ABSTRACT

SAMPATH KUMAR, VARUN. P3/PPP in the context of autonomous driving vehicles (Under the direction of Dr. George F. List)

The purpose of this study is to identify, understand and determine how Autonomous Vehicles would bring change to existing road transit model, thus affecting stakeholders. Their onset will introduce new untapped markets and players into the industry while simultaneously changing the roles of existing stakeholders. Surveys and interviews were conducted to obtain qualitative data to establish current state highway business model. This highway model is identified to share an implicit Public Private Partnership (P3) wherein stakeholders are not bound by contracts. Transition state and future state projections were derived highlighting the transition from user driven vehicles to Autonomous Vehicles (AVs). User driven vehicles will transition to Connected Vehicles (CVs) supporting Vehicle to Everything Communication protocols (V2X) using Dedicated Short-Range Communication (DSRC) before transitioning into fully autonomous vehicles sequentially over the next couple decades while simultaneously changing roles and functions of the stakeholders gradually. Both explicit and implicit P3 arrangements are found to be part of this emerging future. Stakeholders will share an implicit P3 relationship and new explicit P3 opportunities will be available to private entities.

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P3/PPP IN THE CONTEXT OF AUTONOMOUS DRIVING VEHICLES

by

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BIOGRAPHY

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During his undergraduate program at College of Engineering Guindy, Anna University, Chennai in India, Varun was inducted into the National Cadet Corps- Navy Wing, and in May of 2015 received his Bachelor of Engineering in Civil Engineering. He was then invited into the graduate program in the Department of Civil, Construction and Environmental Engineering, where he researched P3/PPP business models for Autonomous Driving Vehicle, and received his Master of Science in Civil Engineering in August 2017.

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LIST OF ABBREVIATIONS

ATM - Air Traffic Management

AV - Autonomous Vehicle

CV – Connected Vehicle

DoT – Department of Transportation

FAA – Federal Aviation Administration

U.S. GAO – U.S. Government Accountability Office

IMPC – Integrated Maintenance & Parking Facility;
Integrated Manufacturing & Parking Facility

LIDAR – Light Detection & Ranging

NextGEN – Next Generation Air Transportation System

NHTSA – National Highway Traffic Safety Administration

OBD2 – On Board Diagnostics System V2.0

P3/PPP – Public Private Partnership

R&D – Research & Development

RADAR – Radio Detection & Ranging

SESAR - Single European Sky ATM Research

V2I – Vehicle to Infrastructure Communication

V2V - Vehicle to Vehicle Communication

V2X – Vehicle to Everything Communication

1. INTRODUCTION

This research aims to determine how the autonomous vehicle revolution will affect current highway model by affecting various stakeholders involved. The highway mode is already a public-private partnership (P3), where private individuals and other entities (e.g., rental companies and trucking firms) own the vehicles used to provide the service. But the advent of autonomous vehicles and ridesharing is going to alter this paradigm. The question is, how? The aim of this research is to help answer that question. It will strive to identify the most effective public/private business model sought by the stakeholders involved.

The concept of autonomous vehicles (AVs) is attracting much attention with the potential to resolve most traffic problems that are prevalent today. However, AVs are not ready for deployment – yet. A multitude of factors including sensors & hardware, maps/GIS solutions, software and artificial intelligence algorithms need further advances before commercial operation is viable. The exponential rate of technological advance in this domain is likely to bring AVs into the market very soon, probably within this decade. Moreover, this transition to AVs from conventional vehicles will happen over different stages of technology release over a period of time.

What happens when technology, ethical, cultural issues have all been addressed with appropriate solutions and the vehicles are mass produced and sold commercially? How will the new business model function and how are its constituent stakeholders related to one another? What role would they be involved with towards supporting AVs and how are they benefitted in return? What happens when consumers begin to adopt AVs?

Will people readily sell their old vehicles and buy new ones? Will this set a trend similar to the iPhone – Touch Screen revolution? The simile is that the traditional vehicles are Nokia cell phones and the AVs are iPhones. How will people finance their new vehicles, which are much more expensive than their mobile phones? Will there be any ripple effects? Will people be able to sell their old “obsolete” vehicles? Will this affect world trade and open a global economic rift? Will people in developing countries suddenly have access to old vehicles from developed countries?

What will happen to this story if OEM’s (Original Equipment Manufacturer) also sell aftermarket kits to convert traditional vehicles to AVs? Will this be practically possible? If it is, will this lead to cannibalization where consumers prefer to “modify” their existing vehicles rather than purchase new ones?

Will people prefer to buy AVs or pay for transit and ridesharing services instead? Will operators and manufacturers be willing to provide financial assistance to customers? Will it be possible to buy a vehicle on “contract” just as people buy an iPhone from a service provider? How economical will it be to pay for transit service instead of owning, insuring and operating an AV? If fleet vehicles are readily available anytime on demand and cost very little when compared to outright ownership, will people be willing to accept a new culture of fleet AVs operated by service providers, just the way smart phones are served by telecom service providers?

Moreover, would conventional vehicles directly transition to AVs? Would this process be immediate or executed in different phases?

Before answering these questions, do we even need AVs? What makes AVs so important that they are worth addressing so many socio-economic issues?
Their primary benefit is to eliminate highway fatalities and to reduce frequency and severity of accidents. The human element will no longer be involved in making decision which alone is responsible for almost all accidents.

AV’s are also likely to reduce congestion and facilitate parking. Cities with limited public transit options, busy city centers and downtowns, central business districts are always crowded with roads operated above capacity limits most of the day. Peak and off-peak times also impact the traffic flow at these hubs and congestion can only be reduced or in some cases controlled to certain degree with TSM (Transportation System Management) and TDM (Travel Demand Management). Many interstate highways operate at or near peak capacity. But the advent of AVs makes possible new TSM and TDM strategies that can greatly reduce congestion in large cities.

AVs reduce congestion in two ways. They can be programmed and operated in closely packed platoons. More vehicles can be accommodated per lane-mile. And the fleet size can be reduced. Most vehicles today spend their time idle when parked. An average working class family with two or three cars might now just need one AV that can serve the entire family. Multiple families may be able to share the same vehicle.

An additional question is: will people be willing to give up driving? Will they use autonomous vehicles instead? Will they be willing to use ridesharing services? Or transit? Moreover, can governments intervene and force compulsory use of AVs in high risk or highly congested regions for the overall betterment of the society. Will road safety interest governments to enforce the use of AV's in selective regions? If they can, will they seek to attract private partners to finance, operate and maintain the facilities necessary to enable these fleets to operate, such as a ubiquitous network of DSRC (V2V) antennas?

This study is focused on answering all previous questions using quality data obtained from various stakeholders obtained through a series of interviews and surveys. Results have been then visualized as flow charts to understand better.

2. LITERATURE REVIEW

2.1 Introduction

It is evident that AVs, on commercial inception will need some form of Public Private Collaboration as its backbone to be utilized effectively and for consumers to patronize them, considering the diverse stakeholders involved and affected. It is true that AVs are the future in ground transportation, but it might take much time, probably a few decades to materialize globally. P3 could be a viable tool to reduce this timeline, especially in developed countries.

2.2 Public Private Partnership (P3/PPP)

A public-private partnership[1] is a contractual arrangement between a public agency (federal, state or local) and a private sector entity. The skills and assets of both sectors are shared in delivering a service or facility for the use of the general public. In addition to the sharing of resources, each party shares in the risks and rewards potential in the delivery of the service and/or facility. The contractual relationship is typically of a long-term nature. P3s need not necessarily have exactly one public and one private entity. They can be conglomerates of several public and private entities working together to deliver a service or project.

They are generally used to finance and operate projects that are considered important or desirable to the general public and which can generate a profitable revenue stream.

Successful P3s are achieved through formation of a Special Purpose Vehicle (SPV)/ Special Purpose Entity (SPE). SPV allows for improved financing and a greater degree of operational control for the private agent. SPV function as subsidiary entities of parent organizations and can raise capital without carrying the debt or other liabilities of the parent organization. Likewise, any debt or liability of the SPV cannot be traced back to parent organizations. Parent organizations control SPV to limits set by the SPV share it holds and/or the terms of the P3 contract.

P3s with well-defined contractual agreement binding its stakeholders (public & private entities) are explicit where stakeholders have clear liabilities and deliverables.

An example is the High-Speed Electric Vehicle Charging Stations[2] that exist at four service areas along the New York State Thruway in the Hudson Valley. This project brings together the New York Power Authority and Nissan Motor Company Ltd. The SPV is a subsidiary of New York State Thruway Authority. These charging stations enable electric vehicles to fast charge in less than 30 minutes and hence promote long distance travel without the need for conventional I.C. engine vehicles. These charging stations are part of the state's Charge NY initiative to install 3,000 charging stations across the state by 2018. The station users are in turn charged by NYS Thruway Authority for services provided.

2.3 NextGen & SESAR

A primary source of inspiration for this study is the implementation of NextGen[1] – Next Generation Air Transportation System in the United States, and SESAR – Single European Sky ATM Research in the European Union.

NextGen is the new National Aerospace System scheduled to roll out between the years 2015 – 2025 in different phases and aims to upgrade America's air traffic control system from radar/radio communication based to satellite/ GPS based system. Primary benefits of this system are shorter air routes, reduced journey time and fuel consumption, reduced traffic delays, increased capacity, and greater safety margins while monitoring air traffic. These advances will also enable planes to fly closer to one another, take more direct routes and reduce delays caused by "stacking" – planes lined up awaiting take-off authorization. Eliminating gridlock in the air and on the ground, is another important mission for these advances.

NextGen aims to achieve these benefits by introducing a higher level of automated control systems and to replace radio communication with data exchange. These changes would simplify managing the system, especially to crew members. Like NextGen, SESAR aims to incorporate new technology and air traffic management techniques to make air travel across European Airspace more efficient. As both SESAR and the NextGen progress with these transformations, they should harmonize well with one another, making global travel more efficient and safer.

To understand the similarity between NextGEN to our problem statement, it is important to consider the environment which dictated to the formation of NextGEN.
The transition to NextGEN is motivated by the user benefits and cost savings it promises. NextGEN provides a better functionality with lower life-cycle/operational costs, after considering the value of initial investment for returns.

Without NextGEN, the FAA[2] (Federal Aviation Administration) estimates that the increasing congestion in air transportation system of the United States will cost the American economy $22 billion annually in lost economic activity by 2022. It estimates that by 2018, NextGen will reduce aviation fuel consumption by 1.4 billion gallons, emissions by 14 million tons and hence save $23 billion in costs. Each mile in the air costs an airline about approximately $0.10-$0.15 per seat in operating expenses like flight crew and fuel. Flying directly from one airport to the next and reducing congestion around airports can reduce the time and miles spent in the air for the same trip.

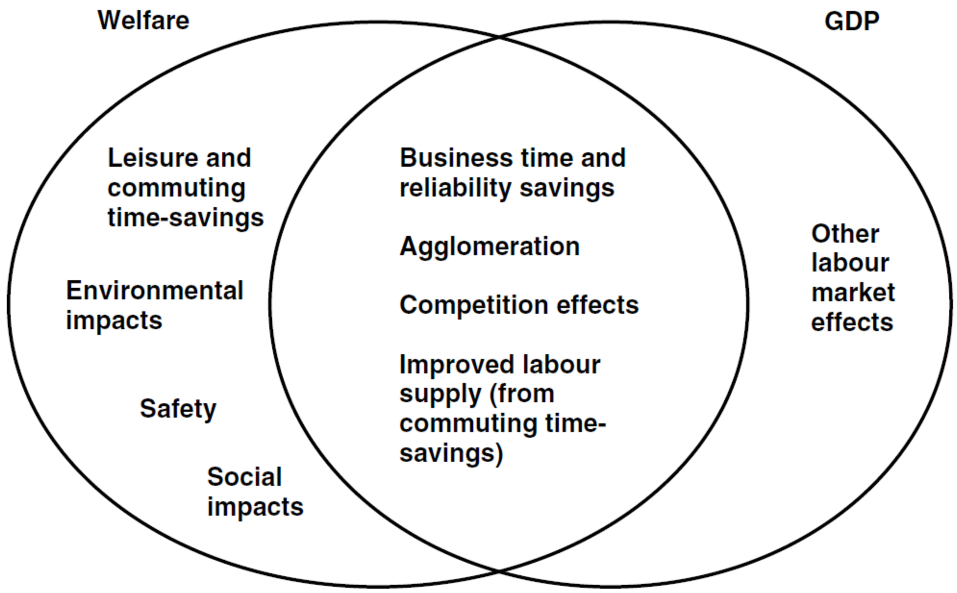

Figure 2.1 Potential Welfare and GDP Effects of Transportation Investment

Key NextGen features (from Sheridan et al, 2006) (excludes weather & security elements).

- Network Enabled Information Access – Secured information channel that updates in real-time.
- Satellite-Based Precision Navigation Service
- Aircraft Trajectory-Based Operations – Planning and executing system operations are now based on 4D gate-to-gate trajectories, which essentially integrates time as the fourth dimension.
- 'Evaluator' – integrated computer-based artificial intelligence system that helps planning and executing various system operations through a large degree of automation.
- Super High Density Operation Capabilities - for the busiest airports by reduced arrival/departure spacing, equivalent visual capability, and integration of better tools to detect and avoid wake vortices.

SESAR features (extracted from EC, 2007) (excludes weather & security elements)

- Operations based on Better Forecasting - Change from reactive ATM to anticipatory ATM – to reduce stress on human operators
- Better Anticipation of Problems - Collaborative decision-making procedures – stakeholders share and negotiate relevant information. Merge the different trajectory representations into one, as established by the on-board computers. Accurate monitoring of the scheduled trajectory by means of extremely accurate satellite navigation.
- Efficient Telecommunications Network - Ground-to-air data link networks to enable accurate trajectory information exchanges. All stakeholders to have effective and simultaneous access to flight information status.
- Airport Use Optimization - Smooth approach to reduce noise and gaseous emissions during landing. Better forecasting and detection of turbulence phenomena.
- Increased Automation of Air Traffic Control Tools.
  Share workload between the air traffic controller on the ground and the pilot. Includes various tools to reduce work load and stress on human operators including pilots. Example: Visualization tools in cockpit to visualize surrounding traffic etc.,

The introduction of AVs into the highway environment is similar to NextGEN/ SESAR with both being enhancing current system with new technology. Hence it is important to understand how NextGEN is implemented.

NextGEN[3] implementation is being made possible by joint ventures and partnerships involving multiple public and private stakeholders. Besides the FAA and the RTCA (Radio Technical Commission for Aeronautics), other key partners include Airline Pilots Association, Air Transport Association of America, the Aircraft Owners and Pilots Association. the Boeing Company, the Department of Defense, GARMIN International, Honeywell International, Rockwell Collins, Stanford University, Lockheed Martin, MIT Lincoln Laboratory, Harris Corporation, NASA, National Business Aviation Association, and Raytheon. It is clearly a group of stakeholders with different interest including regulatory/ government, OEMs, educational/ institutional, user groups, consumers either in public or private sector. Other stakeholders include user organizations like DELTA Air Lines and FedEX who are primarily interested in the systems functional effectiveness and its utility value and do not necessarily contribute towards its R&D.

