

**Working Paper #6:**  
**Timelines for Industry and Government Preparation in Advance  
of AV Transit Implementation**

To the

**National Highway Cooperative Research Program  
(NCHRP)**

On project

**20-102 (02): Impacts of Laws and Regulations on CV and AV Technology  
Introduction in Transit Operations**



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## Foreword

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This working paper uses the following terminology and focus of its content in a manner consistent with all the associated working papers of the NCHRP 20-102(02) project.

**Definition of Automated Vehicle (AV) Transit** – The “system” comprising AV Transit includes:

1. Driving automation system(s) and technology per SAE J3016<sup>1</sup>;
  - a. Other vehicle systems and components which provide driver assistance such as lane departure warning when a human driver is performing the dynamic driving task (DDT) from inside the vehicle or from a remote location; and
2. Other monitoring, supervisory control and passenger safety systems, technologies and facilities necessary for public transit service, such as precision docking, automated door operation, and dispatch functions.

**Definition of Transit Vehicle Operator** – The typical term used to identify the person operating a transit vehicle is the “vehicle operator”. However, under SAE J3016 definitions and terminology, a human “driver” is the person who manually exercises in-vehicle braking, accelerating, steering, and transmission gear selection input devices to operate a vehicle. Considering the SAE standard’s intent to define terms for driving automation systems only, the term vehicle driver is specified. In the working papers, the terms vehicle driver and vehicle operator may be used interchangeably, depending on the context and point of emphasis. Likewise, the terms “remote driver” (per SAE J3016) and “remote operator” will likewise be used interchangeably.

**Definition of Transit Operating Agency** – Transit operating agencies can be any type of public, governmental or non-profit entity, such as transit authorities created with certain governmental responsibilities; municipal, county and state government public transportation departments; medical/educational institutions; and local management authorities/districts.

**Focused Nature of the Working Papers** – Each working paper has a focused purpose and is not intended to provide a comprehensive set of steps, actions or preparations encompassing the full evolution of AV Transit technology applications in public transit service. Some aspects of this project’s research have focused more on the ultimate operating conditions when AV technology is fully mature to understand the long term, ultimate state of automated transit technology, policy and regulations.

**Conclusions on AV Transit in the Final Report** – The Final Report will address information on the probable benefits and impacts of AV Transit, as well as articulate a roadmap of further research activities that technology, policy and regulations should follow over the next few decades.

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<sup>1</sup> SAE J3016 is the Society of Automotive Engineers Standard titled – Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles; the standard was revised September 30, 2016.

# 1. Introduction

Public Transit Agencies will face changes in the way they approach operating policy with the introduction of automated roadway vehicle (AV) technology over the next few decades. The impacts could require a rethinking of many aspects of the agency operations, with the results of the decisions affecting employees, agency management structure, and transit patrons. Throughout the first five working papers we have explored the following topics:

1. AV technology evolution for public transit
2. Safety considerations for AV transit
3. Workforce deployment issues
4. Agency operating policies
5. Laws and regulations

A wide range of actions have been identified from studying these aspects of AV transit. In this working paper, we consolidate all the identified actions across the five previous working papers into a “roadmap” of sorts that describes the implementation timeline for each activity. Many of the activities are inter-related to some degree. While technology may continue to develop in research and demonstration projects, widespread operations are limited by the sticky issues presented by the regulatory environment of public transit.

The existing framework of laws and regulations will need to be adjusted and adapted over the course of time to address AV transit applications. However, there is an equally important consideration of what must be changed and adapted in transit vehicle designs to satisfy laws and regulations that will not be changed.

There are many other relevant laws and regulations that are not being considered in this working paper which do not focus strictly on transit services, such as driving registration and licensing, product/vehicle liability, roadway infrastructure design standards and insurance requirements. The roles of local, state and federal government in establishing these types of laws and regulations are still developing. Other

## SAE J3016 Levels of Automation

- **Level 0** – the human driver does everything.
- **Level 1** – an automated system on the vehicle can *sometimes assist* the human driver conduct *some parts of* the driving task.
- **Level 2** – an automated system on the vehicle can *conduct* some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task.
- **Level 3** – an automated system can both conduct some parts of the driving task and monitor the driving environment *in some instances*, but the human driver must be ready to take back control when the automated system requests.
- **Level 4** – an automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate only in certain environments and under certain conditions.
- **Level 5** – the automated system can perform all driving tasks, under all conditions that a human driver could perform them.

**NOTE:** These levels of driving automation will be referred to in this document as **L1, L2, L3, L4** and **L5**. Refer to Working Paper #1, Chapter 3 for a more complete discussion.

