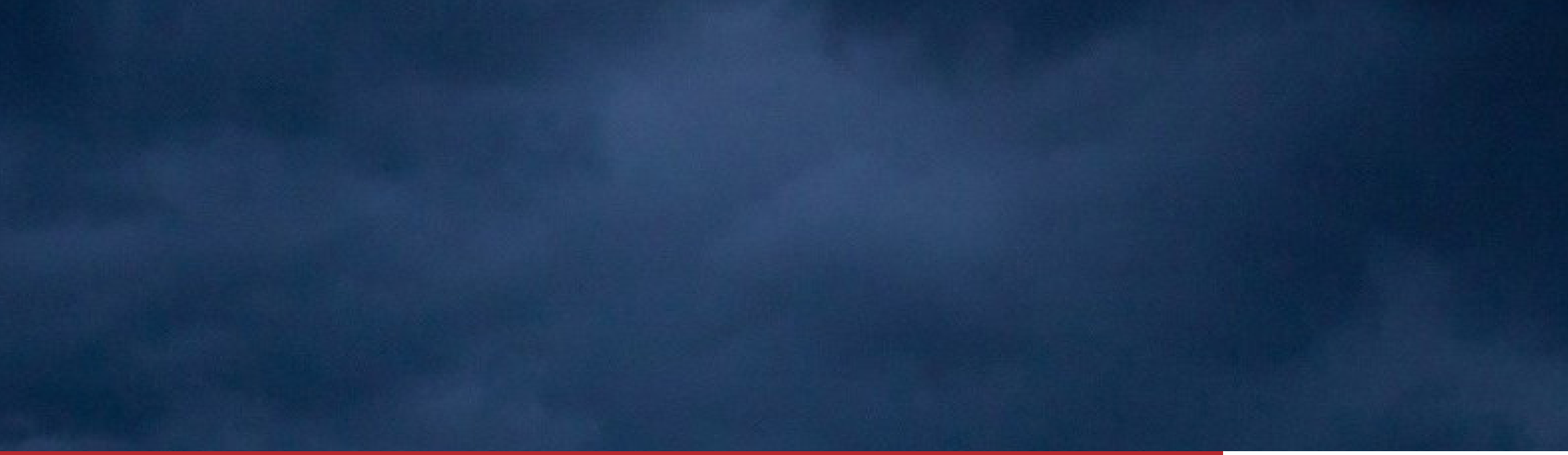
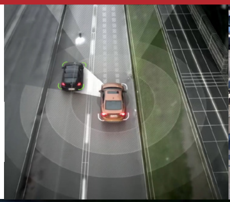


# AUTONOMOUS CAR POLICY REPORT

2014




Carnegie Mellon University

New Technology Commercialization Project Class



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Pittsburgh, PA

Course: New Technology Commercialization: Non-Market Public Policy Strategies for Entrepreneurs and Innovators

**Non-Market Strategy Analysis Project Report**

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MAY 2014



Report Design by Serban Mogos

**Disclaimer and Explanatory Note**

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# Executive Summary

Fully autonomous vehicle (AV) is a promising technology that is expected to have a number of significant benefits to society: increased mobility, better utilization of lands, reduced costs of congestion or increased road efficiency, and dramatically decreased car accidents. This technology is still in its early stage and is far from being fully autonomous with several technical challenges yet to be overcome. The timeline of widespread autonomous car adoption is uncertain and contingent on a number of factors: legal, policy and public acceptance, infrastructure support, and the achievement of technological milestones. Carnegie Mellon University (CMU) autonomous vehicle research group has established core competence in researching and developing this technology and proved itself a technology leader in this emerging frontier.

The non-market environment of the CMU AV project is characterized by the following components:

**Issues** : liability control, regulatory testing, labor force implication, security and privacy, fuel economy improvements, safety standards, distracted driving, governance, and public perception.

**Interests** : the Carnegie Mellon AV research group, General Motors, Auto Alliance, Google, insurance companies and transportation companies and groups. Interests are also discussed with respect to auto manufacturers, research universities, the transportation industry, regulatory bodies, and the common user of automobiles.

**Institutions** : the National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT), Society of Automotive Engineers (SAE), Institute of Electrical and Electronics Engineers (IEEE), potential AV companies, Traffic 21 at Carnegie Mellon, the Association for Unmanned Vehicle Systems International (AVUSI), and unionized groups.

**Information** : regulatory and legal status of AVs, important competitors, safety improvements, efficiency with respect to fuel economy and traffic, standards, insurance costs, and liability.

In order to facilitate early market entry, it is essential to have more test miles, to educate policy makers and the public, and to advocate the technology. Based on literature review and expert interviews, it is also determined that lobbying is the most effective way to address the liability issue. The following recommendations have been proposed in order to address these two key aspects:

**Create a strong brand and leader image** for CMU AV team through collaborations within and outside Carnegie Mellon University, positioning CMU & Pennsylvania as leaders of future autonomous mobility. The CMU research group is expected to act as leader, taking initiative to represent the whole industry to interact and influence public awareness and acceptance. This policy will be effective and efficient in achieving the goal of facilitating market entry by boosting policy and public acceptance

**Position Carnegie Mellon as the platform** to facilitate collaboration between key players in the emerging industry. Take advantage of the unique position of CMU as a leading research organization in areas of robotics, artificial intelligence, public policy and engineering to establish communication between the different parties involved in the AV environment, such as Google, General Motors and the Auto Alliance.

# Contents

# Introduction

**Self-driving cars and automated traffic infrastucture might have been only subjects of science-fiction movies, yet the latest advances in cumputer technology and communication systems are promising to make this a reality during our lifetimes.**

In 1939, New York hosted the second largest World Fair of all times. In an exposition covering over 1,216 acres of land, the Fair was an innovation for its time, being the first one to focus on "the world of tomorrow". Under the slogan "Dawn of a New Day", the trade show encouraged presenters to imagine the future based on the possibilities conceivable at that point in time. Why should we reminisce about the 1939 World Fair? Because 75 years ago, part of the Transportation section, the General Motors Futurama exhibit depicted the first public imagination of autonomous vehicles in the form of "electric cars powered by circuits embedded in the roadway and controlled by radio".

This concept presented in 1939 was a portrayal of humanity's fantasy to create self- driving cars as a safe, efficient and clean method of transportation. Once a topic only to be found in science fiction contexts, usually one of the wonderful technological achievements of utopian societies, today we find ourselves faced with the reality of potentially achieving this dream in our lifetimes. Since 2004, DARPA has spearheaded the research in the field of vehicle autonomy with its "Grand Challenges", in which Carnegie Mellon University was a strong competitor and winner in 2007. The Stanford team that won the challenge in 2005 started the Google Car project, which is currently the most visible effort in the area.

The conversion to a fully autonomous road infrastructure will be one of the most momentous challenges that humanity will face in the 21st century. While market-related issues will play an important role, this report is dedicated to analyzing in-depth the non-market issues that autonomous vehicles will face – public acceptance, regulation, liability. We believe the non-market strategy will be at least as important in ensuring the long-term success of this emerging technology. In order to address these issues, we propose a set of recommendations that are specifically targeted to the Carnegie Mellon team working on autonomous vehicles.

# Carnegie Mellon University

## Autonomous Car Project

## Prof. Raj Rajkumar

## CMU - General Motors Autonomous Driving Collaborative Research Laboratory

General Motors (GM) gave a gift of $3 million in 2000 and a renewed investment of $8 million in 2003 to the Information Technology Collaborative Research Labs (CRL) at Carnegie Mellon. The Information Technology CRL's goal is to improve the human interaction a vehicle through advancements in the vehicle's electronic, computing, reliability, and usability systems.

In 2007 the Carnegie Mellon AV team finished first in the DARPA Urban Challenge, a highly competitive research challenge testing research AV capabilities through a 55 mile long course with simulated traffic, maneuvers, merging, passing, parking, and negotiating traffic patterns. Due to the team's success GM donated $5 million to establish the Autonomous Driving CRL.

The CMU – GM AV project is being developed with four areas of research focus: perception, motion planning, tactical driving, and system architecture. The AV is unique compared to all other AV systems. The AV technology is concealed within the car, so it would not be likely for an untrained eye to tell the difference between the CMU-GM AV and a regular vehicle. Other systems have protruding sensors and supports on the top, sides and back of the vehicle. The CMU-GM AV is also expected to be affordable with a roughly $5,000 upgrade after commercialization.

Licensing and commercialization legalities will be handled through the Carnegie Mellon Technology Transfer office. The CMU team owns filed and pending patents relating to the software development of its four areas of research and CMU and GM have established agreements for IP collaboration.

Core Competence

Holistic Development

History of Excellence

Aesthetics

Low Cost

GM

Industry Partnership

## Features of the CMU Autonomous Car

# Technical Overview

Modern vehicles are increasingly adding features with the goal of simplifying the driver's job and automatizing parts of the driving process that can be safely translated into computer algorithms. For example, the 2014 version of select Mercedes models offers a Driver Assistance package that includes lane-guidance, collision prevention (automated braking and distance keeping), adaptive cruise control with radar technology and blind spot assist (source: mbusa.com). Based on the National Highway Traffic Safety Administration (NHTSA) classification of autonomous vehicles, we estimate that the current status of the technology is Level 2 (multiple functions), slowly approaching Level 3 (limited autonomous).

