

NCHRP Project 20-113F  
**Preparing for Automated Vehicles and Shared  
Mobility: State-of-the-Research Topical Papers**

# CROSSWALK SUMMARY

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# 1 Introduction

In coordination with the National Cooperative Highway Research Program (NCHRP), the TRB Forum on Preparing for Automated Vehicles and Shared Mobility (Forum) has developed nine (9) topical papers to support the work of the Forum (Project). The final versions of the papers are available on the Forum's website (<https://www.nationalacademies.org/our-work/forum-on-preparing-for-automated-vehicles-and-shared-mobility-services>).

Across the nine topical papers, key themes emerged within the findings and additional research recommendations. This “**Crosswalk Summary**” summarizes the findings and additional research within the following themes that are most prevalent across the nine topical papers:

## *Crosswalk Themes:*

1. Safety;
2. Environmental and Socio-economic Impacts;
3. Data and Data Governance;
4. Equity, Accessibility, and Inclusion; and
5. Automated Vehicle (AV) and Shared Mobility Services.

This Crosswalk Summary is meant to assist the understanding of the connections across the nine topical papers based on the five Crosswalk Themes. (**See Table 1**) It will provide a snapshot of the synergies across the topical papers, but is not meant to summarize the findings of the papers. Readers are encouraged to review each topical paper as well. Within each topical paper, readers will find more information on the research reviewed related to the paper's identified focus areas.

Within this Crosswalk Summary, the topical papers are referred to as follows:

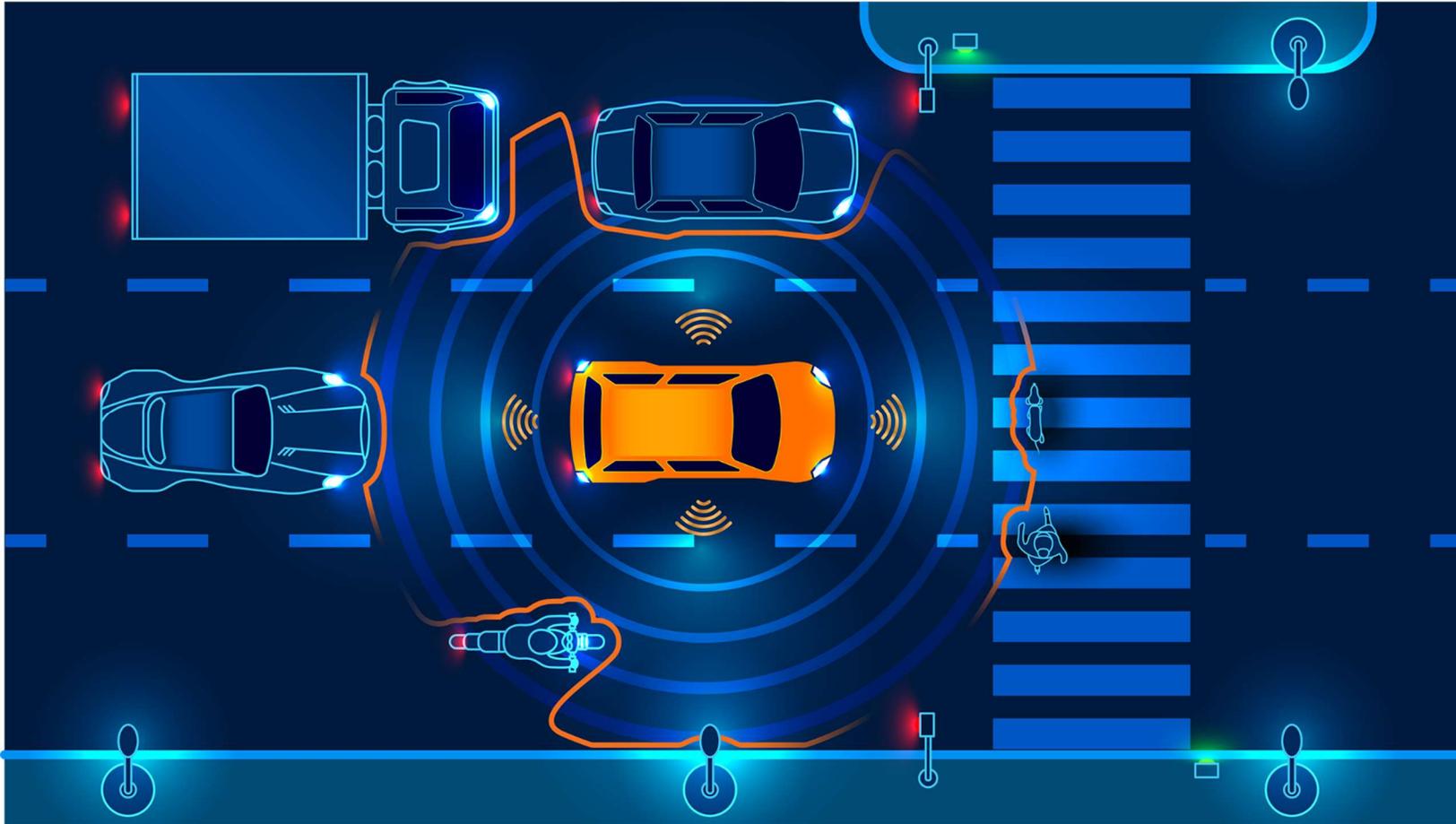
- Models for Data Sharing and Governance (referred to herein as “**Data Paper**”)
- Safety Scenarios and Engagement during Transition to Highly Automated Vehicles (referred to herein as “**Safety Paper**”)
- Infrastructure Enablers for Automated Vehicles and Shared Mobility (referred to herein as “**Infrastructure Enablers Paper**”)
- Maximizing Positive Social Impacts of Automated Vehicle Deployment and Shared Mobility (referred to herein as “**Social Impacts Paper**”)
- Prioritizing Equity, Accessibility and Inclusion Around the Deployment of Automated Vehicles (referred to herein as “**Equity Paper**”)
- Potential Impacts of Highly Automated Vehicles and Shared Mobility on Movement of People and Goods (referred to herein as “**Goods Movement Paper**”)
- Impacts of Automated Vehicles and Shared Mobility on Transit and Partnership Opportunities (referred to herein as “**Public Transit Paper**”).
- Implications for Transportation Planning and Modeling (referred to herein as “**Planning Paper**”)
- Impacts and Opportunities Around Land Use and Automated Vehicles and Shared Mobility (referred to herein as “**Land Use Paper**”)

With the Project, we note that the topical papers summarize common themes from the research available to date, while acknowledging that various scenarios may impact the issues, recommendations, and areas for future research identified in each paper. Many of the issues addressed in the research are forward-looking and anticipate an environment where fully automated vehicles (SAE Levels 4 and 5) are a standard part of the transportation system.

