# Center for Advanced Multimodal Mobility Solutions and Education

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# What do we want from Autonomous Vehicles (AVs)?

*Using Participatory Planning to Identify Stakeholders' Desired Outcomes from the Strategic Deployment of Emerging Transportation Technology*

**Final Report**

by

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## DISCLAIMER

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# EXCUTIVE SUMMARY

The overarching goal of our research is to reframe debate about the AVs from its current perspective that encourages states to understand **how to respond to this evolving technology** to a more proactive stance organized around the question of **what outcomes society would like to obtain from the strategic deployment of AV technology?** In other words, rather than accept that AVs are an inevitable technology that state DOTs need to prepare for and accommodate, a more forward-looking approach would be to think through some potential consequences of AV adoption, and use the outcomes from these analyses as the basis for public engagement with stakeholders to determine what outcomes would be preferred. This approach of using scenario analysis as a form of exploration to determine stakeholder preferences gives agency to stakeholders, will help to highlight areas of potential conflict between different interest groups, and will also likely help to identify and hopefully avoid potential unintended and unwanted consequences of technology adoption.

For this project we adapted three scenarios from the National Issues Forum for using in structuring a discussion with the general public at a public forum held in Bloomfield, Connecticut. The three scenarios were chosen to reflect many of the issues that are highlighted in our Connecticut Transportation Index for Sustainable Places (TISP). The three scenarios considered were i) Promote human control behind the wheel, ii) Preserve jobs and expand employment, or iii) Support the rapid development of driverless vehicles to improve safety and traffic on highways

Participants in our workshop generally favored retaining human control at the wheel, yet could see benefits of various autonomous features, if there is legal provision that these features can be overridden. The challenge would be in keeping drivers attentive to the scene. Humans, they believe, have an element of moral judgement about what to do, and vary their driving by the place where they are. Furthermore, the participates were concerned that weather affects the functionality of autonomous vehicles, so adoption of the technology must take this into consideration.

Autonomous vehicles as mass transit was highly favored by the participants. This is at variance with the typical discuss in the USA which is almost always focused as AVs as cars. This focus on AVs as mass transit was partly a response to the concern that the expense and affordability of AV technology will further exacerbate inequalities already built into the existing transportation system. The participants also emphasize the point that legislators need to protect pedestrians, workers, and citizens when crafting legislation. Participants agreed that there is a tension between unemployment and advancement of technology, and what they see as important is that jobs be preserved.

The second stage of the project was to bring the perspective of our participants to Connecticut state legislators that are working on crafting AV legislation and to conduct structured interviews with these legislators. To do this we crafted a questionnaire to guide the interview with the legislators. This stage of the project was designed both as research dissemination but also for learning the perspective of the law makers as it relates to this issue. This stage of the project is still ongoing as we have had to conform to the very restrictive legislative calendar in Connecticut.

# Chapter 1: Introduction

## Problem Statement

Increased testing of various types of autonomous vehicles (AVs) on the world's roads has prompted intense speculation about the future of transportation and its societal implications. Futurist, Thomas Frey, depicts driverless vehicles as a disruptive technology that will revolutionize society. Various scenarios have been sketched out to consider how that revolution may unfold. In its mildest form, the transformation consists of AVs replacing existing vehicles on a 1:1 basis. Another pathway suggests that people will no longer own personal vehicles and will instead shift entirely to using shared vehicles. One dramatic possibility being floated is that shared AVs will be embraced to such an extent by society that they will render public transportation obsolete (1).