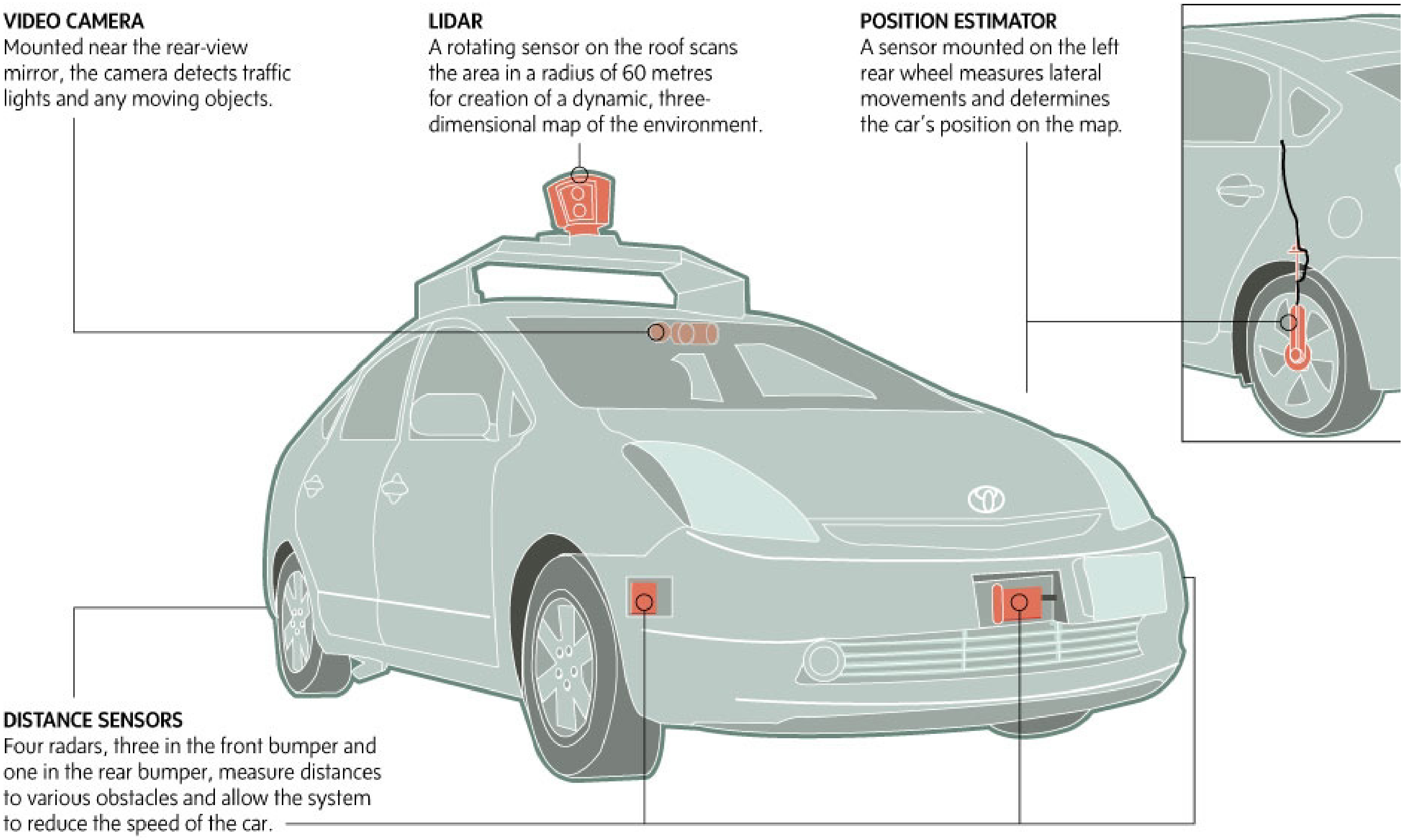
## Design of Autonomous Vehicles

The autonomous vehicle (AV) technology employs the "Sense-Plan-Act" design, fundamental to many robotic systems (see below, Forrest & Konca, 2007). For a perfectly autonomous car system, the sensors such as radar, light detection and ranging systems (or LIDAR - "light detection and ranging"), camera or GPS detect the environment and location of the vehicle. The software algorithms then interpret and process the sensor data, identify obstacles in the surrounding, categorize driving situations, plan the trajectories so as to exert the full control, for example, brake, steer, change lanes, throttle or provide warnings when conditions require the driver to retake control.

***Autonomous systems are already being used in vehicles today, like cruise control, lane keeping, collision detection, park assists, and even blind spot warnings.***

Our analysis will focus on the perspective of having Level 4, fully autonomous cars. Since this is a relatively long-term view, our final recommendations will also include suggestions for taking advantage of the intermediary, and more immediate, step of driver-assisted Level 3 car, which is more likely to enter into policy review in short term (4-5 years). The rest of this section will present an overview of the technology and a brief analysis of the potential market.

Many "Sense-Plan-Act" loops may be run in parallel on an AV with different frequencies (RAND, 2013, PP.59) to enable vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication. These technologies provide improved responsiveness and safety for AVs and use the DSRC (dedicated short-range communications) spectrum managed by the U.S. Government specifically for the use of the transportation industry.




CARRIE COCKBURN/THE GLOBE AND MAIL » SOURCES: GOOGLE; ARTICLESBASE.COM; WHEELS.CA

## Levels of Autonomy

Autonomous vehicles are vehicles whose operation is partially or fully controlled by computer programs, which may eventually require no human driver at all. Technological advancements have made possible the progression from traditional human-driven vehicles to completely autonomous vehicles. In the United States, NHTSA has established a definition of autonomous vehicles by level of automation [ (NHTSA, 2013)], summarized as the following:

**Level 0 - No-Automation :** The driver is in complete and sole control of the vehicle at all times.

**Level 1 - Function-specific Automation :** One or more specific control functions are automated independently, for example electronic stability control or dynamic brake support in emergencies. The driver is fully engaged and responsible for overall vehicle control.

**Level 2 - Combined Function Automation :** At least two controls are automated and work in unison, such as adaptive cruise control in combination with lane keeping. The driver disengages from active control in certain limited driving situations, and is still responsible for monitoring the roadway and safe operation.

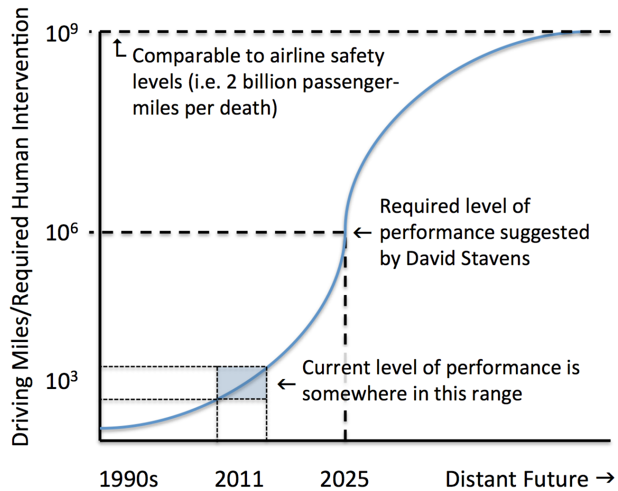
**Level 3 - Limited Self-Driving Automation :** The driver cedes full control of all safety-critical functions under certain traffic or environmental conditions, relying heavily on the vehicle to sense changes in those conditions that require the driver to take back control within a comfortable transition time.

**Level 4 - Full Self-Driving Automation :** The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. The driver is not expected to operate at any time or else the vehicle can be unoccupied.

## Current Status of Technology

Several major scientific challenges still persist and the current autonomous car technology is far from absolutely autonomous. Using the metric of "mean failure distance", which is the average number of autonomous miles driven per required human intervention, the following figure presents the technical S-Curve for mean failure distance drawn in year 2011 (Moore & Lu, 2011). It was predicted that it would take another 10 to 20 years for the technology to achieve the desired level in consistent of "six sigma" concept of quality (i.e. 3.4 failures per million).

**Figure 1:** Technological S-curve for mean failure distance (driving miles per required human intervention) for autonomous vehicle technology.




Note. From Autonomous Vehicles for Personal Transport: A Technology Assessment. Social Science Research Network. Jun 2011 by Moore & Lu.

## Technological Challenges

Though certain level of vehicle automation is possible today, for example the Google car in Level 3, it is fair to say that there are still significant improvements to be made in AV technology, and the most difficult challenges so far are perceived as "sensor perception and decision-making under conditions of uncertainty" (Moore & Lu, 2011).

With perfect perception (data gathering and interpretation), AVs could execute the best action among alternatives, achieving the optimal reliability that's far more than that of a human driver. The imperfection of the sensor systems lies in a variety of aspects such as accuracy limitation in computer vision and other sensor algorithms that can detect, recognize and locate objects, poor sensor performance during certain weather conditions (fog or rainstorms), reflectivity limitations of the radar and LIDAR systems, inaccurate positioning of GPS, sensor failures as a result of electrical break down, physical damage or age (Rand, 2014).

Yet another challenge faced by the technology is decision making of AV under condition of uncertainties. With traffic environment being fairly complex, consisting of many different elements such as other vehicles and road users that operate independently and dynamically, obstacles or unexpected traffic scenarios (poorly marked roads, construction zones, ambulances, crashes), it is challenging for the vehicle "to better understand surrounding vehicles' intentions / movements to perform..." not only "socially cooperative" but also safe behaviors (Wei et al., n.d.). Specifically, the task of performing a lane changing automatically is difficult because it is hard to understand and foresee intentions of other vehicles or road users. Many other challenges exist, conclusively human drivers are still expected to exert some level of supervisory role, being ready to switch to operate manually if the system is out of the comfort zone.

## Competitive Outlook

It is likely new cars in the future will be AVs, and Ford, GM, Toyota, Nissan, Volvo, and Audi, have already demonstrated their versions of self-driving cars. Below figures lists out major competitors of autonomous vehicles (Knight, 2013).

The Google Car for example, currently use a military grade $80 thousand dollar LIDAR system. Whereas BMW, Mercedes-Benz, and Nissan have been able to successfully integrate components and systems into what appears to be a normal looking car. The level of autonomy are comparable to that of the CMU-GM AV.

Other major competitors are companies like Honda, Acura, Ford, Toyota, Audi, and Volvo. All of which have semi-autonomous or fully autonomous vehicles being tested in R&D facilities and local highways (Tannert, 2014b).