NCHRP 20-102 projects and parallel research efforts at AAMVA, USDOT JPO, and NHTSA are discussing such issues.

Ultimately, the impacts of AV deployment in public transit services are implied by the answers to these key questions:

1. What changes to the laws and regulations must be addressed?
2. What will the vehicle technology suppliers need to change in their designs to fulfill mandatory laws and regulations?

## **Purpose and Organization of the NCHRP 20-102(02) Study**

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This project identifies a roadmap of activities to be performed by industry groups, legislatures, the federal government, and others that will facilitate automated roadway transit operations. The project is focused on the potential barriers imposed by operating authority policies, agency regulations, and governmental laws relative to the transit environment. Without adjustment, the combination of new technology with old rules could result in undue delays and restrictions to deployment, which reduces the cumulative societal benefits that could have accrued if automated systems technology was implemented earlier.

The project consists of five tasks:

1. Develop of a technology baseline for the current state of the practice in AV transit
2. Identify issues and impacts on transit vehicle driver and associated staff
3. Identify government regulations and laws impacting AV adoption in transit
4. Develop an implementation plan to address the challenges identified in Tasks 1-3
5. Prepare a final report consolidating Tasks 1-4

We have organized the five tasks to produce six working papers, and an implementation roadmap for transit automation in the final report. The Working Paper #1 provides an overview of the deployment scenarios for AV technology in transit applications.

Working paper #2 provides a foundation of technical information concerning safety from which subsequent considerations of operating agency policy and governmental safety regulations can be addressed.

Working Papers #3 Workforce Deployment and #4 Operating Agency Policy address the implications of automating roadway transit vehicles with respect to local operating agency issues, including labor relations and training, broad operating planning and policy, and response to governmental laws and regulations.

Working Paper #5 addresses issues and possible changes to the federal and state governmental laws and regulations over public transit that should be researched, as well as issues and possible changes that may be required in vehicle designs to effectively comply with regulations.

Finally, Working Paper #6 addresses the preliminary timeline for deployment of progressive transit automation in overall consideration of technology, policy and regulatory changes that will be required.

Then in the final report for the project, an assessment is discussed of the overall benefits and impacts of AV technology on public transit, and a proposed “roadmap” for further research will be described.

## **Organization of this Working Paper Contents**

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This working paper is organized by discussing key actions and activities identified in each of the first five working papers:

1. AV technology evolution for public transit
2. Safety considerations for AV transit
3. Workforce deployment issues
4. Agency operating policies
5. Laws and regulations

Under each of these categories activities are listed in a standardized format describing:

1. The nature of the activity
2. The urgency or potential timeliness of the activity
3. Other related precedent or antecedent activities
4. Likely schedule and budgetary (particularly for research and development tasks that may be added to the 20-102 series of projects or undertaken by TCRP or other programs) estimates

## 2. AV Technology Evolution in Transit

Actions identified in WP#1 include:

1. Assessment of restrictions on transit platooning strategies
2. Research identifying possible changes to transit facilities and stations
3. Research on transit vehicle sizing, dynamic “entrainment”, and other innovations enabled by automation
4. Research on design of platform edge protection and automated entry for vehicle berths

### **Assessment of restrictions on transit platooning strategies**

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**Description** – Platooning of transit vehicles has been demonstrated as feasible more than 14 years ago. Several states have restrictions on following distances that may preclude platooning of vehicles at short headways. This applies to both trucks and buses. AV/CV technologies enable platooning of vehicles that can have many benefits including fuel usage and increased capacity, without need for articulated coaches in BRT guideways. This review of existing regulations would focus on identifying the safety case for relaxation of such restrictions to deliver the anticipated benefits. Differences between truck and bus platooning would also be highlighted.

**Urgency** – May resolve naturally as the trucking industry demonstrates that platooning has significant benefits for interstate travel. Not a critical path element, but worthy of attention in 2018-2020 time frame.

**Related activities** – Studies on virtual entrainment, design of multi-berth stations, and use of AV for high-speed BRT

**Budget/Schedule** – Small-scale study, \$150K, 9 months

### **Changes to transit facilities and stations**

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**Description** – Dynamic-dispatch, direct route systems of smaller shuttle-type vehicles will likely need station and intermodal center designs that are much different from existing transit facilities. AV transit vehicles without human attendants will need station designs that safely accommodate all types of passengers.

**Urgency** – AV transit shuttle systems are not yet proven at speeds that can perform as large-scale revenue-service systems without dedicated guideways. As transit agencies gain more experience with small-scale point to point systems and simple loops, this issue will be more relevant as network possibilities are realized. 2020-2022 target date.

