



# NCHRP 20-102(19) Update AASHTO's Connected Vehicle/Automated Vehicle Research Roadmap

*2018 Joint Annual Meeting of the  
AASHTO Committee on Transportation System Operations (CTSO)  
and  
TRB Regional Transportation Systems  
Management and Operations Committee (AHB10)*

*Technology Subcommittee: Connected and Autonomous Vehicles  
Working Group*

AUGUST 28 2018

# NCHRP 20-102(19) PROJECT

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## **PROJECT TITLE:**

- Update AASHTO's Connected Vehicle/Automated Vehicle Research Roadmap

## **PROJECT OBJECTIVES:**

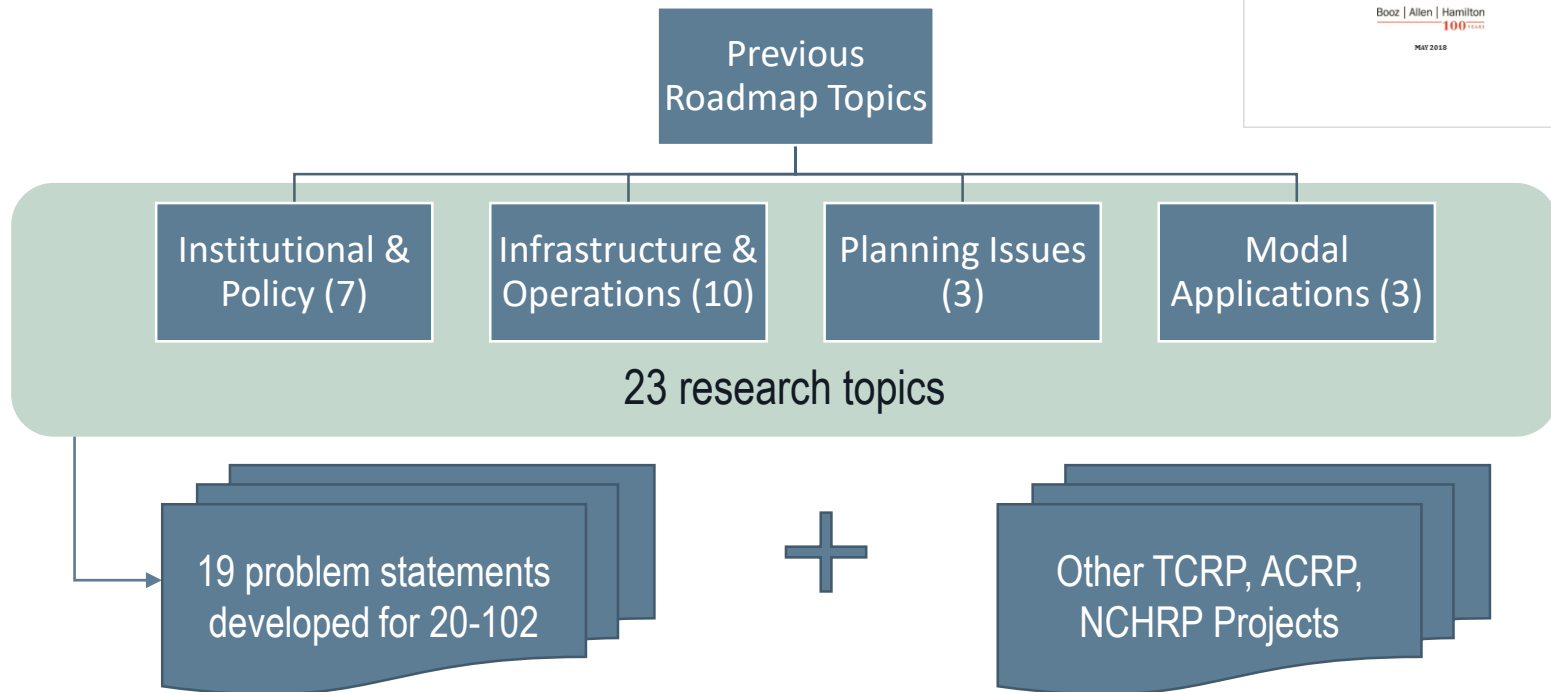
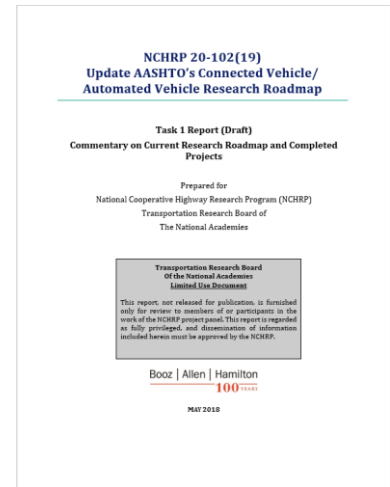
- Update and maintain the research roadmap to reflect the current landscape.