**Traffic Ahead** Many carmakers are developing prototype vehicles that are capable of driving autonomously in certain situations. The technology is likely to hit the road around 2020.

| | BMW | Mercedes-Benz | Nissan | Google | General Motors |
|---|---|---|---|---|---|
| VEHICLE | 5 Series (modified) | S 500 Intelligent Drive Research Vehicle | Leaf EV (modified) | Prius and Lexus (modified) | Cadillac SRX (modified) |
| KEY TECHNOLOGIES | • Video camera tracks lane markings and reads road signs<br>• Radar sensors detect objects ahead<br>• Side laser scanners<br>• Ultrasonic sensors<br>• Differential GPS<br>• Very accurate map | • Stereo camera sees objects ahead in 3-D<br>• Additional cameras read road signs and detect traffic lights<br>• Short- and long-range radar<br>• Infrared camera<br>• Ultrasonic sensors | • Front and side radar<br>• Camera<br>• Front, rear, and side laser scanners<br>• Four wide-angle cameras show the driver the car's surroundings | • LIDAR on the roof detects objects around the car in 3-D<br>• Camera helps detect objects<br>• Front and side radar<br>• Inertial measuring unit tracks position<br>• Wheel encoder tracks movement<br>• Very accurate map | • Several laser sensors<br>• Radar<br>• Differential GPS<br>• Cameras<br>• Very accurate map |

MIT Technology Review

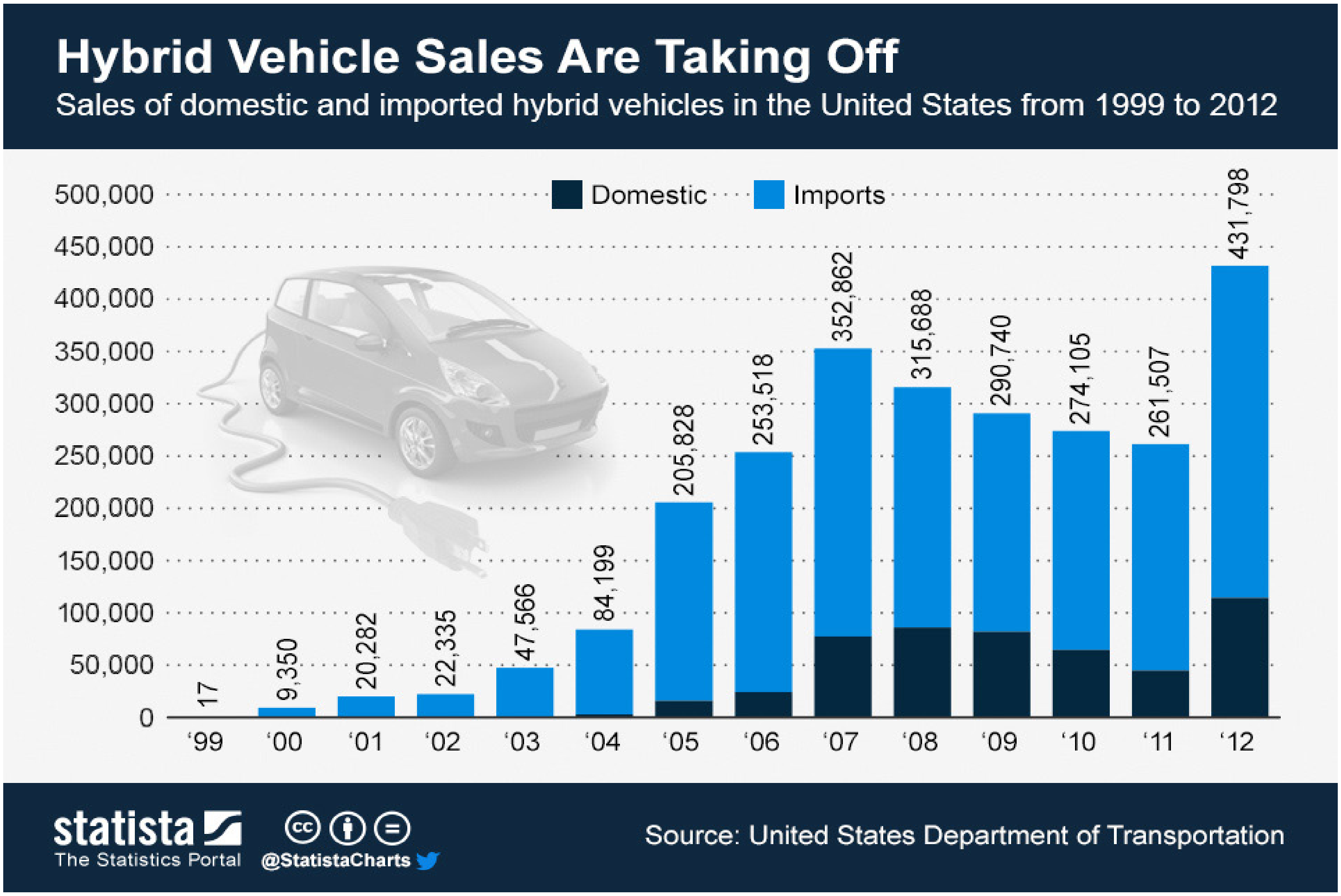
Note. From Driverless Cars Are Further Away Than you Think. MIT Technology Review. Oct 2013 by Knight.

# Potential Market

In the very long run, arguably decades later, fully AVs will have a potential to eventually replace most vehicles in the United States. The timeline is, however, uncertain, and is contingent on a number of factors, for example, legal, policy and public acceptance, infrastructure support, and when those major technological milestones will be achieved.

On the other hand, in the near future, say in next 10 - 20 years, adoption rate of semi autonomous vehicles (level 3) is not optimistic either. As a reference, in the united states it took 12 years for sales of hybrid cars, an intermediate between normal and fully electric cars, to hit 3% of annual total car sales since its introduction in 1999, which is 430,000 out of 14, 441, 000 cars sold in year 2012 (Cobb, 2012).

Summing up total sales of hybrid vehicles since its introduction, there were 2.57 million hybrid vehicles sold until 2012. In parallel, we believe 2.57 million would serve as a cap for the total addressable market size for level 3 autonomous vehicle within 12 years after its introduction, since driverless car is expected to encounter more political and public obstacles than that of hybrid cars, largely because of safety and reliability concerns.



1.2 million [1]

yearly global deaths from car accidents

10% (5 Gt) [2]

percentage of greenhouse gases due to road transportation (actual global amount)

$121 Billion [3]

yearly cost of traffic congestions in US

Safety and traffic efficiency can be greatly improved with the use of autonomous cars. However, the path to widespread adoption is full of challenges, given the disruptive nature of this technology.

[1] Source : World Health Organization (WHO) 2014. http://www.who.int/gho/road_safety/mortality/en/

[2] Source : Ecofys World GHG Emissions 2010. http://www.ecofys.com/files/files/asn-ecofys-2013-world-ghg-emissions-flow-chart-2010.pdf

[3] Source : TTI Urban Mobility Report 2012. http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/mobility-report-2012.pdf

# Opportunities

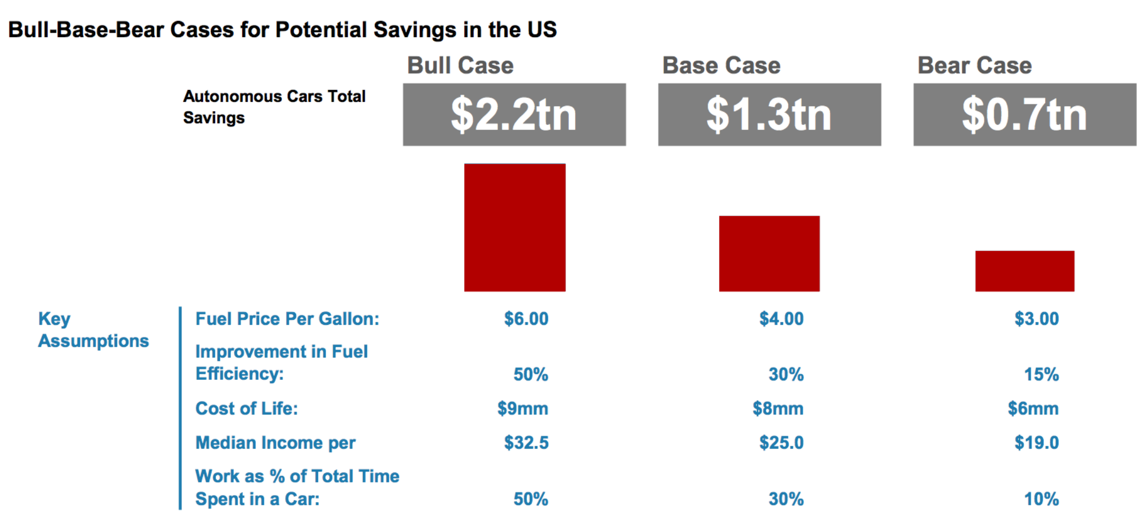
Vehicle automation is expected to have a number of significant benefits to society, such as reducing driver stress, reducing costs of travel and transportation, or increasing efficiency and safety (Eno Center for Transportation, 2013). AV manufacturers, when shaping their non-market strategy, could advocate these benefits so as to raise public awareness and acceptance of this new technology. We will briefly present all major benefits we identified.

## Safety

"Traffic crashes remain the primary reason for death of Americans between 15 and 27 years of age." (Eno, 2013). Today, there are 5.5 million automobile accidents, 2.22 million fatal or injurious, per year in the United States, 93% of which are attributed to be caused by a human factor associated with alcohol, speeding, and distraction. The net costs of the accidents reaches levels of $300 billion per year, 2% of the U.S. GDP. (Eno, 2013), driven mainly by the cost of the 34,000 lives lost. The adoption of autonomous vehicles has the ability to greatly reduce or almost completely eliminate the number of crashes. It is believed that AVs will eventually reduce accident fatalities to roughly 1% of current figures, but cannot eliminate crashes completely because some people will occasionally take control of their vehicles.

## Mobility

Today, many people do not drive because they are disabled, too young or too old. For example, in the United States alone, there are 36 million people with disabilities, making it very difficult for them to drive on their own (U.S. Census Bureau, 2011). Autonomous vehicles will greatly enhance further mobility for these populations, which may in turn increase the well-being of these populations. In addition, given the mobility and autonomy of this technology, there will be increased space utilization as parking lots can be relocated to less-expensive areas, and better ride sharing services as one could order an autonomous car for pick up from a mobile app. Lastly, the logistics industry will be positively impacted, as by then, autonomous trucks could work 24/7 and achieve maximized efficiency.