The primary drive towards NextGEN is the proactive involvement and cooperation of government/ public stakeholders. Without regulatory actions that encourage implementation, NextGEN could have remained a concept. This portrays the importance of collaboration between stakeholders, presided by the government for successful implementation of new technology.

While NextGen has demonstrated improvements over traditional systems, there are still several ongoing and potential issues that will challenge[4] its success. Like any new technology at this scale, NextGEN is not 100% problem free. There are several issues that have been brought to light with others still brewing, yet to be discovered. Some of these are as follows:

1) Increases in costs
2) Delays in implementation schedule.
3) Environmental Impacts; especially noise pollution due to changes in flight patterns.
4) Interdependency of a numerous systems – NextGEN is a system of many sub-systems which are designed to work together and are mutually dependent on one another. It is necessary that all sub systems be in place before NextGEN goes online and is 100% functional.
5) FAA’s potential budget reduction by 20% is a major setback towards propelling forward.
6) Cyber Security concerns- unencrypted & unauthenticated signals are used as part of ADS-B (Automatic dependence surveillance – Broadcast). ADS-B is a sub system of NextGEN and enables aircraft tracking.

Key takeaways from the NextGEN implementation are:

1) The importance of defining and understanding benefits of technology transition. Apart for direct benefits, its lifecycle implications will also have to be considered. Again, cost to benefit comparisons must be carried out.
2) The value in defining and understanding the perspectives of all stakeholders involved along with their interest alignment. It is also important to identify stakeholders that are critical towards implementing this technology and attention must be given towards their ability to influence.
3) Potential problems/ challenges that need to be overcome to implement new Technology.
4) Potential problems that could arise from use of new Technology.
5) With respective to finances, on board equipment to support NextGEN/ SESAR are borne by aircraft owners including all private and public entities. Ground based control equipment on ATCs etc. are funded by the existing airport authority, either government entity or P3/PPP special purpose vehicle if any. It is hence important to identify and recognize financial responsibilities of different stakeholders.

2.4 Autonomous Vehicles

A vehicle capable of sensing its environment and navigating without human input are AVs. NHTSA[5] (National Highway Traffic Safety Administration), defines AVS as those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode.

NHTSA's policy primarily addresses:

- An explanation of the many areas of vehicle innovation and types of automation that offer significant potential for enormous reductions in highway crashes and deaths.
- A summary of the research NHTSA has planned or has begun to help ensure that all safety issues related to vehicle automation are explored and addressed.

- Recommendations to states that have authorized operation of self-driving vehicles, for test purposes, on how best to ensure safe operation as these new concepts are being tested on highways.

The policy statement also describes NHTSA's research efforts related to autonomous vehicles. While the technology remains in early stages, NHTSA is conducting research on self-driving vehicles so that the agency has the tools to establish standards for these vehicles, should the vehicles become commercially available.

NHTSA defines vehicle automation as having five levels:

- Level 0: No-Automation: The driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – always.
- Level 1: Function-specific Automation: Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
- Level 2: Combined Function Automation: This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.
- Level 3: Limited Self-Driving Automation: Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. Tesla “Autopilot” is an example of limited self-driving automation.
- 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. Such a

design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles. Google self-drive car, once approved by NHTSA would fall in this category.

Today, most vehicles fall into Level 0 or 1. Some luxury car makers offer Level 2 Automation with features such as blind spot monitoring system, lane keeping assist, adaptive cruise control etc., Level 3 automation is evident only with select OEMs such as Tesla Motors (Model S – AutoPilot) or experimental projects (Google – Project X/ Self Driving Car). Level 4 is still far from reality and will rely on further technology advances.

2.5 Connected Vehicles, V2X & DSRC

Another closely related concept to AVs are Connected Vehicles (CVs). A standard definition for CVs are those vehicles provisioned to access the internet or any LAN (Local Area Network) wirelessly. But in today's scenario, this definition has been extended as those vehicles equipped to provide V2V (Vehicle to Vehicle), V2I (Vehicle to infrastructure) and/or V2X (Vehicle to everything) communication using advanced equipment such as DSRC (Dedicated Short Range Communication) systems. V2V forms the basis of CVs and in many a case, CVs are simply referred to as vehicles with V2V or V2X capabilities.

Studies indicate conventional vehicles will transition to CVs before transitioning to AVs. The full benefits of Autonomous driving will require vehicle level integration for maximum efficiency and hence CVs will be required to reach Level 4 Autonomous driving capability.

AV's and CV's form part of the Intelligent Transport Systems (ITS), which in turn form a part of the Smart Cities concept and the IoT (Internet of Things) concept. Simply put, the first generation of V2V systems would warn the driver but not take control of the car. Later implementations would improve to brake or steer around obstacles and eventually merge with self-driving cars. Moreover, V2V is targeted to be a mesh network, meaning every node (car, smart traffic signal, etc.) could send, capture and retransmit signals.

The IoT concept application to conventional vehicles pioneered the first CVs offering more travel convenience by making vehicles “Smart” using tethered connection via a smartphone or using an embedded system with an antenna and chipset. The primary objective here is app integration, provide OEM with performance data, provide wireless software updates (Very helpful to OEM, especially on recalls) and up to Level 2 Autonomous Driving capability such as e-hailing, Stop & Go/ Adaptive/ Radar Cruise Control. These systems rely on several sophisticated sensors, RADAR and LIDAR based technologies. Governments are not much inclined towards these convenience features, as it might not offer overall higher safety ratings and can in fact lower it with additional distraction sources to the driver.

This brings up to the second phase which is sphere headed by the V2V systems. V2V/X allows autonomous vehicle communication and enables all compatible vehicles to function collectively. Hence this can help increase overall highway safety and hence interest governments. DSRC technology forms the backbone for these advanced communication systems.

The first phase is primarily pushed on by the OEMs as a step toward providing more comfort and convenience features. Automakers are ramping up these efforts for several reasons. Internet connectivity in vehicles allows car companies to release software updates in real time, which is extremely important during a recall. Second, automotive companies can use data from the car to analyze its performance and obtain valuable data on how drivers use their cars. Finally, more connectivity provides more ways for automakers to cross-sell their products and services to customers.

BI Intelligence[6] premium research service, expects 94 million CV’s to ship in 2021, and for 82% of all cars shipped in that year to be connected. This would represent a compound annual growth rate of 35% from 21 million CVs in 2016.

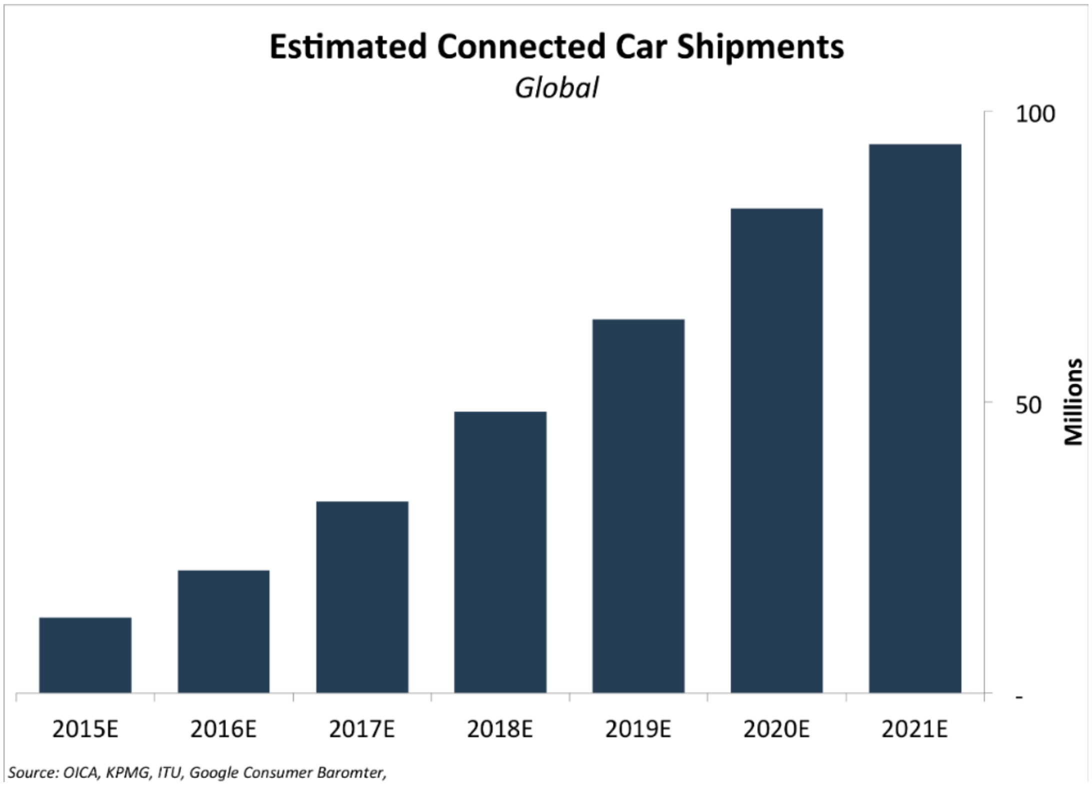

Figure 2.2 First Generation Connected Vehicle Shipments Estimate

The Second Phase is however being pushed over by the government considering its higher safety performance. Automakers, however only pursue it on compulsion considering the increased production costs and added technical complexity. V2V are however the more important aspect of CVs.

There are various additional equipment packages offered by OEMs today, especially in the luxury vehicle market segment. These packages provide an array of sensors to make driving more safe and less stressful. Some of the most advanced crash avoidance technologies present on vehicles today include a host of on-board sensors, cameras, and RADAR applications. These technologies may warn drivers of impending danger so that the driver can take corrective action, or may even be able to intervene on the driver's behalf. The question arises on what makes V2V systems, which forms the base of CVs better than these sensor based systems.

In order to identify these benefits it is important to explore and understand the importance of DSRC systems for vehicles and how they function. DSRC is the very tool behind the concept of V2X system and hence CVs.

By definition, Dedicated Short Range Communications (DSRC) is a data-only communication protocol with one-way or two-way short-range to medium range wireless communication channels specifically designed for automotive. There are two broad categories of DSRC: Vehicle-to-Vehicle (V2V) communication and the Vehicle-to-Infrastructure (V2I) communication. Other advanced protocols such as V2X (Vehicle to everything) are also available, but still at large in development stages. DSRC systems by itself is limited to providing a channel for fast data transfer/ communication in real time. It will require other systems such as GPS, Maps/ Virtualization, Sensor/ Radar based systems to provide fast response. When DSRC is used in conjunction with these systems, studies show an enormous increase in highways safety rating with near zero accident rate.
DSRC was developed with a primary goal of enabling technologies that support safety applications and communication between vehicle-based devices and infrastructure to reduce collisions.

DSRC is the only short-range wireless alternative today that provides:

- Designated licensed bandwidth: Enabling secure and reliable communication channel.
- Fast Network Acquisition: Ability to operate at close to instant speeds at real time.
- Low Latency: Can recognize other DSRC channels and transmit messages to each other in milliseconds without delay.
- High Reliability when Required: High level of link reliability. DSRC works in high vehicle speed mobility conditions and delivers performance immune to extreme weather conditions (e.g. rain, fog, snow, etc.).
- Priority for Safety Applications: Safety applications on DSRC are given priority over non-safety applications.
- Security and Privacy: DSRC provides safety message authentication and privacy.

Potential applications of DSRC include:

- Electronic toll collection
- Cooperative adaptive cruise control
- Intersection collision avoidance
- Approaching emergency vehicle warning
- Automatic vehicle safety inspection
- Transit or emergency vehicle signal priority
- Electronic parking payments
- Commercial vehicle clearance
- In-vehicle display of road signs and billboards
- Traffic data collection
- Rail intersection warning
- Blind spot warning
- Sudden braking ahead warning
- Rollover warning

A few tested and ready to deploy important applications in detail are as follows:

➔ Forward Obstacle Detection and Avoidance: In this application DSRC channel is used to communicate traffic information or accident warnings back through vehicles to caution the drivers of a possible danger ahead. Communication with vehicles directly behind or in front of an automobile can be used to enhance the functionality of adaptive cruise control systems. Information passed from vehicle to vehicle can warn the driver of obstacles or road hazards thousands of feet ahead.

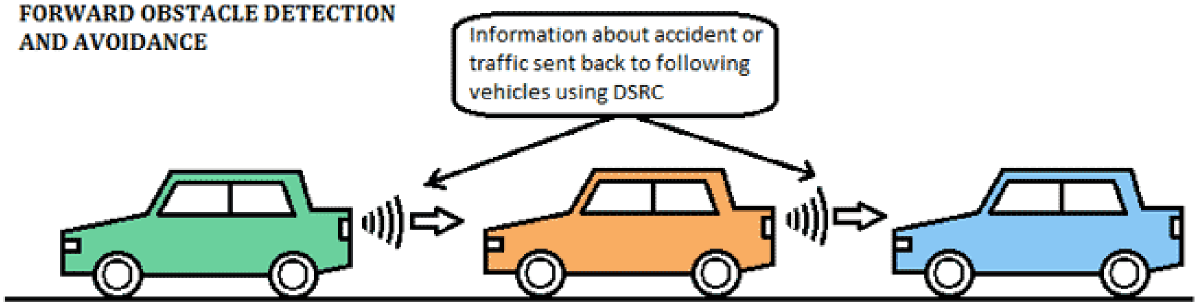

Figure 2.3 Forward Obstacle Detection and Avoidance

➔ Approaching Emergency Vehicle Warning: Vehicle to vehicle DSRC would enable information about an approaching emergency vehicle to be relayed from vehicle to vehicle forward through traffic. This would help to clear the way for the emergency vehicle and reduce the risk to other vehicles.

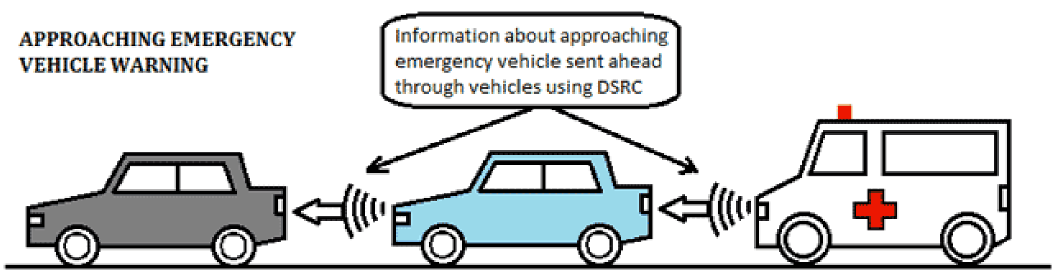

Figure 2.4 Approaching Emergency Vehicle Warning

➔ Cooperative Adaptive Cruise Control: This system is effective when the adaptive cruise control fails to perform correctly due to the radar's line-of-sight scanning. When the car approaches a sharp curve, the DSRC system warns the adaptive cruise control system of any slow-moving vehicles just around the turn.

