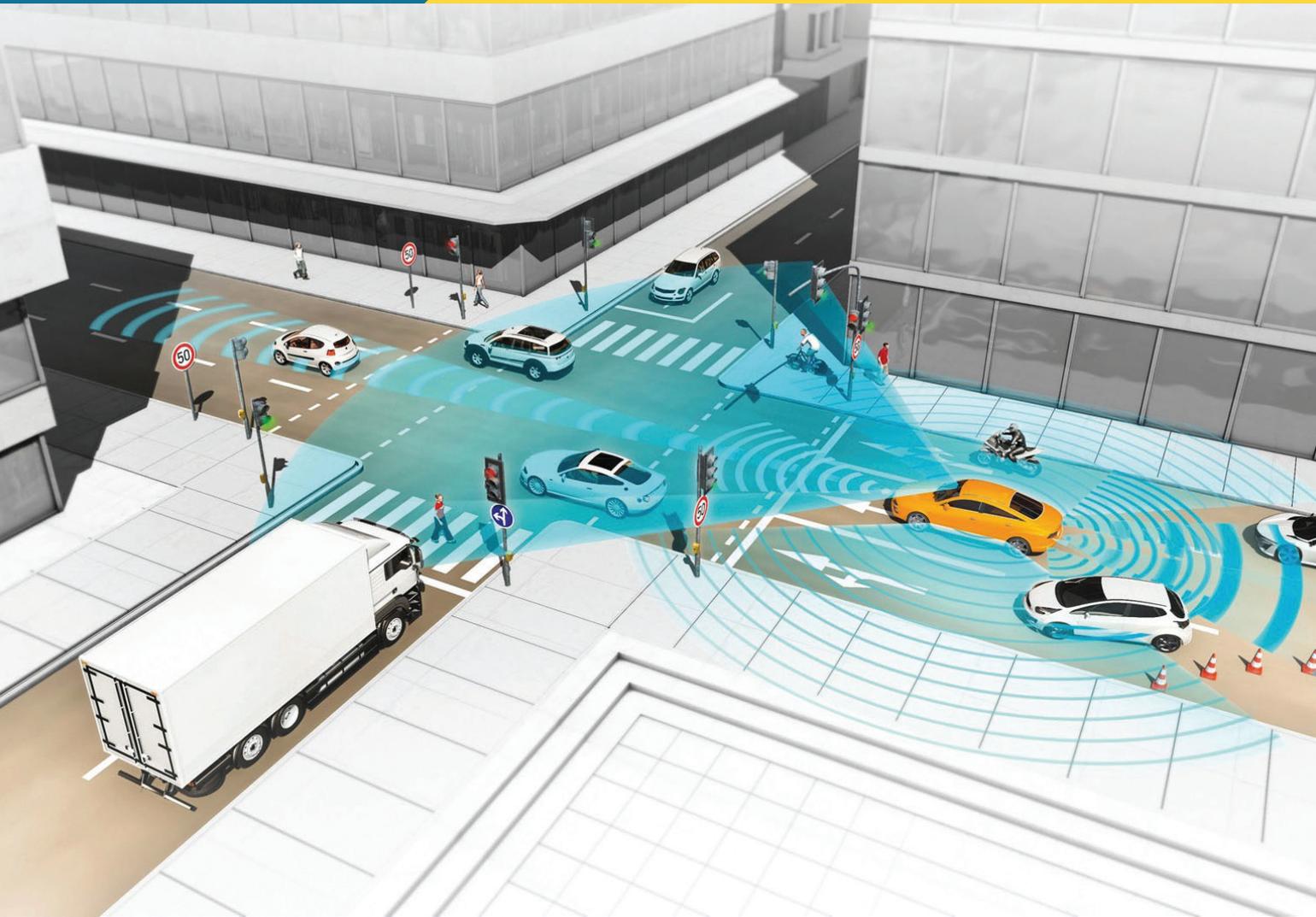


SELF-DRIVING VEHICLES (SDVS) & GEO-INFORMATION



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Abbreviations

ADAS	Advanced Driver Assistance System	OEMs	Original Equipment Manufacturers
AMS	Amsterdam Institute for Advanced Metropolitan Solutions	OGC	Open Geospatial Consortium
AV	Autonomous Vehicles	RTK	Real Time Kinematics
ERTICO	European Intelligent Transport Organization	SDVs	Self-Driving Vehicles
GNSS	Global Navigation Satellite System	UK	United Kingdom
GPS	Global Positioning Software	UN	United Nations
HD	High Definition	US	United States
IT	Information Technology	V2V	Vehicle to Vehicle
LiDAR	Laser Illuminating Detection and Ranging	V2I	Vehicle to Infrastructure
MIT	Massachusetts Institute of Technology	V2N	Vehicle to Network
NHTSA	National Highway Safety Administration	V2P	Vehicle to Pedestrian