## **PROJECT REQUIREMENTS**

- Literature review and review of relevant research underway or planned by other research institutions,
- Information gathering from
  - Relevant AASHTO events,
  - Annual Automated Vehicle Symposium sponsored by TRB and AUVSI, and
  - TRB Forum on Preparing for Automated Vehicles and Shared Mobility.
- Desk scans of particular topics.

# TASK 1 – COMMENTARY ON CURRENT RESEARCH PLAN

- Submitted a Task 1 Report summarizing:
  - Previous Roadmap Topics
  - Commentary on Completed Projects
  - Review of Completed Projects
  - Gaps in Research Implementation



# NCHRP 20-102 PROJECTS STATUS (1/2)

Project No.	Title	Status	
20-102(1)	Policy and Planning Actions to Internalize Societal Impacts of CV and AV Systems into Market Decisions	Completed in May 2017 by TTI	✓
20-102(2)	Impacts of Regulations and Policies on CV and AV Technology Introduction in Transit Operations	Completed in May 2017 by Kimley Horn	✓
20-102(3)	Challenges to CV and AV Application in Truck Freight Operations	Completed in January 2017 by Booz Allen	✓
20-102(4) + 08-116	Framework for Managing Data from Emerging Transportation Technologies to Support Decision-Making	Not started	✗
20-102(5)	Strategic Communications Plan for Project 20-102	Not started	✗
20-102(6)	Road Markings for Machine Vision	On-going work conducted by TTI	▶
20-102(7)	Implications of Automation for Motor Vehicle Codes	Completed in February 2018 by VTTI	✓
20-102(8)	Dedicating Lanes for Priority or Exclusive Use by CVs and AVs	Completed in April 2018 by Booz Allen	✓
20-102(9)	Providing Support to the Introduction of CV/AV Impacts into Regional Transportation Planning and Modeling Tools	On-going work conducted by TTI	▶
20-102(10) + 03-127	Cybersecurity Implications of CV/AV Technologies on State and Local Transportation Agencies	On-going work conducted by SWRI	▶

# NCHRP 20-102 PROJECTS STATUS (2/2)

Project No.	Title	Status	
20-102(11)	Mobility-on-Demand and Automated Driving Systems: A Framework for Public-Sector Assessment	On-going conducted by Booz Allen	▶
20-102(12)	Business Models to Facilitate Deployment of CV Infrastructure to Support AV Operations	On-going conducted by WSP	▶
20-102(13)	Planning Data Needs and Collection Techniques for CV/AV Applications	Not started	✘
20-102(14)	Data Management Strategies for CV/AV Applications for Operations	Not started	✘
20-102(15)	Impacts of Connected and Automated Vehicle Technologies on the Highway Infrastructure	On-going conducted by Booz Allen	▶
20-102(16)	Preparing Traffic Incident Management (TIM) Responders for Connected Vehicles and Automated Vehicles	Not started	✘
20-102(17)	Deployment Guidance for CV Applications in the Open Source Application Development Portal	Not started	✘
20-102(18)	Minimum Safety Data Needed for Automated Vehicle Operations and Crash Analysis	Not started	✘
20-102(19)	Update AASHTO's Connected Vehicle/Automated Vehicle Research Roadmap	On-going conducted by Booz Allen	▶