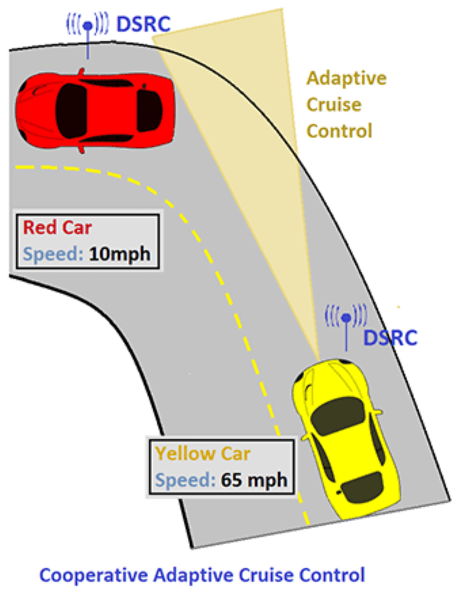

Figure 2.5 Cooperative Adaptive Cruise Control

In short, DSRC forms a very reliable and secure communications channel which can achieve a very high traffic safety rating while simultaneously providing more convenient driving environment.

DSRC[7] communications are governed by the IEEE 802.11p standard (Wireless standards). This communication protocol does not rely on access points but relies on direct communication between stations by forming a vehicular ad hoc network (VANET). DSRC applications are recognized on a global platform, especially amongst major automobile manufacturing countries. In the U.S., the FCC has allocated 75 MHz of bandwidth at 5.9 GHz for DSRC communications. In Europe, 30 MHz has been set aside for vehicular communications at 5.875–5.905 GHz, solely intended for road traffic safety applications. Non-safety-related applications are assigned a 20-MHz band at 5.855– 5.875 GHz. In Japan, the allocated frequency is 5.8 GHz. Generally, at 5.8 - 5.9 GHz, communication at data rates of 6 to 27 Mbps can occur at distances of several hundred meters. Understanding these technical capabilities of DSRC proves its reliability.

CVs have significant advantages over these technologies appearing in high-end. For one thing, CV technologies and applications have a greater range than on-board vehicle equipment, which will allow you to receive alerts of hazardous situations much earlier, providing more time to react and prevent an accident. This additional step in helping to warn drivers about impending danger use on-board dedicated short-range radio communication devices to transmit messages about a vehicle's speed, heading, brake status, and other information to other vehicles and receive the same information in return. These messages are channeled across a short to medium range area of influence which is typically much larger than that of sensor based systems. This longer range and ability to "see" around corners or "through" other vehicles helps V2V-equipped vehicles perceive some threats sooner than sensors, cameras and radar based systems and hence warn their drivers accordingly. V2Vs are also independent of "line of sight" phenomenon and are hence not affected by obstructions. Despite these advanced systems, CVs are not fully autonomous (Level 4) and will always require a driver to be in control of the vehicle. It however, simplifies and makes the drivers job easy with additional safety.

CV technology also enables vehicles to exchange information with infrastructure, such as traffic signals, through vehicle-to-infrastructure (V2I) communications. V2I communications help to extend the benefits of CVs beyond safety, to include mobility and the environment.

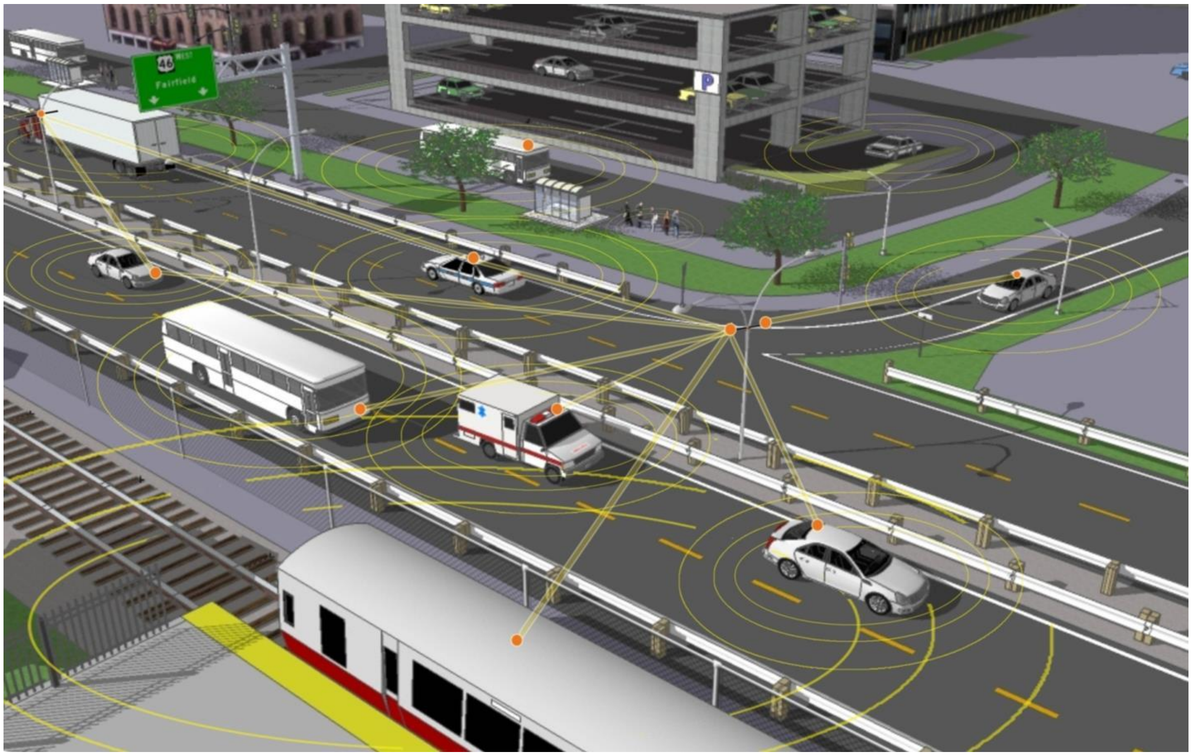

Figure 2.6 NHTSA V2V/ DSRC Visual representation

Considering these benefits, NHTSA aims to deliver a Notice of Proposed Rulemaking on vehicle-to-vehicle (V2V) communications technology for light vehicles by 2016. This will mandate that automakers must include V2V systems hardwired onto all new vehicles manufactured after a certain date. This is similar to OBD2 (On Board Diagnostics) systems which were mandated to be hardwired onto all light vehicles (Cars & Trucks) manufactured after 1996 in the United States. These mandates rely on the region and could be affected by Federal and State policies.

NHTSA preliminary estimates of safety benefits show that two safety applications—Left Turn Assist (LTA) and Intersection Movement Assist (IMA)—could prevent up to 592,000 crashes and save 1,083 lives saved per year. V2V technology could help drivers avoid more than half of these types of crashes that would otherwise occur by providing advance warning. Additional applications could also help drivers avoid imminent danger through forward collision, blind spot, do not pass, and stop light/stop sign warnings. It should also be considered that current technologies such as advanced airbag systems, anti-lock brakes have significantly contributed in bringing down fatalities and improving highway safety, they are more inclined towards reducing the severity of a crash. CVs are designed to prevent the crash from occurring and hence are perceived to a higher highway safety rating. It is estimated that safety applications enabled by V2V and V2I could eliminate or mitigate the severity of up to 80 percent of non-impaired crashes, including crashes at intersections or while changing lanes.

NHTSA studies estimate that every year, there are over 5 million crashes on American roads. Of these crashes, over 30,000 people die, and many more sustain grievous injury. The Centers for Disease Control says the leading cause of death among young children and young adults is vehicle crashes. Reducing these rates to achieve a higher safety rating has always been a key objective for the government.

In addition to the tremendous safety potential of CVs, they also promise to increase transportation options and reduce travel times. Traffic managers will be able to control the flow of traffic more easily with the advanced communications data available and prevent or lessen developing congestion. This could have a significant impact on the environment by helping to cut fuel consumption and reduce emissions. On implementing more advanced systems such as V2I or V2X, CVs would provide benefits that extend beyond drivers to include pedestrians and travelers using public transportation, a few applications as follows:

- Pedestrian in Signalized Crosswalk Warning: An application that warns transit bus operators when pedestrians, within the crosswalk of a signalized intersection, are in the intended path of the bus.

- Mobile Accessible Pedestrian Signal System (PED-SIG): An application that allows for an automated call from the smart phone of a visually impaired pedestrian to the traffic signal, as well as audio cues to safely navigate the crosswalk.
- Transit Bus Stop Pedestrian Warning: An application that alerts transit bus drivers and pedestrians at major bus stops when passengers are in harm's way as buses pull into and out of a bus stop.

Apart from safety benefits and applications, CVs promise to enhance travel reliability and increase resource use efficiency further. Couple applications are as follows:

- Dynamic Speed Harmonization (SPD-HARM): An application that aims to recommend target speeds in response to congestion, incidents, and road conditions to maximize throughput and reduce crashes
- Queue Warning (Q-WARN): An application that aims to provide drivers timely warnings of existing and impending queues
- Cooperative Adaptive Cruise Control (CACC): An application that aims to dynamically adjust and coordinate cruise control speeds among platooning vehicles to improve traffic flow stability and increase throughput.

Applications could also improve carpooling experience, such as:

- Dynamic Ridesharing (D-RIDE): An application that uses dynamic ridesharing technology, personal mobile devices, and voice activated on-board equipment to match riders and drivers.

Other applications include reduced environmental impacts by the enhanced efficiency and bad weather assistance systems.

Current studies indicate that OEMs and suppliers would have an adequate supply of readily available, mass-produced, internal components for a V2V device approximately 2.5 to 3 years after NHTSA moves forward with any regulatory action[8].

Primary concerns on passing regulations are the increased vehicle manufacture costs and privacy protection with this large-scale data transfer. Collected data for FDOT studies indicate a reasonable increase in initial costs of $350 per vehicle in the year 2020 and a $18 per year increase in fuel costs. This may seem as a very reasonable amount on a per vehicle basis, but is a large sum considering total costs. The total cost is ultimately important here as CV aim to provide benefits collectively. A total cost to benefit analysis is still unclear at this stage and hence is a point of concern. Data Privacy is another controversial topic, that can be easily resolved but can also be easily misused, not only by the private partners but also the government on grounds of National Security. Moreover, FDOT/NHTSA states that V2V technologies do not pose a significant threat to privacy and have been designed to help protect against vehicle tracking by the government or others[9]. CVs technology does not involve exchanging or recording personal information or tracking vehicle movements[10]. The safety applications require that the wireless devices in CVs send and receive basic safety data—vehicle location, speed, direction, brake status, etc. The information sent between vehicles does not identify the vehicles or their drivers. Nearby motor vehicles will only use that information to warn drivers of crash-imminent situations. Data Security to prevent outside hacking/ intrusion are also an issue that the NHTSA is addressing alongside. Firewall and security systems must be created, funded and managed by private entities as dictated by NHTSA. This in turn brings into picture another private partner specialized to provide secure data services to operate CVs. Wireless network providers best fit into this category and will look to establish long term relationship with the customers directly or indirectly through manufacturers/ dealers. This would also increase the operation costs for CVs.

Other challenges towards CV's include[11]:

- Finalizing the technical and management framework of a V2V communication security system, which will be unique in size and structure

- Ensuring that a possible sharing with other wireless users of the radio-frequency spectrum used by V2V communications will not adversely affect V2V technology's performance
- Ensuring that drivers respond appropriately to warnings of potential collisions
- Addressing the uncertainty related to potential liability issues posed by V2V technologies

FDOT through NHTSA and in partnership with Transport Canada and AASHTO are currently developing a preliminary general concept of a national CVs field infrastructure footprint.

Their milestones are as follows:

- 2016 – Issue Notice of Proposed Rulemaking
- 2018 – Issue regulation mandating V2V technology
- 2019 – Begin phase-in period for new car production
- 2021 – V2V technology included on 100% of new car production

Future applications of CVs are AVs includes Smart Cities with high performance TSM and TDM modules. Another drawback with V2V applications is that they will not be fully functional until a significant percentage of cars on the road are equipped with DSRC systems. It is based on peer- cooperation models and hence government support to enforce DSRC equipment on new vehicles is important.

2.6 Current Public Policy

NHTSA’s policies are based upon research on a variety of topics related to AVs development such as:

- Human Factor Research
- Electronic Control Systems Safety - Reliability & Cyber Security
- Develop System Performance Requirements

NHTSA does not recommend that states authorize the operation of self-driving vehicles for purposes other than testing now. Several technological issues as well as human performance issues must be addressed before self-driving vehicles can be made widely available. Self-driving vehicle technology is not yet at the stage of sophistication that it should be authorized for use by members of the public for general driving purposes. Should a state nevertheless decide to permit such non-testing operation of self-driving vehicles, at a minimum the state should require that a properly licensed driver be seated in the driver's seat and always be available to operate the vehicle in situations in which the automated technology is not able to safely control the vehicle.

The following map shows the states that have acted towards AVs[12].

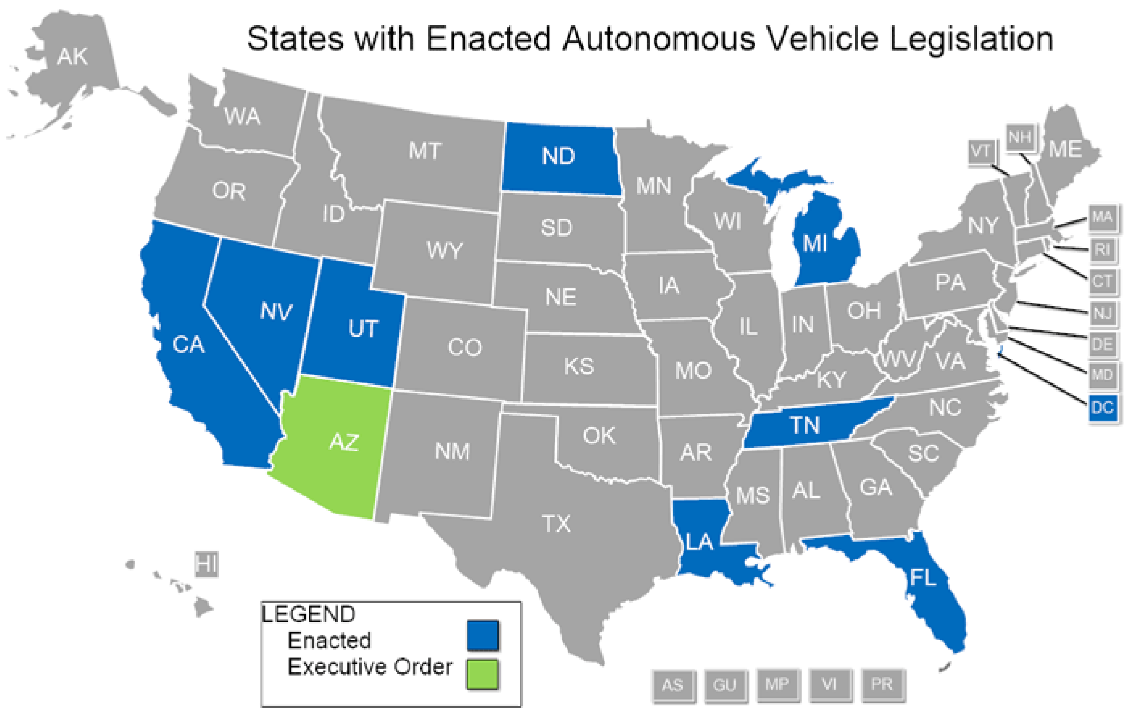

Figure 2.7 States with Enacted Autonomous Vehicle Legislation

Sixteen states have introduced legislation related to AVs in 2015, up from 12 states in 2014, nine states and D.C. in 2013, and six states in 2012. Since 2012, at least 34 states and D.C. have considered legislation related to autonomous vehicles.