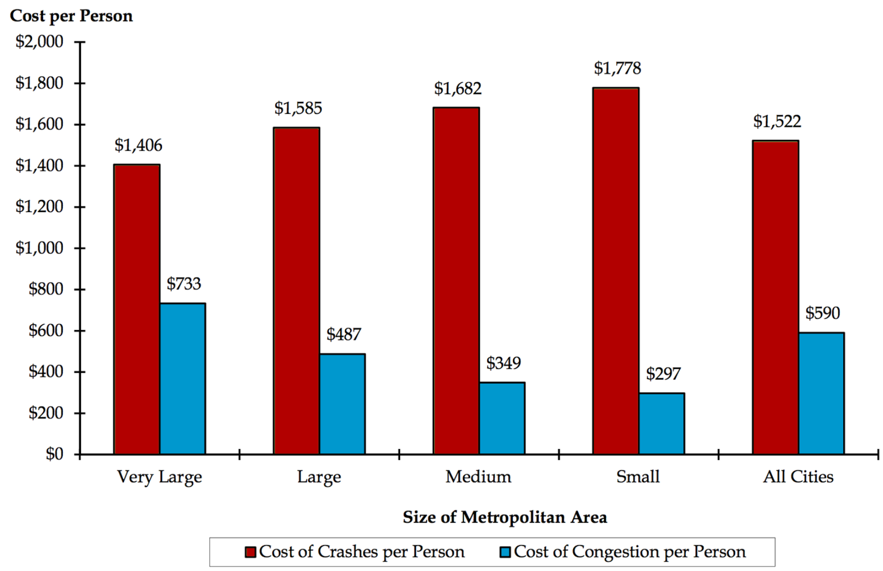



Note. From: "Autonomous Cars: Self-Driving the New Auto Industry Paradigm." Morgan Stanley Research.

## Improved Road Efficiency

Congestion and traffic operations can be reduced using autonomous vehicle through the use of sensors that can sense traffic flows by monitoring vehicle braking and acceleration through V2V monitoring. V2I monitoring can also be used to improve flow and safety in intersections and high-problem areas. These systems will utilize information from other vehicles, smart traffic systems and other forms of smart infrastructure, allowing for a much higher throughput of traffic and further reducing the risk of accidents through the use of predictive trajectory modeling.

**Annual Cost of Crashes and Congestion per Person**
*2009*




Note. From CRASHES VS. CONGESTION - What's the Cost to Society? Nov 2011, Cambridge Systematics, Inc.

## Reducing Cost of Congestion

Congestion represents a major cost to the society. "When all costs are totaled, the cost of traffic congestion to Americans in 2011 was up $1 billion over 2010 for a total of $121 billion. " (Tomlinson, 2013). Autonomous vehicle technology would reduce the cost of congestion since passengers could pursue other activities during a congestion. Furthermore, delays and congestion as a result of crashes will possibly be eliminated due to low crash rate. The decreased cost of driving, however, might increase the overall miles of travel, and in turn worsen the congestion. Therefore, net effect on congestion is uncertain, despite the reduced cost of congestion.

## Reducing Energy Use and Fuel Emissions

A lighter and efficient autonomous car that potentially drives itself to refueling areas would permit a viable system of electric and other alternative fuels with fewer refueling stations than would otherwise be required, because currently one of the disadvantages of vehicles powered by electricity or fuel cells is the lack of a refueling or recharging infrastructure (Rand, 2014).

## Opportunity - Early Market Entry in the Fierce Competition

With many different entities concurrently and independently researching AV technology, be it Auto Manufacturers such as BMW, Mercedes, Nissan, General Motors, or giant tech company like Google, competition of AV is deemed to be fierce. In such a crowded space, the winning technology will be the one that is early to market with an acceptable price and proven reliability; customers will expect a safe and reliable autonomous car. Based on the status quo, the CMU research groups stands in a strong position in technology, as discussed in the technology overview. If CMU autonomous vehicle technology could quickly move up the S-curve and validate its safety and reliability. There is a great potential that it could stand out, enter the market early and lead the competition.

# Challenges

The introduction of AV technology is expected have a huge positive impact in the long-term, as presented above, and will deeply change our society. Nevertheless, there are a number of challenges which will act as barriers to the implementation and commercialization of this disruptive innovation. We will outline the major obstacles below and focus on the key challenges in the next section.

## Technological Challenges

The technology is still far from being ready to be commercialized. Several companies including Mercedes (Garvin, 2014), Audi (Drew, 2013) , BMW (Stephen, 2013), Google (Soct, 2013), and Nissan (White, 2013) have already announced that they will have partially autonomous vehicles (Level 3) ready in the next 5-6 years. However, the ability to deal with any road situation under any weather condition, as required for a fully driverless car, will only be achieved after extensive research and testing, which experts estimate that it will take an additional 10-15 years (Moore & Lu, 2011). The challenge for a manufacturer of AV systems is to minimize potential risks of failure that can arise from improper identification of obstacles and classification of situations. The best strategy is to begin early testing of the technology in real-life conditions, thus generating valuable data on the operation of the car in autonomous mode, and identifying problems before mass production.

## Cost

The current cost of the systems that are still in research is too prohibitive for mass market. Only the AV module in the Google Car is estimated to be around $80 thousand (Knight, 2013) and it is expected to be reduced to half of that amount on commercialization. Even so, a 30-40k system additional to the base car is a premium that will limit the reach of autonomous cars in the early stages. Experts suggest that it will take over 10 years from the initial push to market for the cost to drop under 10k (Tannert, 2014a).

Additionally, an exponential increase in positive network externalities requires large investments in the V2V and V2I infrastructure. These systems will only be feasible once a critical mass of AVs on the roads has been achieved, and will enable impressive traffic efficiency through automatic coordination and accident prevention. Therefore, the benefit for the early adopters will be much lower at a very high cost, making market penetration even more challenging.

However, this also presents an opportunity considering the fierce competition in technology. The system that will manage to achieve similar results at lower costs will have a prime advantage for mass market penetration. Disruptive innovation in terms of low-cost and high-quality can shape the market even before the launch. One such example is the technology developed by a 19-year-old Romanian high-school student, Ionut Budisteanu, who created a camera and radar system for autonomous cars that costs only $4000, a fraction (10%) of the cost for the existing solutions.

## Labor Force Implications

Fully autonomous vehicles can replace millions of workers currently earning their income as professional drivers. Even though it can be argued that the economy will benefit as a whole by the increase in productivity, and that workers can be retrained, the introduction of AVs will cause an economic shock and is expected to be opposed by the affected parties. The most important unionized industries expected to be affected are taxi, trucking and marine freighting. The estimated number of people employed in these industries is 233,000 taxi drivers (BLS, 2012), 1,701,500 truck drivers (BLS, 2012) and 81,600 (BLS, 2012) in water transportation operations. AV manufacturers must recognize this side-effect early on and engage in discussions with the unions in order to ease their fears. Unions and other organized parties will likely attempt impose regulations to mandate an operator remain near the controls, similar to engineers on trains. The backlash received by the recent introduction of Uber cars in New York from the taxi drivers can act as an example of potential reaction to autonomous vehicles.

## Security & Privacy

A major concern in the debate surrounding AVs is the potential risk of a malicious attacker taking control of the car while in operation and provoking intentional accidents. Additionally, one could pinpoint the exact location of a person by knowing when the vehicle is in motion and its direction, and can create logs of his movements. Overall, the autonomous system is considered to create much larger security and privacy related issues than the on-board computers currently used in cars. AV manufacturers must invest a large portion of their R&D in researching methods for protecting the information and blocking any unauthorized access.

## Spectrum

In order for V2V and V2I systems to work properly, they must be provided with an appropriate amount of data on the spectrum. It will be important to convince the FCC to keep the spectrum available for the development and use of autonomous vehicles. “However, the FCC announced that they were considering reallocating the bandwidth to enhance Internet access, a move many stakeholders believe could cause harmful interference with communications among autonomous vehicles. The authors recommend that the FCC defer taking this step until further testing proves that it will not interfere with the development of communications among autonomous vehicles.” (RAND, 2014)

## Standards & Regulation

Standards are a means of uniformizing the manufacturing process across an industry. They have been considered a valuable instrument for increasing efficiency in organizations, reducing costs by 6% on average, according to Gary W. Pollack, Program Manager of Technical Projects from SAE International, as outlined during his guest lecture in Carnegie Mellon University in Feb 2014. Additionally, standards facilitate the quality assurance process and enable streamlined testing and certification. In new industries, a standard tends to emerge as the natural progression from a dominant design. Since there are usually several competing designs, the company who owns the chosen design will greatly benefit from standardization, while the rest might have to pay a premium for non-compliance. Overall, standards can shape the competitive landscape, with winners having an advantage in taking the lead, especially when a certain standard becomes required by law. Since the technology is still a few years away from completion, the regulatory landscape is still undefined, yet the discussions have already started, thus it is important for AV manufacturers to get involved in the process early on.

## Liability

In very close connection with standards and regulation lies the issue of liability, arguably the most challenging aspect of having mainstream driverless cars. When the driver is eliminated from the equation, the liability in case of an accident will fall on the car manufacturer and the suppliers of AV system hardware and software. This creates a major additional risk for the companies, since compensation in a liability lawsuit has to cover for medical expenses and other inconveniences caused by the accident, and is usually in the range $1-2 million dollars per incident (no life lost) (Miller, n.d.). This illustrates the importance of minimizing liability risk through any means possible, either by improving the technology or by passing favourable legislation at federal or state level. We will dedicate Chapter 4 of this report to explore in details the context around the liability issue and discuss potential outcomes of different policies.

## Risk of Market Failure

The key selling point of the AV technology is the huge social benefit arising from decrease in accidents and traffic improvements. However, these benefits will never be realized if the manufacturers do not have sufficient incentive to invest in the production and commercialization of autonomous cars, and if the consumers are not willing to pay the high initial price. It has been suggested (Rand, 2014) that the shift of liability from driver to manufacturer will expose the latter to huge risks of product liability lawsuits, with massive damage costs. This aspect, in combination with the high price of the system can cause a market failure, severely limiting the adoption of AVs. In such situations, the federal government is expected to intervene with subsidies and tax incentives, to lower the price and facilitate consumption.