PREFACE

Transportation systems globally are on the verge of a major transformation. An innovation that is expected to disrupt the entire automobile industry, the driverless revolution has just begun. With the onset of sophisticated technological advances which combine artificial intelligence and robotics capabilities, interest in **'Autonomous vehicles'**, 'Self-driving vehicles' or 'driverless' cars has been surging. Critical to the growth of the **'Self-driving vehicles'** industry is the geospatial industry. Equipped with satellite navigation, sensor compliments and other positioning technologies, autonomous vehicles along with geospatial industry brings in a paradigm shift in the driving experience while improving safety and efficiency simultaneously.

The data information required by self-driving vehicles needs to be rich, diverse, and accurate especially concerning spatial precision and frequency of updates than what is currently in use for day-to-day navigation. Geospatial content providers, therefore, will have a crucial role to play to drive an entirely new business model as compared to the conventional ones. These cars will not only 'need' geospatial content to build a thriving eco-system but will also 'provide' content for further use.

There is an extreme reliance of the autonomous vehicles on geospatial content. Understanding that maps are going to be of fundamental nature when it comes to autonomous vehicles, the density of information needed for driverless cars is going to be much higher and harder to collect. A whole array of sophisticated content providing geospatial technologies will exist simultaneously for the successful navigation of self-driving vehicles.

BACKGROUND & SCOPE

Compared to 10 years ago, today, the idea of self-driving vehicles has started to become less far-fetched. Major automakers plan to get their autonomous vehicles on the road by 2025 which is less than a decade away. The questions are many and the answers too little. In this report, we take an in-depth study to understand the crucial role the automobile industry, geospatial industry and the government together play in bringing evolution in the autonomous vehicles industry. The report has been produced as a knowledge initiative to answer the 'mystery' questions around the role of geospatial information in self-driving vehicles, the role of the autonomous vehicle ecosystem and the government,

The study, therefore, is largely directed at all the stakeholders of the driverless car ecosystem and the reader would gain insights into:

- The concept of self-driving vehicles
- Current market trends and benefits and costs associated with driverless cars
- Action points of the self-driving cars ecosystem
- Role of the geospatial industry
- The defining role of the government

The report, in summary, examines the core of the driverless car ecosystem i.e. the data and how the other defining factors of the self-driving cars ecosystem form an inter-linkage to transform the complete landscape of the transportation industry in the near future.

WHERE IN THE WORLD ARE SELF-DRIVING CARS?