NHTSA is clear in its guidance that states retain their traditional responsibilities for vehicle licensing and registration, traffic laws and enforcement, motor vehicle insurance and liability regimes and that the model state policy included in NHTSA's policy release is in no way binding on states wishing to take action regarding use of AVs in their state. Separately, NHTSA issued an enforcement bulletin regarding its authority to issue recalls on such automated technology. This policy is a result of the current technology backlogs that will need to be addressed before Level 4 AVs are street legal.

It is crucial that the federal government proactively establishes policies and regulations for driverless cars to ensure that passengers and bystanders are safe, but also because it is inefficient, costly, and confusing for all stakeholders to familiarize themselves with multiple, disparate state laws. The following are a range of issues that are most appropriately addressed at the national level:

- Safety. The federal government should lead the charge in establishing safety standards for AVs, similar to those already in place by the Federal Motor Vehicle Safety Standards and Regulations. Specifically, the federal government should establish standards around manufacturing, vehicle design, infrastructure, and all aspects of data and communications - all with the intent of maintaining safety on our roadways.
- Privacy/Data Sharing. Because AVs will gather a large volume of data to operate most effectively, there are significant concerns about data ownership, collection and use. The federal government should require that the driverless car industry is transparent with consumers about data ownership, sharing, and any security breaches.
- Cyber Security. AVs could be targets for terrorists, and an attack carries the risk of significant, coordinated traffic disruptions or collisions. The National Institute of

Standards and Technology (NIST) is currently developing a framework to improve critical infrastructure cyber security and it is vital that the government ensures that this encompasses the risks associated with AVs.

The following are a range of issues that are most appropriately addressed at State/ local level:

- Mobility. There are many factors that will influence the level of congestion within and around our cities. For example: People may continue to own their vehicles and mostly travel alone, or the shared economy model (Uber) may become more prevalent. More people may travel due to increased mobility options for elderly, disabled, and youth populations. People may be willing to live farther from the jobs. Cars will likely have shorter headways, roads may have more capacity, and parking circulation may be reduced.
- Infrastructure. Depending on the evolution of AVs local infrastructure will need to keep pace. Specifically, local governments may need to update and reconfigure signage, speed limits, signal timing, roadways and parking spaces.
- Transit. As AVs become more popular, everything from service coverage to vehicle types to labor requirements stands to change. Transit agencies will need to completely re-think their services and fee structure in order to stay competitive in the new transportation environment.
- Revenue. Local governments will have significant financial consequences associated with driverless cars. Taxes, parking fees, speeding tickets, parking real estate, and incident management costs are just a few of the government revenues and costs likely to be affected. Local governments should understand the impact of AVs ahead of time and prepare accordingly.

Local and regional governments should proactively plan for and develop policies in these areas. It will be vital that, in the near-term, local and regional government organizations follow AV developments. Moreover, states will likely continue to be responsible for AV licensing and testing requirements. This includes establishing the standard for who is liable an AVs, and how and where it must be tested. In the medium to long-term, these government organizations will need to consider more significant actions, including proactively managing congestion, altering the transit service model, investing in relevant infrastructure, and updating their financial mechanisms.

3. METHODOLOGY

3.1 Introduction

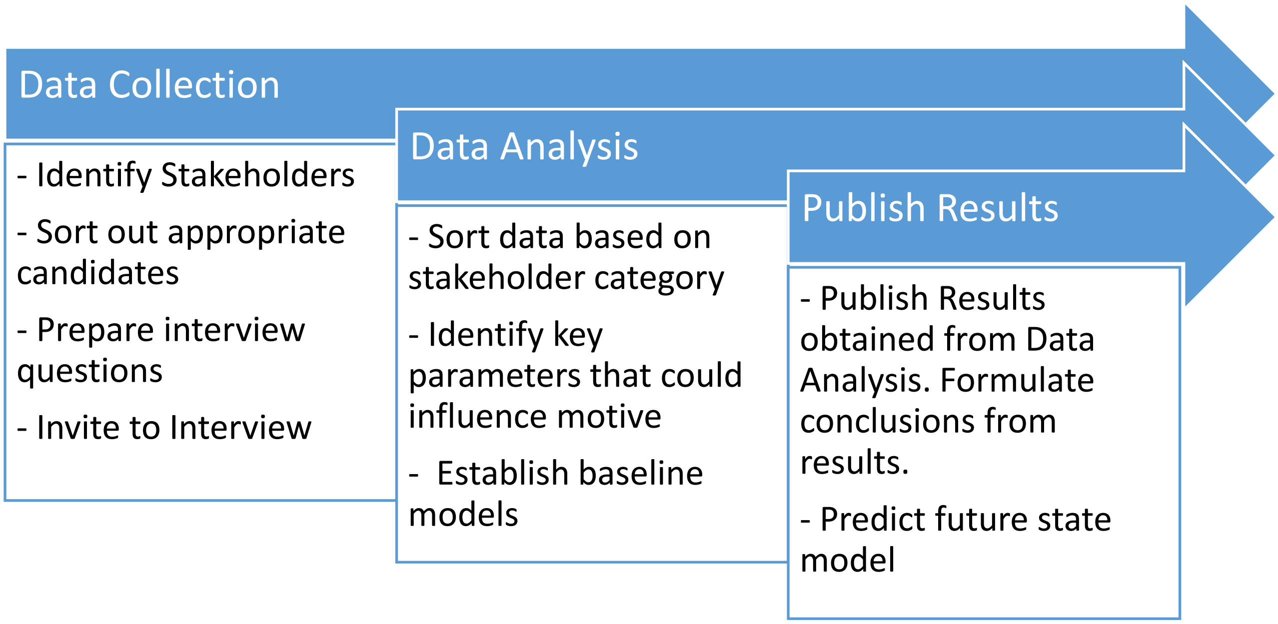

Figure 3.1 Steps in Process

The steps in this study involve formulating questions that need to be addressed by various stakeholders who can directly influence or can be influenced by inception of AV technology. The collected data will need to be processed and common goals will need to be identified. It is also important to identify effective tools to utilize these key points and represent them such that sensible conclusion may be derived from it.

3.2 Stakeholder classification

As the first step, it is important to determine all valid stakeholders and classify them as primary or secondary depending on their role toward AVs development and how socio-economic changes brought will impact them.

Technology suppliers and OEMs can directly affect and can play a key role in AVs development. Thus, they are also the first to be impacted. The following tabulation will describe potential primary stakeholders.

Table 3.1 OEM & Technology Stakeholders

Technology Suppliers & OEMs		
OEM (Original Equipment Manufacturer)		
Parent Organization	Subsidiary	Industry/ Market
Volkswagen Group	Volkswagen	Passenger Automaker
	Audi AG	Luxury Automaker
	Scania Group	Commercial Vehicles
	MAN SE	Commercial Vehicles
Daimler AG	Mercedes-Benz	Luxury Automaker
	AMG*	Performance Division
	Daimler Trucks	Commercial Vehicles
BMW group	BMW AG	Luxury Automaker
FCA (Fiat Chrysler Automobiles)	FCA	Passenger/ Luxury Automaker
	IVECO	Commercial Vehicles
Ford Motor Company		Passenger Automaker
General Motors		Automaker
Honda Motor Company		Passenger Automaker
Hyundai Kia Automotive Group	Hyundai Motor Company	Passenger Automaker
Tata Motors	Land Rover	Passenger Automaker
	Jaguar Cars	Luxury Automaker
Groupe Renault	Nissan Motor Company	Passenger Automaker
	Renault	Passenger Automaker
Tesla Motors, Inc.		Automaker/ Energy Storage
Toyota		Automotive Group
AB Volvo		Automotive Group

Table 3.1 OEM & Technology Stakeholders (continued)

Software/ Technology Providers		
Parent Organization	Subsidiary	Industry/ Market
Alphabet Inc.	Google	Technology Company
Apple Inc.		Technology Company
Intel Inc.		Semi-Conductor Manufacturing
Baidu Inc.		Internet Services
Robert Bosch GmbH	Bosch	Automotive Components
Delphi Automotive PLC		Automotive Components
Mobileye		Technology Company
Savari		DSRC & Tech Solutions
Nvidia		Technology Company
Tata Group	Tata ELXSI	Design Development

* Opinion necessary to determine impact of AVs on performance/ pleasure/ sport cars

Apart from OEMs and Technology Companies, the most important stakeholders are the consumers. The purpose of AVs is to satisfy consumer needs in the most efficient possible way at reasonable costs. Consumers can be broadly classified as the general public and commercial clients such as car rental agencies and fleet operators. These agencies are generally secondary stakeholders as they will most certainly be affected by AVs but have limited say in development depending on their position.

Policy stakeholders are interested in regulating the safe use of these new technologies for public benefit. In the context of AVs, the government's role is primarily restricted towards passing legislations with respect to use of AVs on a state to state basis, in the United States. The government is likely to supplement the interests of the general public consumers and their interests. It can be considered a prime stakeholder especially in the later phases of AVs use and will form the public entity in the business model.

Academic institutions fall into this category along with government entities. They can play an influential advisory role toward technology development in partnership with OEMs and government entities.

Table 3.2 Policy Stakeholders

Policy Stakeholders		
Parent Organization	Subsidiary	Industry/ Market
DOT's	Various State/Federal agencies	Motor Vehicles Administration
Academic Institutions		Various research groups

User stakeholders purchase and utilize the equipment. This includes three main categories: people who purchase and use the vehicles, fleet owners who purchase and lease the use of the vehicles, and shippers and carriers who use the vehicles for freight-related purposes.

Table 3.3. User Stakeholders

User Stakeholders		
Ride Sharing/ Fleet Operators		
Parent Organization	Subsidiary	Industry/ Market
Uber Technologies Inc.		Ride Sharing
Lyft		Ride Sharing
Sidecar		Ride Sharing
Hertz Global Holdings	The Hertz Corporation	Vehicle Rentals
Enterprise Holdings	Enterprise Rent A Car	Vehicle Rentals
	National Car Rental	Vehicle Rentals
AVIS Budget Group	AVIS Rent A Car	Vehicle Rentals
	Budget Rent A Car	Vehicle Rentals
	Zipcar	Short Term - Vehicle Rentals
People		
Organization	Subsidiary	Comment
NC State Students	Civil Engineering Class	Class of 68 students in age group 18-23 years.

Table 3.3. User Stakeholders (continued)

Freight Shippers / Supply Chain		
Parent Organization	Subsidiary	Industry/ Market
Amazon.com, Inc.		Online Retailer / Supply Chain
UPS		Logistics
FedEx		Logistics
USPS		Postal Services
Deutsche Post	DHL Express	Logistics

Supporting stakeholders provide services for the AV market but do not manufacture, operate or maintain the vehicles. This includes the insurance industry, vehicle care and maintenance service providers (other than OEMs), vehicle sales organizations, and the power supply industry. Say something more about this group.

Table 3.4. Supporting Stakeholders

Supporting Stakeholders		
Insurance Companies		
Parent Organization	Subsidiary	Industry/ Market
Allstate		Auto Insurance
State Farm		Auto Insurance
Progressive		Auto Insurance
Liberty Mutual		Auto Insurance

Car Care Services		
Parent Organization	Subsidiary	Industry/ Market
Bridgestone	Firestone Complete Auto Care	Maintenance & Repairs
Meinake Car Care Centers, Inc.,		Maintenance & Repairs

Table 3.4. Supporting Stakeholders (Continued)

Wireless Providers		
Parent Organization	Subsidiary	Industry/ Market
Verizon Communications	Verizon Wireless	Wireless Communication
AT&T		Wireless Communication
Deutsche Telekom	T Mobile US, Inc.,	Wireless Communication

Energy & Power		
Parent Organization	Subsidiary	Industry/ Market
Duke Energy	Progress Energy Inc.,	Electricity & Utilities
ExxonMobil		Oil & Natural Gas
Chevron Corporation		Oil & Natural Gas
PPL Utilities		Electricity & Utilities

Auto – Dealers		
Parent Organization	Subsidiary	Industry/ Market
Hendricks Automotive Group		Auto Dealer
CarMax		Auto Dealer

3.3 Establish Baseline

Vetted associates from different stakeholders considered are to be interviewed as part of obtaining quality data on their organization's role towards AVs and how they are expecting to adapt or be influence by it. This data will be utilized to generate a flow chart depicting the entire system and how different stakeholders are related to one another. The flow chart will be complimented with results from the various interviews conducted. A flow chart based representation is used considering visualization needs of quality data.

3.4 Points of Interests

It is important to identify important questions and points of concern to ask stakeholder candidates for an efficient survey/ interview response. The following questions and/or points of concerns will need to be addressed in order to predict a future state with respect to AVs.

OEMs & Technology Stakeholders

(1) OEM's:

- Expected market entry date
- Market Strategy: Premium Incumbents, Attackers, Fast Followers
- Target Audience: Fleets/ Specialized (or) General Public
- Key obstacles towards goal including Technological Constraints, Legislative Constraints & Public Support
- After Sales Services & Commitment
- After Market Kits to modify non-autonomous vehicles to support autonomous driving
- Operations Liability
- Additional services inclusion: In Vehicle Entertainment/ Communication
- Collaboration with other business such as Insurance, Technology Partners
- Sales Strategy & Vehicle Ownership: Owning/ Financing/ Leasing.

(2) Technology

- Key obstacles towards goal including Technological Constraints, Legislative Constraints & Public Support
- Collaboration with other business such as Insurance, OEM's
- Market Strategy: Vertical Collaboration with OEM's/ Horizontal Collaboration with other Technology Providers
- Operations Liability
- Intrusions & Cyber Security

Policy Stakeholder- Government Agencies & Institutions

- Interest & Understanding of Benefits – Safety, Congestion, Lower Life Cycle Costs
- Willing to enforce us of AV (or in AV mode) in high risk areas, if technology successful?
- Obstacles to pass legislations in favor of AVs
- Operations Liability

- Cyber Security/ Data Sharing/ Privacy
- Mobility: Additional infrastructure/ Public Transit/ Finances/ Revenue
- Licensing framework & role of DMV
- Manufacturing, inspection & certifications – Rules & Regulations
- Financial responsibility

User Stakeholders

(1) Ride Sharing/ Fleet Operations

- Partnership/ Collaboration with OEM's, Technology provider
- Operation Liability
- Current staff (Chauffeurs) status
- Vehicle Ownership
- Data Sharing/ Privacy

(2) Logistics & Supply Chain

- Partnership/ Collaboration with OEM's, Technology provider
- Expectations/ solutions from technology

(3) Public Users

Support Stakeholders

(1) Auto-Care

- Change in business plans/ disruptions
- Future business strategy

(2) Automotive – Insurance

- Change in business plans/ disruptions
- Future business strategy

(3) Auto -Dealers

- Change in business plans/ disruptions
- Future business strategy

(4) Wireless Providers

- Data Sharing/ Privacy
- Liability

(5) Energy Providers

- Effect on current business model

3.5 Publishing Results

Making use of obtained data, visualizations of the different stages can be drawn. These stages are predicted points on timeline based on which current state map can be plotted. Based on the current state and obtained data, a future state map can be plotted. Conclusions can then be drawn upon based on these visual representations.