## Insurance

One of the first questions that comes up when talking about the prospect of fully autonomous cars is “what will happen in the insurance market?”. We have yet to see a definitive answer, speculations being around the idea that the insurance companies will remain neutral in the process, since they will not actually experience any significant change to the bottom line. It is true that monthly premiums are expected to decrease, but also payouts will decrease since accidents will be rarer. Additionally, AV manufacturers will take in substantial product liability insurances to protect them in highly damaging lawsuits.

Insurance can also play a key role in fostering adoption of self-driving cars. CarInsurance.com ran a survey about whether drivers would be willing to buy the emerging technology, and the results indicated that the insurance rate can be a strong motivator. Without any incentive, only 20% of the respondends would be willing to buy an AV. When adding a 80% reduction in insurance rate, 90% of people were willing to consider the change.

# OPPORTUNITY

## Early market entry

We have briefly introduced the benefits of this technology, which in translation could bring us with numerous potentials in shaping the non-market strategy of raising public awareness. However, we decided to focus on ***early market entry in the fierce competition*** as our opportunity spotlight.

An early market entry is seen as an opportunity rather than a challenge. The CMU research group has established and demonstrated the capability of its AV to "do it all — from changing lanes on highways, driving in congested suburban traffic and navigating traffic light, Carnegie Mellon continues to be a leader on this emerging frontier." ("Press Release", 2013)

With many other independ players researching and developing on this technology, we believe that whoever brings the product to market early with an affordable price and validated safety and reliability will earn an early entry advantage. Our client should leverage its technology and the opportunity to be the early mover and market leader.

All of the other benefits mentioned will be more convincing should the product launch into the market and reach the consumers. The most viable path is through numerous tests and validation to prove the safety and reliability of the autonomous system.

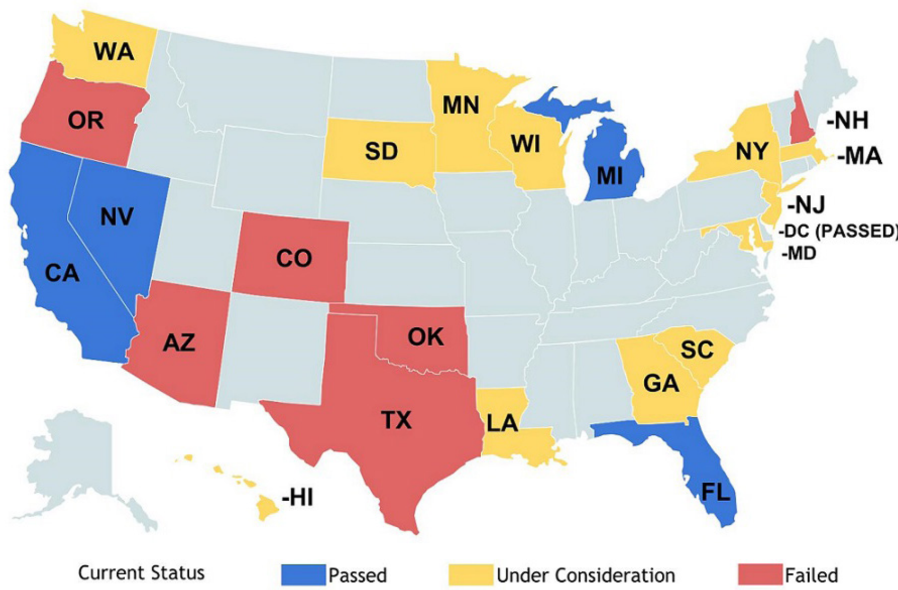
The following sections will focus on the topics of how the CMU AV team could possibly work more effectively and efficiently in achieving the goal of having its technology validated and gaining the early entry advantage to market.

# SPOTLIGHT

# Policy Context

## Status Quo

To date Michigan, Florida, California, and Nevada are the only states to approve autonomous vehicles use on public road while Washington, South Dakota, Minnesota, Wisconsin, New York, Massachusetts, New Jersey, Maryland, South Carolina, Georgia, and Louisiana are currently considering legislation. Nevertheless, the lack of legislation by most states could impact the rate of adoption of autonomous vehicles. In this case, it is the role of the private industry to attract new legislation in support of the development of autonomous driving systems. The director of the Nevada DOT said, "Make a [self-driving] product that the consumers wants, and we will adapt and follow."(KPMG, n.d., pp. 21).




Note. From Automated Driving: Legislative and Regulatory Action. 2014 by Weiner & Smith.

However, legislation has not been successful for some other states, for example "Arizona's bill failed on February 9, 2012 in the House Transportation Committee after members expressed concern that the technology was not ready and the rulemaking burden on the state's Department of Transportation would be too great" (Pino, 2012). Nevertheless, Google's and CMU's success of having autonomous cars drive themselves on road proved that this technology is indeed ready for testing. This example shows that there is a need to better inform the public on benefits of the AV and how it is ready for testing on road. Another example of failure is State of Oregon, balking at the legislation because driverless cars could be used as "drones" to deliver armed bombs for terrorists, in the wake of the Boston Marathon bombing (LeSage, 2013).

To date, Pennsylvania has neither accepted nor declined the notion of AV driving on public roads. We observe the lack of state support as being a hindrance to the fluid nature of testing that is required to bring the technology to market in a timely manner.  Currently, for an autonomous vehicle to use public roads in Pennsylvania, there must be a driver occupying the car. Right now the CMU research group is actively testing the prototype on road in the Pennsylvania with permission. A human driver is exerting the supervisory role and immediately ready to retake back control while the autonomous vehicle is operating.

## Competitor's Status Quo in the U.S.

A competitive advantage that is being developed by the University of Michigan involves the V2V and V2I infrastructure that will be used to enhance the autonomous vehicle's performance. The university is working in close partnership with Mobility Transformation Center (MTC) and Ford Motor Company. The MTC has a goal to make personal and commercial vehicles fully autonomous and operates in support of public and private efforts. The goal is to develop the largest group of connected vehicles in the world. As of February 24, 2014 data has been collected from over 2800 connected vehicles and more than 21.5 million miles have been driven throughout the city (Chicklas, 2014). By 2021 the city of Ann Arbor wants to become the first city in the world with a fleet of autonomous vehicles (Moore, 2013).

Ford is also working with MIT and Stanford who are assisting in the development of real-time predictive modeling behavior of drivers to improve autonomous decision-making (Atiyeh, 2014). Because the state of Michigan allows the driving and testing of autonomous vehicles on public roads, data can be collected in real time and in real road conditions.

Google has been acting aggressively in lobbying on topics of autonomous vehicles, and achieved legislative success in in Nevada, Florida and California. According to Efrati, a wall street senior reporter that "Google spent nearly $9 million in the first half of 2012 lobbying in Washington for a wide variety of issues, part of which includes speaking to U.S. Department of Transportation officials and lawmakers about autonomous vehicle technology". As for the mile driven, Google's fleet of autonomous cars secretly drove more than 100,000 miles on road before the company disclosed it in the fall of 2010 (Efrati, 2012). Furthermore, there has been no revelation that Google's lobbying actions will force out other competitors, therefore, getting these laws passed is beneficial thus far to the industry at large. Google's relentless pursuit of autonomous vehicle legislation proved its determination on the market. Considering these initiatives, Google is expected to enter the market early as a strong leader, which might be regarded a potential threat to the CMU-General Motors partnership.

## Policy Options

In the context of fierce competition, with competitors taking different approaches and initiatives facilitating the development of technology and policy-making, relentlessly pursuing to be the first mover, a few policy options have been proposed for consideration. These alternatives will be discussed in detail in the Policy Analysis section.

Option 1 : Status Quo - maintain the status quo by continuing the test.

Option 2 : Seek for legislation of testing at the Pennsylvania state level.

Option 3 : Create a strong brand image for Carnegie Mellon as an AV leader through collaborations within and outside Carnegie Mellon University, positioning CMU & Pennsylvania as leaders of future autonomous mobility. In achieving this policy option, the CMU research group is expected to act as leader, taking initiative representing the whole industry to interact and influence the public and social awareness and acceptance. We shall address the detailed implementation plans in the strategy section.

# Policy Forum

## Forum Locations

### National Highway Traffic Safety Administration

"NHTSA is responsible for developing, setting, and enforcing Federal motor vehicle safety standards (FMVSSs) and regulations for motor vehicles and motor vehicle equipment…[its] research will inform agency policy decisions, assist in developing an overall set of requirements and standards for automated vehicles, identify any additional areas that require examination, and build a comprehensive knowledge base for the agency as automated system technologies progress." (NHTSA, 2013b).

In its policy, NHTSA mentioned that driverless cars are not ready for widespread implementation, but the agency said further testing of the technology was encouraged, and so was guidance to states (as cited in Laing, 2013). "We offer these recommendations to state drafters of legislation and regulations governing the licensing, testing, and operation of self-driving vehicles on public roads in order to encourage the safe development and implementation of automated vehicle technology, which holds the potential for significant long-term safety benefits," NHTSA wrote.

### Pennsylvania State Department of Transportation (for AV license and testing requirements)

The AV research groups will depend on DMV at the state level to issue regulations for testing and licensing. "The State of Nevada has adopted one policy approach to dealing with these technical  and policy issues. At the urging of Google, a new Nevada law directs the Nevada Department of Motor Vehicles (NDMV) to issue regulations for the testing and possible licensing of autonomous vehicles and for licensing the owners/drivers of these vehicles." (Pino, 2012)

## Organizations likely to support action on some options

### Competitor Autonomous Vehicle companies

Competitor AV companies, though they may or may not directly collaborate with CMU & General Motors on testing regulations, are likely to affect the outcome. For example, Google's lobbying effort in enabling several states to enact legislations for AV testing has served as a solid start for other states, and is beneficial to the whole autonomous vehicle industry. Moreover, the state-level efforts are indeed building groundwork for future possible federal regulations governing autonomous vehicles.

### Traffic 21

Traffic 21 is a smart transportation research initiative by a group of researchers from CMU whose goal "is to design, test, deploy and evaluate information and communications technology based solutions to address the problems facing the transportation system of the Pittsburgh region."(Traffic 21, n.d.)

### Association for Unmanned Vehicle System International

Another strong ally who is already investing millions in on lobbying efforts in favor the AV technology is the Association for Unmanned Vehicle Systems International, AVUSI. The AVUSI's core focus is to represent the efforts of autonomous research, policy implementation/lobbying, and advocating public awareness (AUVSI.org -> Advocacy).