# Crosswalk Themes Summary

Table 1

THEME + Sub-Theme	Papers Containing Theme:								
	Data	Safety	Infrastructure Enablers	Social Impacts	Equity	Goods Movement	Transit	Planning and Modeling	Land Use
<b>SAFETY</b>	•	•	•	•	•		•	•	•
Safety and the Built Environment			•				•		•
Safety Consideration Based On Users		•		•	•				
Safety Challenges	•	•	•	•				•	
<b>ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS</b>	•	•	•	•	•	•	•	•	
Sustainability and Climate Change			•	•		•			
Public Health		•		•	•				
Public and Consumer Acceptance of AVs	•		•	•				•	
Workforce Implications				•		•	•		
<b>DATA AND DATA GOVERNANCE</b>	•	•	•	•	•		•	•	•
Data Standards, Regulations, and Frameworks	•		•				•	•	
Data Sharing	•		•				•		
Data and Role of Governments	•	•	•	•				•	
Data and Infrastructure	•		•		•		•	•	•
<b>EQUITY, ACCESSIBILITY, AND INCLUSION</b>	•		•	•	•	•	•		•
Accessibility and the Built Environment				•	•	•	•		•
Improved Access for Excluded Groups			•	•	•	•	•		
Affordability	•			•	•				
<b>AV AND SHARED MOBILITY SERVICES</b>	•			•	•	•	•	•	•
Shared Mobility	•			•	•	•	•	•	
Competing Uses of the Curb				•		•			•



## 2 Discussion by Theme

### THEME 1: Influences on the Safety of AVs

*Preface: Safety is cited often in the research and determining the path forward on the development and adoption of safety standards for AVs is noted as an important element for AV adoption. Research notes both the need and challenge of testing outside of controlled environments and the safety concerns associated with a mixed-use operating environment of traditional human operated vehicles and AVs.*

Across the research in eight of the nine papers, this theme can be broken down into three sub-themes: as further detailed in Table 2.1 below.

- safety and the built environment,
- safety considerations based on users, and
- safety challenges.

THEME + Sub-Theme	Papers Containing Theme:								
	Data	Safety	Infrastructure Enablers	Social Impacts	Equity	Goods Movement	Transit	Planning and Modeling	Land Use
<b>SAFETY</b>	•	•	•	•	•		•	•	•
Safety and the Built Environment			•				•		•
Safety Consideration Based On Users		•		•	•				
Safety Challenges	•	•	•	•				•	

Table 2.1 Influences on the Safety of AVs Overview

## Safety and the Built Environment

This sub-theme rose to the surface in three of the topical papers. Various research efforts in the Infrastructure Enablers Paper address how the expansion of connected and automated vehicles aligns with increasing levels of safety-focused infrastructure including intelligent transportation systems devices and embedded sensors, traffic cameras, and communications technologies. Another area of emphasis is around the opportunities, once Highly Automated Vehicles (HAVs) are at “full deployment”, for the reduction of required investments in traditional safety infrastructure, like 12-foot travel lanes or guard rails. An area of uncertainty in the infrastructure research surrounds reserving the 5.9GHz spectrum for smart vehicle technology and the communication of critical safety data to public agencies like state Department’s of Transportation.

The research in the Land Use Paper follows the communication theme, but from the opposite perspective, concentrating on how the increased use of 5G in AVs will likely be an enabler of more reliable communication for vehicles. This in turn could play a key role in managing safety challenges such as efficiency, reliability, and the range needed to support AVs. With the Public Transit Paper perspective, the focus is on the physical side – stressing that accessible infrastructure at the curbside, such as vehicle or curb heights, accessible sidewalks, and bus stops, is vital for the safety of all passengers.

### Crosswalk Point(s):

*A key element across the papers relating to the built environment is the importance of new types of infrastructure in supporting the safe operation of HAVs. Further, the new types of infrastructure that AVs initiate will transform the built environment such as changing roadway infrastructure requirements (lanes widths), the required digital infrastructure, and what is needed for curb infrastructure to ensure of safety of all users across modes.*

## Safety Consideration Based on Users

Safety considerations based on users and mode are addressed in three of the papers. Research in the Safety Paper itself focuses on education and procedures for various users. For users, much of the stated concerns center around the stages prior to full automation where safety could be impaired if uninformed users expect greater capabilities than are available. Research also raises the challenges this evolving environment creates for law enforcement and emergency responders when they must deal with HAVs at a crash site, including the ability to access data.

Research in both the Social Impacts and Equity Papers spotlight the potential for safety barriers to impact the acceptance of HAVs. In the Social Impacts Paper, research discovered that barriers to acceptance of new mobility strategies includes concerns about the safety of AVs. The unease from the general public largely stems from an overall lack of trust in the concept of HAVs, which is likely the result of knowledge and experience gaps. In the Equity Paper, research highlights geographic concerns that could limit the reach of HAVs to all segments of the population. Along a similar line, the research notes that personal safety concerns can be a

barrier for women currently using shared or subscription formats of mobility, and this could continue as HAVs are introduced in similar formats.

**Crosswalk  
Point(s):**

*A key element across the papers is the potential barriers to HAV use stemming from safety concerns. Safety issues arise around the transition period to full autonomy both from unrealistic capability expectations by users and interactions with new technology by law enforcement and emergency responders. From a trust perspective, the research notes that user experience with AVs helps alleviate user trepidation and can assist in overcoming misconceptions around the capabilities of the technology which is also a safety concern.*

### **Safety Challenges**

The challenges around potential crashes with HAVs are an area of crossover in four topical papers. As this is a broad topic, the challenges found in each of the papers are diverse. Research in the Safety Paper itself identifies a number of safety challenges for AVs. There is considerable discussion on how the exclusive reliance on traditional test track and road testing for HAVs is likely to take too long to advance the technology. Further, the conventional concepts and approaches to setting safety standards embodied in the Federal Motor Vehicle Safety Standards framework are based on existing vehicles and do not account for either specific operational design domains or the artificial intelligence involved in HAVs. While analysis is ongoing to understand what changes are needed for HAVs, that process is time and resource intensive, and has not kept up with the advancement in HAVs.

The research suggests that alternative options may include moving to third party validation or using certification processes similar to those in aviation, but little work exists to establish how these would apply for HAVs. Another factor is that existing demonstration programs do not address managing safety in an operational environment that includes different levels of automation and different vehicle types.

The Data Paper research takes a different perspective as it finds that the new regulations around privacy and data protection may impact government's ability to collect data associated with the safe operation of AVs on public roads. At the same time, there remains substantial uncertainty as to precisely what types of data are needed to support the safe operation of AVs. Additionally, the research considers addressing consumer protection within the context of privacy and data security and how the sharing of data may be impacted by "opt-out" approaches to data privacy for users.

Research in the Infrastructure Enablers Paper addresses challenges around precisely what infrastructure is needed to address safety for AVs in mixed fleet environments. In addition, safety-focused infrastructure development issues include concerns around providing an adequate communication spectrum, i.e., 5.9 GHz band or similar. The Planning Paper research also addresses safety issues around AV evolution with the need for fleet transition considerations for planners and policy makers, such as the expected behavior of HAVs in mixed fleet environments, speed variability, and the speed of the transition to HAVs. Additionally, the paper suggests that the current long-range planning cycles should begin to consider the potential implications of AVs, including safety and associated measures like infrastructure needs and potential increases in vehicles miles traveled.