The qualitative nature of the data makes it difficult to build and/or simulate any mathematical models and adopting a flow chart based visualization would be the only sensible option. It may require multiple charts logically linked with one another to satisfy visualization requirements.

4. RESULTS

4.1 Introduction

It is important to obtain opinion form all stakeholder groups of the exiting public private partnership highway transit model to draw results and to arrive on sensible conclusion.

A preliminary assessment of the possible future public/private AV market has been developed by a review of the literature available and a very brief survey. The results of that assessment are presented below.

Later sections disclose results of in-depth surveys conducted at various private and government stakeholder level. These results are then utilized to draw conclusions using logical visualizations.

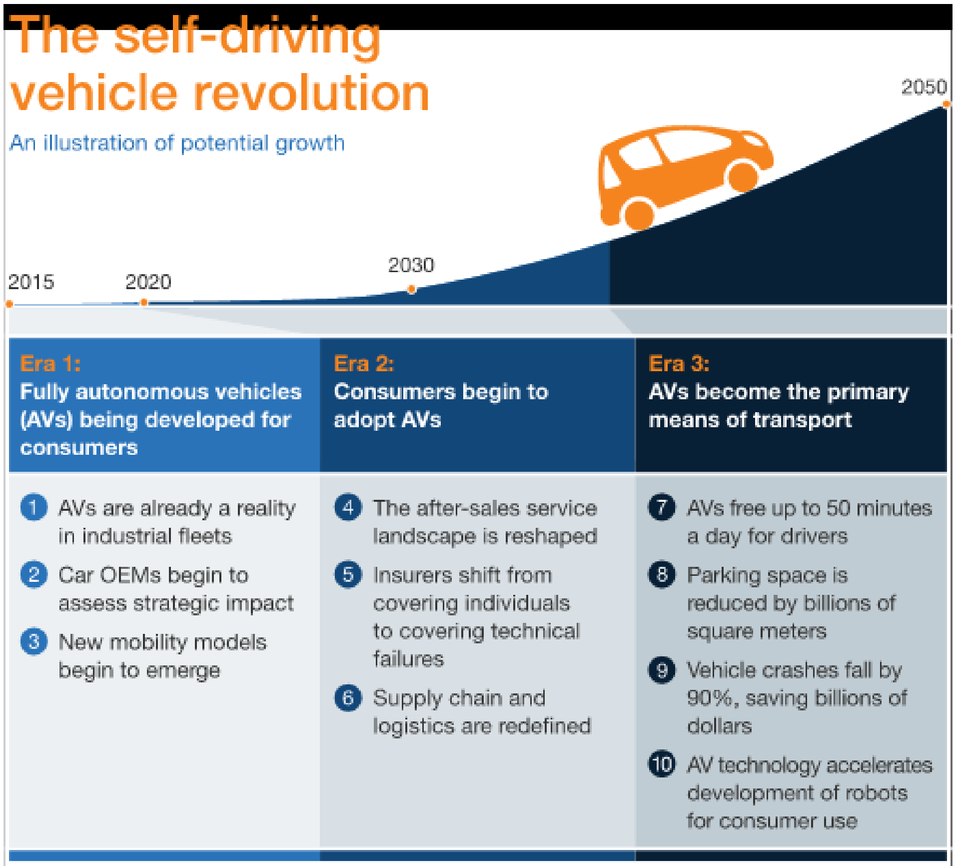

Figure 4.1 Preliminary study by McKinsey & Company

4.2 Projected effects of AVs on different industries

The widespread use of AVs could profoundly affect a variety of industry sectors. There are three hypothetical time phases of AV diffusion to consider: [13]

- Phase #1: Before such vehicles are commercially available to individual buyers
- Phase #2: When they are in the early stage of adoption
- Phase #3: When they become the primary means of transport

Phase#1

(a) Industrial Fleets are likely to be the first to adopt AVs: Industrial fleets are required to satisfy selected applications that operate in controlled environments, such as mining and farming. In these cases, the restricted nature of operations and the possibility to operate on private roads facilitate adoption of AVs. Some of the benefits of autonomy in these fields include labor-cost savings and the reduction in emissions through optimized driving. Other adjacent industrial applications—for example, the construction and warehousing sectors have potential AV applications for vehicles such as excavators, forklifts, and loaders. The next step in Industrial AVs is inclined towards highway trucks. Prototypes already exists with rapid advancements that will eventually deliver the finished product in the next couple years.

(b) Auto OEM's will develop strategies related to the AV market: OEM's worldwide will define and communicate their strategic position on AVs and will fall into any of these typical categories:

- Premium Incumbents: Established premium players with extensive customer bases and strong technical and commercial legacies will probably take an incremental approach to AVs. They are inclined to gradually introduce increasing levels of advanced driver-assistance systems (ADAS) in their vehicles.
- Attackers: New industry players developing "radically new" vehicle architectures—such as high-tech giants, first-tier suppliers, and mobility operators—will focus on the "accessible mobility" consumer segment to capture volumes quickly and sustain ancillary business models.
- Fast followers: These OEMs have significant technical and commercial legacies. They will most likely invest in AV research and then wait for the vehicle-level costs of the core technologies to drop while penetration in, as the premium segments grows.

- Late entrants/non-adopters: As the name implies, these automakers will avoid entering the AV market in the short to medium term. They will typically include exotic car manufacturers.

Identifying and prioritizing stakeholders will be critical for this research as their opinion on AVs development and how it is going to reshape existing transit conditions will help establish their roles and needs towards developing a balanced and successful business model.

(c) New Mobility Models

A variety of other transport mobility innovators are hitting the road. Many of these include pay per use (Ride Sharing/ Car Pooling, E- Hailing, Peer to Peer rentals). Many of these already exists today and are experiencing strong growth in terms of investment funding and market penetration.

Phase #2

(a) After Sales Environment is affected: After-sale maintenance and repairs of AVs will play a role different than that which is common today. A large majority of car service shops today are independent from OEM's. Given the safety-critical nature of AV technologies, customers might strongly prefer strict adherence to OEM service processes and the use of original service equipment when it comes to maintaining and repairing AV systems. This could create a disadvantaged position for independent service providers unable to afford AV-maintenance systems. Beyond the benefits of a bigger after-sales revenue stream, OEMs will have a strong incentive to service these vehicles, since regulators could ultimately force them to take on the greatest portion of the responsibility and risk associated with crashes caused by AV technical failures.

(b) Car Insurance: Car insurers have always provided consumer coverage in the event of accidents caused by human error. With AV, auto insurers might shift the core of their business model, focusing mainly on insuring car manufacturers from liabilities from technical failure of their AVs, as opposed to protecting private customers from risks associated with human error in accidents. This change could transform the insurance industry from its current focus on millions of private consumers to one that involves a few OEMs and infrastructure operators, like insurance for cruise lines and shipping companies.

(c) Supply Chain & Logistics Reshaping: AV technologies could help to optimize the industry supply chains and logistics operations of the future, as players employ automation to increase efficiency and flexibility. AVs in combination with smart technologies could reduce labor costs while boosting equipment and facility productivity. What's more, a fully automated and lean supply chain can help reduce load sizes and stocks by leveraging smart distribution technologies and smaller AVs.

Phase #3

(a) Travel Convenience: AVs commuters will be able to spend traveling time working, relaxing, or accessing entertainment. It could also create a large pool of value, potentially generating global digital-media revenues when people access mobile Internet while in a car.

(b) Redefining "Parking": AVs could change the mobility behavior of consumers, potentially reducing the need for parking space. Multiple factors will contribute to the reduction in parking infrastructure.

(c) Accident Rates Drop: The penetration of AVs and other ADAS might ultimately cause vehicle crashes to go down in terms of their lethality ranking among accident types. Today, car crashes have an enormous impact on the US economy. For every person killed in a motor-vehicle accident, 8 are hospitalized, and 100 are treated and released from emergency rooms. The overall annual cost of roadway crashes to the US economy was

$212 billion in 2012. Taking that year as an example, advanced ADAS and AVs reducing accidents by up to 90 percent will have potentially saved about $190 billion.

(d) AVs impact on society and other fields: A broad penetration of AVs will likely accelerate the development of robotics for consumer applications, since the two share many technologies. These include remote advanced sensing, hyper precise positioning/GPS, image recognition, and advanced artificial intelligence. In addition to sharing technology, AVs and robots could benefit from using the same infrastructure, including recharging stations, service centers, and machine-to-machine communication networks.

The immediate impact of AVs can be summarized as follows:

- Manufacturer liability is likely to increase while personal liability is likely to decrease. If a vehicle and a human share driving responsibility, the insurance issues could become more complicated.
- Inconsistent state regulations pose a risk — if 50 states have 50 different regulations, it will be difficult for manufacturers to match them all. Likewise, vehicle owners might not be able to travel outside their state of residence.
- Because many of the benefits of AVs accrue to those other than the purchaser, subsidies or taxes may be necessary to maximize social welfare by equalizing the public and private costs and benefits.

Another aspect on advancements of AVs is that it is not driven from a consumer demand standpoint but is a ramification of Auto Manufacturers thinking through. It is obviously more supply driven when assessing the technological possibilities versus customers longing for this product today. But this is also common in many tech areas where, in a way, innovation should provide or must create markets—and is basically tapping into unmet or latent demand.

Younger people today are much towards mobility services and are maybe less keen on driving a car. This is compounded by a variety of reasons. The economics and the problems associated with owing a car seems to overweigh the economics associated with pay-per use transit services. The traffic situation in many major cities is a mess along with environmental situation including air quality. So, big cities are looking for opportunities to have less or better-flowing traffic. And at the same time, having less traffic also free up additional land and today, in many cities, a very significant portion of the land is occupied by parking spaces. This all might lead to a new question if Auto- manufacturers should anticipate to sell fewer vehicles. But it will turn out to be around the same number growing at the same rate. Model calculation will prove that cars in car-sharing or e-hailing services have a much higher amount of utilization. Thus the lifetime of such vehicle is significantly lower. Calculating it through with realistic use cases, the number of cars sold is probably pretty much the same, but their life cycle is much shorter.

OEMs are gearing up towards a hybrid of offerings with respect to the scenario when AVs enter the market. Designing, manufacturing, distributing and servicing cars will still be a core business for OEMs as even the new mobility providers will need vehicle. They will however have to go beyond the car itself in terms of the more core service around the vehicle in terms of maintenance and support service for the vehicle itself. A situation where vehicles and devices share a thin interface, OEM's will need to foster a more proactive and dynamic relationship with their client base, which need not necessarily be the masses but will be fleets and vehicle sharing networks.

The automobile retail market will change. There will be a hybrid of traditional dealer formats, as many customers will still want to see a car at least at some point in the customer decision journey. The physical experience will stay important. On the other hand, there will also be a need for digital interaction. A hybrid model will provision a seamless customer decision journey in the digital arena, combined with the physical interaction with test-driving, touch, and feel of the vehicle. Key take away here is that an automobile is the second most expensive purchase that consumers make after a house. Hence it will not be completely digitized in terms of information, inquiry, evaluation, and transaction. But this digitization could play a much bigger role than present day.

Obviously, there will also be some innovative options that give customers even more or better offerings for their needs. This may include vehicle lease plans extended as "in contract" plans similar to what telecom companies offer phones as.

It is also important to explore the role played by Federal & State Governments and their policies towards AVs use. Apart from setting safety standards and use regulation, their legislations are intended to generate a feeling of trust to the consumers to adopt AVs.

4.3 NC State Students Survey

The following survey[14] was conducted at a Civil Engineering Undergraduate Class with roll of 68 students and had recorded 62 responses successfully. Motive behind this step is to understand how the upcoming generation views the AV technology. Is it embraced with open hands or not? Irrespective of the results, it should be taken to note that the despite the target audience doesn't include much diversity, the variance in result is primarily contributed through the environment in which they were raised.

Survey Question #1:

Type of place where I was brought up:

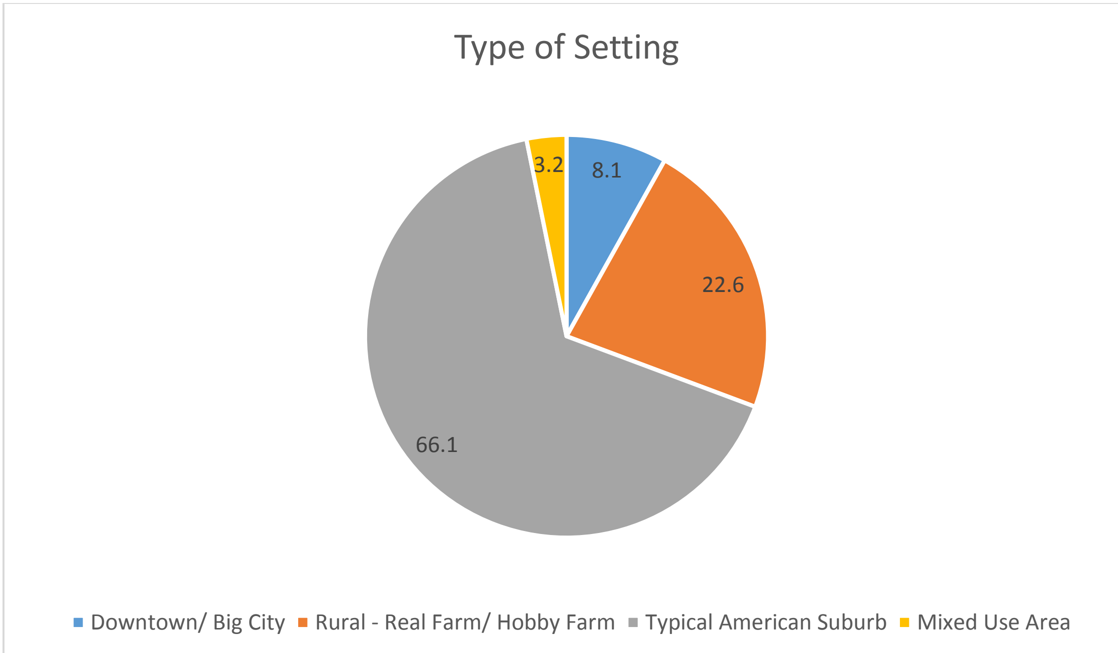

Figure 4.2 Internal Survey Poll Results #1

Key takeaway is that a majority were brought up in American Suburbs. Only 8.1% were brought up in densely populated regions. It can be assumed to some extent that most student would not have faced traffic gridlocks and congestions that are frequent in most major cities and densely populate regions.