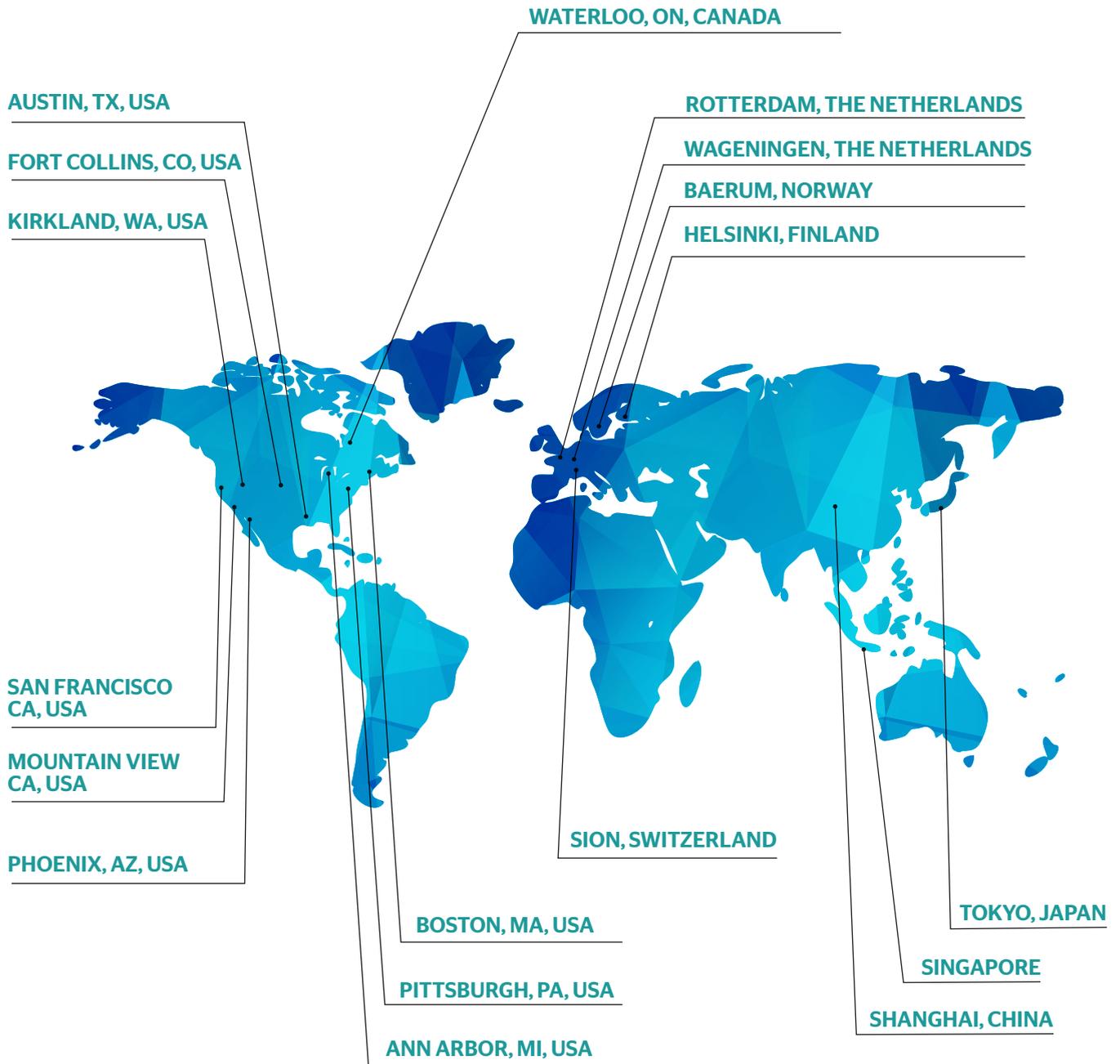


Figure 1.1 Where in the World are Self-Driving Vehicles (SDVs)

SELF-DRIVING VEHICLES

In today’s context, most of the cars have been digitised to provide the driver with easier operation and better information such as real-time traffic information, performance data assessment like speed, music streaming from the cloud, etc. All in all, the cars today are a technological marvel and there is still so much more to come. Transforming the auto industry will be tomorrow’s car that will be a step change from what is now in the offering.

Self-driving vehicles or autonomous vehicles have been a long held dream, a dream that has repeatedly failed to materialise. ‘Cars that drive themselves’ are no longer a work of science fiction. A very niche and specialised market, the self-driving vehicle industry is making rapid strides in integrating a lot of technologies from different eco-system to build the self-driving vehicle.

First of all, what are self-driving vehicles? According to the National Highway Safety Administration (NHTSA), self-driving vehicles are vehicles that can drive themselves without any human supervision or input to control the steering, acceleration and braking. The above definition implies that autonomous technologies imbibed in self-driving vehicles, enable the car to go from Point A to Point B by performing all the required functions for a vehicle to move safely without any human on board. Even though, the common belief is that the driverless vehicles are a futuristic concept, the race to bring these vehicles to our roads has already begun. These vehicles represent a disruption that is unprecedented in both magnitude and scope.

The self-driving car or the smart car achieves autonomy at five levels. These levels are:

Level 0 : No-Automation

At the ‘no-automation’ level, the driver is entirely responsible for the vehicle and its control system – brake, steering, motive power, navigation – at all times.

Level 1: Function Specific Automation

Automation at the ‘function specific level’ involves automation in few i.e. one or two specific control functions. Automation at this level includes electronic stability control or pre-charged brakes. In such a situation, the automation feature in vehicles assists with braking while the driver regains control of the vehicle.

Level 2: Combined Function Automation

The Level 2, ‘combined automation function’, involves automation of two primary control functions designed to work together. An example at this level could be enabling the adaptive cruise control in combination with lane centring.

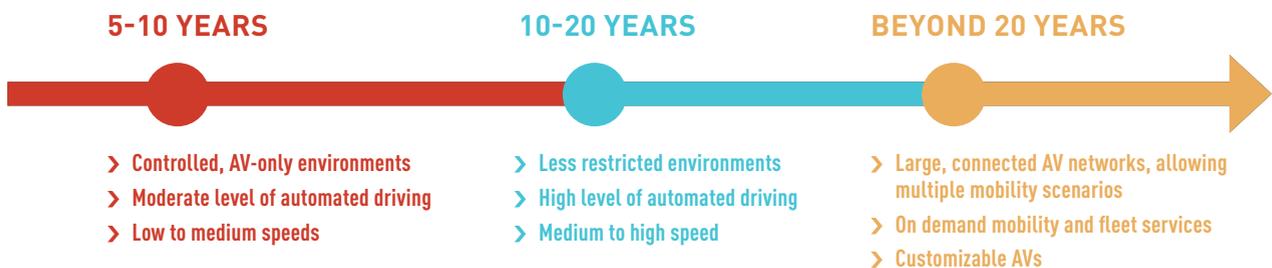
Level 3: Limited Self Driving Automation

In this level of automation, vehicles have full control of all safety critical functions under different traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor the complete driving process. The driver is also needed for occasional control but with sufficiently comfortable transition time.