Discussions about AVs are not limited to futurists. Former Transportation Secretary, Anthony Foxx, described a similar vision of a 'driverless America' across all transportation sectors including air (2). Proponents of AVs—especially the private sector developers—are positioning this new technology as able to solve a wide array of problems including safety, congestion, and parking provision in urban areas. Barely any consideration has been given as to how AVs will affect the remit and day-to-day operations of government entities involved in transportation. A notable exception is a list of rules that city planner, Jeff Speck, has devised to help city mayors intended "*to ease the pain and increase the pleasure of eventual AV proliferation*" (3). At a recent summit on Autonomous Vehicles in Mystic, CT, Connecticut DOT Commissioner Redeker acutely observed that while AVs may potentially reduce the operating costs of public transportation through salary savings for vehicle operators, considerable amounts of funding will still be needed for physical infrastructure such as roads and bridges that need to be repaired and replaced (4). We wholeheartedly agree and would add that we have not yet heard any discussion of who will pay for and maintain the cyber infrastructure needed for AVs to communicate with their surroundings. The prevailing assumption is that this will be worked out (5), but how and to whose cost/benefit is extremely fuzzy.

## Objectives

The overarching goal of our research is to reframe debate about the AVs from its current perspective that encourages states to understand **how to respond to this evolving technology** to a more proactive stance organized around the question of **what outcomes society would like to obtain from the strategic deployment of AV technology?** In other words, rather than accept that AVs are an inevitable technology that state DOTs need to prepare for and accommodate, a more forward-looking approach would be to think through some potential consequences of AV adoption, and use the outcomes from these analyses as the basis for public engagement with stakeholders to determine what outcomes would be preferred. This approach of using scenario analysis as a form of exploration to determine stakeholder preferences gives agency to stakeholders, will help to highlight areas of potential conflict between different interest groups, and will also likely help to identify and hopefully avoid potential unintended and unwanted consequences of technology adoption. It is important to clarify that the intention of this project is not to avoid technological adoption but instead to recognize that important decisions about disruptive technologies that may affect society can and should be based on reasoned and informed inquiry.

## Research Questions

The overarching question that we will address in this project is "**what outcomes would stakeholders like to achieve from the strategic deployment of AVs**?" To inform this question, we will use Transportation Index for Sustainable Places (TISP) already developed by our research group and make the necessary adaptations that are needed for AVs in order to help frame the discussion. We will then use the outcomes of this framework as the basis for structured and semi-structured interviews and focus groups with two main groups of stakeholders: (1) members of the general public; and (3) state legislators. We will ask each group to comment on what potential outcomes people object to the least/most, and more general open-ended inquiry as to what they would prefer AV technology to be able to do for society. We will pay particular attention to the following areas of focus:

- How will transportation financing be impacted by various adoption rates and ownership models (i.e. shared versus personal) for AVs?

- How much traditional physical as well as cyber infrastructure will different adoption rates and ownership models of AV require?

- Will AVs undermine or reinforce transit use in different contexts?

# Chapter 2: Theoretical Background

*"By 2021, we will see autonomous vehicles in operation across the country in ways that we [only] imagine today... Families will be able to walk out of their homes and call a vehicle ... that will take them to work or to school. You'll see companies ... start to use unmanned aircraft to deliver products to us."* Anthony Foxx, Former US Secretary of Transportation (2).

Our motivation to take a critical look at how the technological advancements associated with AVs is being framed has been inspired by historical inquiry into earlier socio-technological shifts (6-8). With specific respect to the automobile, our thinking has been heavily influenced by Peter Norton whose work revealed how the transition to automobiles in American cities resulted from 'motordom' (those who had a vested interest in promoting the automobile) winning a heated and sometimes bloody battle with society over the 'appropriate use' of the street (9). This retelling of history contrasts sharply with the narrative promoted by 'motordom' in which automobiles inevitably dominated American streets because they were a superior technology embraced by all. Technological innovations are almost universally framed as representing 'progress' that is good for society (10-11). Technological innovations do bring progress, but this progress can come at a cost—the trick for society is to maximize the advantages while minimizing the costs.

## Theoretical Framework

The general framework that informs our analysis is a Transportation Sustainability approach. A sustainable transportation system is defined as one that:

- Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, with equity both within and between generations;
- Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy; and
- Limits emissions and waste to those within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources, reuses and recycles components, and minimizes the use of land and the production of noise.