Research in the Social Impacts Paper indicates public health and safety concerns surrounding AVs and concludes that service providers should be responsible for ensuring the safety of their services in a rapidly fluctuating environment, such as the COVID-19 pandemic. That research also notes that the Federal Transit Agency is establishing guidance to protect passengers and employees on public transportation in the COVID-19 pandemic and implies applicability to public health and HAVs deployed in shared format.

**Crosswalk  
Point(s):**

*A key element across topical papers is safety challenges and concerns in the transition to HAVs, including considerations around a potential mixed fleet environment of both human driven and self-driving vehicles. There is still debate in much of the research on the best avenues to overcome those safety challenges and what data is needed for the safe operation of vehicles.*

The following is a summary of the identified “Further Research Opportunities” from the original topical papers that align with the cross-walk theme and subthemes discussed for **Safety**. Some research recommendations cross to more than one theme.

## Further Research Recommendations Theme: Crosswalk

**Theme:** Safety

**Source Topical Paper:** Research Recommendations

<b>Subtheme: Safety and the Built Environment</b>	
<b>Land Use</b>	Analyze new aspects of the curb, including new curb designs, allocation of curbside space, pricing of the curb, and new curbside technology. <i>(See also in AV and Shared Mobility Services: Competing Uses of the Curb for Shared Mobility)</i>
<b>Infrastructure Enablers</b>	Evaluate what devices and sensors should be approved for purchase and installation on the National Highway System and other network components with considerations around interoperability.
<b>Infrastructure Enablers</b>	Create best practices guidance for managing work zone markings, cone/barrel placements, duration, and other elements that can support improved operations for AV and shared mobility providers. Some research questions could include: <ul style="list-style-type: none"> <li>• What are effective communication tools?</li> <li>• Are there standardized equipment markings, colors, or sign placements that would benefit AVs?</li> <li>• How do AVs respond to human presence in work zones versus pedestrians to determine expected behaviors?</li> <li>• Are vehicles used in construction areas properly categorized through machine vision?</li> <li>• Are real-time databases of work zone activity feasible?</li> <li>• How can we equip workers' safety equipment (vests, hard hats, etc.) with V2X devices to communicate with vehicles?</li> </ul>
<b>Subtheme: Safety Considerations Based on Users</b>	
<b>Data</b>	Recommend model standard for data reporting related to crashes or collisions. Consider interests including, but not limited to law enforcement, insurance, and applicable transportation agencies. Identify best practices for protecting information considered to proprietary or trade secrets and personal user information. <i>(See also in Data and Governance: Data Standards, Regulations, and Frameworks)</i>
<b>Safety</b>	Validate education for specific demographic subsets including aging population. <i>(See also in Environmental and Socio-economic Implications of HAVs: Public/Consumer Acceptance of HAVs)</i>
<b>Safety</b>	Create a uniform guidebook for law enforcement and first responders.
<b>Safety</b>	Create a guidebook covering insurance and liability considerations for AV incidents.
<b>Social Impacts</b>	Create a resource for AV consumer education tools including public engagement. <i>(See also in Environmental and Socio-economic Implications of HAVs: Public/Consumer Acceptance of HAVs)</i>
<b>Equity</b>	Identify best practices for community and stakeholder outreach for deployments with focus on equity and accessibility.
<b>Equity</b>	Identify best practices in participatory design by persons with disabilities in the creation of standards for both shared mobility and AVs. <i>(See also in Equity, Accessibility, and Inclusion: Improved Access for Disadvantaged or Excluded Groups)</i>
<b>Subtheme: Safety Challenges</b>	
<b>Data</b>	Identify and evaluate alternative classifications for data collected by AVs and/or shared mobility on-demand platforms to better assess use cases and challenges.
<b>Safety</b>	Assess risk of efficiency attacks versus those focusing on weaponizing vehicles; develop best practices to mitigate risks and consequences of attacks.

<b>Safety</b>	Assess voluntary or industry standard setting safety models and create options for applying to AVs.
<b>Safety</b>	Develop and assess alternative audit, validation, and certification approaches. These would include aviation schemes and testing center approaches such as American Mobility Center, GoMentum Station, AVerify, and Aviation Federally Funded Research and Development Centers.
<b>Safety</b>	Create safety scenario repositories; examine presence and evaluation of “edge cases” (where the problem only occurs at an extreme operating parameter such as unusual obstacles, strange behaviors, or extreme weather).
<b>Safety</b>	Assess performance-based safety standards and testing based on safety scenarios (e.g., performance standards based on safety critical scenarios such as: to navigate environments with obstructed views, or to detect and avoid pedestrians and bicycles).
<b>Safety</b>	Research the roles and responsibilities that cities may have for ensuring safety of AVs including crashes due to road design, personal physical safety, and cybersecurity.
<b>Safety</b>	Develop potential alternatives to disengagements as a safety indicator metric.

## THEME 2: Environmental and Socio-economic Implications Around HAVs

*Preface: The societal impacts of AVs are not yet known, and those impacts will be influenced by how HAVs are deployed and accepted by users. Potential impacts to labor and workforce development are also an area of research interest. The COVID-19 pandemic raises awareness of the opportunities and challenges of public health and infectious disease.*

Across the nine papers, this theme surfaced in the research of eight papers and can be broken down into four sub-themes as further detailed in Table 2.2 below:

- sustainability and climate change,
- impact of HAVs on public health,
- public and consumer acceptance of HAVs, and
- workforce implications of the transition to HAVs.

THEME + Sub-Theme	Papers Containing Theme:								
	Data	Safety	Infrastructure Enablers	Social Impacts	Equity	Goods Movement	Transit	Planning and Modeling	Land Use
<b>ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS</b>	•	•	•	•	•	•	•	•	
Sustainability and Climate Change			•	•		•			
Public Health		•		•	•				
Public and Consumer Acceptance of AVs	•		•	•				•	
Workforce Implications				•		•	•		

Table 2.2 Environmental and Socio-economic Impacts Overview

### Sustainability and Climate Change

Sustainability and climate change implications with HAVs occur in three papers. As transportation remains a key cause of air pollution and greenhouse gases, the research in the Infrastructure Enablers Paper notes two areas where the extended deployment of AVs could generate positive impacts for the environment. First, if AVs contribute to increases in pooling, emissions could decrease through a reduction in the energy used in the transportation of goods and people. If electricity is the preferred system for HAV automation and electric HAVs become more prominent, they could also play an important role in the transformation to a low-carbon mobility option. However, the research also raises the issue that without the use of sustainable fuels combined with proper planning and policy approaches, HAVs have the potential of increasing miles driven (particularly around “empty” miles with no passenger), total energy use, and emissions. The Social Impacts Paper notes similar findings.

As explained in the Infrastructure Enablers Paper, if HAVs are powered by internal combustion engines or operated primarily as single occupancy vehicles, they could compound congestion and worsen air quality. On the other hand, the research in the Goods Movement Paper finds that automated heavy-duty trucks offer significant energy and emission savings compared to traditional trucks because of the potential for platooning. Studies of non-automated truck platooning show fuel savings between 10% and 17% and automated trucking research expects these more efficient operating conditions to yield similar fuel savings.