**Related activities** – Studies on virtual entrainment, design of multi-berth stations, and use of AV for high-speed BRTs

**Budget/Schedule** – Medium-scale study, \$1M, 18 months

## Transit vehicle sizing, entrainment, and other innovations

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**Description** – Dynamic-dispatch, direct route systems of smaller shuttle-type vehicles may allow new concepts such as virtual entrainment that can increase capacity of highly traveled routes without operation of today’s traditional coaches, articulated coaches, or even light rail. Groups of smaller vehicles may be able to be coupled dynamically to serve different demands between specific stations without the limitations of traditional operations that stop at all stops in-between.

**Urgency** – AV transit shuttle systems are not yet proven at speeds that can perform as large-scale revenue-service systems without dedicated guideways. As transit agencies gain more experience with networks of dynamically-dispatched individual vehicles, this issue will be more relevant. 2022-2025 target date.

**Related activities** – Studies on design of multi-berth stations, technology evolution, progress of safe shuttle operations at arterial speeds

**Budget/Schedule** – Large-scale study, \$1M, 24 months; may also take form of “AV transit challenge” similar to DARPA grand challenge, Smart City challenge, etc.

## Platform door protection and automated entry at AV berths

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**Description** – AV transit vehicles without human attendants will need station designs that safely accommodate the loading and unloading of all types of passengers including the disabled and elderly.

**Urgency** – As transit agencies gain more experience with networks of dynamically-dispatched individual vehicles, this issue will be more relevant. 2020-2022 target date.

**Related activities** – Studies on design of multi-berth stations, progress of safe shuttle operations at arterial speeds

**Budget/Schedule** – Pilot-projects: \$5M-\$20M, 24 months

### 3. Safety Considerations for AV Transit

Actions identified in WP#2 include:

1. Categories of hazards and risks for L3 and L4 AV transit
2. Hazards analysis methodology for L3 and L4 AV transit implementation
3. New consensus safety standard(s) for AV transit systems
4. Transit operational design domain definitions
5. Hazards assessment and mitigations for L3 operations

#### Categories of hazards and risks for L3 and L4 AV Transit

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**Description** – This study would comprehensively itemize all categories of risks and hazards in AV transit operations as defined by MIL Std 882 and its derivatives. All phases of transit service would be covered including stations, berths, boarding and alighting, dedicated guideways, mixed-traffic operations, and so on.

**Urgency** – As the popularity of low-speed L4 shuttles is growing, this guidance is needed imminently before systems are introduced into regular revenue service. 2018-2019 target date.

**Related activities** – Generic hazards analysis methodology, consensus safety standard

**Budget/Schedule** – medium-scale study, \$250K; 12 months

#### Hazards analysis methodology for L3/L4 AV transit implementation

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**Description** – This study would follow the definition of hazards and risks. The design guidelines would be used by transit agencies to plan the implementation of AV transit routes. Separate yet compatible guidelines are needed for L3 and L4 systems. All phases of transit service would be covered including stations, berths, boarding and alighting, dedicated guideways, mixed-traffic operations, and so on.

**Urgency** – As the popularity of low-speed L4 shuttles is growing, this guidance is needed imminently before systems are introduced into regular revenue service. 2018-2019 target date. L4 operations dependent upon regulatory issue resolutions.

**Related activities** – hazards and risks identification, consensus safety standard

**Budget/Schedule** – medium-scale study, \$500K; 18 months

#### Consensus safety standard(s) for AV Transit systems

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**Description** – Existing automated guideway transit safety standards should be adapted for rubber-tire L4 AV systems. The design standards would assist transit agencies in system procurement, installation, and safe operations. Separate standards may also be needed for L3 systems. All phases of transit service would be covered in the standards including stations, berths, boarding and alighting, dedicated guideways, mixed-traffic operations, and so on. Some pilot project experiences may be needed before developing ratified standards.

**Urgency** – As the popularity of low-speed L4 shuttles is growing, this guidance is needed imminently before systems are introduced into regular revenue service. 2021-2023 target date. L4 operations dependent upon regulatory issue resolutions.

**Related activities** – hazards and risks identification, consensus safety standard

**Budget/Schedule** – large-scale effort, \$1.5M; 24 months

## **Transit Operational Design Domain Definitions**

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**Description** – Relative to the definition of safety standards and hazards analysis, it would be helpful to define a standard set of AV transit operational design domains (ODDs). This concept proposed by NHTSA in the AV model guidance is a helpful construct for everyone to “speak the same language”. This set of standard definitions would help agencies with procurement and discussing issues with a common vernacular. This activity could be developed in conjunction with the hazards analysis and safety standard definitions, or precede those activities.

