space on city streets.
Elimination of on-street parking	X		For many communities, removing on-street parking is a hotly contested proposition. With shared autonomous vehicles, parking demand will decrease as should the corresponding political opposition to parking removal
Buffered bike lanes		X	On certain streets, such as low volume residential streets, a designated passenger drop off zone may not be necessary. Instead, vehicles can simply stop in the travel lane for disembarking passengers. However, open doors and pedestrians could conflict with cyclists in the bike lanes. A wide painted or raised buffer provides space for pedestrians to exit their vehicle and wait for passing cyclists before crossing to the sidewalk.

DISCUSSION

WHAT KIND OF TRANSPORTATION FUTURE DO WE WANT?

With traffic-related deaths rising, pollution and climate change threatening community health, and the social inequities of auto-oriented transportation coming to light, it isn't surprising that most cities are working to make changes to their transportation systems. **Most cities desire a transportation system that is safe, sustainable, and equitable.** These goals have been key components of transportation plans for decades, but it can be argued that limited progress has been made towards achieving them. Autonomous vehicles are unlikely to change city goals. Cities can capitalize on the political disruptions and functional changes of autonomous vehicles to promote active transportation if they aim to continue pursuing a safe, sustainable, and equitable transportation system.

HOW DO WE GET THERE?

Complete streets create a transportation system that supports the goals of safety, sustainability, and equity by encouraging active transportation modes. Cities can capitalize on the political disruptions and functional changes of autonomous vehicles to promote active transportation if they aim to continue pursuing a safe, sustainable, and equitable transportation system.

The disruptions and the corresponding opportunities caused by AVs are more likely if the majority of vehicles are operated in shared fleets. Therefore, cities can promote vehicle sharing as a component of their strategy for achieving city transportation goals. Cities have a variety of tools available to reduce the attractiveness of private vehicle ownership, the most feasible of which create financial incentives for vehicle sharing.

FEASIBLE ECONOMIC TOOLS

Parking fees: Parking fees can continue to be charged in an autonomous vehicle future. However, because autonomous vehicles do not require parking at the passenger destination if parking fees are too high they could encourage empty vehicles circling the street or returning to the owner's home.

Vehicle miles traveled (VMT) tax: Autonomous vehicles are likely to be electric, meaning an alternative to the gas tax will be needed. A VMT tax is a possible alternative, and private vehicles could be charged a higher rate per mile than shared vehicles.

Sales tax: Vehicles purchased for personal use could include a sales tax.

Tolls: Similar to congestion pricing, tolls can be used for use of a particular road and could also be charged when vehicles begin using the road.

Congestion pricing: During times of heavy congestion, a fee can be charged to vehicles operating in a specified area. Fees can be charged when vehicles enter the designated area. Because AVs will continuously be monitoring their location, congestion pricing will likely be administratively easier to implement.

Loading zone fees: Vehicles could be charged a fee to drop off or pick up passengers.

Cities could use multiple tools in order to reduce behavioral trade-offs. For example, tolls or congestion pricing could be used to prevent unwanted vehicle behaviors caused by parking fees.

RADICAL ECONOMIC AND REGULATORY TOOLS

Vehicle property taxes: Private vehicles could be included in property taxes. New Jersey currently collects annual property taxes on vehicles.

Empty seat charge: Since private vehicles often operate below capacity, they use a disproportionate amount of the street space. Sensors or cameras could be installed inside cars or on streets to monitor vehicle capacity and charge a fee for empty seats.

Operating locations: Specific streets or drop-off zones can be designated for shared vehicles only. Limiting the places where private vehicles can operate reduces the ease of using them. This will likely be most effective if the busiest or most popular streets and locations are reserved for shared vehicles. Such operational limits could also help alleviate congestion since private vehicles often transport a single person at a time.

Operating times: During times of peak congestion such as rush hour, cities could prevent private vehicles from entering congested zones. Congestion pricing is the corresponding pricing tool that would likely be more politically feasible to implement.

CAN NEGATIVE IMPACTS OF SHARED AVs BE MITIGATED?

Autonomous vehicles, whether shared or not, **create new challenges** for active transportation modes.

Vehicle spacing: Since autonomous vehicles can react more quickly to changes in movement from other vehicles they can operate with little distance between them. This improves vehicle flow but reduces gaps that allow pedestrians to initiate street crossing. This could make street crossings more difficult, especially if traffic signals are removed.

Curb space management: Autonomous vehicles are likely to pull over to the curb to let out passengers at the sidewalk. This will cause them to be in direct conflict with existing bike lanes and bus stops which are often in the same space adjacent to the sidewalk. These negative impacts can be addressed through design strategies or regulations.

MITIGATION STRATEGIES

Controlled vehicle spacing: To allow pedestrians to cross the street freely at regular intervals, autonomous vehicle movement could be regulated to ensure appropriate spacing between each vehicle on streets where pedestrian activity is desired.

Bike lane placement: Conflicts caused by vehicles crossing bike lanes can be reduced through strategic placement of bike lanes and drop-off zones. Just as parking spaces can be placed between the vehicle lane and the bike lane to create physical separation and reduce the potential for dooring, drop-off zones could be placed in the same location. By placing bike lanes to the right of drop-off zones, AVs don't need to cross the bike lane to unload passengers. One difference in the design of these zones compared to parking lanes is that an additional space buffer will be needed between the bike lane and the spot where vehicles stop. Passengers are likely to exit the right side of the vehicle, away from the traffic lanes, and they will need a space to wait and look for cyclists before crossing the bike lane to the sidewalk. Such a buffer could be painted or raised pavement. Alternatively, bike lanes could be placed in the center of the street, leaving the space adjacent to the sidewalk free for passenger loading and unloading. These bike lanes will likely require some form of physical separation from vehicle lanes to ensure they feel comfortable and safe for users.