### Crosswalk Point(s):

*AVs have the potential to reduce emissions. However, realizing these optimal outcomes will require leadership as well as effective planning and policies to avoid the potential negative environmental impacts of AVs from potential increase in miles driven and inability to incentivize shared and pooled mobility.*

## Impacts of HAVs on Public Health

The impacts of HAVs on public health is addressed in four of the topical papers. In the Safety Paper, research around public health finds that HAVs may reduce morbidity and mortality from vehicle crashes. Research in the Social Impacts Paper highlights several additional possible public health benefits from HAVs including the potential to increase quality of life through enhanced access to jobs, improved personal mobility, and the transformation of existing areas such as parking to more environmentally supportive land uses. Some of the potential new land uses include more room for sidewalks or dedicated bike/micromobility lanes plus health or recreation spaces like parks.

Research in the Equity Paper finds that AVs have the potential to increase access to transportation that could improve health outcomes by better access to healthy foods and medical care for those with disabilities, underserved communities, and other at-need populations.

Due to the recency of the COVID-19 pandemic, that specific issue is not incorporated in the much of the existing research yet. However, the Social Impacts Paper highlights that health and safety concerns impact shared transportation ridership. The opportunity to maximize opportunities for positive socio-economic impacts from HAVs will require overcoming the current reluctance to share rides triggered by the pandemic. This issue applies to overall public transit and shared mobility as well as AVs, and it is unclear if this is a long-term impact. It is also not definite what policy responses, automated or otherwise, might offset these concerns.

### Crosswalk Point(s):

*Potential health benefits, such as reduced crashes, healthier cities, and better access for at-need populations, resulting from full deployment of HAVs are significant. However, corresponding policy leadership is needed to support these outcomes. This optimism about the potential benefits is somewhat tempered by concerns that the COVID-19 pandemic and fear of future pandemics may reduce shared transportation ridership.*

## Public and Consumer Acceptance of HAVs

The current research on acceptance of HAVs is either based on a severely limited source of information from AV deployments or speculation on how the future will unfold. The Data Paper's research finds that public trust and acceptance are key policy considerations for mobility data use and that effectively addressing privacy considerations is a critical issue to achieve consumer acceptance. A discussion trend across research in the Infrastructure Enablers Paper is the strong influence of consumer acceptance on the growth of HAV adoption. Currently, public perception of AVs is mixed and is usually based on little or no exposure to HAVs. Stated barriers to acceptance range from distrust of AVs and related safety concerns to the long-established car culture. In many research efforts, individuals indicated that the opportunity to

personally experience an HAV increased their comfort level. Research findings in the Infrastructure Enablers Paper and Social Impacts Paper were very similar. Research in the Social Impacts Paper also addresses public and consumer acceptance of HAVs and moving to greater levels of shared mobility. Similar to the Infrastructure Enablers Paper, the noted barriers to consumer acceptance include distrust of automated technology, safety concerns, and shared mobility concerns around giving up vehicle ownership. Research also noted that increasing consumer trust in AVs, often through public education, is necessary for acceptance. Research in the Planning Paper found that effective planning and modeling efforts require an understanding of market and consumer acceptance.

**Crosswalk  
Point(s):**

*There is general agreement in the research that public and consumer acceptance will be a critical component in how quickly and extensively HAVs are adopted. However, the current limited exposure policy makers and the general public have with HAVs limits the ability to accurately predict future activities around AVs. This is also further complicated by the level of overlap between the overall HAV discussion and the related issues around moving to greater use of shared mobility, including public transit, and reduced car ownership.*

## Workforce Implications of Transition to HAVs

Workforce implications around the transition to HAVs are discussed in three papers. Addressing concerns around job impacts from HAVs is a theme across the Social Impacts research. While the rise of HAVs could cause job displacement for current positions like taxi or truck drivers, new jobs will likely be created over time in technology fields and non-driving fields. A critical element to addressing these new jobs is proactive work force training and assistance in career transitions. Similarly, job loss related to highly automated trucking is an important topic in the Goods Movement research where literature reviewed highlights the expectation of new opportunities through the creation of new jobs around automation in transportation, including logistics and freight movement.

The level of potential net jobs, whether the new jobs will be better quality or inferior, and the associated timeline (which is highly dependent on HAV truck/bus deployments) are all much debated in the research. The Public Transit Paper research also finds that the number of driver positions will reduce once HAVs are deployed in large numbers. Just as in commercial trucking, some jobs will likely be replaced, while others will shift to new roles with different required skill sets. The research notes that impacts and approaches in the public transit arena will be heavily influenced by both public policy and union agreements.

**Crosswalk  
Point(s):**

*Like many technological transitions, the move to HAVs will likely displace some jobs, such as traditional driving jobs, but new jobs and careers will be created as well. There is not yet a consensus on the timing or the ultimate impact to the affected work force. Research notes opportunities around job training and coordination with technology companies around future workforce skill sets that will be in demand.*

The following is a summary of the identified “Further Research Opportunities” from the original topical papers that align with the cross-walk theme and subthemes discussed for **Environmental and Socio-economic Implications for HAVs**. Some research recommendations cross to more than one theme.

**Further Research Recommendations Theme:** Crosswalk  
**Theme:** Environmental and Socio-economic Implications of HAVs  
**Source Topical Paper:** Research Recommendations

<b>Subtheme: Impacts of HAVs on Public Health</b>	
Safety	Identify best practices in areas such as sanitation, contact tracing, and social distancing seen in other modes (rail, public transit, and air) that would specifically apply to AVs.
Social Impacts	Develop a synthesis of research on the impact of AVs on property loss, morbidity, and mortality resulting from crashes.
Social Impacts	Study whether the COVID-19 pandemic affects consumer acceptance of AVs, particularly within the subscription and shared mobility context. <i>(See also in Public/Consumer Acceptance of HAVs subtheme below.)</i>
Goods Movement	Develop a practitioner’s guide to best practices in automated cleaning and decontamination of vehicles.
<b>Subtheme: Public/Consumer Acceptance of HAVs</b>	
Data	Create a guide to effective strategies for public education and engagement related to data collection from transportation services, management and sharing of such data by private and public entities, and public benefit from data sharing. Investigate the value of potential education campaigns and curriculum in maintaining/gaining public trust for AVs and shared mobility strategies through platforms focused on digital applications.
Safety	Validate education for specific demographic subsets including aging population. <i>(See also in Safety: Safety Considerations Based on Users)</i>
Social Impacts	Create a resource for AV consumer education tools including public engagement. <i>(See also in Safety: Safety Considerations Based on Users)</i>
Social Impacts	Study whether the COVID-19 pandemic affects consumer acceptance of AVs, particularly within the subscription and shared mobility context. <i>(See also in Impacts of HAVs on Public Health subtheme above)</i>