CMU is currently a member of this association, and CMU AV research group is recommended to further explore this platform in order to help implement the policy options proposed earlier on, leveraging the association's special relationship with the government, attending the advocacy-related events to connect with pioneers and to look for partnerships in implementing those autonomous vehicle advocacy initiatives. In addition, good practices or lessons could be learned from counterparts of other countries regarding how best to facilitate policy makers' interactions with the technology.

## Organizations likely to oppose action on some options

### Nongovernmental organizations with opposing interests

In the long run, as the technology gets fully autonomous and ultimately removes human driver in autonomous vehicles, truck industry will be dramatically impacted. Companies that eliminate truck drivers from their logistic systems will greatly reduce costs in both salaries and liability, and realize 24/7 non-stop operations. Therefore, unions of truck drivers such as the Teamsters Union is expected to go against the introduction of this technology. Truckers from logistics industry is just an illustration of how one type of stakeholder can be negatively affected by the technology. As mentioned earlier, many other occupancies from different industries will be affected by the technology, for example taxi and marine freighting, with a total workforce implication of 2 million (BLS, 2012).

Nevertheless, one could still argue that these organizations, instead of lobbying against the technology, will likely lobby for having a human driver as a safeguard, despite the driverless feature of autonomous vehicle. This reaction would be similar to the requirements of labor unions in the case of driverless trains, according to an interview with James Flannery, associate professor of Legal Writing from the University of Pittsburgh School of Law (Flannery, personal communication, 15 April, 2014).

# Policy Analysis

One desired outcome for the CMU research group is to reduce or dispel policymaker and public concerns about possible reliability related to the technology, such that CMU car could achieve early entry to market with desired level of reliability. In this analysis, we are examining the ***effectiveness, efficiency, responsiveness*** and ***equity*** of achieving this goal by implementing each of the policy option proposed earlier.

## Range of Outcomes

When evaluating the effectiveness of the status quo and alternatives, we are interested in projecting the degree to which the current and proposed policies are likely to achieve this outcome. When evaluating the efficiency, we are interested in which policy is likely to get the most "bang for the buck." In this case, the "buck" is not only the cost of the activity but the impact on our ability to get our products to market in a timely manner so that we can attain the early entry advantage.

The status quo policy, running the test with permission within the Pennsylvania state, is likely to be effective in obtaining test results and validating the technology. However, there is a lack of a clear time to market since Pennsylvania State has not even regulated testing of autonomous vehicles, as compared to Google in California where operation of autonomous vehicle has already been legalized. Therefore, the efficiency might be negatively impacted under this policy option because, even though CMU research group is a leader in the technology, it may lose the race to enter the market.

CMU research group may be able to facilitate the efficiency through the second option, in which the group is recommended to persuade its partner General Motors to lobby after Department of Transportation at Pennsylvania state to adopt regulations allowing testing of autonomous vehicles on public roads in the state. It should be as effective as the status quo in responding to public reliability concerns, and it could serve as a solid start for the autonomous vehicle to be legally approved nationwide in long run. As far as efficiency is concerned, though the pursuit of legislation requires a commitment of time and resources, once such a bill gets signed, it will not only legally support testing and validation of autonomous vehicle, but also greatly facilitate the long-run process for legal approval of autonomous vehicle. This would be a major win in our goal to reduce time to market.

Yet another policy option, Option 3, of shaping the opportunity is to create a strong CMU brand by pinpointing the benefits of autonomous driving, advocating the technology, and positioning Pennsylvania and CMU as leaders in the development of future mobility. In pursuing the alternative, a large impact, or effectiveness, will be observed since a large many of "joint ventures" will be expected under this initiative among research groups, authorities, public and private investors that is rarely seen in the history of this technology. Furthermore, the immediate benefits of this technology will be directly unveiled to the public and all partners, thus it is also a more efficient option.

## Bargaining Context

When evaluating the **responsiveness** of the status quo and alternatives, we are interested in projecting the degree to which these policy options are likely to feasible and supported by policy actors. When evaluating the **equity**, we are interested in what impact the policy is likely to have on these players (i.e., who are the winners and losers).

For all options proposed earlier, the political feasibility, or responsiveness is expected to be positive, even for the second option (Seek for legislation of testing at PA State Level) in which policy feasibility is not that obvious, and the following analysis justifies. As mentioned, Nevada, Florida and California and Michigan have so far authorized testing of autonomous vehicles, and there has been legislation proposed in some other states. Pennsylvania has shown interest in regulating the application, back in early 2013, "PennDOT and CMU started to look at how to regulate self-driving vehicles and how they might affect policy decisions in a study which is expected to take a year to complete", said by Allen D. Biehler, a former PennDOT secretary (Pennlive.com, 2013). Given the success of other states, the technology leadership position of CMU AV research group and joint research effort between CMU and PennDOT, the likelihood of the legislation getting passed is expected to be high, thus a positive responsiveness.

The equity issues involve the possible impact of policy options on both the public as well as its competitors. Under both Option 1 (Status Quo) & 2 (Seek for legislation of testing at PA State Level), public will stand to gain because testing, improving and validating the technology will eventually offer them safe and reliable autonomous vehicles. For Option 3 (Create a strong brand and leader image), by no means the public will lose either, since they will be directly unveiled the benefits and get to know more about the technology.

From a competitor standpoint, option 1, the status quo, would be equitable to competitors since they might possibly get into the market faster. Option 2 (Seek for legislation of testing at PA State Level) would possibly provide a time to market disadvantage to competitors as CMU's autonomous car would be able to enter the market in an expedited manner, and Option 3 (Create a strong brand and leader image) would make other players less competitive. However, on a long-term basis, as it is possible for other manufacturers to be opposing to CMU's early mover as a leader strategy, the net effect of implementing either Option 2 or 3 is arguably beneficial to overall development of AV technology. The manufacturers and involved parties will benefit from positive network externalities as V2V and V2I systems become more effective with more users. In conclusion, equity to competitors are positive under all options, but in different ways.

***Manufacturers of autonomous vehicles will have to educate both the public and the policy makers about the benefits of the technology. Drivers will initially be reluctant to adopt fully computerized cars, thus the automakers must be proactive in demonstrating the safety and advantages of their systems.***

| | Status Quo | PA Legislation | CMU Brand |
|---|---|---|---|
| Effectiveness | + | + | + |
| Efficiency | - | + | + |
| Responsiveness | + | + | + |
| Equity - Public | + | + | + |
| Equity - Competitors | + | + | + |

Key: “+” = metric goal is likely to be achieved “-“ = metric goal is not likely to be achieved

Option 1 : Status Quo - maintain the status quo by continuing the test.

Option 2 : Seek for legislation of testing at the Pennsylvania state level.

Option 3 : Create a strong brand image for Carnegie Mellon as an AV leader through collaborations within and outside Carnegie Mellon University, positioning CMU & Pennsylvania as leaders of future autonomous mobility. In achieving this policy option, the CMU research group is expected to act as leader, taking initiative representing the whole industry to interact and influence the public and social awareness and acceptance. We shall address the detailed implementation plans in the strategy section.

# CHALLENGE

## Liability

Liability is expected to be the most difficult barrier to widespread commercialization of autonomous vehicles (Rand, 2014). On one side, a high liability risk on the AV manufacturers will de-incentivize production, while on the other, strong policies to address this market failure through limiting liability will de-incentivize investment in safety features that prevent failures.

Finding the right balance of market stability and policy regulation will require consistent efforts from both industry players and government legislators. This section will explore the issue of liability, the policy context around it and analyze several options that for addressing this challenge, with a focus on the Carnegie Mellon AV project.

“AVs have sensors, visual interpretation software, and algorithms that enable them to potentially make more informed decisions. Such decisions may be questioned in a court of law, even if the AV is technically not “at fault.” Other philosophical questions also arise, like to what degree should AVs prioritize minimizing injuries to their occupants, versus other crash-involved parties? And should owners be allowed to adjust such settings?... Other semi-autonomous technologies, such as parking assist and adaptive cruise control, will likely provide initial test cases that will guide how fully autonomous technologies will be held liable.“ (ENO, 2013, pp. 17)

# SPOTLIGHT

# Policy Context

The main question is "where does the liability lie in an accident involving an AV"? In the case of a Level 3 autonomous vehicle it can be argued that the limited self-driving ability is not that different (conceptually) compared to cruise control, which has been a feature in vehicles for more than 40 years. In this situation, a small part of liability shifts to the manufacturer (because they advertise "collision avoidance systems"), but the driver still remains responsible for monitoring the operation of the technology and should be ready to intervene at first sign of trouble. However, in the case of a Level 4 AVs, the entire responsibility shifts to the manufacturer, because the driver is not expected to intervene anymore in the operation of the vehicle (Marchant & Lindor, 2012).

Additionally, insurance underwriting will be another controversial issue. Interviews conducted by KPMG with insurance risk firms indicate that "the entire underwriting process will need to be revamped, and a greater portion of the liability could transfer to manufacturers and infrastructure providers (federal and state).These legal concerns, and the question of who "owns" the risk, will need to be addressed for convergence solutions to gain mass-market adoption. Litigation-related issues that come with widespread use of autonomous vehicles will be a challenge." (KPMG, n.d. pp.21)

## Status Quo

The current law for assigning liability in the case of a car accident clearly distinguishes three possible causes, with the respective combinations: the driver, a vehicle malfunction or defect and/or unavoidable natural conditions (ex: weather, road conditions, animal on the road) (Marchant & Lindor, 2012). Most liability lawsuits attribute culpability to one or both of the first two categories: the driver and the automobile manufacturer. The situation becomes more complex when multiple vehicles are involved in the accident, with any combination of the drivers and the manufacturers being potentially responsible, and therefore liable (Marchant & Lindor, 2012).