**Urgency** – As the popularity of low-speed L4 shuttles is growing, a set of standard definitions could be helpful to focus conversations. 2018-2020 target date. L4 operations dependent upon regulatory issue resolutions.

**Related activities** – hazards and risks identification, consensus safety standard

**Budget/Schedule** – small-scale effort, \$150K; 9 months

## **Hazards assessment and mitigations for L3 AV Transit**

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**Description** – L3 systems pose significant challenges as the AV system is not in full control all the time. The handoff between vehicle and user control poses some risk, and potentially more risk for transit operations than for private vehicles. This study would identify mitigations to L3 handoff risks and define a standardized mitigation strategy for use of L3 AV transit.

**Urgency** – AV BRT systems are nearing introduction into service in Europe and the Middle East. Although regulatory issues need resolution for introduction of L3 AV in the U.S., at least one pilot project has already been conducted with L1 AV. Medium term target 2020-2023.

**Related activities** – hazards and risks identification, consensus safety standard

**Budget/Schedule** – medium-scale effort, \$350K; 15 months

## 4. Workforce Deployment Issues

Actions identified in WP#3 include:

1. Definition of AV transit employee roles and responsibilities
2. Employee involvement guidelines
3. Union Contracting Guidelines
4. Automation of employee actions in compliance with ADA

### Definition of AV transit employee roles and responsibilities

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**Description** – While there is much concern about AV transit systems displacing vehicle drivers, there will be plenty of other jobs and positions at transit agencies to manage the operations of AV systems. This includes staff to remote-pilot the vehicles, security monitoring, station attendants, cleaning, and maintenance and repair. The role of remote pilots is a particularly important one that requires careful design and specification. Staff training and KSAs will need attention as well. Standards will need to be developed for re-training.

**Urgency** – As transit agencies gain more experience with pilot deployments of low-speed L4 shuttles, this issue will require attention if/when agencies decide to scale up operations to revenue service and networked operation. 2020-2022 target date.

**Related activities** – Employee involvement guidelines, union contracting guidelines

**Budget/Schedule** – Medium-scale effort; \$350K: 18 months

### Employee involvement guidelines

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**Description** – While there is much concern about AV transit systems displacing vehicle drivers, there will be plenty of other jobs and positions at transit agencies to manage the operations of AV systems. As an agency begins to adopt AV transit services, interactions with union representatives and employee advocates will ensue. This planning guide may assist new agencies in following best practices for resolving issues with win-win outcomes.

**Urgency** – As transit agencies gain more experience with pilot deployments of low-speed L4 shuttles, this issue will require attention if/when agencies decide to scale up operations to revenue service and networked operation. 2021-2023 target date.

**Related activities** – AV transit employee roles and responsibilities, union contracting guidelines

**Budget/Schedule** – Small-scale effort; \$200K: 12 months

## Union contracting guidelines

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**Description** – While there is much concern about AV transit systems displacing vehicle drivers, there will be plenty of other jobs and positions at transit agencies to manage the operations of AV systems. As an agency begins to adopt AV transit services, interactions with union representatives and employee advocates will ensue. This effort will develop, in conjunction with existing union representatives, draft language for future union contracts that include provisions for AV transit services.

**Urgency** – As transit agencies gain more experience with pilot deployments of low-speed L4 shuttles, this issue will require attention if/when agencies decide to scale up operations to revenue service and networked operation. 2021-2023 target date.

**Related activities** – AV transit employee roles and responsibilities, employee involvement guidelines

**Budget/Schedule** – Medium-scale effort; \$500K: 18 months

## Automation of employee actions in compliance with ADA

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**Description** – AV transit is particularly challenged by ADA requirements. This study would document existing employee actions and responsibilities for ADA compliance and identify potential technology functions and features that could assist in providing win-win solutions.

**Urgency** – Deeper analysis of ADA requirements beyond what was done in this project can be started at any time, and it is important to resolve ADA issues as soon as possible for realization of benefits. 2019-2020 target date.

**Related activities** – AV transit employee roles and responsibilities

**Budget/Schedule** – Small-scale effort; \$250K: 15 months

## 5. Agency Operating Policies

Actions identified in WP#4 include:

1. Long range planning AV transit benefit/cost analysis guidelines
2. Integration of AV transit scenarios in regional transit master planning
3. AV transit service types and operational planning parameters
4. Benefit/cost analysis of conversion from L3 to L4 operations
5. AV Cybersecurity issues affecting transit agencies
6. Management of “big data” in AV transit systems
7. AV Operations Control Center Concept of Operations
8. Investigation of risk, liability, and insurance for AV transit operations

### Long range planning AV transit benefit/cost analysis guidelines

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**Description** – While conceptually it appears that dynamically-dispatched, point-to-point L4 AV transit service will provide mobility benefits (i.e. reducing travel time for transit patrons), it is unclear if operating costs will also be reduced for agencies. In addition, there are no existing tools for sizing of vehicles, fleets, stops, and designing networks and routes (which is not surprising, since the systems do not yet exist except in limited locations). This project would develop such a tool(s) for use by transit agencies in determining cost estimates for system delivery and benefit comparisons with existing services. Simulation tools will likely be required to develop trade-off formulas that can then be used by lower fidelity planning tools for agency planning activities.