# NON 20-102 PROJECTS FROM TRB

Project No.	Title	Status	
ACRP 11-03 (S03-11)	Transportation Network Companies: Challenges and Opportunities for Airport Operators	Completed in August 2017	✓
ACRP 03-48	Advanced Ground Vehicle Technologies (AGVT) for Airside Operations	Not started	✗
TCRP J-05 (18-03)	Workplace Implications of Autonomous Vehicles on the Transit Workforce	Not started	✗
TCRP J-11 (21)	The Impact of New Technology-Enabled Mobility Services on Public Transportation	Completed in May 2016	✓
TCRP J-11 (26)	Collaborations and Partnerships between Public Transportation and Transportation Network Companies	Not started	✗
TCRP J-11 (27)	Analysis of Low-Speed Automated Vehicle (LSAV): Pilots and Deployments	Not started	✗
20-24(111)	State CEO Leadership Forum on Connected & Autonomous Vehicles and Transportation Infrastructure Readiness	Completed in August 2017	✓
20-24(112)	Connected Road Classification System (CRCS) Development	On-going work	▶
08-117	Impact of Transformational Technologies on Land Use and Transportation	Not started	✗

# GAPS ANALYSIS CONSIDERATIONS (1/2)

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- FAVP revisions and iterations.
- USDOT and other projects that were funded in the past four years.
- Greater emphasis on data-related themes with the expansion of data availability, collection, sharing, aggregation, and re-dissemination through crowd-sourced, private, and public-sector sources facilitated through Application Program Interfaces (APIs) and other third-party tools.
- Shared economy research areas, including shared mobility and mobility-on-demand are increasingly impacting transportation systems operations and planning, travel demand modeling, and even revenue-driving business models.
- Taxonomy adoption and changes such as SAE J3016 for ADS and SAE J3613 for shared mobility and enabling technologies.
- The state-of-the-industry with respect to automation is more advanced in all modes, including automated truck platooning, automated trains, low-speed automated shuttles, automated personal vehicles (higher-levels of automation becoming market ready), etc.
- Growing recognition throughout the industry on the importance of issues, such as ethics, personal privacy protection, and cybersecurity for the implementation of road vehicle automation systems.

# GAPS ANALYSIS CONSIDERATIONS (2/2)

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- Implemented regulatory frameworks by states to govern the testing and public operation of Highly Automated Vehicles (HAV).
- Better understanding of road vehicle automation operational concepts.
- Active role by IOOs in supporting CAV testing on facilities, engaging in CV pilot deployments, and considering CAV impacts on both short- and long-term planning exercises and modeling, as well as on operations and maintenance of new devices.
- Realization of issues such as adverse weather, human factors, and under-developed infrastructure on the operation of highly automated vehicles.



# GAPS IN RESEARCH FROM PREVIOUS ROADMAP (1/3)

Title	Comments
Harmonization of state regulations	While some of the aspects of this research was undertaken as part of NCHRP 20-102(7) on Implications of Motor Vehicle Codes, this research requires ongoing updates based on changes in the state and federal regulatory and legislative policies. As the USDOT releases updates to its original guidance, and federal legislation possibly takes shape, the state regulatory processes need to be reviewed to determine the extent to which harmonization is achievable.
Federal-state-local boundaries of responsibility	This research need is still valid, and it could be tied to another research need that assesses the CV/AV deployment scenarios.
Lessons learned from other transportation technology roll outs	There are lessons to be learned from CV pilot implementations, smart cities, AV pilot programs conducted by state and local agencies, Mobility-on-Demand (MOD) Sandbox demonstrations, etc.
Lessons learned from CV Pilot Deployments	There are multiple projects aiming at documenting the lessons learned from CV pilot deployments. For example, NCHRP 20-102(17) aims at looking into developing deployment guidance for CV applications on OSADP. In addition, a review of lessons learned from the “data management” piece of CV Pilots is included in other projects, such as NCHRP 08-116. There are also numerous non-USDOT sponsored projects aiming at deployment of Connected Vehicle applications in response to the National SPaT Challenge. Consequently, there may be value to consolidating lessons learned from all these deployments.
Tools for predicting AV/CV impacts	CV/AV impacts is a widely researched topic, but most of these studies rely on assumptions that may be outdated. Developing tools or a toolkit to predict the CV/AV impacts would serve as a common platform for agencies to justify investments. This was one of the topics that required such substantial resources that it could not be funded within the resources that were already available, indicating the need for a higher level of investment.