Level 4: Full Self Driving Automation

At the final level of automation, the vehicle is designed to perform all functions of driving by itself. The car will be able to perform all safety-critical driving function and monitor roadway conditions for an entire trip. In

AUTONOMOUS VEHICLE DEPLOYMENT TIMELINE



SOURCE: UN World Urbanization Prospects, World Business Council for Sustainable Development, Factiva, Navigant Research, EY analysis European Commission, directorate General Information Society and Media, Informal document No.: ITS-13-07

Figure 1.2 Autonomous Vehicle Deployment Timeline

CONNECTED AND AUTONOMOUS VEHICLE TECHNOLOGY ROAD MAP

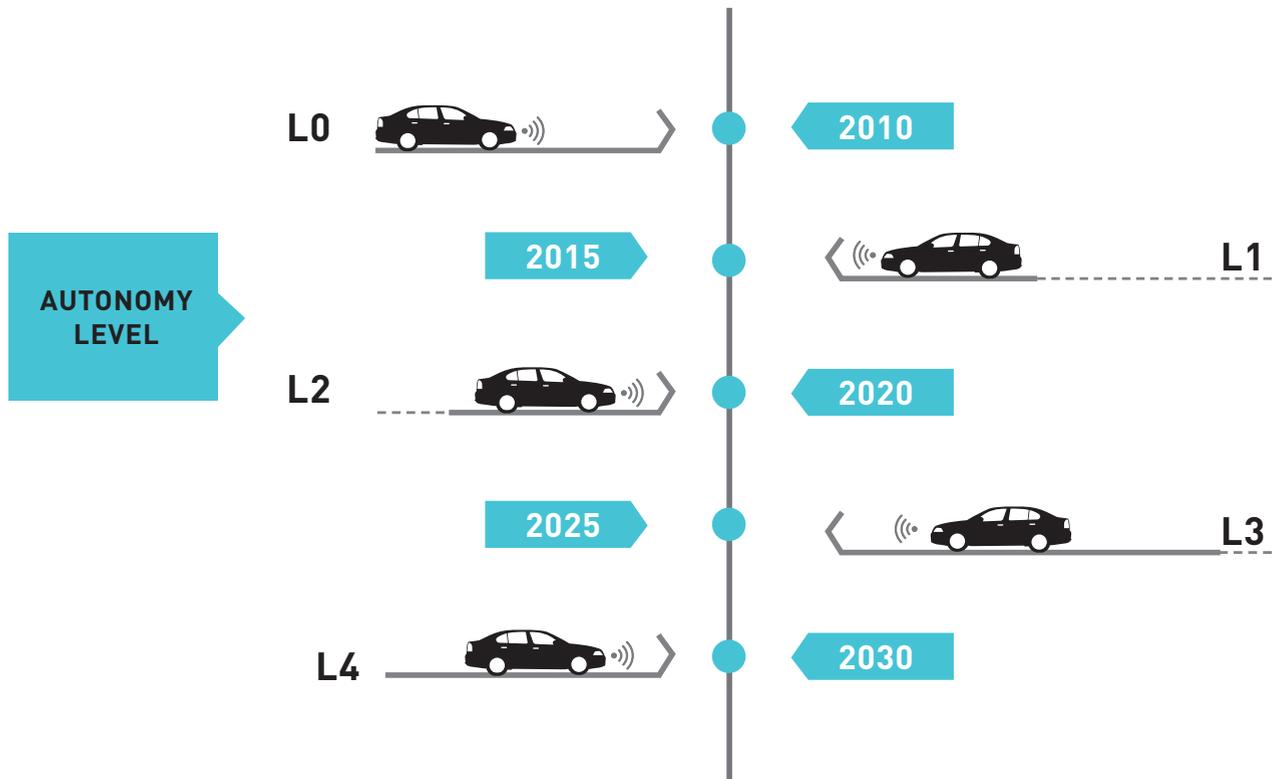


Figure 1.3 Connected and Autonomous Vehicle Technology Road Map

such a design the driver or in this case the passenger will only have to input the destination in the car but will not be needed to control the vehicle at any time during the trip.