**Urgency** – As transit agencies gain more experience with small demonstration projects of L4 AV transit in loops and single routes, networks are the next logical step. 2020-2022 target date.

**Related activities** – Integration of AV transit scenarios in regional transit master planning

**Budget/Schedule** – Large-scale effort, \$1M; 24 months

### Integration of AV transit scenarios in regional transit systems planning

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**Description** – Regional long-range transportation plans, whether they be for transit or for all transportation modes, generally look 10-20 years into the future. AV transit technologies will likely be available in that time frame. No current transportation planning tools consider L4 AV transit capabilities. Assuming regulatory issues can be mitigated, these services need to be included in long-range transportation plans such as a regional transit systems plan. This project would evaluate the current state of the art in long-range transit system planning and identify gaps that need to be addressed for agencies to properly consider L4 AV transit services in future scenarios. The project would also implement these functionalities in prototype planning tools and demonstrate the results on test cases with real-world transit agencies.

**Urgency** – As soon as practicable. 2019 target date.

**Related activities** – Long-range planning benefit/cost analysis

**Budget/Schedule** – Large-scale effort, \$750K; 24 months

## **AV transit service types and operational parameters**

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**Description** – Transit ridership suffers greatest from the first-mile, last-mile problem. Several types of AV transit operations can resolve these issues and likely boost ridership, or replace the need for high-capacity line-haul systems by operating point-to-point. In this research study, several types of services should be identified and detailed operational plans developed to illustrate how the services would be managed on a daily basis. Simulation tools may be needed to identify vehicle fleet sizing, dispatch characteristics, passenger service performance (e.g. station wait times) and other operational aspects such as recharging and refueling, maintenance, and deadheading.

**Urgency** – As transit agencies gain more experience with small demonstration projects of L4 AV transit in loops and single routes, using such systems for first-mile, last-mile solutions is a logical next step. 2019-2021 target date.

**Related activities** – Long-range planning benefit/cost analysis

**Budget/Schedule** – Large-scale effort, \$1M; 24 months

## **Benefit/cost analysis of L3 to L4 conversion**

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**Description** – Removing the operator may be generally considered a cost-saving measure, but it may be offset by other costs such as liability insurance, technology, and station enhancements. In this study, the benefits and costs associated with L3 and L4 operations should be compared.

**Urgency** – L3 transit BRT systems are only now being piloted in Europe and the Middle East. Confidence in L4 transit for standard and articulated coaches may require many more years of L3 experience. 2021-2022 target date.

**Related activities** – Integration of AV transit scenarios in long-range transit master planning

**Budget/Schedule** – Small-scale effort, \$250K; 12 months

## **AV Cybersecurity issues affecting transit agencies**

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**Description** – Cybersecurity of AVs is one of the most challenging technology issues faced by developers today. It is inherently necessary in transit operations that remote connections to the vehicle must be available, much more so than that for privately operated AVs. At the same time, those remote connections need to be strongly protected. In this study, the security risks to the vehicle, the communications system, and the operations center should be identified. Technically feasible mitigations should be designed and a standards guide and technical architecture for cybersecurity protections for transit be developed. Experiences in cybersecurity measures as developed for CVs in the USDOT pilot programs currently on-going in Tampa, New York City, and Wyoming will be a starting point for this work.

**Urgency** – Confidence in cyber-protection of AV transit systems is paramount to their successful introduction into revenue service. 2019-2020 target date.

**Related activities** – Security Operation Concepts in USDOT CV Pilots, AUTO-ISAC standards

**Budget/Schedule** – Medium-scale effort, \$750K; 18 months

### **Management of “Big Data” in AV transit systems**

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**Description** – The connected vehicle data available from AV transit systems including video/audio, location and status, command and controls, and diagnostics will be many orders of magnitude larger than any operations data collected by transit agencies today. Big data tools and technologies are currently mainstreamed in many commercial markets to manage huge data sets while gaining “actionable insights” through analytics and data science. In this study, guidance for transit agencies on use of big data systems for managing CV data from transit operations will be developed. The guide will educate transit agencies on use of the current state of the art, and identify strategies for integration of new tools and technologies with legacy systems and new operations practices.