<b>Subtheme: Workforce Implications of HAVs</b>	
Social Impacts	<p>Develop a synthesis of research on workforce development strategies, impacts of the “gig” economy in transportation, secondary economic impacts, and alternative investment strategies. Scope could include:</p> <ul style="list-style-type: none"> <li>• Workforce development: Return on financial investment, employee satisfaction, and efficacy in job placement, retraining in manufacturing including automotive</li> <li>• “Gig” economy: recent court actions regarding contractor versus employee status, health care and related benefits, work conditions, and relative earnings</li> <li>• Secondary impacts: economic impacts on related industries, businesses en route, and the like</li> <li>• Alternative community investment strategies</li> </ul>
Goods Movement	<p>Subdivide workforce impacts by specific market segments, such as long haul versus networked trucking, and regional economies rather than strictly national economies and markets. Analyze which jobs will be lost by whom, when, and where to align training for new job types.</p>
Public Transit	<p>Identify the timing of workforce impacts by work classification, demographics, and geography of widespread HAV deployment. Evaluate pilot efforts in training and develop a model for a labor-management partnership on provision of microtransit/AV service.</p>



## THEME 3: Data and Data Governance

*Preface Within the research reviewed in completing the Project, data was referenced as both a tool and challenge. Across the topical papers, data influences issues around pricing, equity, social impacts, planning, and land use. However, with the use of data, issues associated with data governance, including privacy, management, and security, are identified as important considerations to address.*

Across the research in all nine papers, this theme surfaced in eight papers and can be broken down into four sub-themes as further detailed in Table 2.3 below:

- Data standards, regulations, and frameworks;
- Data sharing;
- Data and the role of governments; and
- Data and infrastructure.

THEME + Sub-Theme	Papers Containing Theme:								
	Data	Safety	Infrastructure Enablers	Social Impacts	Equity	Goods Movement	Transit	Planning and Modeling	Land Use
<b>DATA AND DATA GOVERNANCE</b>	•	•	•	•	•		•	•	•
Data Standards, Regulations, and Frameworks	•		•				•	•	
Data Sharing	•		•				•		
Data and Role of Governments	•	•		•				•	
Data and Infrastructure	•		•		•		•	•	•

Table 2.3 Data and Data Governance Overview

## Data Standards, Regulations, and Frameworks

Data standards, regulations, and frameworks are addressed in four topical papers. In the Data Paper, the research discussion focuses on standards, regulations, and frameworks for data and data governance that exist within transportation services. Next generation mobility strategies, including micromobility and AVs, will require new standards given the “on-demand” nature of services that are being provided primarily through use of digital applications on mobile devices.

Research in the Infrastructure Paper finds that data collection frameworks have a large impact on infrastructure. Research reveals that digital infrastructure, including data collection frameworks, is becoming an important element in distinguishing the readiness of the public system to accept emerging AV technologies. Research in the Planning Paper identifies several new frameworks for planning for AVs that leverage new sources of data for transportation planning and forecasting. A consideration linking the topical papers is the relative newness of many data standards, frameworks, and regulations seeking to address issues, including privacy and data security considerations, that arise with the evolving use of data in a more connected world. However, research efforts across topical papers concur that consistent data standards, regulations, and frameworks are important for the transition to HAVs.

The research discusses data frameworks for emerging infrastructure and transportation technologies. For instance, the Data Paper references evolving standards and platforms such as SharedStreets and the Mobility Data Specification around micromobility. The Data Paper also discusses the development of new potential standards associated with next generation and on-demand mobility strategies. The Public Transit Paper research notes that transit or Mobility as a Service partnerships must comply with privacy standards or best practices for data, which vary depending on jurisdiction. That research also addresses the considerations around data licensing and ownership which can impact the sharing of data across platforms.

Additionally, the introduction and implementation of new regulations associated with privacy and data management create questions around the collection and use of data from AVs and shared mobility services. Relevant regulatory standards include the General Data Protection Regulation in Europe and the California Consumer Privacy Act. The implementation of both regulations creates questions around “opt-out” provisions for users and whether such provisions may inhibit the deployment of HAVs and the use of data from mobility services for planning.

### Crosswalk Point(s):

*A review of existing research identifies that data is an important and evolving topic, particularly when it comes to AVs and shared mobility services. Whether and how existing standards will be updated in consideration of evolving regulations and best practices around data privacy and management is anticipated to be a relevant topic around the continued integration of AVs and shared mobility services into the transportation system.*

## Data Sharing

Data sharing for HAVs is addressed in three papers. In the Data Paper, the research notes that the discussion around data sharing for HAVs should be narrowed around identified use cases for the technology and accompanying data anticipated to be collected and needed for the safe operation of vehicles. Various research efforts agree there is a need to create a more common

standard for data sharing for HAVs and shared mobility services centered around digital applications for scheduling. Research in the Infrastructure Enablers Paper focuses on enabling data sharing through infrastructure. This includes data sharing in work zones, which is the subject of ongoing research with federal funding. Finally, research in the Public Transit Paper focuses on data sharing in transit focused partnerships around first/last mile opportunities, including demand responsive microtransit. On the other hand, formal transit partnerships struggle to establish data sharing agreements while informal partnerships foster little to no data sharing. Policy focused papers reviewed express the opportunity for aligning needs and interests around data sharing, particularly between the public and private sector. Additionally, data is recognized in the research as a tool to assist in the development of regulations for next generation mobility strategies.

### Crosswalk Point(s):

*Research across the topical papers emphasizes the importance of data sharing for AV and shared mobility focused services. However, the development of data sharing frameworks has been inhibited by the lack of solidified use cases for new mobility strategies and an understanding of what data will be collected and what is actually needed for safe operations. Finding alignment between the public and private sector to promote data sharing is anticipated to be an important part of the continued integrated of AV and shared mobility focused services.*

## Data and Role of Governments

Data and the role of governments is an area of crossover in five papers. Research in the Data Paper acknowledges that local governments, states, and the federal government are all working to understand the opportunities and challenges of data. Key challenges for both the private sector and governments include considerations around privacy protection and data security. Research in the Safety Paper focuses on data regulation and governments. How access to safety data from AVs will be managed is an important jurisdictional question for the federal and state levels that is raised in the research reviewed. Additionally, how traditional data collection by states around road use will potentially change with the integration of AVs on the roadways is also a subject the research raises. Data that may include sensitive geolocation information result in privacy and data security questions, and policy implications are also raised in the literature around how data should be stored and by what type of entity – public, private, or third-party. The Social Impacts paper addresses the importance of collecting appropriate data to inform better planning, allocation of resources, including from an equity perspective, and investments around AVs as well as smart mobility strategies.

Research in the Infrastructure Paper focuses on government investment in data collection. A large amount of the research reviewed describes a renewed emphasis on the digital infrastructure requirements of emerging technologies. Many government investments in data collection are being reconsidered as new mobile technologies come online, in addition to growing fee-for-service considerations. Research in the Planning Paper concludes that governments have a role to play in advanced data management for scenario-based planning. Planning focused agencies will need to coordinate with private industry to identify the types of data needed for transportation planning. Again, how that data is collected, stored, and kept safe is an issue raised in the research. An additional consideration is what level of approval or notice

may be needed to users.