# GAPS IN RESEARCH FROM PREVIOUS ROADMAP (2/3)

Title	Comments
<b>CV/AV applications for maintenance fleets</b>	CV/AVs have great potential in maintenance fleets, such as snow removal, work-zone dampeners, etc. Some of these would be even near-term owing to the controlled environments they operate in.
<b>Relationships of Connected Vehicle and Automated Vehicle systems.</b>	Given the importance of taking a holistic view that treats the infrastructure and the vehicles as portions of an integrated system rather than as distinct systems, there needs to be some basic research identifying the opportunities and challenges of both scenarios.
<b>Traffic control strategies with consideration of AV</b>	Given that legacy vehicles will still dominate the traffic mix for the foreseeable near- and medium-term, this research could wait. However, there is merit to researching the impacts of CAVs on existing traffic control strategies and how those strategies can be enhanced to support mixed traffic including CAVs and conventional vehicles.
<b>Geometric design concepts for AV systems</b>	Given that legacy vehicles will still dominate the traffic mix for the foreseeable near- and medium-term, this research could wait. However, there is merit to researching alternative design concepts for AV-only facilities, such as dedicated AV lanes.
<b>Workforce capability strategies for state and local agencies</b>	In most cases, the agency workforce that is affected by CAVs is broad. For example, it could impact traffic engineers, planners, TIM-responders, emergency maintenance personnel, work-zone contractors etc. Detailed study of implications on each of these categories would entail a significant effort. The current funded roadmap deals with implications on TIM-responders, and is covered under NCHRP 20-102(16).

# GAPS IN RESEARCH FROM PREVIOUS ROADMAP (3/3)

Title	Comments
Including consideration of AV systems in the regional planning process	The team also sees that expanding the scope beyond AVs, to include implications of MOD and shared mobility on regional planning process is also important. NCHRP 20-102(09) formed a good first step in this series, but it was limited in scope. This is a resource-intensive activity that needs additional resources invested.
Assessing transportation system impacts of CV/AV Effects of AV/CV on land use, travel demand, and traffic impact models	This is still one of the high-priority research needs that requires on-going and in-depth research. While topic 2.2 focused on developing the tools, this topic focuses on specific impacts summarized for different scenarios of CV/AV deployment. Research projects, such as NCHRP 08-117 (pending) and USDOT-funded “Benefits estimation framework for Automated Vehicles,” are conducting some of this research, but are only taking the first small steps of many that will be needed, and the first small investments out of a larger total that will be needed.
Benefit-Cost analysis of AV transit systems	This research need is still very relevant to public transit agencies to plan their investments. Although some of this is partially covered under certain TCRP J-11 Task Orders, a dedicated study assessing the benefits and costs of automated transit systems, including LSAVs, is important.

# TASK 2 – CATALOG OF WORTHY RESEARCH TOPICS

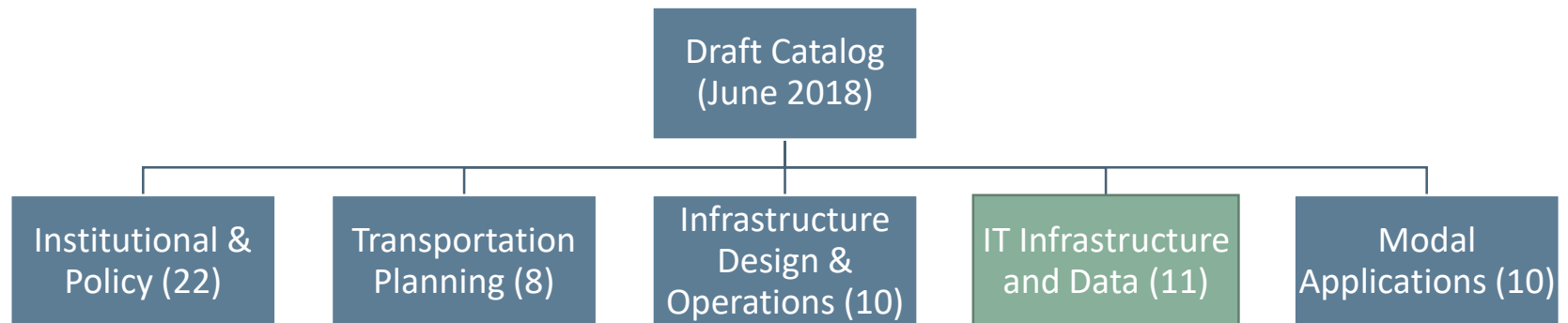
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## TASK OBJECTIVE:

- To develop a catalog of research projects that should be pursued to assess the open issues and unanswered questions.
- Catalog developed in 2018 will be updated again in 2019.