Survey Question #2:

Inclination towards AVs rated on a 0 to 5 scale where

Scale 0 – I can't wait! (High inclination toward AVs)

||

Scale 5 –Always be in the driver Seat (Aversion toward AVs)

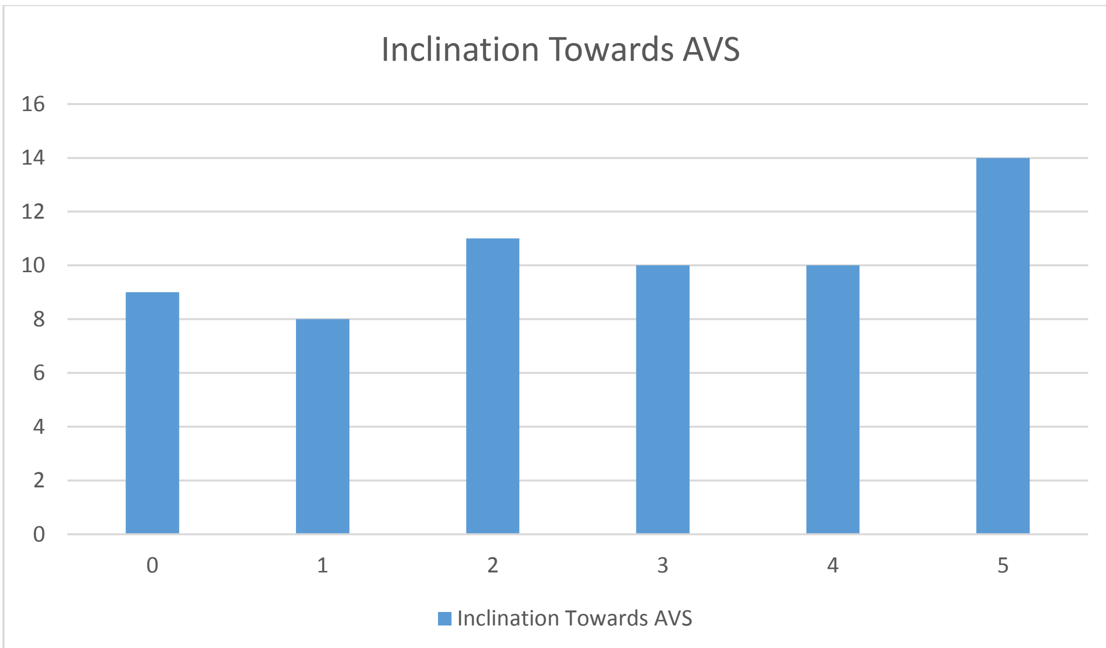

Figure 4.3 Internal Survey Poll Results #2

Key takeaway here is that, on a basic skim, it is evident that AVs may not be the most sought after transit mode. But considering the fact that, the result is almost flat lined and that a good majority of students were brought up in not so densely packed environment such as Downtown or the Central Business district and are less likely to have experienced peak hour traffic, it can be inferred that AVs are more likely to have a good market on commercial inception. These results are preliminary and a broader study is to be implemented before drawing to conclusions.

Moreover, the demographics of this preliminary study is restricted to students mostly in age group 18 years – 23 years and all currently residing in the same city. Hence the accuracy of the study is diminished when considering a broader region as the entire Country or even the given State.

4.4 Stakeholder Surveys

Adopting tabulation of stakeholder classification as reference, stakeholders were invited to take part in surveys and/or interviews to provide data to generate results. Obtained results were qualitative in nature and are based on different stakeholder roles and expectation towards AVs.

The primary challenge in this process is gathering quality data from reliable sources. Tools including email conversations, LinkedIn / Professional networking, and phone conversations were used to reach associates with various stakeholders. To ensure data quality, candidates were shortlisted based on their seniority level (Vice Presidents/ Directors/ Chiefs), years associated with organization (Preferably 2+ years) and job function (Directly related with AVs, in some cases like insurance companies – associates in Public Relations and Market Strategy were shortlisted instead).

150 vetted candidates were requested to provide opinion and 33 responses were submitted. Out of these, 3 responses were incomplete and generic in nature and were discarded, hence totaling 30 quality responses. The split-up of requested and received responses are given as follows, sorted based on their industry types.

Table 4.1. Tabulation of Received Response

Stakeholder Industry	Number Shortlisted	Responses Received	Success rate (%)
OEM/ Automotive Service/ Maintenance	47	11	23.40%
Technology/ Software/ Wireless Provider	23	4	17.39%
Public Agency/ Institutions	16	10	62.50%
Fleet Operators	26	1	3.85%
Insurance/ Dealers/ Third Party	29	2	6.90%
Supply Chain	4	1	25.00%
Energy Provider	5	1	20.00%
Total	150	30	20.00%

The success rates are to be compared with their respective industry types and considering only the total success rate would be an inappropriate measure, keeping in mind the variable success rate amongst different incompatible industry types.

A summary of collected responses is provided as the next section.

4.5 Industry Specific Stakeholder Response Summary

- **OEM/ Automotive**

  Most respondents have predicted late 2020/ early 2021 to be the timeline around which new entrant AV (NHTSA Level 4) would reach market inception. However, CV (Connected Vehicles) (NHTSA Level 3 and below) are bound to be available to consumers much earlier and/ or already available today. Important point of note here is that despite these AVs could be Level 4 fully Autonomous, a steering wheel and other control devices will be in place and a licensed driver is to be present at the wheel to operate the vehicle. Liability issues apart, if any, AVs would still need to be tested under real world conditions, without any experiment control systems in place. A driver can take over control, if any systems were to fail under unanticipated or untrained conditions.

Most of the OEM companies regard themselves as Attackers, with respect to market strategy, where they adopt and develop new technologies in parallel to existing ones. Apart from luxury vehicle manufacturers, most OEM target fleet operators as their target audience. Luxury vehicle manufacturers standalone target the general public and will most likely retain the steering wheel and other input components. This is to provide services like e-hailing which requires level 4 capabilities without compromising the option to manually drive the vehicle for driving or recreational purposes. This is backed by the notion that luxury vehicles are intended to provide excellent driving experience and that much of the target audience are above the middle age. Studies indicate that older working people are least inclined towards Autonomous Driving with a conservative attitude towards new, unproven technology.

Heavy vehicle manufacturers are more likely to follow a build to order business model, offering different levels of autonomous driving capability depending on order requirement. The operation liability is very unclear at present before an official legislation is passed under NHTSA guidelines and will most likely be taken up by the OEM. However, when the OEMs client is a Fleet operator or supply chain solutions provider, operational liability will not be taken up by OEM as the vehicles would most likely be tailor made to fit client requirements.

Future ownership models are most likely to remain the same. Leasing vehicles will be possible through dealerships and/or capital services but will not be provided by OEM's directly.

Care maintenance and care providers are more likely to be unaffected and current models are likely to remain the same. The only challenge they face is that special training is required to service V2X systems. Dealer owned service centers and national level service providers (Such as Firestone/ Bridgestone) are most likely to provide training to their staff and charge premium fee for service provided, till regional and/or small service provider begin to offer V2X maintenance services. Aftermarket parts are also to be available gradually over time once market demands reach threshold until which OEMs will be one stop shop.

Currently V2V systems will be provided as additional options/ packages to potential clients who might purchase them for additional costs. However, it may be decided mandatory, by law (To be discussed in detail as part of Public Agency response summary) for all OEMs to provide DSRC/ V2X capable equipment in all future products. Most OEM regard lack of a formalized regulatory system as the key obstacle to reaching their goals. Technology reliably and fine tuning, especially under unknown conditions are another obstacle. Overall, all OEM companies are very much interested to get this technology reach its commercial inception.

- **Technology/ Software/ Wireless Providers**

  Most respondents have predicted early 2021 to be the timeline around which AV (NHTSA Level 4) would reach market inception. This matched closely with OEM respondent.

  It would not be possible to provide aftermarket kits to modify older vehicles or provide hardware upgrades for AV/ CV capabilities. Also, technology companies will not be taking over any operation liability and state that OEM will be fully responsible. Data privacy and cyber security are issues that need to be addressed but can be easily resolved, once regulatory guidelines have been released. Endowing vehicles with human-like negotiation skills and to avoid level 4 vehicles being too conservative is considered a major challenge. Advancements in machine learning/ artificial intelligence especially in simulated experience training is necessary. A lot of this technology is designed to "learn with experience" after commercial inception.

  OEMs are interested in partnering with national (or) international level Wireless Providers for connected vehicle capabilities. These partnerships already exist today, example BMW North America with AT&T for connected drive/ iDrive package onboard new BMW vehicles sold to public.

- **Government Agencies/ Educational Institutions**

  Most respondents have predicted late 2021 as AV market entry date. If AV/ CV technology proves to improve highway safety, cost savings and provide more benefit, they are willing to enforce compulsory AV/ CV use. Primary concern for DOT's is if AV's can prove a higher highway safety rating than the current system and if it will not cause new issues to arise. DMV's will need to evaluate driver training, vehicle licensing, vehicle safety inspections and law enforcement interactions with AV and are currently unclear on how their roles will transition. Legal proposals to make V2V communication systems mandatory on new vehicles manufactured for sale in the United states are already being passed. This law could be made effective as early as start of 2019. OEM's must include vehicle housed V2V system costs with vehicle base price. DOT's must take on infrastructure housed V2V systems costs. Funding sources currently unclear and will most likely be provided by public taxation. NHTSA will have to set new framework to set manufacturing, inspections and certifications standards through FMVSS (Federal Motor Vehicle Safety Standards). Current safety inspection process is incapable of determining whether electronic control systems on board are functioning right. Moreover, general public is concerned with privacy issues/ cyber security and are generally uncertain about how these vehicles work. There is a need to get people comfortable with AV to ensure their support. Also, legislation should come incrementally and in step with the other states so there aren't major disparities across state boundaries.

- **Fleet Operators**

  Unsure on exact timeline when AV will hit commercial market, however believe they will pioneer the usage of this technology before large scale public acceptance. Heavy reliance on OEM support and are more inclined towards developing in house software / control technology infused with TDM algorithms to make efficient use of resources. Primary obstacle are legal regulations and restrictions. Unsure on future for current employees who could be directly affected example, Chauffeurs.

  They are however open to negotiate P3/ PPP with governments on specific regions where expected return rates are possible. In these cases, fleet operators would most likely take on all operational liability, finance & maintain required infrastructure such as DSRC systems with V2X capability and would most likely be the only public transport service provider for that region without competitors. It is important for the government to regulate prices and the P3 contract duration.

- **Supply Chain**

  Unsure and uninterested on pioneering technology development and introduction. More interested on utilizing technology once commercially available. More inclined to work in a similar role to fleet operators with objective to provide transit to goods instead of people.

  Exception to this are heavy vehicle/ freight operators, who are extremely interested towards this technology as much as fleet vehicle operators. Would most likely automate all short trips or sections of long trips which have safe weather conditions. Plan to expand slowly to other routes, as technology is refined to perfection over time. Will have to take on operation liability.

- **Insurance/ Dealers and third parties**

  Insurance companies should transition to provide two layers of risk management/ indemnification for AV usage. First layer includes automobile owner/ operator (Fleets) for coverage against any general incident, similar to existing system. Second layer to be provided exclusively to OEM's to indemnify any incidents caused solely by equipment malfunction/ failure.

  OEM licensed/ official Auto Dealers to enjoy even higher levels of participation. By United States federal law, OEM's are to sell vehicles to general public only through dealerships. Moreover, repairs and maintenance of AV's will now be restricted to factory trained and certified professionals exclusive to official Auto Dealers, hence competition from third party/ aftermarket car care professionals and dealers is nearly eliminated for AV sector.

- **Energy Providers**

  Energy providers including fossil fuels (Exxon, Chevron, BP etc.) and electricity providers (Duke Progress) will be least affected by AVs. Even with advances in electric vehicles, majority of OEM will remain with conventional propulsion systems (I.C. Engines) and would work to offer more efficient vehicles over time. Fossil fuels are readily available and accessible today and require no time to refuel. Electric vehicles face this major drawback that it takes time to recharge their battery packs and that they have limited operation range when compared to I.C. engines. Moreover, they tend to be more expensive than I.C. engine vehicles are not economically accessible to most working class people. Also, most electric vehicles (Such as Tesla) are new brands to commercial market and no clear data on their total vehicle ownership costs (Which includes ownership & operational costs such as maintenance, depreciation & salvage value) is available yet. Only time can tell if electric vehicles could be as reliable or better than conventional vehicles. All this uncertainty combined with more efficient technology (such as Turbo Charging), Hybrid drivetrains makes I.C. engines the unrivaled choice of most OEMs today. Hence fossil fuel suppliers are most likely to remain unaffected.

Question may arise that with more efficient cars, fossil fuel consumption should go down. However true that might be, more new automobiles are sold every year and only a small fraction of operational vehicles are decommissioned every year. Hence there is a steady growth in number of road vehicles every year, which in turn compensates for lower per capita fuel consumption with efficient vehicle.

Moreover, electric vehicle boast on that they are environmentally friendly, but when considering the big picture that most power produced by electric companies today are derived from burning fossil fuels in thermal power plants, their claims are diminished.

4.6 Visualization of obtained results

Flow chart based representations on obtained data are plotted for different stages in time depicting current stage to future state transition. Flow charts are easy to interpret visual representation tools that clearly brings out the relationship shared amongst various constituents in a system.

4.6.1 Current state model: Estimated time frame (~2018 - 2020)

Today's road transport model is a typical public private partnership where roads and transit channels are owned, operated and maintained by government (or through P3s with private entities) for use by vehicles that are owned, operated and maintained by the general public. OEMs in collaboration with their suppliers (Predominantly hardware and component specialist) design, develop and release road vehicles to the commercial market. Most of technology and software components are designed in house without requiring specialized software support in many cases.

The target audience is broadly classified in two groups – public and fleet operators (including ride sharing agencies). In the United States, it is illegal for OEMs to sell their products (including spare parts, etc.) to customers directly. Law mandates a third party or Authorized dealership as requirement. This law applies to selling vehicles to both the public and fleet operators. Financial assistance options such as leasing a vehicle or taking a loan is provided by various financial institutions such as banks, credit unions, dealerships etc.

The OEMs and their suppliers must qualify on certain standards as governed by the NHTSA, before they can release a product into the market. DOTs compliment this system by handling the customer end of the chain by providing various services like driver licensing, vehicle registration etc. framework. Insurance companies target fleet operators and the general public where they sell indemnity solutions as required by law and customer requirements for vehicle operations. DOTs also maintain physical assets such as roads, bridges etc. directly or indirectly (P3s).

The OEMs and suppliers are not liable for vehicle operations and do not require any vehicle operation indemnity. They however would carry a general liability insurance and several umbrella level protections as required by industry standards and/or law to run their business, which is out of scope with vehicle operations.

Most fleet operators perform vehicle service & maintenance in-house or through a partner dealership. The public users have broadly three options for vehicle service – self maintenance, dealer owned & operated facilities or private/ independently owned facilities.