**Crosswalk  
Point(s):**

*Data is anticipated to play an important role around infrastructure considerations and across the planning process. The data collected through the use of digital applications provides the chance for a more up to date and real time understanding of travel behavior in an area; however, how that data are stored, kept safe, and privacy is protected will be important policy considerations.*

## Data and Infrastructure

Data and infrastructure are an area of crossover in six topical papers. Research in the Data Paper focuses on what data will be collected around infrastructure and potential data issues with connected infrastructure. The Infrastructure Enablers Paper focuses on digital infrastructure and connectivity and how it may contribute to the overall readiness to implement HAV technologies. Research in the Equity Paper raises concerns about potential discrimination with use of artificial intelligence combined with the increased reliance on digital applications. Research in the Public Transit Paper focuses on app-based digital payment systems and points out a lack of standardization and openness in digital application programming interfaces for public transit and Mobility as a Service. Research in the Planning Paper focuses on the opportunities that a combination of smart sensors in transportation infrastructure and automated vehicles may bring for planning. Finally, research in the Land Use Paper describes the type of digital communications technology that will support automated and connected vehicles, including considerations of 5G.

**Crosswalk  
Point(s):**

*A key element across papers is the importance of data and digital communications technologies for HAVs and possible connected vehicles. The research considers how such data can support determination of infrastructure needs and maintenance. Additionally, research also addresses how potential installation of hardware may be necessary and what implications need to be considered from a land use perspective, including with 5G and small cell installations to support a connected network.*

The following is a summary of the identified “Further Research Opportunities” from the original topical papers that align with the cross-walk theme and subthemes discussed for **Data and Data Governance**. Some research recommendations cross to more than one sub-theme.

## Further Research Recommendations Theme: Crosswalk

**Theme:** Data and Data Governance

**Source Topical Paper:** Research Recommendations

<b>Subtheme: Data Standards, Regulations, and Frameworks</b>	
Data	Identify and evaluate model data sharing and governance standards that can be used across all transportation modes. Assess practicability of implementation of a universal or differentiated standards based on data source and use case. <i>(See also in Data Sharing subtheme below)</i>
Data	Recommend model standard for data reporting related to crashes or collisions. Consider interests including, but not limited to law enforcement, insurance, and applicable transportation agencies. Identify best practices for protecting information considered to proprietary or trade secrets and personal user information. <i>(See also in Safety: Safety Considerations Based on Users)</i>
Infrastructure Enablers	Digital Infrastructure: Assess data frameworks and other digital infrastructure that could enable AVs and shared mobility. Among the research areas that could be considered are: <ul style="list-style-type: none"> <li>• How can data frameworks be used to advance the state of the practice for advanced driver assistance systems and AVs/shared mobility options?</li> <li>• Are specific needs emerging from the demonstration projects related to the digital spectrum for DSRC and other safety messages?</li> <li>• How do we avoid a “digital divide” between communities and states that make advanced infrastructure investments?</li> <li>• Are there additional investments that the public sector side needs to consider, beyond fiber optics, to enable new technologies? What is the sequencing of said investments?</li> </ul>
<b>Subtheme: Data Sharing</b>	
Data	Document use cases for data anticipated to be collected from AVs and demand responsive shared mobility services. Evaluate risks and benefits/needs associated with collection and sharing of data by use case.
Data	Identify and evaluate model data sharing and governance standards that can be used across all transportation modes. Assess if the implementation of a universal or differentiated standards based on data source and use case is practicable. <i>(See also in Data Standards, Regulations, and Frameworks above)</i>
Social Impacts	Develop full suite of metrics for efficiency, safety, equity, personal mobility, access to jobs, health care, education, recreation, and health. Research should include model policies and case studies on data collection, sharing, management, and privacy.
<b>Subtheme: Data and the Role of Governments</b>	
Data	Analyze and evaluate the different parties that have an interest in data collection from AVs and shared mobility platforms. Potential parties include manufacturers, software developers, commercial operators, transit providers,

	consumers, cities, regions, states, and federal government. Evaluation can consider the public benefit around data collected and provide analysis on where interests align within context of creating a data sharing standard and best practices.
<b>Subtheme: Data and Infrastructure</b>	
Land Use	Assess if more broadband and internet access will be needed to support connected AVs and/or related information collection.
Infrastructure Enablers	<p>Assess data frameworks and other digital infrastructure that could enable AVs and shared mobility. Among the research areas that could be considered are:</p> <ul style="list-style-type: none"> <li>• How can data frameworks be used to advance the state of the practice for advanced driver assistance systems and AVs/shared mobility options?</li> <li>• Are specific needs emerging from the demonstration projects related to the digital spectrum for DSRC and other safety messages?</li> <li>• How do we avoid a “digital divide” between communities and states that make advanced infrastructure investments?</li> <li>• Are there additional investments that the public sector side needs to consider, beyond fiber optics, to enable new technologies? What is the sequencing of said investments?</li> </ul> <p><i>(See also in Data Standards, Regulation, and Framework subtheme above)</i></p>

## THEME 4: Equity, Accessibility, and Inclusion

*Preface:* The theme of equity crossed over into seven of the topical areas. Within the research reviewed in completing the Project, the opportunities for positive socio-economic impacts from AVs often cite increased mobility for those with disabilities and access to mobility options for those living in areas where transportation services are limited. However, challenges exist around markets for deployment and pricing, in addition to other factors that may impact the realization of such socio-economic benefits.

Across the nine papers, this theme surfaced in the research of seven of the nine papers and can be further broken down into three sub-themes as further detailed in Table 2.4 below:

- accessibility and the built environment,
- improved access for disadvantaged or excluded groups, and
- affordability.

THEME + Sub-Theme	Papers Containing Theme:								
	Data	Safety	Infrastructure Enablers	Social Impacts	Equity	Goods Movement	Transit	Planning and Modeling	Land Use
<b>EQUITY, ACCESSIBILITY, AND INCLUSION</b>	•		•	•	•	•	•		•
Accessibility and the Built Environment				•	•	•	•		•
Improved Access for Excluded Groups			•	•	•	•	•		
Affordability	•			•	•				

Table 2.4 Equity, Accessibility, and Inclusion Overview

### Accessibility and the Built Environment

As shown in Table 2.4 above, accessibility and the built environment are discussed in five of the topical papers. In particular, the papers discuss physical accessibility for persons with disabilities including the accommodation needed in vehicle designs. Various research efforts in the Social Impacts Paper found that a lack of appropriate built environments, like uniform curb heights and level boarding platforms, could add challenges for people with disabilities. In the Equity Paper, research addressed several aspects of physical accessibility and the built environment. It was particularly noted that while concepts like universal design for vehicles can improve physical accessibility and equity, there has yet to be an approval of uniform standards for infrastructure design and devices for vehicles around accessibility on AVs. The Goods Movement Paper focuses on accessibility issues from delivery vehicles. Here, research identified that small sidewalk AVs, like automated sidewalk delivery devices, could block the sidewalk and limit physical accessibility for persons with disabilities.



Across the research reviewed, the closely related topic of the built environment, including the curb, is highlighted for consideration so that people with various disabilities can navigate to mobility services. In the Land Use Paper, research focuses on accessibility and competing uses for curb and sidewalk space. This issue becomes important when considering multi-modal connections, including through evolving concepts like “mobility hubs.” With this in mind, the research notes that regulations based on the Americans with Disabilities Act (ADA) should also be considered for vehicles and the built environment. Research in the Public Transit Paper focuses on the applicability of ADA rules, universal design standards, and physical accessibility for public transit and other shared AVs.