Our research group has used this concept to operationalize a Transportation Indicator for Sustainable Places (12). This framework forms a useful starting point for thinking about the various impacts that AVs may have. We will combine this framework with scenario analysis, a well-established technique that allows stakeholders to think through the implications of various decisions (13-15). It has been used in a wide variety of situations, notably to understand what outcomes may arise from taking different approached to climate change mitigation, and to envision 'alternative futures' for cities (16-18). Deploying rigorous scientific approaches to envisioning alterative futures allows stakeholders to engage in discussion about outcomes with a view to deciding which of them will be the most beneficial to society. This process frames the public discourse about the impacts of technology as a process that can be shaped by society to maximize the benefits and minimize the costs. This deliberative process that involves stakeholder engagement stands in sharp contrast to dominant discourses regarding technology that assume that adoption will be 'inevitable' because of its 'superiority'.

## Literature Review

Autonomous vehicles (AVs) or self-driving cars uses technology to partially or entirely replace the human driver in navigating and controlling a vehicle from an origin to a destination. The National Highway Traffic Safety Administration (NHTSA) has developed a five-level classification scheme based on the adaptation level and vehicle capabilities. Level 0 refers to the vehicles equipped with no automated features and completely navigate by driver. On the other side of the spectrum, Level 4 AV is fully autonomous vehicle that in theory it could drive with or without a driver present (19). The emergence of new automotive technologies has the potential to change travel in a way that will have significant impacts on transportation safety, fuel consumption, congestion, and travel costs. In recent years, a growing body of literature has studied various aspects of this emerging technology and their impacts. In this section, we will limit our discussion to those studies that have tried to evaluate a wider range of impacts of the AV technology rather on a focus on a single outcome.

Fagnant et al. conducted a study that classified AV impacts into benefits and barriers (or cost). They concluded that crash savings, travel time reduction, fuel efficiency and parking improvements are key potential benefits involved in the development of AVs. On the other hand, they considered market penetration, security and privacy, vehicle and technology costs, and litigation and liability issue as key barriers for the adoption of AVs. To minimize costs and uncertainties, they recommended the following: expanded research into autonomous vehicle, developing national guidelines for AV licensing, and determining appropriate standards for liability, privacy and security (20).

In response to the debate about the environmental impacts of AVs, Raphael Barcham (2015) developed a study to assess the energy and climate effects of this new technology (21). He identified that major environmental impacts involved in the adoption of AVs include fuel efficiency, vehicle emission, land use, and changes in travel behavior as measured by VMT. He stated that the climate impacts of AVs are, at this point, ambiguous and will depend on adoption patterns, which at this point in time are unclear (21). In 2016, Wadud et al. identified specific mechanisms through which vehicle automation may affect travel and energy demand and the resulting GHG emissions (22). They brought all of these elements together in a coherent energy decomposition framework. They also explored the net effects of automation on emissions under several different scenarios based on % change in energy consumption due to vehicle automation. They found that that automation might plausibly reduce road transport GHG emissions and energy use by half—or conversely, might double them—depending on which effects come to dominate. They also found that many potential energy-reduction benefits might be realized through partial automation, while the major energy/emission downside risks appear more likely at full automation (22).

Kockelman et al. quantified the crash-related gains of various scenarios of emerging AV technology and evaluated near-term and long-range impacts on car crashes in Texas. This study reviewed AVs impacts on safety and estimated crash count and crash cost reductions via various AV technologies. Finally, they provided a benefit-cost analysis to identify best safety strategies for Departments of Transportation to follow in the transition to new technologies and travel choices (23). Clement et al. made a series of assumptions to evaluate the economic impacts of AVs. They tried to monetize different impacts of AVs including their effect on the insurance industry, freight transportation, land use change, auto repair industry, oil and gas market, savings in medical costs, infrastructure and construction costs, and traffic congestion. Assuming that AVs eventually capture a large share of the automotive market, they found that, on average the development of the AVs would result in a huge economic value to the society on the order of $1.2 trillion total or $3,800 per American per year.