DIRECTIONS AND TRENDS

Self-driving vehicles, also coined as the 'vehicle of the future' or 'smart cars', are already moving in a forward direction by taking shape in a variety of forms. Bringing about the next 'automotive revolution' is not only the automobile manufacturers but also the technology giants. At present, innovation on self-driving vehicles is happening in the digital ecosystem, the geospatial ecosystem, the automobile ecosystem, etc. to support the transformation of the automobile industry. Innovation in all these ecosystems is going to bring about a new level of connectivity among vehicles, new kind of cars, features like safety sensors, smartphone integration, etc., to progress the autonomous vehicles industry. Driven by both traditional automobile companies as well as technology giants, there is a rapid acceleration in the innovation efforts taking place in the autonomous vehicle

industry. While traditional automaker companies such as Audi, BMW, Toyota, etc., are stepping into the self-driving vehicle industry by introducing autonomous technologies that offer driver support feature, technology giants like Apple and Google are entering directly into the smart car market.

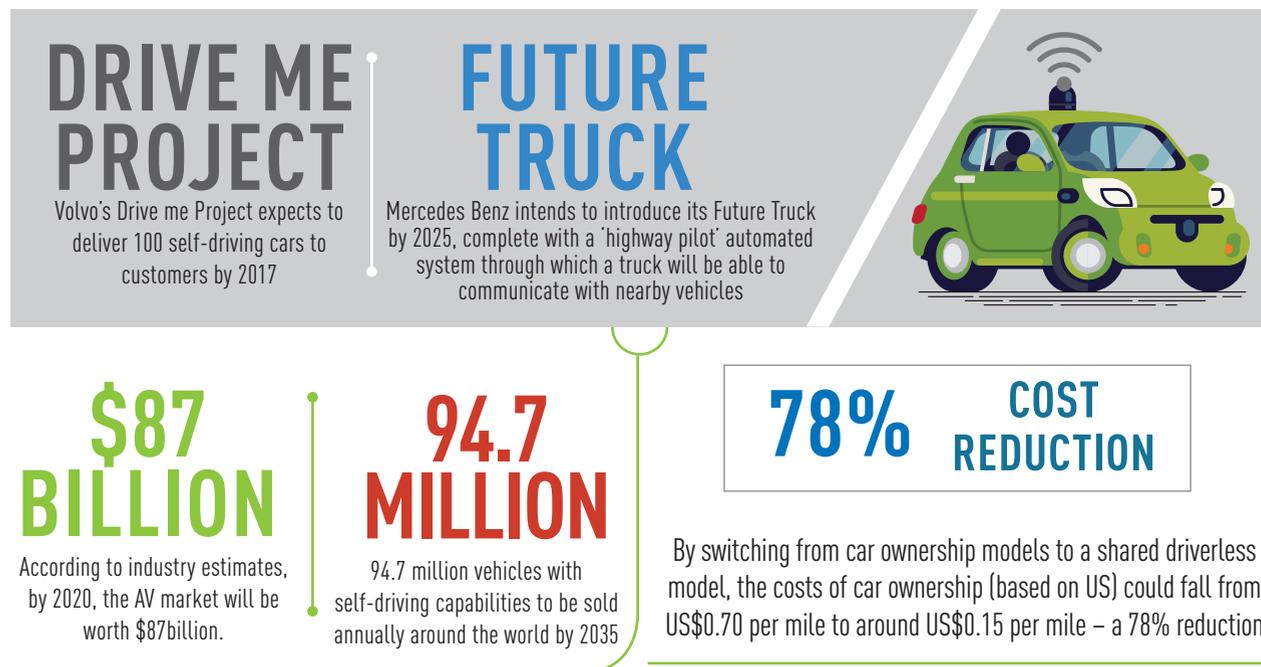
Bringing disruption in the traditional vehicle technology value chain is the gaining traction in the very technology that makes the driverless cars run. As the technology innovation is accelerating, given that the fifth generation of wireless technology makes it possible to stream data in real time on cloud, the quality of connectivity in between the vehicles has improved. The evolution of multiple, complex low cost sensors, the computing speeds to work the artificial intelligence component to steer the self-driving vehicles, all come together to drive the self-driving vehicles. Technology innovation companies are investing in new technologies and new services along with the increasing investments being made by automakers like Tesla, BMW and Audi who are pushing technology to the limit.