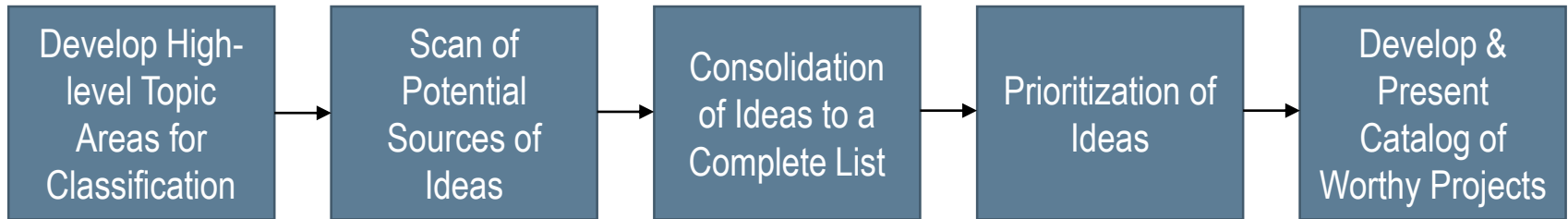
## OUTPUT:

- Developed a DRAFT Catalog with 62 topics under five different areas:



# TASK 2 – METHODOLOGY

- Developed a DRAFT Catalog with 62 topics under five different areas:



- Institutional and Policy
- Transportation Planning
- Infrastructure Design and Operations
- IT Infrastructure and Data
- Modal Applications

- Sourced from TRB Forum.
- SMEs within the team.
- SMEs outside the team/industry needs search.
- Proposed by the team.

- Draft List submitted to the panel with 62 project needs.
- Presented at AVS 2018.

- Panel survey and comments
- TRB Forum Priority List

- 1-page problem statement on each.
- List will be updated in 2019



# INSTITUTIONAL AND POLICY TOPICS (1/2)

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1. Clarification of federal-state relationship in the Federal Automated Vehicle Policy 3.0; State-Local and Federal boundaries of responsibilities.
2. Guidance standards for CV/AV pilot testing.
3. Research alternative non-governmental mechanisms for vetting automated vehicle safety.
4. Effective interactions between AVs and law enforcement and first responders.
5. Research focusing on guidance for CV/AV implication in public agencies and public policy.
6. Development of public education and outreach materials regarding the perception of vehicle automation.
7. Development of common system guidelines for reporting vehicle testing and operations for public awareness.
8. Review of regulatory approaches and development of innovating approaches.
9. Impacts of AVs and Shared AVs on public transportation.
10. Harmonization of state regulations.
11. Lessons learned from other transportation technology roll outs.
12. Workforce capability strategies for state and local agencies.

# INSTITUTIONAL AND POLICY TOPICS (2/2)

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13. Potential Safety Impacts of AVs.
14. Determining how safe is safe enough.
15. Liability in a world of AVs.
16. Impacts of shared mobility during evacuations, disaster relief etc.
17. Critical paths to Highly Automated Vehicles.
18. Synergy within the transportation ecosystem.
19. Evaluation of pilot deployments to determine contributions to various societal goals.
20. Framework for connected vehicle pilot and smart cities data analytics for policy guidance.
21. Alternative scenarios for synergy among automated vehicles, shared mobility, & alternative fuels.
22. Certification of AV performance and safety.