A synthesis of the literature mentioned above demonstrates that no study has yet evaluated the impact of AVs from a comprehensive sustainability viewpoint. Accordingly, one contribution of this project will be to bridge the concept and goals of sustainability and the consequences of emerging AV technology. To operationalize this contribution, we set out a comprehensive framework based on the sustainable transportation approach to assess the main impacts of introducing AV technology. Applying this framework to AVs will help to structure the discussions and also identify some of the many areas that have been overlooked in the existing literature on AV impacts.

The TISP framework was developed by our research group to assess the performance of different transportation systems through the lens of sustainability. This hierarchical model consists of three domains and 12 dimensions. The domains represent the three aspects of sustainability: environmental, social, and economic. These domains are characterized by different dimensions that represent a goal or a major objective that should be achieved in order for a transportation system to be considered sustainable (13-15).

Sustainable Transportation Goals: Based on the CST framework and the recommended definition of sustainable transport, Nichols et al. and later, Zhang et al. used a framework with 12 dimensions that serve as the backbone of the TISP (14-15). Each dimension represents a goal of the transportation system, which needs to be achieved under the concept of sustainability. This framework is discussed in more details below.

Environmental Sustainability Goals: Based on the literature analysis Zhang et al. distinguished four main goals for the environmental domain:
1. Minimize consumption of non-renewable and renewable resources for transportation. 2. Maximize land use efficiency for the transportation and the related place-making systems.
3. Minimize transportation and place-making system's impact on ecological systems.
4. Limit transportation-related waste and noise pollution.

These goals address what many would consider the most fundamental aspect of sustainability: the limited carrying capacity of the Earth. Under this domain, Dimensions 1 and 4 establish the importance of a sustainable transportation system to minimize resource use and limit related wastes, including pollution. Dimension 2 speaks to the amount of land used being consumed for transportation and human settlement (which has been shown to be a function of the type of transportation travel that predominates). Dimension 3 addresses the health of the overall ecosystem as affected by transportation and includes greenhouse gas emissions.

Social Sustainability Goals: The next four dimensions are categorized within the social aspects of transportation sustainability. They include the following:
5. Transportation system meets access needs in a way that is consistent with human health and safety.
6. Transportation planning, management and decision making is open, inclusive, equitable and democratic.
7. Transportation and placemaking system promotes social interaction and social equity.

8. Transportation and placemaking system meets the basic access needs of all individuals in an equitable manner.

Social sustainability, as it relates to transportation, is most often considered as planning to achieve social equity. From this perspective, dimension 5 emphasizes the importance of the safety and security of the transportation system and its impact on human health. Dimension 6 suggests the importance of a democratic decision-making process through collaboration between government agencies and community input. Dimension 7 sets a goal that the transportation system should improve social equity and social interaction, thereby strengthening the bonds within and between communities. Dimension 8 measures the ability of all classes of people to access services and goods via non-automobile means.

Economic Sustainability Goals: Zhang et al have identified four main goals for this sphere of sustainability:
9. Transportation is affordable for individuals.
10. The Transportation system is efficient for movement of people and goods.

11. The Transportation system is locally self-sufficient.
12. The Transportation system does not contribute to economic vulnerability of society.

To achieve a sustainable transportation system, the system must offer affordable choices for every individual in terms of the monetary and time costs. Dimension 9 captures the need for a cost-efficient transportation system. The ideal would be to expand gross domestic product with the smallest increase (or even a decrease) in vehicle miles traveled. Domain 11 addresses the importance of a transportation system that supports the local economy. Domain 12 focuses on the fiscal vulnerabilities that the transportation system imposes on society. In terms of monetary costs to society, one of society's risks is the long-term vulnerability and exposure to higher oil prices and limited supply of resources. If a place is economically sustainable or resilient, it should be able to endure potential shocks to the system.

Sustainable Transportation Indicators and Variables: Indicators represent specific objectives to needed to achieve the desired goals of sustainable transportation. Zheng et al identified 19 sustainable transportation indicators: 8 environmental, 7 social, and 4 economic indicators.