**Crosswalk  
Point(s):**

*An element that connects the topical papers across accessibility and the built environment is physical accessibility and ADA regulatory considerations, particularly to make sure individuals with disabilities are able to access next generation mobility services and to avoid impediments in the public right-of-way.*

## **Improved Access for Underserved Groups**

Improved access for underserved groups is addressed in research in five topical papers; those groups include the aging population, low-income individuals, persons with disabilities, unbanked individuals, and those facing a transit gap.

Research in the Infrastructure Enablers Paper finds differences in rural and urban infrastructure needs to support AVs. The research finds that rural challenges exist for implementing AVs, including a lack of adequate infrastructure, such as roadway conditions, narrow bridges, and limited markings. On a related note, research in the Goods Movement Paper finds that AVs can be a strategy to increase delivery options for people living in rural areas provided adequate infrastructure is in place.

Research in the Equity Paper notes that AVs have the potential to increase access to transportation for various groups that have faced transportation barriers or have not had reliable access to the transportation system. The Social Impacts Paper also addresses the issue of the social equity benefits of AVs, including increased mobility for the aging population, persons with disabilities, and those in transit-poor areas. The Public Transit Paper focuses on improving mobility opportunities through AVs.

Continued barriers for persons with disabilities may result if AVs are not designed to be accessible, both inside and out, or there are an insufficient of accessible AVs within fleets. Research efforts in the Equity Paper focus on barriers to use of AVs for persons with disabilities, including those of a cognitive nature, and potential discrimination when using artificial intelligence to identify passengers. Research also noted that personal safety concerns can be a barrier for women using shared or subscription formats. Language, cultural barriers, and lack of digital accessibility (such as web content accessibility guidelines) are additional socio-economic considerations identified that can inhibit a user’s comfort when using shared transportation modes.

**Crosswalk  
Point(s):**

*AVs and AV partnerships can improve access for underserved populations and help in addressing mobility gaps for both transportation and delivery services with AVs for various populations including the aging, those with disabilities, and those in transit-poor areas. A range of hurdles, including accessible vehicle design, safety concerns, discrimination, and cultural barriers, must also be overcome to provide improved access across all groups.*

## **Affordability**

Affordability around AVs is addressed in four topical papers. Research in the Data Paper focuses on the limitations and challenges for the use of data and the related affordability components in fare payment programs, Mobility as a Service platforms, or digital applications due to contracting and licensing challenges. The Social Impacts Paper focuses on pricing tools and subsidies as a means to encourage AVs and increase equity. For instance, research finds that pricing tools could subsidize rides as a strategy to increase equity for low-income groups; however, there are challenges around the need to implement “fees” to provide the funding for such subsidies. The Equity Paper research notes that the unbanked and those without access to a connected mobile device may have difficulty paying for mobility services, especially as digitally focused fare payment systems are more widely used. Issues around unpredictable (such as peak pricing) or expensive fares could also hinder equitable access to AVs. For example, in the Public Transit Paper, research found that public-private mobility partnerships must deal with considerations around “surge” pricing in transit deserts.

**Crosswalk  
Point(s):**

*Topics that linked papers across affordability were fare payment considerations, addressing unbanked access, and ensuring access with connected mobile devices. Also, the considerations around potential implementation of dynamic pricing for HAVs, as seen with on-demand shared mobility, may limit access across all income classes to HAVs during peak demand hours.*

The following is a summary of the identified “Further Research Opportunities” from the original topical papers that align with the crosswalk theme and subthemes discussed for **Equity, Accessibility, and Inclusion**. Some research recommendations may cross to more than one theme.

## Further Research Recommendations Theme: Crosswalk

**Theme:** Equity, Accessibility, and Inclusion

**Source Topical Paper:** Research Recommendations

<b>Subtheme: Accessibility and the Built Environment</b>	
Equity	Develop ADA guidance for all types of AV vehicles including purpose built, electric, and light duty vehicles (vans and sedans).
Goods Movement	Identify best practices (planning, policy, and technology) for curbside management and off-road shared use of sidewalks and trails. <i>(See also in AV and Shared Mobility Services: Competing Uses of the Curb for Shared Mobility)</i>
Public Transit	Conduct a literature synthesis on universal design for vehicles, facilities, and infrastructure that accommodates diverse abilities.
Land Use	Develop a guide on curbside management for accessible pickup for passengers with disabilities. <i>(See also in AV and Shared Mobility Services: Competing Uses of the Curb for Shared Mobility)</i>
Land Use	Research the opportunities for land use in the context of the ADA to ensure that (1) AVs are compatible with existing accessibility requirements for entrance and egress and (2) evolving standards are proactively incorporated into building codes.
<b>Subtheme: Improved Access for Disadvantaged or Excluded Groups</b>	
Data	Determine the role of data to ensure equitable deployments of AVs and shared mobility within communities. Create a best practices guide for using data to inform equitable deployments of AVs and shared mobility.
Safety	Validate safety education for specific demographic subsets including aging population.
Social Impacts	Analyze economic effects of automation in transportation across socioeconomic and demographic categories.
Equity	Develop strategies for using AVs to increase service in underserved areas, including rural geographies, and best practices to facilitate fare subsidies.
Equity	Identify best practices in participatory design by persons with disabilities in creation of standards for both shared mobility and AVs. <i>(See also in Safety: Safety Considerations Based on Users)</i>
Equity	Establish metrics for inclusion, equity, and access to AV and shared mobility service.
Goods Movement	Identify use cases, safety, and land use considerations for rural and urban applications for advanced air mobility and unmanned aerial systems (i.e., drones).
Public Transit	Assess ways in which AV and other shared services best complement and expand mobility services in underserved areas.
<b>Subtheme: Affordability</b>	
Data	Consider implications of an approach like “privacy by design” (proactively embedding privacy into the design and operation of technology services) on potential revenue generation for the purpose of providing fare free or

	reduced fare service. Compare models that provide “free” access to platforms like email and social media in exchange for the collection of data that may be used to generate revenue through various means, including advertising.
Equity	Evaluate policy tools such as road user pricing mechanisms and TNC surcharges for equity impacts and efficacy in encouraging use of pooling.
Data	Compile case studies on approaches to addressing limited digital access and unbanked persons in fare payment, including Mobility as a Service / Mobility on Demand approaches for AVs and shared mobility.
Public Transit	Create guides for cross-border subsidies across cities and agencies to support fare integration and creating sustainable shared mobility services.

## THEME 5: AV and Shared Mobility Services

*Preface:* The integration of TNCs into the transportation system provides an example of what AV services deployed in a subscription format may look like. It is important to also note that AV services are connected to both the movement of passengers and goods. The research notes that an anticipated issue will be management of the curb from increased demand on the public right-of-way. The papers also consider how the continued deployment of AV and shared mobility services may either positively or negatively impact public transit.