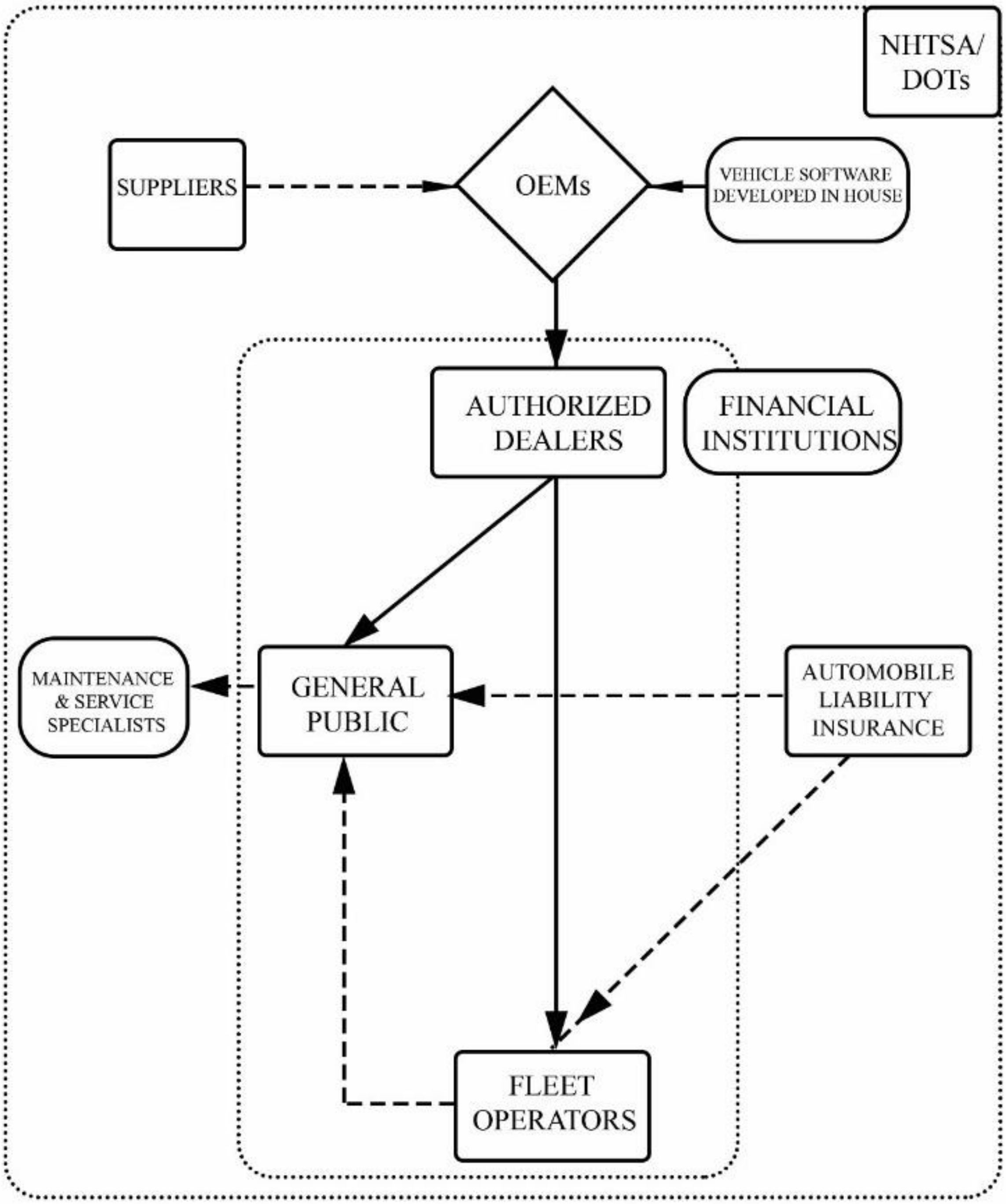

Figure 4.4 Current State Model

5. FUTURE PREDICTIONS AND CONCLUDING REMARKS

5.1 Introduction

The current state model depicts existing highway public private business model accurately. A future state paradigm is necessary to project changes to the current state model each time a mandated technology is released.

5.2 Implicit P3s

While there is no concrete evidence from the survey that P3s are a major part of the picture they present for the AV-based system, none-the-less, a significant degree of private funds is involved in creating and operating the system. Vehicle owners are ultimately responsible to pay for on-board DSRC systems which will be included in its final price. The government will most likely have to muster funding for roadside/ infrastructure mounted DSRC system to enable connected vehicles/ V2X protocols. In effect, this is an implicit P3 where both public and private funds are involved even though there are no explicit contracts.

This appears to be a new idea that was applicable to the NextGEN situation as well. And in that case, as here, does not appear to have been any discussion about the fact that it is an implicit P3.

To make the system work, there will have to be some form of legal or unofficial understanding among the stakeholders involved as to who will do what and who will pay for what and who bears the liability responsibility for the failure of the system to operate as intended. It is these types of issues that are often addressed in the contractual details of the P3 arrangements. Here they are likely to be spelled out in governmental policies and contractual details of the use of the equipment and the coverage provided by the insurance firms.

We are defining an implicit P3 as one where stakeholders are not bound by any contractual relationship and yet work towards achieving a common goal. Stakeholders do not have clear liabilities, responsibilities and returns.

The current road transport model is an example of implicit P3 in that the physical assets (roads & infrastructure) are owned and maintained by the government (and through explicit P3s) and vehicles that use these roads are owned and operated by the general public. The government in turn levies taxes on the road users to maintain current assets and develop new ones. Otherwise there are no contractual obligations amongst stakeholders. The reason behind the success of this relationship between stakeholders at an implicit level, where all parties understand their deliverables and returns is brought about by the role of the government in establishing and enforcing a strong and well proven legal framework. This legal framework brings no contractual relationship between parties, especially for long terms which is the essence idea behind explicit P3s. The set of stakeholder specific rules and regulations are to be fulfilled by interested parties, in order to be a part of this system.

For example, a general public road user will have to pay for the vehicle and complete formalities such as registration and title/tags to effectively own that vehicle. He or she will also need insurance coverage (depending on state) and a valid driver license to operate this vehicle. Additional costs for vehicle maintenance/ repairs, tolls, parking charges are paid for by the same road user, depending on their usage and/or requirement. The bottom line is that all these are optional and are only required if and only if someone would want to own and operate a vehicle to suited to their needs. A person who has no interest in owning a vehicle and is happy using the public transport is in no way affected by the above implicit rules. However, he or she will have to pay for the public transport in a different way.

This non-contractual yet long term relationship that is well understood by constituent stakeholders in a system that is governed by fair and accepted legal framework set up by a public agency can be defined as an implicit P3/PPP.

5.3 Emerging Explicit P3's

The onset of AVs will open new untapped markets which could attract private funds and eventually explicit P3s. To expound these new situations, new transition and future state models have been developed. These models are conceptual and partially based upon supportive data obtained from stakeholders based on their opinion on what they think might happen in future.

The transition state model will represent the first major government mandated nationwide technology release, after the OBD2 system mandate of 1996, which will require all new vehicles to support V2V/X communication.

The second mandate requiring vehicles to support NHTSA Level 4 autonomous driving, is represented by the future state model.

The current, transition and future state models are limited to provide an image of change in highway transit models immediately after each technology release. But what will happen once AVs have normalized as a part of the society, say 10 years after future state model. Will time and widespread acceptance of AVs affect stakeholders even further? What will happen after the future state?

To answer the above questions and to arrive upon a conclusion to our research, beyond future state models have been plotted. Beyond future state models are purely conceptual and are one amongst the several possibilities of what might happen around 20 years into the future.

There seems to be two situations in the future state model where potential explicit P3 business model may arise.

The first is in the installation and/or operation of the DSRC equipment that will be installed along the rights-of-way where the AV-equipped vehicles operates. Here it seems likely that, like toll roads, private companies could be attracted to finance, install, operate and maintain the IT equipment that provides the DSRC connectivity along major highway corridors. The public agencies will provide right-of-way access and some degree of infrastructure support. (e.g., provision of power and cable easements). The private entity involved in the P3 can levy equipment usage fees or data usage fee on road users depending on the amount of data consumed through infrastructure mounted DSRC equipment. Technology suppliers and/or wireless providers are best suited to represent the private entity considering their level of expertise in this field.

Private companies will need to be convinced that a project could yield a desired rate of return for their investments. This again depends on the success of CVs and DSRC systems amongst consumer. A large-scale consumer acceptance could in turn rely on any legal mandates passed by public agencies in favor of DSRC/ CVs. All this would boil down to how effective CV/ DSRC systems are in practice, which only time can tell.

The second is the parking garages that can service and maintain the vehicles as well as provide storage. It seems likely that the public agency will provide the building and the up-fittings to make vehicle storage and servicing possible, typically as a long-term lease contract. The private entity will provide the equipment used for the servicing and maintenance activity. In return, they have the sole right to provide public transport for the region which draws in their revenue stream. Fleet operators would be best suited to represent the private entity in this case, based upon their expertise. The parking garage functioning have been explained in more detail at later sections of conclusion.

In both cases, it seems likely that formal contracts will be established between the public and private operates to specify how the system is to be financed, operated, maintained, etc. and how risks and rewards are shared.

5.3.1 Transition State Model: Estimated time frame (~2020 - 2021)

All new vehicle will have V2X systems hardwired to them from factory, as mandated by law. OEMs will require assistance from specialist in software and advanced technology to provide components and support software to use DSRC systems. These specialist are now categorized as Technology partners/ suppliers and are different from typical hardware ad component suppliers. Technology suppliers could also include wireless providers to offer long term services to customers.

OEMs will now have to include additional cost to manufacture vehicles with DSRC & supportive equipment to their customers. Hence, road users will be financially responsible to bear costs of vehicle mounted V2V/X systems.

Insurance companies could now provide additional layers of indemnity to OEMs for limited vehicle operation liability, as dictated by law.

Other stakeholders will be unaffected and their business models are most likely to remain the same.

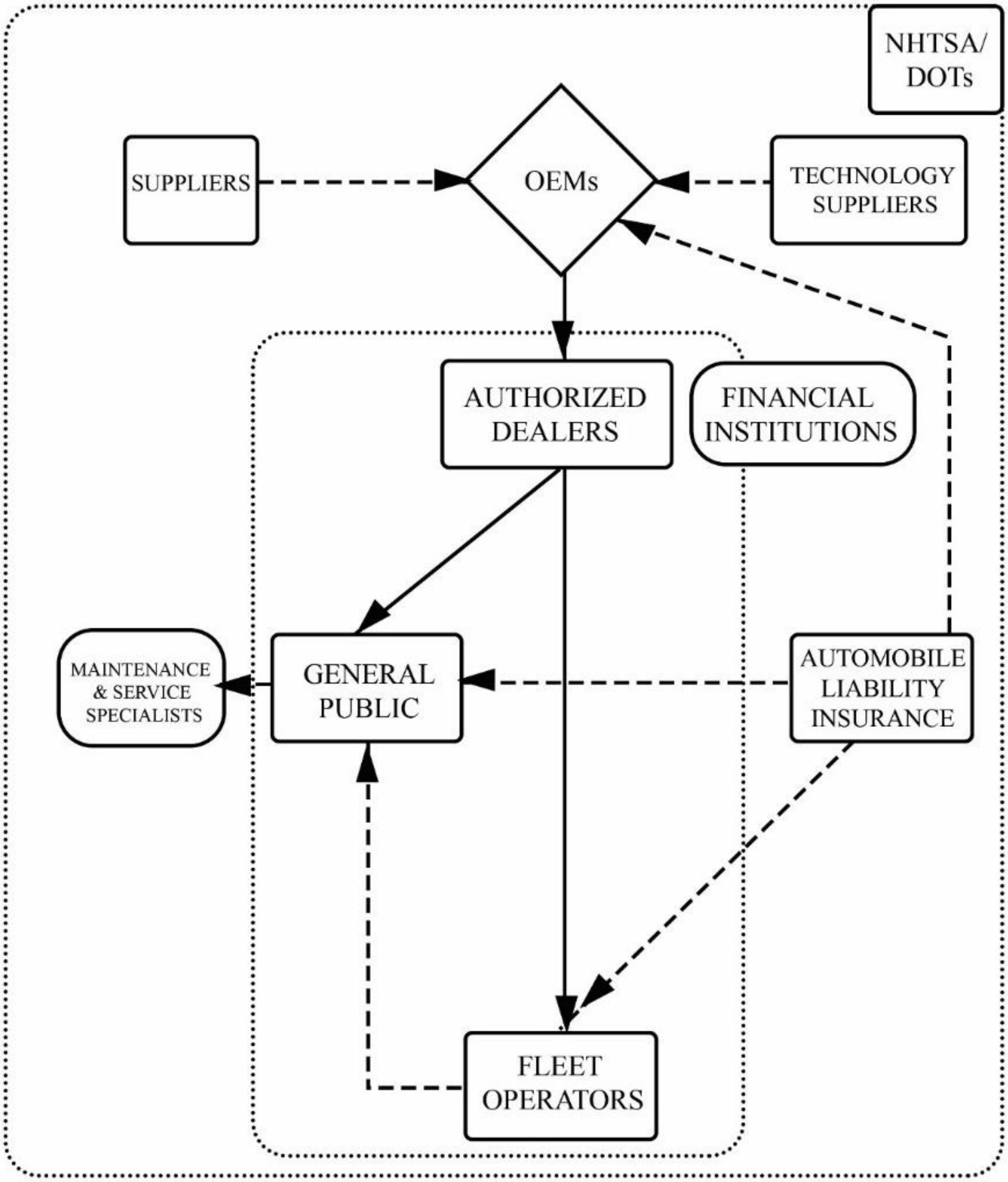

Figure 5.1 Transition State Model

5.3.2 Future State Model: Estimated time frame (post ~ 2021)

This model represents the highway stakeholder scenario once government mandates all new vehicles to support NHTSA Level 4/ Full Autonomous capability.

Major changes here are with respect to vehicle ownership and sales. OEMs will segregate into two exclusive market segments.

Daily driver brands make vehicles to be sold to fleet operators only and are tailor made to order. Fleet operators in turn sell transit services to the public. These vehicles would most likely be full time Level 4 AVs. This could be extremely popular in densely populated cities with various chains of P3 partnerships. Terms of contract could include elimination of a third party/ dealership to sell vehicles to fleet operators, fleet operators to fulfill role of public transport, decline of government provided public transport for intra city travel. Long distance travel including intra state travel are not to be affected and will rely on conventional vehicles. Insurance companies to provide indemnity to OEMs and fleet operators only.

The second segment will focus on selling cars to public. These include luxury vehicles and specialized vehicles such as light trucks, SUVs etc. that are to dominate typical American suburbs. These vehicles would be primarily non-autonomous and designed to be driver operated. They will be available only through dealerships and will have DSRC/ V2X. They could possible support Level 4 autonomous driving capability to synchronize with fleet vehicles that would dominate cities. Insurance companies will provide indemnity to vehicle owners on individual levels.