Designated drop-off zones: There is the potential that autonomous vehicles will dominate curb space, making it difficult for buses to reach bus stops. Autonomous vehicles should only be allowed to drop-off passengers at dedicated locations that do not interfere with transit stops. The efficiency of transit operations should be prioritized over smaller vehicles as transit has greater passenger capacity. The size and placement of AV zones will be context dependent, but they should be designed in a way that reduces their impact on the efficiency of other transportation modes.

WHAT CAN BE DONE DURING THE TRANSITION TO AUTONOMOUS VEHICLES?

If cities want to be proactive in managing the transition to autonomous vehicles, there are several policies that can be implemented today to help shift street space towards active transportation modes before autonomous vehicles reach market saturation.

1. **Remove minimum parking requirements:** It has been well documented that minimum parking requirements have resulted in an oversupply of parking that encourages driving.[61] Cities can remove minimum parking requirements from their development code to allow parking supply to meet demand.

2. **Conduct a parking inventory:** If current parking utilization rates are unknown, cities may consider conducting a parking inventory. On some streets, parking rates may already be low enough to justify the removal of parking in favor of active transportation infrastructure. Either way, cities may find it beneficial to monitor changes in parking demand throughout the transition to autonomous vehicles and will therefor want baseline parking capacity numbers.

3. **Invest in community street activities:** Community events that create opportunities to reimagine street space encourage discussion about how streets should be designed and used. Sunday Streets in Eugene, OR are a good example of such an event. Street events can introduce active transportation and complete streets principles to community members as well as functioning as a space to discuss non-vehicle commute options. Cities can also use these types of events to begin identifying a community vision of what an autonomous vehicle future should look like.

4. **Invest in active transportation infrastructure:** Cities can start or continue investing in sidewalks, bike lanes, and other street design elements that support active transportation.

5. **Establish space reallocation policies:** Underutilized street space can be reallocated for many different purposes. Cities could choose to implement storm water infrastructure, active transportation infrastructure, or use the space for move more vehicles. The best option may depend on street context, so cities may want to determine where they want to see specific types of street design changes. Then, cities can establish conditions for triggering the desired transition. For example, on a street where bike infrastructure is desired, cities could designate that if parking utilization is routinely below 50% on that street then a bike lane will replace parking on one side of the street.

6. **Establish curb management policies:** An increase in passenger drop-offs fundamentally changes the flow of traffic on a street. Cities may be experiencing this issue already with the rising popularity of ridesharing services such as Uber and Lyft. Management of curb space can be done through passenger drop-off fees or by establishing designated passenger loading zones. The correct curb management technique will likely be context specific. Pilot programs could be an attractive options for cities that want to try out the technique that works best for their streets.

CONCLUSION

Autonomous vehicles create both opportunities and challenges for active transportation and complete streets. These impacts need to be understood in order to create a future transportation system that is safer, more sustainable, and more equitable than today's status quo. The promotion of these goals through increasing the use of active transportation modes is heavily influenced by street design. Autonomous vehicles are expected to have three key impacts on street design. First, autonomous vehicles have less need to park, so parking demand is expected to decrease. If the majority of vehicles are operated in shared fleets, on street parking could be reduced dramatically. Second, due to more efficient vehicle movement, both the width of travel lanes and the number of lanes could be reduced, allowing this space to be reallocated for other uses. Third, curb space is expected to become congested due to an increased number of vehicles loading and unloading passengers. This creates the need for curb management through the creation of dedicated loading zones that reduce the impact of autonomous vehicles on other transportation modes.

The first two impacts are expected to benefit active transportation as they allow for space that is currently dedicated for vehicles to be reallocated for other modes. Reductions in street parking and vehicle lanes will allow for more bike lanes or dedicated transit lanes, as well as creating the potential for parklets that improve the pedestrian environment. Lane width reductions are most likely to benefit pedestrians by allowing for the widening of sidewalks, though on streets with multiple travel lanes, enough space could be reallocated for the creation of a bike lane.

Streets that support active transportation in an autonomous vehicle future have only slight differences from the complete streets of today. The only necessary differences are caused by challenges specifically created by AVs. Frequent passenger drop-offs make the space adjacent to sidewalks a potential point of serious conflict. Because of this, autonomous complete streets need to be designed to reduce or eliminate these conflicts. Existing designs that reduce conflicts between bike lanes and parked cars can be adapted to reduce drop-off zone conflicts. Preventing vehicles from using bus stops for drop-offs can reduce conflicts between AVs and transit.

Since today's complete streets and the complete streets of the future do not have overt differences in design, a reasonable question to ask is how autonomous vehicles will create significant opportunities for active transportation. The answer lies in the difference between design opportunities and political opportunities created by AVs. On the two streets used as case studies, the opportunities that were most beneficial for active transportation were political opportunities. Reduced need for parking on residential streets makes the creation of bike lanes more politically feasible. The same is true for dedicated bus lanes on commercial corridors due to a reduction in the number of necessary vehicle lanes. Cities may want to pay close attention to the political opportunities of AVs, as they may be able to use the expected impacts of autonomous vehicles as arguments for creating complete streets now and thus achieve the goals of safety, sustainability, and equity sooner.

A future where the majority of vehicles are operated in shared fleets creates more opportunities for active transportation that if the majority of vehicles are privately owned. Cities can promote shared vehicle use through taxes, fees, and regulations. The negative impacts associated with any type of autonomous vehicle can be mitigated through design and regulations as well. Cities truly have the power to shape their own transportation future, and they can capitalize on the disruption of autonomous technology to create a system that works for everyone.

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