**Urgency** – Even without AV systems, CV technologies are opening analytics opportunities for transit agencies already today. 2019-2020 target date.

**Related activities** – Operations control center concept of operations

**Budget/Schedule** – Medium-scale effort, \$350K; 18 months

### **AV Operations Control Center concept of operations**

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**Description** – L4 AV transit systems will require constant remote monitoring to ensure safety and security of the patrons. Vehicles may need to be remote piloted during unusual circumstances, and communications will need to be available always. This type of operation is much different than current OCC operations of a typical transit agency. New operating principles will need to be developed to ensure staff roles and responsibilities are appropriate and human factors issues are mitigated. It is unlikely that one operator will be needed for each vehicle (this would defeat the basic purpose of removing drivers from the shuttles), but it is currently unknown how many vehicles a single operator could monitor simultaneously (4? 8? 16?). Human factors research is needed to simulate a variety of situations in determining guidance for OCC staffing levels and operating principles to ensure safe operations.

**Urgency** – As L4 shuttles are gaining in popularity and being tested in single routes and loops, the next logical step is networks and larger fleets of shuttles which will require concerted efforts to develop formalized operations concepts. 2020-2021 target date.

**Related activities** – Operations control center concept of operations

**Budget/Schedule** – Medium-scale effort, \$350K; 18 months

### **Investigation of risk, liability, and insurance for AV operations**

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**Description** – It is anticipated that automation will increase safety of vehicle operations with 360-degree situational awareness and standardized vehicle behaviors, but this is currently unproven. Initially, insurance and liability protection of AV transit systems may be costlier. As technology is proven, liability claims will likely drop and self-insurance costs will be reduced, enabling agencies to pay for the technologies. Some of these liabilities may then be passed to

the manufacturer. A primer on liability and insurance issues in AV transit is needed to educate the community and identify models for technology introduction that can be adopted by agencies as they consider providing AV transit services.

**Urgency** – The motivation for AV adoption in transit operations to reduce liability claim costs is profound. 2018-2019 target date.

**Related activities** – Categories of hazards and risks for L3/L4 AV transit systems

**Budget/Schedule** – Small-scale effort, \$150K; 12 months

## 6. Laws and Regulations

Actions identified in WP#5 include:

1. Scenario analysis of AV transit operations without federal funding
2. Possible changes to Section 13c of Federal Transit Act
3. Evaluation of Applicability of transit-related laws and regulations to private contractors (e.g. “TNCs”)
4. Evaluation of OSHA regulations for robotic vehicles in the workplace
5. Evaluation of Minority population involvement and environmental justice in AV transit
6. Evaluation of Title VI adjustments and incentives
7. Evaluation of boarding requirements and exceptions to ADA compliance
8. Evaluation of Buy America requirements
9. Evaluation of Implications of FMVSS for low-speed L4 AV transit vehicles
10. Safety management system development guidance

### Scenario analysis of AV transit operations without federal funding

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**Description** – L4 AV transit systems may reduce operational costs significantly enough that a transit agency could operate without federal funds. As many of the regulatory challenges existing today stem from the provisions of federal funds, it is conceptually possible that many of these issues could be mitigated by operating without federal subsidy. However, this is merely conjecture without detailed analysis. This study would assess this possibility for small and perhaps medium-sized transit agencies to operate without federal support through PPPs and a variety of other fiscal and operational innovations.

**Urgency** – As the issues related to AV operations under receipt of federal funds are considerable, it is of high curiosity to analyze such scenarios sooner rather than later. 2019-2020 target date.

**Related activities** – Changes to Section 13c of Federal Transit Act, Evaluation of Title VI adjustments and incentives

**Budget/Schedule** – Small-scale study, \$150K; 12 months

### Possible changes to Section 13c of Federal Transit Act

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**Description** – As many of the regulatory challenges existing today stem from the provisions of federal funds, identifying potential mitigations are critical to evaluate. This study would further analyze transit regulations related to employee protections and propose innovative mitigations that may allow AV operations by public agencies. Issues include replacement and retraining of employees and how the use of contracted services that supply L4 AVs may or may not be subject to the rules.

**Urgency** – As the issues related to AV operations under receipt of federal funds are considerable, the study is needed as soon as practicable. 2018 target date.