A typical working class family would now own one luxury/ utility brand vehicle to support long distance travel (Including intra state travels) and would rely on fleet operators for daily commute.

Technology suppliers, especially DSRC equipment manufacturers may be interested to collaborate with regional government agencies to set up an explicit P3 SPV. This long-term contract would require technology partner(s) to finance and maintain infrastructure mounted DSRC equipment on sections of the highway. In return, road users will have to pay for the data used.

Other stakeholders are not likely affected in this model.

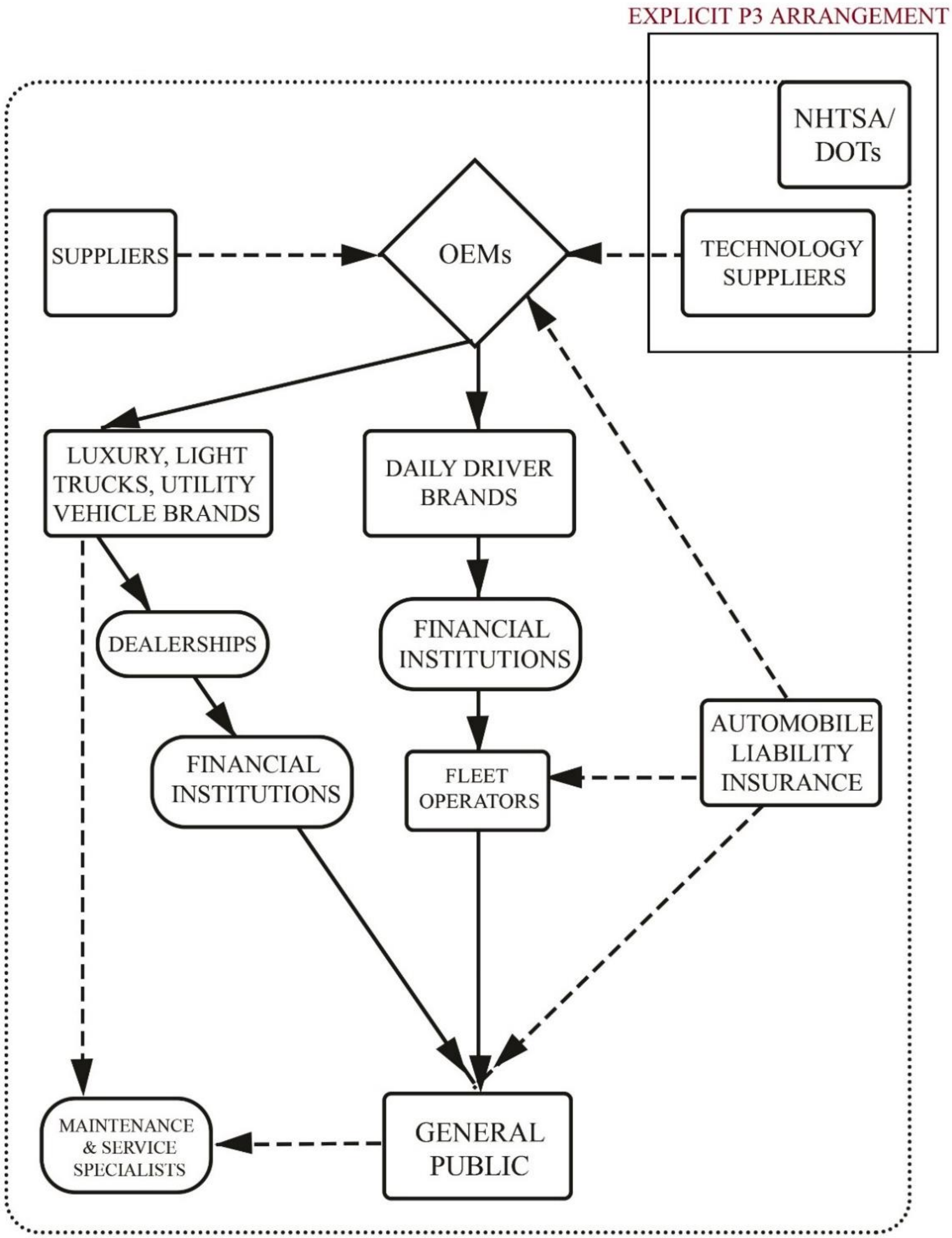

Figure 5.2 Future State Model

5.3.3 Beyond Future state models (Conceptual): Estimated time frame (post ~ 2030)

At this timeline, AVs have normalized as part of the society and conventional vehicle (NHTSA Level 3 and below) production is either obsolete or on the decline. All new vehicles support NHTSA Level 4 autonomous driving capability and are most likely to have any human input hardware such as steering wheel, control pedals etc.,

OEMs with their Technology partners design and manufacture vehicles before shipping them off to dedicated facilities or the IMPCs based on demand. It is even possible for IMPCs to perform the last stages in vehicle customization to suit client demands. It is possible further in time for OEMs to only perform new vehicle design and testing and pass over manufacturing to IMPCs which could be renamed as Integrated Manufacturing & Parking Centers. All this again is a concept and relies largely on technological advancements.

Integrated maintenance and parking centers (IMPCs) emerge which are now store new vehicles, repair/ maintain, refuel, and park commissioned vehicles. These vehicles are fully proven and reliable level 4 full time AVs which now support long distance travel without any restrictions. These IMPCs are most likely to be P3 special purpose vehicles involving the government, fleet operators, wireless providers, energy providers and the general public, and function as a hive or centrally controlled system to provide transit services for an entire region. The government will most likely provide the facility on a long-term lease that could interest fleet operators who would provide, operate and maintain equipment over the contract duration.

Suppliers will now have to provide OEMs and maintain parts inventories at IMPCs. Since repair and maintenance work is done in house by the special purpose vehicle behind IMPCs, only OEM authorized suppliers will be awarded supply contracts. Aftermarket suppliers and third party maintenance facilities are mostly likely to lose all business and get eliminated from this model.

Financial institutions no longer target the public as their market audience and rather focus on financing or partnering with the special purpose vehicle.

Dealers and third parties are eliminated from the model considering business profitability as new conventional vehicles are very few and are made exclusively for specialized use such as motorsports etc. Even utility vehicles would be level 4 autonomous. Insurance companies will provide indemnity to the P3 special purpose vehicle that runs a region’s transit.

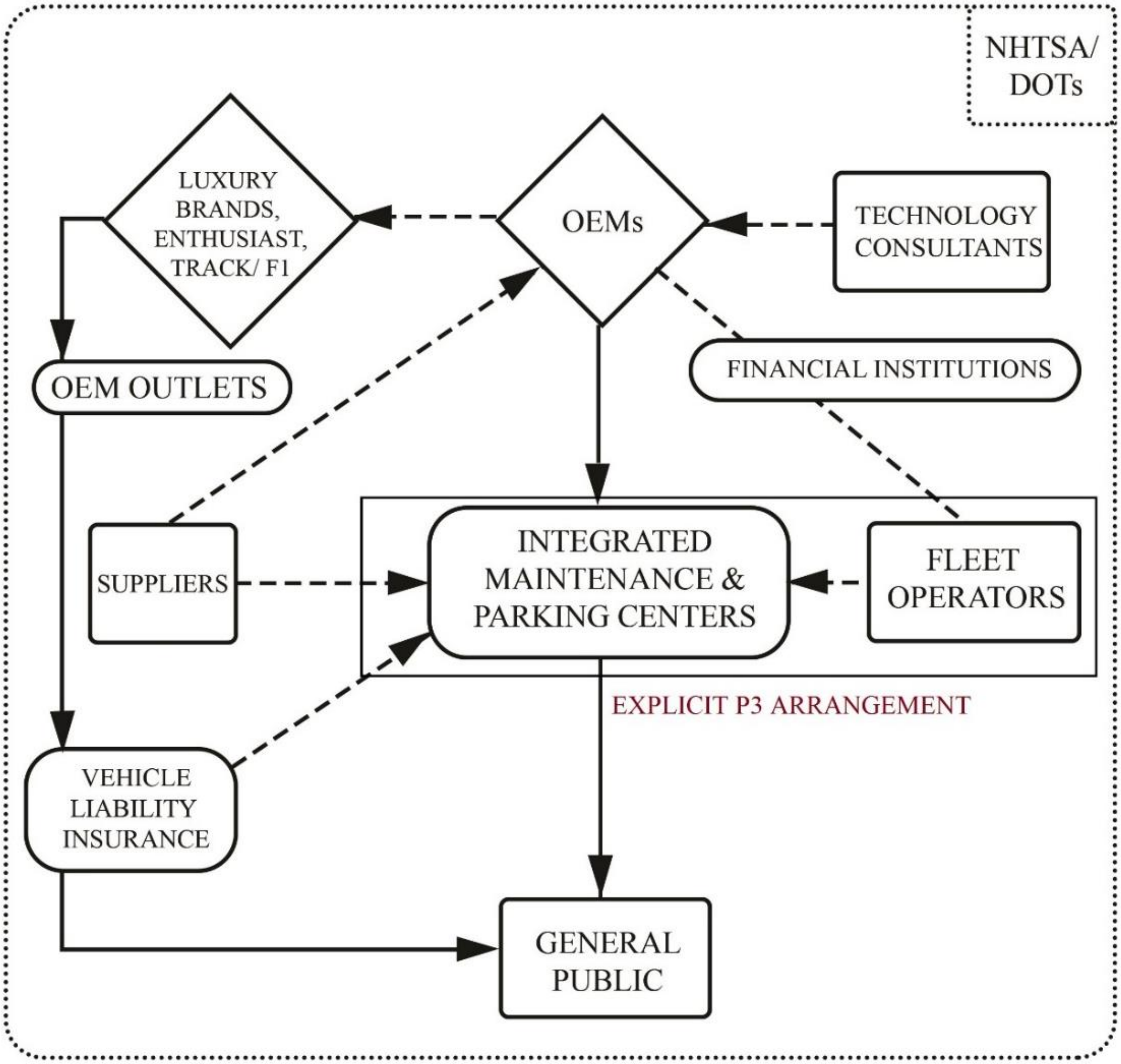

Figure 5.3 Beyond Future State Model #1

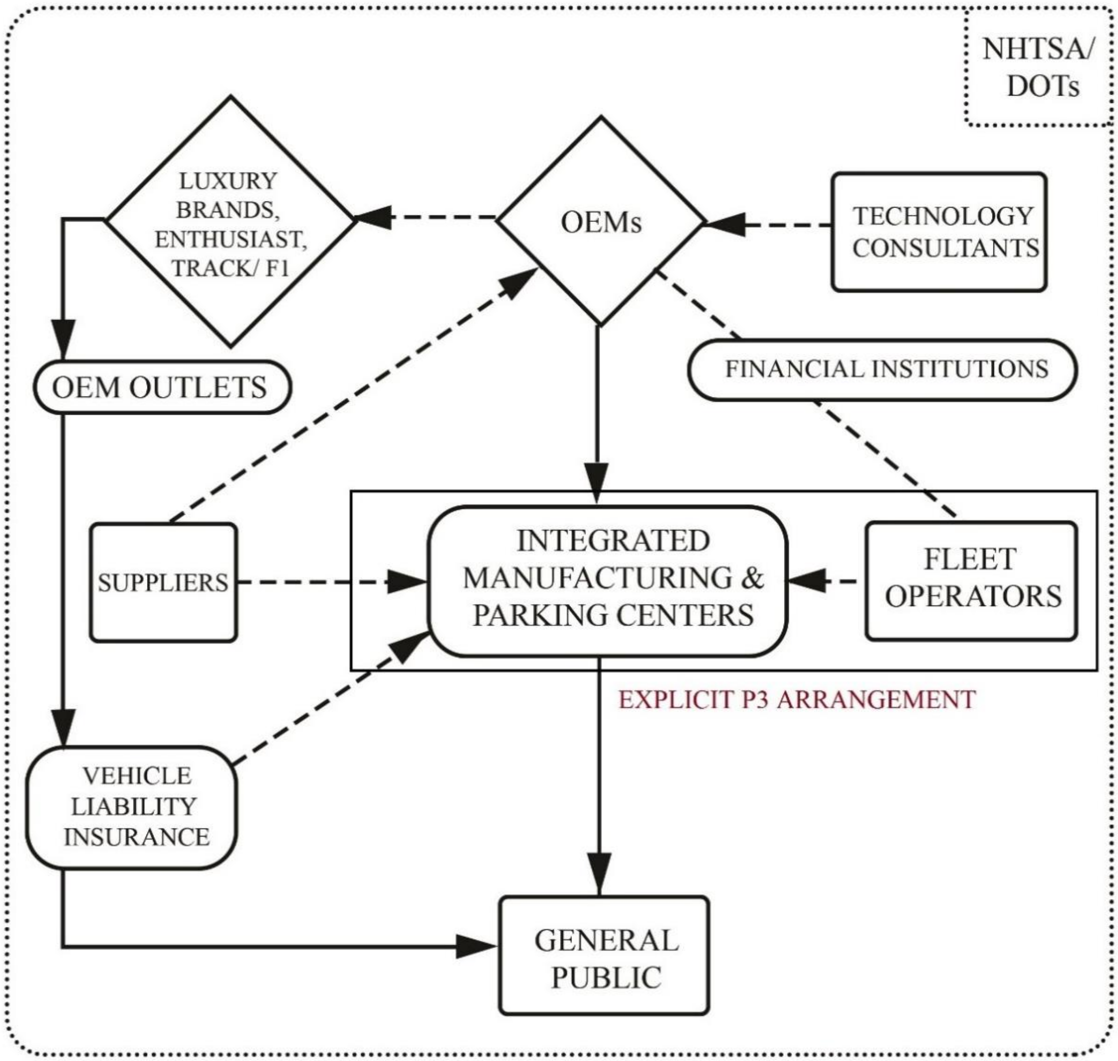

Figure 5.4 Beyond Future State Model #2

5.4 Recommendations for future points of study

Despite that current state model represents the relationship amongst all stakeholders involved in the highway public private partnership, the financial obligation of each stakeholder is relatively unknown. Finance planning and cash flows are essential to any business model and an in-depth analysis could be a point of interest.

IMPCs are highly conceptual future predictions and further research is necessary to understand if they could ever become a reality and if so, how will they be structured. Explicit P3 SPVs comprising fleet operators, public agencies and OEMs could operate IMPCs on compatible locations.

While OEMs fund vehicle based DSRC systems though their customers by including it in vehicle sales price, the government will have to find funding source for infrastructure based DSRC systems. Explicit P3s/ PPP could be a viable solution to this problem. Special Purpose Vehicle comprising government entity, I.T. suppliers (or technology suppliers) and wireless provider could address this issue where return on investment is derived by selling long terms contracts with road users for providing V2X services. Road users will have to pay for DSRC data consumed, thus providing a revenue stream. Another option could be formulating a tax model similar to the gas tax, that road users pay depending on their amount of V2X data consumption.

NextGEN and SESAR were approved and patronized by the government based on various financial metric study such as investment cost to benefit analysis etc., A similar financial study on AVs could be a potential future point of interest.

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