The environmental indicators are: energy consumption, infrastructure materials consumption, vehicle materials consumption, land consumption, ecological system, greenhouse gas emissions, pollution, and waste production. To assess all potential impacts of AVs, we need to take into account all of these indicators.

Zhang et al distinguished 8 social indicators including: health, traffic Safety, government interoperability, community involvement, social interaction, social equity, and accessibility. The review of existing studies reveals that we need to consider another social indicator: security. This term refers to treats that could be involved from hacking the controlling system of AVs. This could impose huge consequences on public health and societal insecurity.

Based on the base model (13), the economic sphere of sustainability is measured by 4 indicators: affordability, mobility, financial security, and economic vulnerability. Beside these indicators, we have identified two more economic indicators that are particularly relevant to understanding the impacts of AVs: labor and job market impacts, and cyber security costs.

## Overview of Workshop

The first phase of this project was a workshop conducted to get a perspective on the expectation for AVs from regular citizens not professionals. To date there has not been much research done to find out how regular citizens might be reacting to this impeding potentially major change in society. In order to provide a structure for this discussion we drawn on the work of the National Issues Forum that have developed a issues guide on "Driverless Vehicles". This guide provides a structured approach for a public discussion of this subject and was ideal for this study because the guide is based on many of the themes highlighted in our sustainable transportation index. This guideline allows for an open end discussion of the many environmental, social and economic considerations that could be potentially affected by the advent of AVs.

The NIF guideline is organized in terms of three scenarios or questions for discussion by the participants in the workshop. The three scenarios ask should we plan and develop policies for AVs to i) Promote human control behind the wheel, ii) Preserve jobs and expand employment, or iii) Support the rapid development of driverless vehicles to improve safety and traffic on highways. A description of the details provided to the participants for each of the three questions are given below.

### *Scenario #1. Promote human control behind the wheel*

"However predictable and consistent automated systems are, they cannot be perfectly reliable 100 percent of the time. The most successful of these systems incorporated the oversight of humans to correct occasional errors, a job that would be especially important in high speed traffic. This option calls for keeping humans behind the wheel of moving vehicles. Rather than attempting to completely control vehicles, autonomous driving features would focus on safety and convenience- for example, technology that enable drivers to park automatically and avoid crashes."

### *Scenario #2. Preserve jobs and expand employment*

"Automation has led to hundreds of thousands of unemployed workers in the past few decades. This option calls for slowing down the rush toward automation to prioritize consideration of the millions of American drivers and other who now earn their living in transportation. The focus should be on preserving jobs in this field and creating new ones. New jobs might include piloting autonomous vehicles in complex traffic conditions, upgrading and maintaining road infrastructure, monitoring the information communication systems that would be necessary for these vehicles to be networked or managing vehicle fleets. "

### *Scenario #3. Support development of driverless vehicles to improve safety and traffic on highways*

"Close to 40,000 Americans died in traffic crashes in 2016. Millions more were injured. If most or all vehicles become fully autonomous within the next two or three decades- as some observers say is possible- there will be far fewer road accidents as well as much cleaner air, and greatly reduced traffic snarls. People would get around more easily, including the elderly, the very young and those who can't drive because of a physical or mental impairment. We should encourage widespread testing of autonomous cars and trucks to ensure optimum safety of the new vehicle and increase people's confidence in them."

# Chapter 3: Results

The results of the workshop are given in this chapter. In addition, we discuss how these results were used to craft the interview questions for the legislators.

## Option #1. Promote human control behind the wheel

The advantages participants saw in the first option were focused on advantages that human drivers have over machines in terms of their ability to consider and evaluate multiple stimuli from multiple sources. Human drivers were understood to have a degree of safety that autonomous vehicles currently do not provide. The participants also made distinctions between public and private transportation options. They further perceived humans driving as having a greater chance for safety of all involved. They felt that any autonomous features should be assistive to the safety and convenience of drivers and pedestrians to avoid crashes.

Concerns about financial costs of autonomous vehicles were also strongly held by the participants. Overall, participants did not offer many consequences, or downsides to this option. Although some items were listed on the "cons" note sheets (not on the "pros"), they still show a clear preference for Option 1.