In the case of autonomous vehicles, when the vehicle is in self-driving mode and thus human error becomes excluded, the potential parties that can be hold accountable for an accident range from the car manufacturer to the manufacturer of a component used in the AV system (ex: sensors, cameras), the software engineer who programmed the code for the autonomous operation of the vehicle or the road designer in the case of an intelligent road system that helps control the vehicle (Marchant & Lindor, 2012). Nevertheless, the component or part of the system that was directly responsible for the incident may be difficult to pinpoint. Autonomous vehicles are expected to use "black boxes" similar to airplanes, which will record all the operational details that are required in identifying the source of an error. For the context of a liability lawsuit, "it will be the vehicle manufacturer who will, for both practical and doctrinal reasons, be the party held liable for a crash involving an autonomous vehicle" (Marchant & Lindor, 2012).

## State and Local: Definitions of "drivers"

State vehicle codes are somewhat obscure when defining the action of autonomous driving. These differences in terminology can make the development of the technology complex as many states do not have consistent definitions regarding "driver" or "operator" of the car. It is clear, however, that an autonomous vehicle probably has a human "driver" or "operator." The extent of intervention is not ubiquitously agreed upon (Smith, 2012).

Nevertheless, some state codes imply there is a "driver," "operator," "owner" who has control of the automobile. "An owner who is not driving her vehicle may nonetheless be responsible for it. This expansive view of responsibility suggests that various persons could be deemed to operate an automated vehicle" (Smith, 2012). A brief summary of state definitions of the terms is provided:

VT

*"Vermont provides the broadest statutory definition: "'Operate',' 'operating' or 'operated' as applied to motor vehicles shall include 'drive,' 'driving' and 'driven' and shall also include an attempt to operate, and shall be construed to cover all matters and things connected with the presence and use of motor vehicles on the highway, whether they be in motion or at rest.*

IL

*"Operate" is statutorily defined in Illinois as "[t]o ride in or on, other than as a passenger, use or control in any manner the operation of any device or vehicle," in Ohio as "to cause or have caused movement of a vehicle," and in Indiana as "to navigate a vehicle"*

MA

*The high court in Massachusetts explained, presciently for 1928, that "[a] person operates a motor vehicle ... when, in the vehicle, he intentionally does any act or makes use of any mechanical or electrical agency which alone or in sequence will set in motion the motive power of that vehicle." And Michigan's high court has held that, for the purpose of the state's drunk-driving statute, "once a person using a motor vehicle as a motor vehicle has put the vehicle in motion, or in a position posing a significant risk of causing a collision, such a person continues to operate it until the vehicle is returned to a position posing no such risk.*

NY

*New York's high court discerned "a definite meaning" in the Highway Law: The word 'operate' is used throughout the statute as signifying a personal act in working the mechanism of the car. The driver operates the car for the owner, but the owner does not operate the car unless he drives it himself. If the meaning were extended to include an owner acting either by himself or by agents or employees, the provisions of the Highway Law would be replete with repetitious jargon.*

WA

*In Washington, similarly in Wisconsin, "[b]oth a person operating a vehicle with the express or implied permission of the owner and the owner of the vehicle are responsible for any act or omission that is declared unlawful." (Smith, 2012)*

The variations in state legislations could make the commercialization of AVs across the United States a daunting task. In this context, a federal intervention might be required to standardize terms and their application to autonomous vehicles.

The role of the federal government will also be to facilitate the standardization of the technologies being used for autonomous driving. Manufacturers and suppliers hope V2I and V2V systems become standardized through government mandates in a similar fashion as the application of seatbelts and airbags. V2I and V2V systems will benefit from reduced costs of production and improved compatibility thus further incentivizing the technological and political development of autonomous vehicles. The USDOT with NHTSA are testing the integration of this system currently through the Connected Vehicle Safety Pilot Program. (KPMG, n.d., pp. 21) "Connected vehicle research will leverage the potentially transformative capabilities of wireless technology to make surface transportation safer, smarter, and greener. If successful, connected vehicles will ultimately enhance the mobility and quality of life of all Americans, while helping to reduce the environmental impact of surface transportation." ("Connected Vehicle", 2014). If a full mandate were not issued, an alternative would be an incentivized program for suppliers and manufactures to produce these systems. The goal would be to converge existing systems to create a industry standard. Suppliers and manufactures stand to gain in early development of the systems to gain a first-mover advantage. (KPMG, n.d., pp 21)

## Policy Alternatives

We based our alternatives on addressing the liability issue on results of our literature search (Rand, 2014; Marchant & Lindor, 2012). It is being suggested that the most efficient way to address liability and therefore close the market failure in the initial stages of the technology would be through lobbying for liability limiting provisions in the case of autonomous vehicles. Because the potential social benefit is huge, it might be a good policy to incur a low social cost in order to enable the benefit from having AVs on the road. These alternatives will be discussed in detail in the Policy Analysis section.

Option 1 : Status Quo

Option 2 : Limit liability at State level by setting maximum caps for damage payment (similar to medical malpractice)

Option 3 : Limit liability at Federal level by legislation or through NHTSA

> *"There are some possible legal and policy tools that may help protect manufacturers from liability. One such tool within the litigation system is the assumption of risk defense. Outside the litigation system, another tool is the pursuit of legislation that provides immunity or other defenses to manufacturers. Legislation could help minimize liability, or alternatively, the National Highway Safety Traffic Administration ("NHTSA") could promulgate regulations that expressly preempt state tort actions." (Marchant & Lindor, 2012)*

Option 4 : Create a platform to facilitate lobbying for liability and testing

# Policy Forum

## Forum Locations

### United States Congress

Federal level legislation designed to limit liability will have to pass the US Congress. This option will be the hardest to achieve since it will require a great deal of resources to be allocated for lobbying. However, the historical cases of limiting liability in special situations (such as the small plane parts manufacturing or vaccines) indicates that there is room for federal measures that can help the new technology in its initial stages of commercialization.

### Local State Congress (PA General Assembly)

Similarly, the local state congresses will be responsible for passing into law any new state-level legislation about liability and testing of autonomous vehicles (Pennsylvania General Assembly for the CMU team). State action should be much easier to be achieve, especially considering that there are already states that have implemented laws about the testing of AVs. However, this highly depends on the political inclination of the state towards more liberal or conservative attitudes. In Pennsylvania, the discussion about driverless cars has not been started yet, and the general attitude is undecided, therefore it represents a great opportunity that CMU can take advantage of.

### National Highway Traffic Safety Administration (NHTSA)

As mentioned before, NHTSA is the regulatory body that is responsible with transportation safety and the management of Federal Motor Vehicle Safety Standards (FMVSSs). With regards to liability, FMVSSs can be used to reduce or eliminate the exposure to tort liability for AV manufacturers. FMVSSs are a method of preempting state tort laws at federal level, thus effectively limiting liability.

## Organizations likely to oppose liability lobbying

### Non-AV auto manufacturers

Besides the labor unions mentioned in the previous section, we believe the companies that do not have the technology to introduce AVs early on will be inclined to oppose limited liability legislation. Since limited liability will be a temporary measure to enable the market to get established, the companies that do not enter early will have a strong disadvantage in the long-term. Although most companies are investing heavily in AV research, we might see players that are not ready to enter the market oppose any legislative action, at least initially, until they are ready to catch up with their competitors.

## Organizations likely to support liability lobbying

### Google

Google is the most visible brand in the newly forming autonomous vehicles industry and it has recorded the most miles driven with a car in self-driving mode. Additionally, Google is also a major player in the lobbying scene, with an annual budget of over $14 million to influence Washington politics.

Google is also an interesting partner to consider due to its longstanding relation with Carnegie Mellon as a partner in different projects, especially in the area of Computer Science. This link has been recently tightened with the new Dean of the School of Computer Science being Andrew W. Moore, former Vice-President at Google.

### General Motors

The collaboration between Carnegie Mellon and General Motors already is a tradition that spans over 14 years, with two laboratories dedicated to improving automobile technology. General Motors is a world leader in automobile manufacturing and it also a leader in spending for government lobbying, with a budget of $10 million. With support from Carnegie Mellon in terms of policy analysis and policy strategy, GM can take the lead in the lobbying effort, considering the experience and history in this area.

### Auto Alliance

The Auto Alliance is a consortium of the leading 12 automobile manufacturers, of which General Motors is a founding member. This already existing platform of collaboration between automakers can be an excellent starting point to initiate discussions on liability issues related to autonomous vehicles. Since almost all of the 12 members are already researching AV systems and are planning to release increasingly autonomous technologies in the next 5-10 years, it would benefit the entire industry if they would manage to coordinate their lobbying efforts.

### Auto insurance companies

The auto insurance companies have not yet expressed any public stance on the issue of liability and they are expected to be a mainly neutral party. However, it can be argued that the introduction of AVs will have a beneficial effect on the insurance industry, with a clear reduction in risk and a potential consolidation and simplification of risk profiles. Additionally, the insurance industry has been the second largest in terms of lobbying spending in 2013 ($153M, OpenSecrets.org), although it is true that most of the top funders are representing medical and life insurance categories. If the auto insurance companies are persuaded to consider AVs as positive technology, they can become powerful allies in the battle for introducing new legislation.

# Policy Analysis

Liability has been identified as the most significant challenge to the commercialization of autonomous vehicle technology, due to exposing the manufacturers to a high risk of lawsuits and penalties. Therefore, our proposed non-market strategies are focusing on reducing the potential impact of liability on the business, by limiting the value and the number of liability lawsuits through federal and state legislation and by collaborating with industry partners to facilitate the lobbying process. We will be exploring these alternatives below.

## Range of Outcomes

**Option 1: Status Quo**

If the current situation in liability regulation remains unchanged, the manufacturer of the AV system will be fully liable for covering damages in an accident situation caused by a malfunction in the hardware or software components of the autonomous module. The injured party will most likely sue both the car manufacturer and the AV manufacturer (quote: David Tungate). This case will be considered as the baseline to which we will compare the effectiveness and efficiency of the proposed alternatives.

**Option 2: Lobby - Maximum cap at State Level**

A potential alternative to using the current regulation on liability would be to use lobbying resources to advance federal regulation specifically designed for autonomous vehicles. A minimal option would be to have a maximum limit of compensation that can be awarded in a liability lawsuits. The current cost of a car accident product liability case is between $1-2 million (Miller, n.d.). and the federal government could use a value based on this range to set a maximum cap (for example $800k for non-fatal crashes). Having a cap could help AV companies to plan for a maximum liability budget and it would reduce the values of payouts. This option is moderately effective, but highly efficient since it would require a medium level of lobbying activity and it might be more easily passed in a State Congress. The proposed option is similar to capped liability lawsuits in medical malpractice cases.