CURRENT SCENARIO: INNOVATIONS IN THE INDUSTRY

<p>Tesla</p>		<p>All Tesla vehicles have the hardware needed for full self-driving capability. 8 surround cameras provide 360 degree visibility around the car, 12 updated ultrasonic sensors and forward facing radar with enhanced processing.²</p>
<p>General Motors</p>		<p>General Motors has started testing self-driving Bolt electric vehicles on some public streets in California, Arizona and Michigan after buying autonomous tech start-up Cruise Automation for \$1 Billion³</p>
<p>Ford</p>		<p>Ford invests \$1billion in an Artificial Intelligence start-up with the intention of having a fully autonomous, level-4 capable vehicle for the commercial market by 2021. ⁴</p>
<p>Fiat Chrysler</p>		<p>Fiat Chrysler Automobiles (FCA) has partnered with Waymo (previously the Google Self Driving Project) to carry out detailed research into autonomous vehicles⁵</p>
<p>Honda</p>		<p>Honda has unveiled a new self-driving concept called the Cooperative Mobility ecosystem that will ensure vehicle to vehicle communication in connected cars and smart city infrastructure, reducing traffic congestion and improving road safety. The Cooperative mobility ecosystem aims to “connect the power of artificial intelligence, robotics and big data”. ⁶</p>
<p>Volvo</p>		<p>Volvo cars has cemented its position as the leader of automotive safety innovation by scoring full six points in the Autonomous Emergency Braking for Pedestrians (AEB) Pedestrian test procedure.</p>
<p>Toyota</p>		<p>Toyota is partnering with Stanford University and MIT to research AI and Robotics in order to bring greater autonomy to Toyota Cars by contributing US\$50 million over 5 years. ⁷</p>
<p>Hyundai</p>		<p>Hyundai already has Level 2 smart sense technology, an advanced driver assistance system that includes smart cruise control. The automobile company is targeting to release highly autonomous vehicles by 2020 and fully autonomous vehicles by 2030.⁸</p>
<p>BMW</p>		<p>BMW is working in collaboration with Intel and Mobileye to put a fleet of 40 autonomous test vehicles on the roads by the second half of 2017.⁹</p>
<p>Audi</p>		<p>Audi is adopting Nvidia’s drive computing platform to accelerate the introduction of next generation automated vehicles, for greater driving safety and new mobility services. ¹⁰</p>
<p>Mercedes</p>		<p>Mercedes’s Drive Pilot is not only relying on its camera and sensors to steer the car but also gathers data from HERE maps to make the car capable of making a turn by itself. ¹¹</p>

Google		There is a fourfold improvement in Google's Autonomous Cars project – Waymo. Safety related disengagements has fallen from 0.8 times per 1000 miles to just 0.2 per 1000 miles. The company has already increased its total driving by 50% last year. ¹²
Nvidia		Nvidia is focusing on putting a lot of compute horsepower in the vehicle itself so that the vehicle can do the autonomous driving by itself without needing to be connected to the network constantly.
Intel		Intel has launched their own solution for gathering, processing and analysing data from autonomous vehicles and helps automakers like BMW manage that data. For autonomous driving, Intel incorporates the endpoint, connectivity and the data centre to offer end-to-end solutions. ¹³
Microsoft		Microsoft's cloud to ingest huge volumes of sensor and usage data from connected vehicles to help use automobile companies to use the data for self-driving ¹⁴