**Related activities** – Evaluation of Title VI adjustments and incentives

**Budget/Schedule** – Medium-scale study, \$350K; 12 months

## **Evaluation of applicability of transit regulations on private contractors (e.g. “TNCs”)**

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**Description** – Currently in some states TNCs are considered taxi services and in others they are not. Without a driver, their argument that the service is “ride sharing” becomes less defensible, and may be considered a transit service, particularly if they service multiple strangers at the same time (who may or may not be going to the same place). This study would identify the legal applicability of transit regulations on TNCs, or private providers that contract such services to a public agency.

**Urgency** – As the issues related to AV operations under receipt of federal funds are considerable, the study is needed as soon as practicable. The recently-released TCRP project on PPPs between TNCs and transit agencies may address some of these issues. 2019 target date.

**Related activities** – Changes to Section 13c of Federal Transit Act

**Budget/Schedule** – Small-scale study, \$150K; 12 months

## **Evaluation of OSHA regulations for robotic vehicles in the workplace**

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**Description** – OSHA 29 CFR Part 1910 contains *Robotics in the Workplace from OSHA Publication 3067 – Concepts and Techniques of Machine Safeguarding*<sup>2</sup>. This aspect of OSHA regulations is worthy of further studies to determine if specific requirements are necessary for AV transit for operations facilities (dispatching and storage yards), as well as maintenance facilities where AVs must be “aware” of human(s) in the vicinity and communicate desired automated actions through some means (audio, lights, text, etc.).

**Urgency** – As L4 shuttles are gaining in popularity and being tested in single routes and loops, the next logical step is networks and larger fleets of shuttles which will require concerted efforts to develop formalized operations concepts. 2020-2021 target date.

**Related activities** – Changes to Section 13c of Federal Transit Act

**Budget/Schedule** – Small-scale study, \$150K; 12 months

## **Evaluation of minority populations and environmental justice in AV transit**

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**Description** – A working plan should be prepared by which minority populations can be engaged and involved in the public outreach process as planning for AV Transit deployment begins. Developed as guidance of transit operating agencies, the study documents will establish a framework for any transit agency to accomplish the required public involvement process with minority communities, as well as provide an initial assessment of how AV Transit can be deployed without violating Title VI Civil Rights law.

**Urgency** – Wide-spread acceptance of L4 transit operations is dependent upon resolution of environmental justice issues. 2020-2021 target date.

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<sup>2</sup> [https://www.osha.gov/Publications/Mach\\_SafeGuard/chapt6.html](https://www.osha.gov/Publications/Mach_SafeGuard/chapt6.html)

**Related activities** – Evaluation of changes to Title VI of the Civil Rights Act

**Budget/Schedule** – Small-scale study, \$150K; 12 months

### **Evaluation of Title VI adjustments and incentives**

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**Description** – The benefits to providing allowances or exceptions to the Title VI requirements should be studied to evaluate advancement of the progress of AV technology during the early years of transit deployment. The study will also assess the use of incentives to encourage AV transit deployment in low density, high transit dependency conditions.

**Urgency** – Wide-spread acceptance of L4 transit operations is dependent upon resolution of Title VI issues. 2020-2021 target date.

**Related activities** – Evaluation of environmental justice issues

**Budget/Schedule** – Small-scale study, \$150K; 12 months

### **Evaluation of boarding requirements and exceptions to ADA compliance**

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**Description** – L4 AV transit vehicles will have no operator to assist disabled patrons. In this study, the options for ADA compliance exceptions and boarding operations should be evaluated. In addition, technical design requirements, challenges and new potential hazards/risks to providing automated ramp deployment and automated wheelchair lift deployment will be identified. The means for automated wheelchair securement, and the potential technology required to allow remote operator involvement in the process will be identified.

**Urgency** – ADA requirements require resolution for wide-scale adoption of L4 AV transit operations. 2019-2021 target date.

**Related activities** – Evaluation of environmental justice issues

**Budget/Schedule** – Medium-scale study, \$500K; 18 months

### **Evaluation of Buy America requirements**

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**Description** – FTA funding for New Starts transit projects is normally contingent on compliance with Buy America regulations in the procurement of systems, facilities and rolling stock. The stipulations of the regulations generally require that equipment and construction materials be purchased from American manufacturing sources specified as a percentage of total content for the subsystems and component parts. As a way to address the evolution of AV technology and to not constrain innovation, this approach of the federal government granting waivers may be a key path to moving forward in the near term. This study will identify the potential for alternative requirements and revisions for L4 AV operations.

**Urgency** – The issue may resolve itself as foreign suppliers work within the existing regulations, but is still worthy of evaluation. 2021-2023 target date.