Across the nine papers, this theme surfaced in the research of eight papers and can be broken down into two sub-themes as further detailed in Table 2.5 below:

- AV shared mobility services and
- Competing uses of the curb

THEME + Sub-Theme	Papers Containing Theme:								
	Data	Safety	Infrastructure Enablers	Social Impacts	Equity	Goods Movement	Transit	Planning and Modeling	Land Use
<b>AV AND SHARED MOBILITY SERVICES</b>	•			•	•	•	•	•	•
Shared Mobility	•			•	•	•	•	•	•
Competing Uses of the Curb				•		•			•

Table 2.5 AV and Shared Mobility Services Overview

### AV Shared Mobility Services

Due to the emphasis in the original research topics, AV shared mobility services was naturally an emphasis point in almost all the Topical Papers. Research in the Social Impacts Paper finds that shared mobility strategies can improve mobility for people in areas that are poorly served by transit, including providing first and last mile services. Further, the research notes that on-demand, flexible, shared mobility AV services can improve access to transit and increase its ridership. The critical issue in making these possibilities a positive reality is creating approaches where the new AV services can complement, rather than replace or degrade, transit options.

Similarly, the Equity Paper found that shared AV services like TNCs, microtransit, and carsharing can improve spatial and temporal equity by filling transit gaps in various cases: in underserved areas, for those who cannot afford personal vehicles, or for people requiring additional services like paratransit. However, equity challenges are also observed for shared

mobility AVs. Specifically, a lack of disabled and wheelchair-accessible AV services as well as not ensuring services to the unbanked and low-income communities would negatively affect equitable AV mobility as has been documented among existing TNC services. There are also specific equity issues around access. For instance, two research studies find that Black riders, especially males, are experiencing higher cancellation rates and longer wait times for TNC and other pooled services. This could also become an issue with HAVs in the event that bias is introduced through artificial intelligence.

Corresponding research areas in the Goods Movement Paper include TNC and carsharing models for shared mobility, as well as new models for transportation of goods and people. On the people movement side, this research suggests policy makers should implement TNC and shared mobility regulations now to ensure a framework is in place for automated shared mobility. From the goods aspect, the rise in e-commerce intensifies the local demand for delivery vehicles; heightening the pressure to develop effective AV delivery strategies that do not compound congestion. Recent research in this area suggests two possible models for AVs to mix passengers with freight. One model envisions passengers and automated delivery robots both using public transportation, with passengers being prioritized. The second model is an integrated system where people and freight are moved together in mixed purpose, compartmentalized shared AVs.

The Public Transit Paper correspondingly identifies various shared AV use cases including first/last mile, fixed route, paratransit, and circulator services; each of these could expand mobility in areas not served by transit. Initial research also indicates that on-demand private AVs could fill temporal or spatial gaps in transit service, as found in the Equity Paper. Partnerships with AV service providers likewise hold the potential for increasing shared mobility options and perhaps to increase connections to transit. To date, these partnerships are taking the form of private sponsorship of pilots for AV shared mobility services including shared rides and shared vehicles. The Public Transit Paper research shows that current mobility hub planning at transit stations routinely includes provisions for shared AVs. At the same time, while the Planning research reveals that current high-level planning efforts (such as master plans or long-range transportation plans) do not routinely include shared mobility AVs, these discussions are gradually emerging in more plans.

**Crosswalk  
Point(s):**

*Overall, the predominant theme around shared mobility is how new shared mobility AV services can become an important element in improving equitable access to transit and other shared mobility services. However, it will be essential that issues around inclusiveness and accessibility be addressed.*

## Competing Uses of the Curb

This cross-cutting research area focuses on the enhanced need for curb space as we move to greater on-demand shared mobility and automated freight. Research in the Social Impacts and Land Use Papers both highlight this expected increase in competition for curb space; whether for parking, passenger pickup and drop-off, micromobility, or deliveries. The Social Impacts research indicates that this increase in curbside demand and resulting congestion could be mitigated through new curb management policies, including regulation of parking and right-of-

way access. Additional suggested options are the intelligent pricing of curb space, such as requiring paid access to loading zones, use of competitive municipal requests for proposals to designate right-of-way-access, or otherwise designating parking or drop-off zones for private use. In the same vein, the Land Use Paper discusses curb flex zones which are prioritized by the needs on each street, as seen in pilots in Washington, DC, and Seattle, WA.

As discussed in the other papers, curbside demand is both a passenger and goods transportation issue. The Goods Movement Paper observes that automated transportation further heightens the challenges in managing competing uses of the curb. The research notes that delivery vehicles, both on-road and on the sidewalk, can increase congestion and traffic at/near to the curbside. Other identified competing curb uses include parking, passenger pick-up and drop-off, and the transformation of traditional curb/street space into extended uses such as parklets, walkways, and bike lanes. The research also addresses curbside delivery approaches such as creating curb flex zones and specific delivery and/or passenger loading zones as well as geo-fencing, camera enforcement, and imposing fines. In the Land Use Paper, research shows that this increased competition for the right-of-way can have even farther-reaching future impacts altering street design itself and the space allocations for each mode of travel on the street as well as the curb. Additionally, ADA requirements need be proactively considered.

**Crosswalk Point(s):** *Competition at the curbside will be heightened from passenger AVs as well as parcel and freight deliveries from AV vehicles. As we change the ways that passengers and goods move, effectively planning and managing curb usage will be critical to the successful deployment of AVs and shared mobility services, and making sure accessibility requirements are met.*

The following is a summary of the identified “Further Research Opportunities” from the original topical papers that align with the cross-walk theme and subthemes discussed for **AV and Shared Mobility Services**.

## Further Research Recommendations Theme: Crosswalk

### Theme: AV and Shared Mobility Services

#### Source Topical Paper: Research Recommendation

Subtheme: AV Shared Mobility Services	
Data Sharing	Assess the benefits and risks from the use of facial recognition technology in AVs considering different contexts, e.g., private vehicle ownership, private shared subscription services, or public transit fleets. Include data governance considerations, including privacy, security, and user rights for each service model.
Public Transit	Develop performance metrics for evaluating AV and shared mobility partnerships.
Public Transit	Evaluate models for Mobility as a Service and Mobility on Demand nationally and globally with public transportation focus and consideration of: <ul style="list-style-type: none"> <li>Fare subsidies across modes, digital access, and the unbanked.</li> <li>App integration, operational best practices, and data ownership.</li> </ul>

<b>Subtheme: Competing Uses of the Curb for Shared Mobility</b>	
Goods Movement	Identify best practices (planning, policy, and technology) for curbside management and off-road shared use of sidewalks and trails. Carsharing, TNCs, microtransit, ecommerce, and other deliveries should be addressed as well.
Land Use	Survey communities to establish a baseline on implementation of and management of land-use questions as they relate to the curb, shared rides, shared vehicles, microtransit, micromobility, and sidewalk robotic delivery vehicles.
Land Use	Analyze how management of the right-of-way to support the deployment of AVs and prioritizing the use of limited space impact shared mobility and land use.
Land Use	Analyze new aspects of the curb, including new curb designs, allocation of curbside space, pricing of the curb, and new curbside technology. <i>(See also in Safety: Safety and the Built Environment)</i>
Land Use	Study an enforcement mechanism to manage growing competition for the right-of-way (ROW). Research could also address the safe use of ROW by both human and automated users.
Land Use	Study pricing, including demand-based pricing, of curb access for automated mobility.
Land Use	Develop a guide on curbside management for accessible pickup for passengers with disabilities. <i>(See also in Equity, Accessibility, and Inclusion: Equity, Accessibility, and the Built Environment)</i>

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