Additionally, data from surveys amplified the positive affirmation participants had regarding human control. Evaluation of the statement that "Laws requiring a licensed human operator of a vehicle at all times EVEN IF roads may not be safer" 65% of responses favor this, with the 61% of those responding that they "strongly favor" this. The bulk (80%) of respondents also favor "Expansion and improvement of public transportation to reduce the need for self-driving vehicles EVEN IF it is expensive."

In the same way that participants affirmed their support for this option, they opposed actions that would lead to loosen regulations on AVs. For example, in response to the statement, 70% oppose the notion that "Lawmakers should have loose regulations on autonomous vehicles to speed their development and use EVEN IF fewer safety and security regulations could leave vehicles open to accidents or hacking," and 20% were in favor (most "somewhat favor"), and 20% were "not sure." This reflects a sense that participants wanted regulations for their societal safety and economics.

## Option #2. Preserve jobs and expand employment

Participants devoted considerable nuance to Option 2, which focused on preserving jobs and expansion of employment. They expressed a preference toward protection of jobs across sectors, from distribution to maintenance to public transportation and ride sharing. They favored unions to support rideshare workers and worker retraining programs. They reinforced the sense that humans must be the center of attention, not the machines, particularly if it was decided to develop more autonomous vehicles.

As in Option 1, participants recorded comments in the "cons" sections that identified general concern about autonomous vehicles (e.g., "Cars can't be programmed to expect everything").
Issues related to insurance, taxation, how people in poverty would be affected, and what laws and police enforcement would be in place were mentioned. There was a concern

about vehicle separation: those with autonomous features should be kept separate from those vehicles with drivers.

Survey responses affirmed that "The state should develop worker retraining programs to help professional drivers transition to new careers EVEN IF some will not be able to start new careers," with 50% in favor, and 40% somewhat opposing that statement, and 5% strongly opposing, with 5% not sure.

**Option #3. Support development of driverless vehicles to improve safety and traffic on highways**
Participants considered whether we should prioritize support for the development of driverless vehicles with the goal of improving safety and traffic on highways.
Advantages to this include opportunities to require autonomous vehicles to be "green" and have "less gas pollution." Opportunities would be provided to determine who is at fault in crashes "through high tech analysis." Innovations like "invisible fencing such as magnetic paint, microchips, lines on roads" could help autonomous vehicles stay in the lanes they are supposed to, as long as there is "self-control override" available (again, presuming a driver is at the wheel).

People envision that speed laws would be enforced. They brought up the question of emergency services vehicles as a concern, that all vehicles would have to stop to allow them quick passage. Participants appreciated estimates about AVs saving lives. They also estimated that commutes could quicken (especially if AVs were in public transit) and that fewer injuries might result. They expressed concern that there is an accessibility issue related to people who do not have access to a regular vehicle.

**Summary**

Participants generally favored retaining human control at the wheel, yet could see benefits of various autonomous features, if there is legal provision that these features can be overridden. The challenge would be in keeping drivers attentive to the scene. Humans, they believe, have an element of moral judgement about what to do, and vary their driving by the place where they are. Furthermore, the participates were concerned that weather affects the functionality of autonomous vehicles, so adoption of the technology must take this into consideration.

Autonomous vehicles as mass transit was favored by the participants. This is at variance with the typical discuss in the USA which is almost always focused as AVs in cars. This focus on AVs as mass transit was partly a response to the concern that the expense and affordability of AV technology will further exacerbate inequalities. The participants also emphasize that point that legislators need to protect pedestrians, workers, and citizens when crafting legislation. Participants agreed that there is a tension between unemployment and advancement of technology, and what they see as important is that jobs be preserved.

Finally, the question of insurance liability was also highlighted as a difficult challenge that lawmakers will face. The overarching issue is who is liable when the AV malfunction? The participants felt that disentangling the responsibility of the various parties involved will pose ethical, moral and legal quandaries.

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