KEY FORECASTS



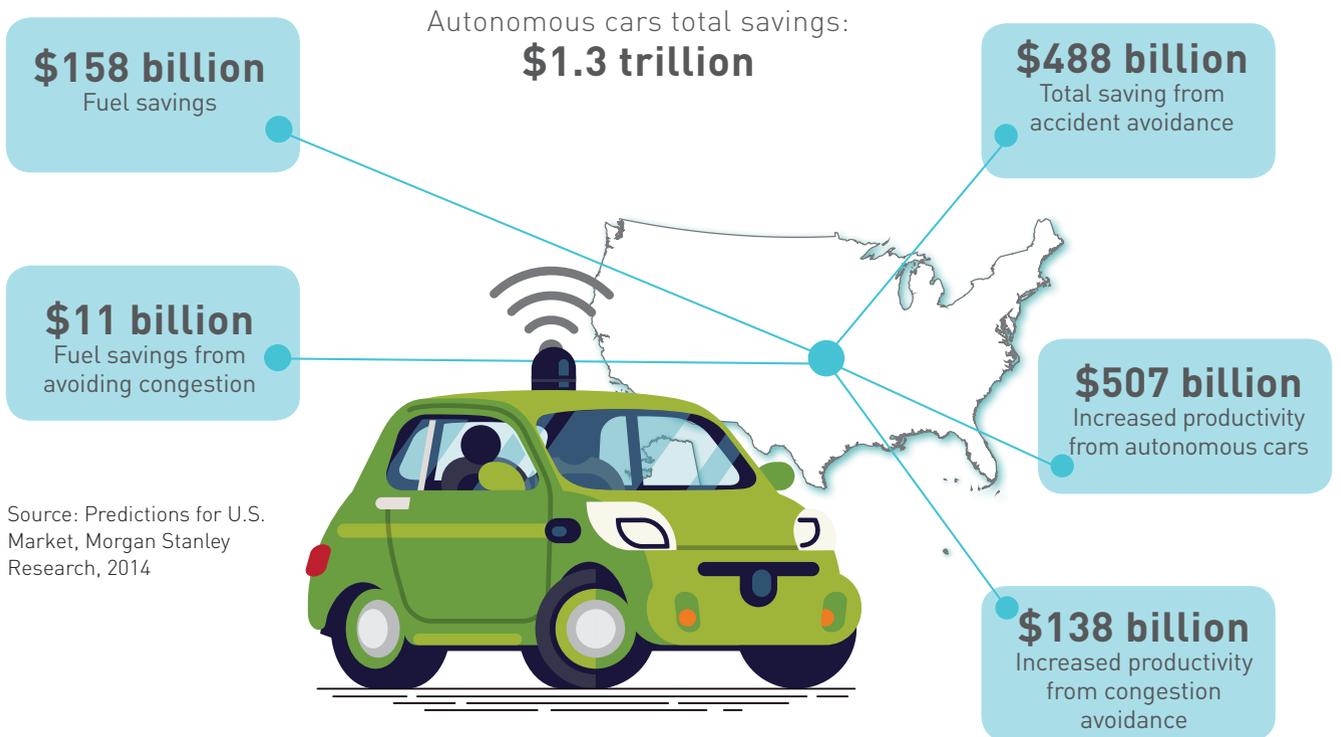
AV MARKET

11 MILLION (2024)

Car sharing to skyrocket from 1.5 million today to 11 million by 2024

Figure 1.4 Key Forecasts

Economic Impact of Connected and Autonomous Vehicles 2014-2030 in the United States



Economic Impact of Connected and Autonomous Vehicles 2014-2030 in United Kingdom



Figure 1.5 Economic Impacts of Autonomous Vehicles in United States and United Kingdom

TABLE 1.2

Industry Directions

Autonomous Boat¹	The 'Roboat', an autonomous boat/vehicle, the result of \$27 million collaboration between the Massachusetts Institute of Technology (MIT) and the Amsterdam Institute for Advanced Metropolitan Solutions (AMS) will make its maiden voyage in 2017. Fitted with a battery of sensors, Roboats will provide information on water and air quality while simultaneously providing an eco-friendly transport option
Autonomous Trucks	Uber's Otto and Ford are reshaping the Trucking industry by exploring how driverless technology is going to be put in use by delivery vehicles. For example: In the first commercial use of the self-driving truck, Otto, hauled Budweiser beer across the United States.
Autonomous Cars	Tesla, Uber, BMW, Audi, Google, etc., are working on developing their own autonomous Cars. Test drives have already begun for Hyundai, Uber, Google autonomous cars.

POTENTIAL BENEFITS OF AUTONOMOUS VEHICLES

Self-driving vehicles are expected to bring significant benefits for user convenience, fuel savings and pollution reduction benefits. Some of the benefits are listed below as:

- › Beneficial to non-drivers, self-driving vehicles will improve independent mobility thus reducing the need for chauffeurs. The other evident advantage is that smart cars may also lead to subsidized rates at the public transit
- › Self-driving vehicles may reduce many common accident risks and therefore crash costs and insurance premiums
- › One of the main benefit that is foreseen is the abundant use of smart cars that may allow platooning (vehicle groups travelling close together), narrower lanes, reduced intersection stops, and roadway costs
- › Autonomous vehicles need not worry about parking as they can drop off passengers and find a parking space if needed on its own. This reduces total parking costs.
- › As autonomous vehicles are going to be driven by technology mostly, this will increase fuel efficiency which in turn will reduce pollution emissions
- › Could facilitate car sharing (vehicle rental services that substitute for personal vehicle ownership), which can provide significant benefits
- › Autonomous vehicles also lead to an improvement in land use. Since self-driving vehicles would be able to drop passengers off, the parking spaces could be used to develop economic purpose. Therefore, autonomous vehicles could improve the available urban space by 15-20%, largely through the elimination of parking spaces.
- › The increased use of fully driverless vehicles will bring on a full driverless motorway which would allow much better utilisation of road space, reduction in energy consumption and smoothing flows across segments
- › The onset of self-driving vehicles will lead to creation of hundreds of thousands of additional jobs in manufacturing and production. Though the 'new' workforce that will exist will need to update their skills according to the market demands
- › Police officers could start focusing more on serious crimes instead of writing traffic tickets and handling car accidents both of which shall reduce dramatically once self-driving cars enter the market