# TRANSPORTATION PLANNING TOPICS

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1. Infrastructure and land use impacts of shared automated vehicles.
2. Equity impacts of SAVs on communities.
3. Research focusing on guidance for socio-economic impacts of transformational technologies.
4. Research focused on urban planning and infrastructure development.
5. Tools for predicting AV/CV impacts.
6. Including consideration of AV systems in the regional planning process.
7. Potential impacts of higher level automated vehicles and shared mobility on traveler behavior and freight movement.
8. Implications for transportation planning and planning models.



# INFRASTRUCTURE DESIGN AND OPERATIONS

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1. Infrastructure modifications to improve the Operational Domain of Automated Vehicles.
2. Infrastructure analysis of automation systems and work zone interactions.
3. Safety Implications in a mixed vehicle environment.
4. Traffic management strategies with consideration of AV.
5. Geometric design concepts for AV systems.
6. Infrastructure enablers for connected and automated vehicles and shared mobility - Near term and Mid-term.
7. Long-term infrastructure enablers for CAVs/SAVs.
8. Impacts on infrastructure funding.
9. AVs impact on asset management practices.
10. Implications for work zones.

# IT INFRASTRUCTURE AND DATA TOPICS

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1. Recommendations for privacy and open data standards with respect to AVs/CVs.
2. Developing frameworks and best practices for managing data from emerging technologies.
3. Minimum set of data sharing between public agencies and private deployers.
4. Data sharing between AVs and law enforcement, first responders.
5. Minimum set of safety data needed for AV operations and crash-investigations.
6. Getting the most out of "Big Data".
7. Models for exchange of data.
8. Meeting cybersecurity and privacy challenges.
9. Framework for connected vehicle pilot and smart cities data analytics for policy guidance.
10. Data formatting standards for AVs.
11. Data analytics mechanisms to improve infrastructure-AV integration.

# MODAL APPLICATIONS TOPICS

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1. Analysis on the impacts of Advanced Automated Transit.
2. State and local impacts of automated freight transportation systems.
3. CV/AV applications for maintenance fleets.
4. Benefit-Cost analysis of AV transit systems.
5. Critical paths to highly automated transit and freight vehicles.
6. Impacts of shared mobility on transit.
7. CAVs and shared mobility impacts on travelers with accessibility restrictions.
8. Alternative scenarios for synergy among automated vehicles, shared mobility, & alternative fuels.
9. Preparing drivers and travelers for automated transit/freight vehicles.
10. Consumer willingness to share “driverless” AV taxis with strangers.

# PRIORITIZED RESEARCH TOPICS

No.	Prioritized Research Topics (1-pager developed for each topic, covering Background, Research Objectives, and Intended Outcomes)	Benefits							
		Improve Safety	Increase Efficiency	Costs Saving	Ease Congestion	Accessibility	Economic Dev.	Increase Security	Public Awareness
1	Workforce capability strategies for state and local agencies						✓		✓
2	Alternative scenarios for synergy among automated vehicles, shared mobility, & alternative fuels						✓		
3	Infrastructure/Land Use Impacts of shared automated vehicles	✓	✓	✓	✓	✓	✓		
4	Potential impacts of higher level automated vehicles and shared mobility on traveler behavior	✓	✓		✓				
5	Infrastructure modifications to improve the Operational Domain of Automated Vehicles	✓	✓	✓	✓	✓			
6	Infrastructure enablers for connected and automated vehicles and shared mobility - Near term and Mid-term	✓	✓						
7	Implications for work zones	✓	✓						
8	Analysis on the impacts of Advanced Automated Transit		✓	✓		✓			
9	State and local impacts of automated freight transportation systems		✓		✓		✓		
10	CV/AV applications for maintenance fleets		✓		✓		✓		
11	CAVs and Shared Mobility Impacts on Travelers with Accessibility Restrictions		✓			✓	✓		

# NEXT STEPS

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- Task 2:
  - Gather feedback on 1-page problem summaries.
- Task 3:
  - Develop white-papers on selected topics 3x each year.
  - Recommended topics for 1<sup>st</sup> year:
    - Topic 1 – Educating the public on Automated Vehicles, their implications, myths and facts.
    - Topic 2 – Future of Transportation – Convergence of Connected and Automated Shared Electric (CASE) Vehicles in a Multi-modal World.
    - Topic 3 – Implications of AV/CV Cybersecurity for State and Local Agencies.