**Related activities** – N/A

**Budget/Schedule** – Small-scale study, \$150K; 12 months

### **Evaluation of implication of FMVSS for low-speed AVs**

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**Description** – The National Highway Traffic Safety Administration (NHTSA) establishes and maintains safety standards known as the Federal Motor Vehicle Safety Standards and Regulations (FMVSS) for the automobile industry in the United States. The FMVSS are only one part of NHTSA’s responsibility, but the ultimate regulation of AV technology will likely come through new FMVSS regulations. A study will evaluate if the crashworthiness criteria can be adjusted for AV technology and if less stringent crashworthiness and crash survivability criteria be made in the near term for AV transit vehicles that operate in protected environments dedicated to transit vehicles and pedestrians (such as campuses, parking lots, and guideways).

**Urgency** – Low speed shuttles currently do not adhere to FMVSS for operation in mixed traffic facilities. As the interest in L4 AV shuttles is growing quickly, this evaluation study is needed sooner rather than later. 2019-2021 target date.

**Related activities** – N/A

**Budget/Schedule** – Small-scale study, \$150K; 12 months

### **Safety Management System development guidance**

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**Description** – Recent updates to these FTA safety programs have included a Safety Management System (SMS) component which has drawn extensively from the safety program experience of the Federal Aviation Administration (FAA). As with other FTA regulatory guidelines, noncompliance with these safety rules by a transit operating agency could potentially jeopardize FTA New Start funding or conceivably even incur fines or other penalties imposed by FTA if unsafe practices and/or designs are determined to be deployed. Many operators that do not have fixed guideway transit and have never implemented such a thorough safety program as part of their bus operations will likely face a reorganization of their decision-making process, as well as enacting policies and procedures to develop, implement and maintain a comprehensive system safety program plan. Guidance is needed for these agencies on the establishment of SMS for AV transit.

**Urgency** – As the interest in L4 AV shuttles is growing quickly, this guidance is needed in the next few years. 2019-2021 target date.

**Related activities** – Hazard and risk identification, Safety assurance procedures

**Budget/Schedule** – Medium-scale study, \$350K; 18 months

## 7. Summary of Activities

Activity	Budget	Schedule (months)	Timeframe
Assessment of restrictions on transit platooning strategies	\$150K	9	2018-2020
Research identifying possible changes to transit facilities and stations	\$1M	18	2020-2022
Research on transit vehicle sizing, dynamic “entrainment”, and other innovations enabled by automation	\$1M	24	2022-2025
Research on design of platform edge protection and automated entry for vehicle berths	\$5M-\$20M	24	2020-2022
Categories of hazards and risks for L3 and L4 AV transit	\$250K	12	2018-2019
Hazards analysis methodology for L3 and L4 AV transit implementation	\$500K	18	2018-2019
New consensus safety standard(s) for AV transit systems	\$1.5M	24	2021-2023
Transit operational design domain definitions	\$150K	9	2018-2020
Hazards assessment and mitigations for L3 operations	\$350K	15	2020-2023
Definition of AV transit employee roles and responsibilities	\$350K	18	2020-2022
Employee involvement guidelines	\$200K	12	2021-2023
Union Contracting Guidelines	\$500K	18	2021-2023
Automation of employee actions in compliance with ADA	\$250K	15	2019-2020
Long range planning AV transit benefit/cost analysis guidelines	\$1M	24	2020-2022
Integration of AV transit scenarios in regional transit master planning	\$750K	24	2019
AV transit service types and operational planning parameters	\$1M	24	2019-2021
Benefit/cost analysis of conversion from L3 to L4 operations	\$250K	12	2021-2022
AV Cybersecurity issues affecting transit agencies	\$750K	18	2019-2020
Management of “big data” in AV transit systems	\$350K	18	2019-2020

Activity	Budget	Schedule (months)	Timeframe
AV Operations Control Center Concept of Operations	\$350K	18	2020-2021
Investigation of risk, liability, and insurance for AV transit operations	\$150K	12	2018-2019
Scenario analysis of AV transit operations without federal funding	\$150K	12	2019-2020
Possible changes to Section 13c of Federal Transit Act	\$350K	12	2018
Evaluation of Applicability of transit-related laws and regulations to private contractors (e.g. "TNCs")	\$150K	12	2020-2021
Evaluation of OSHA regulations for robotic vehicles in the workplace	\$150K	12	2020-2021
Evaluation of Minority population involvement and environmental justice in AV transit	\$150K	12	2020-2021
Evaluation of Title VI adjustments and incentives	\$150K	12	2020-2021
Evaluation of boarding requirements and exceptions to ADA compliance	\$500K	18	2019-2020
Evaluation of Buy America requirements	\$150K	12	2021-2023
Evaluation of Implications of FMVSS for low-speed L4 AV transit vehicles	\$150K	12	2019-2021
Safety management system development guidance	\$350K	18	2019-2021