**Option 3: Lobby - Legislative protection at Federal Level**

In a similar scenario, an AV manufacturer, either alone or together with fellow companies in the industry, could push for the introduction of a provision that limits liability for autonomous vehicles in order to facilitate the introduction of the new technology which is expected to save thousands of lives annually. Such measures have been used in the past in the case of nuclear energy, small plane manufacturers or vaccines. The selling point is that AVs have a huge social benefit - through the reduction in traffic, pollution, accidents, deaths - and thus large-scale adoption should be facilitated. The counter-argument is that limited liability would reduce (or even eliminate) the incentives for the AV manufacturers to invest in improving safety of their systems. This option would be highly effective, but it would require a massive mobilization of resources to convince the government to adopt it.

### Option 4: Create a platform for facilitating lobbying

Finally, we suggest that the Carnegie Mellon AV team should capitalize on its strengths and create a platform for communication between industry giants and key players. By being closely connected to the policy creation process, CMU can have early access to information and manage the policy directions in way that are beneficial for the technology developed here. Additionally, such a platform is valuable for all participants, because state or federal measures for limiting liability will affect all manufacturers. Moreover, the platform can be used to also address other issues, such as state regulation for AV testing. Only 4 US states have introduced laws for allowing AVs on the road and a combined effort of multiple parties will be successful in determining other states to take a stance as well. We believe that this option is both efficient and effective in addressing the liability issue, by bringing together the means and resources to inform and educate policy makers, and guiding their decisions with the goal of realizing the huge social benefit of autonomous technology.

## Bargaining Context

### Option 1: Status Quo

Based on the status quo in which the manufacturer is expected to be fully liable in case of an accident caused by a malfunction in the components of the autonomous module, the responsiveness of this option is positive, because demanded by the common law of products liability, “a producer may be held fully responsible even if it was not at fault and could not have prevented the injury” and “the only absolute defense is that the product was not associated with the injury or was not the proximate cause of the injury” (Baron, 2012, pp. 399).

In terms of equity, the status quo situation, when no specific law is introduced to limit liability, is the baseline for our analysis, therefore considered neutral. However, if we take into account the loss of potential social benefit due to suboptimal commercialization of autonomous vehicles (AV manufacturers will delay the introduction of the technology due to high risks associated with liability lawsuits), we can consider that the public, manufacturers and competitors will be the “losers” in this situation. The parties that would be negatively affected by the introduction of AVs, such as trucking and taxi unions, will consider the baseline as their most positive option.

### Option 2: Lobby - Maximum cap at State level

This option is justified by the federal/state’s propensity to limit liability faced by certain promising technology like autonomous vehicles, “for example, many states have adopted laws that cap allowable damages in medical malpractice actions, largely in an effort to encourage physicians to continue to practice medicine in their states and to lower the overall cost of healthcare.” This option is a specific form of seeking legislative protection, and aim of which is to put a cap for each accident/injury incurred based on a reasonable estimate, which will allow manufacturers for liability budget planning, and reduce its liability exposure. Depending on how reasonable the estimate is and how much effort/resources will be devoted to option, chances that the state will approve this policy is optimistic because of the precedents. Meanwhile, “information provision” is the key to effective lobbying (Baron, 2012, pp. 34), and it’s believed sufficient information could be used to justify the feasibility of the estimated cap.

Introducing a maximum cap at state level would enable states to take the lead with introducing AVs to their constituents. The public will benefit from the increased overall traffic safety, and the positive externalities associated with driverless cars - reduction in pollution and traffic congestion. Additionally, it will also incentivize AV producers to invest in the technology, knowing that there are markets where liability risks can be accounted for in advance. The market will also be open for competitors, therefore the equity is positive for all the 3 parties analyzed - public, manufacturers, competitors.

**Option 3: Lobby - Legislative protection at Federal Level**

Likelihood of this option getting adopted is not that high because it is “relatively rare for legislatures to intervene to protect specific technologies or products from liability”. By examining the precedents, a large proportion of the technology that had its liability protected by legislations enacted by the Congress were those in the medical industry. The most relevant industry to that of autonomous vehicle was the “small plane industry, protected by The General Aviation Revitalization Act of 1994 for a period of eighteen years in response to the potential for widespread bankruptcy in that industry”, with an arguably more imperative reason (Marchant & Lindor, 2012). Conclusively, the responsiveness should be negative.

Successfully securing protection at federal level requires huge amounts of resources and a well organized strategy. Most likely this is an action that cannot be achieved individually and it should be executed as part of a trade association or lobbying group. There are expected to be advocacy groups that would rally against this measure, as limited liability could be seen as an infringement of consumer rights. Moreover, the AV manufacturers will lose all or part of the incentive to invest in improving the safety of their systems, as they are protected anyway. For these reasons, the equity for the public is negative, while for manufacturers and competitors is positive, since limited liability will greatly increase their market power. Unions of workers affected by the introduction of AVs will oppose any legislative action in favour of reducing liability (same in option 2).

**Option 4: Create a platform for facilitating lobbying**

An unified platform for collaboration, cooperation and communication between AV industry players is expected to be well-received and have a positive impact. Because the technology is in very early stage, the policy makers are not taking risks by proposing very disruptive legislation. They are waiting to receive more data and information from the market before starting the regulatory process. A collaborative movement from the industry to provide this information, to actively educate and engage legislators will likely have positive results for both the public and the manufacturers. For example, one of the crucial pieces of research that needs to be achieved before making any attempts to take regulatory decision, is a cost-benefit analysis of AV introduction. CMU together with its partners could combine forces in creating such an in-depth analysis, and then communicate the results to government officials through the usual advocacy channels.

| | Status Quo | State Caps | Federal Law | Platform |
|---|---|---|---|---|
| Effectiveness | - | + | + | + |
| Efficiency | 0 | + | - | + |
| Responsiveness | + | + | - | + |
| Equity - Public | 0 | + | - | + |
| Equity - Competitors | 0 | + | + | + |

Key: “+” = metric goal is likely to be achieved “-“ = metric goal is not likely to be achieved

Option 1 : Status Quo

Option 2 : Limit liability at State level by setting maximum caps for damage payment (similar to medical malpractice)

Option 3 : Limit liability at Federal level by legislation or through NHTSA

Option 4 : Create a platform to facilitate lobbying for liability and testing

# Strategy

In achieving the two goals, to launch product into market the first with validated reliability and gain the first mover advantage, and to minimize liability exposure of AV system manufacturers (CMU), we are making the following recommendations.

Firstly, the autonomous car research group is suggested to create a strong CMU brand and image by internal collaborations and external outreach. This non-market approach will strengthen position of the team in both market and nonmarket environment, obtaining effectiveness and efficiency in achieving the goal of early market entry with proven reliability.

In implementing this, the CMU AV research group is advised to leverage the resources and capabilities internally within the university. Carnegie Mellon University has a strong team of established researchers with a number of relevant programs and projects and collaboration potential. Similar to seeking policy recommendations from students participating in the New Technology Commercialization course, the research team is encouraged to engage more with the Department of Engineering and Public Policy, and create PhD positions for in-depth research on topics relevant to autonomous vehicle. For example, analyze the policy implications of autonomous vehicle, or make a cost-benefit calculation for the technology. Furthermore, the autonomous car team could collaborate internally with the CMU Cylab, whose capability and expertise lies in building a trustworthy computing platforms and devices, addressing usable security and privacy. The potential collaboration could help the research team to tackle the data privacy issue at early stage. By taking this proactive approach, CMU AV research group might attain a competitive advantage. Finally, the team is expected to continue taking advantage of Traffic 21 as a platform to reach policy makers, and possibly initiate certain public/policy awareness advocacy projects.

Outside CMU, it is suggested that the AV research team to have more on-road demonstrations to increase awareness of the public and policy makers. This increased visibility will demonstrate the advanced nature and the market readiness of the technology, thus ultimately facilitating the law-making process. In addition, the research team could also take initiative in establishing digital communication tools, such as the digital libraries, online education or advocacy tools that will not only expedite public awareness and acceptance, but will also enable and enhance access to the knowledge base on autonomous vehicles. Lastly, it is recommended to form an advisory board consisting experts in law and policy, policy makers, and other key stakeholders on autonomous vehicle such as autonomous vehicle manufacturers and research teams. Establishing such a community will facilitate key policy issues of autonomous vehicles to be addressed and strategic policy guidance to be sought.

Secondly, the CMU autonomous car research group is recommended to act as intermediary to enable collaboration between industry players in order to facilitate lobbying for testing and limited liability at state and federal level.

Apart from the actions mentioned above, Carnegie Mellon can use its unique position to promote communication between two of the industry's largest players. Considering that CMU already has close connections with both Google and General Motors, it can establish itself as the platform and can initiate dialog in the common issues to be faced in the future by autonomous vehicles manufacturers. Convincing Google and General Motors to work together might be seem like a disheartening task, yet the advantages of this collaboration stand to be great for all parties involved. Furthermore, being a front-runner in the policy debate surrounding AVs, CMU will be recognized as leader in this emerging industry.

Additionally, General Motors is also part of the Auto Alliance, an association of the leading 12 automobile manufacturers, which are all investing in autonomous technology. The existing structure can be used to form a trade association for all future AV manufacturers, which will represent the interests of the industry and focus on the commercialization of a safe and reliable product.

Finally, the CMU team can use its internal resources to draft a detailed plan of how it should interact with policy makers at different technological milestones. The AV technology is still in research phase, however, once it is ready for commercialization, a number of organizations will become involved in regulating it (NHTSA, DoT). The CMU AV project will benefit by being involved early in the process of defining standards, testing procedures, safety measures etc., by facilitating external collaboration with the organizations that are responsible for this (SAE, IEEE).

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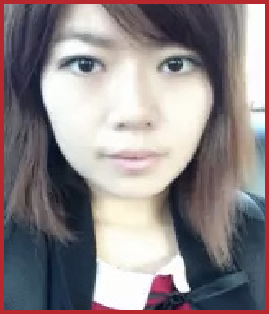

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