POTENTIAL RISKS AND COSTS OF AUTONOMOUS VEHICLES

The costs and risks associated with autonomous driving are by at large uncertain. The potential risks and costs of self-driving vehicles can be briefly listed down as:

- › Autonomous vehicles require additional vehicle equipment, services and maintenance and roadway infrastructure which means additional costs
- › The self-driving vehicles will introduce new risks related to software failures, system failures. System failures can be fatal to vehicle occupants and other road users
- › Driverless vehicles are prone to information hacking which can be used by criminals and terrorists for creating traffic management. Similarly data sharing and GPS data are liable to privacy concerns
- › The traditional cars will be driven simultaneously with the self-driving vehicles which may have adverse impacts on the convenience and safety of the other modes of travel
- › An on-going debate with respect to self-driving vehicles is that as these cars are adopted, jobs for drivers will decline. Simultaneously, because these cars will run on software, the need for auto-vehicle body shops shall also decline causing loss of employment
- › Privacy is seen as one of the major concerns of the naysayers of the self-driving vehicles. Because a lot of information has to be stored in the software, individuals are concerned that the computer shall collect personal data (without permission) which risks the privacy of the common citizen
- › The cars may not operate at high levels of safety all the time. For instance, a heavy rainfall or a difficult weather condition has the potential to damage the laser sensors mounted on the cars roof. Also, for instance, if the traffic signals fail then whether the cars will be able to interpret human signals or not is a big question.
- › The impact on the gasoline industry too is going to be tremendous given that the newly improved self-driving cars would be electric.

SELF-DRIVING VEHICLES ECOSYSTEM

Defining the ecosystem of the autonomous vehicle industry has always been difficult for the industry has only recently begun evolving. The concept of 'smart cars' was initially at a nascent stage and to define what industries belonged to the autonomous vehicles community was difficult. However as the penetration of autonomous vehicles is accelerating, the ecosystem is also getting established simultaneously.

The past year has highlighted that autonomous vehicle industry is working in collaboration with multiple stakeholders at one single time. Recent developments in technology highlight the gaining momentum of the autonomous vehicles industry. The past year has highlighted the active role that technology giants, the automobile industry, the geospatial industry and the government play as part of the autonomous vehicles ecosystem. As various milestones of autonomy come into focus, there begins a growing interest of new stakeholders in the driverless car ecosystem. Insurance provider, energy providers, mobile service providers etc., are few important stakeholders that have begun to play a well-defined role in the self-driving vehicles ecosystem.

ACTION POINTS FOR THE ECOSYSTEM

The self-driving vehicles' ecosystem is still getting defined every day. As Original Equipment Manufacturers (OEMs), technology providers, the government and transport authorities come together, it is important to determine the action points for them. These action points define the role and responsibilities of the ecosystem for the self-driving vehicles.

Software Companies: Substantial opportunities are going to be available for a range of technology providers' esp. software companies who are involved in application development for example, cloud and IT services, security software and vehicle engineering. For instance, there is an unspoken agreement amongst all the stakeholders that the data so generated by the autonomous vehicles will use cloud as a medium for storage. Transportation agencies will then be able to use this data, use software and analytical tools to understand the data and then implement the findings in designing and developing 'smart' roads and an efficient transport system.

Software providers can provide the right framework for the proper functioning of the autonomous vehicles. Getting the right software in place is important. World's top computing companies like Apple, Google, Cisco, etc., are already integrating their innovative products with in-vehicle systems. The role of the technology and software providers is:

- (a) Boosting software reliability and cyber security
- (b) Securing the software that runs the car and integrating all the components that need connection to the internet
- (c) Securing applications running within the vehicle
- (d) Establishing communications between vehicles and internet enabled devices

Deep Learning and Artificial Intelligence: Deep Learning and Artificial Intelligence will play a vital role in imitating the human neural networks. Deep Learning uses algorithms to analyse the data and solve the problems that may come in the functioning of autonomous vehicles. The algorithms are more accurate at object recognitions than humans and these, in turn, will make the roads available to fully autonomous vehicles for they allow detection & recognition of multiple objects, improve perception, reduce power consumption and enable identification and prediction of actions. Artificial Intelligence and Deep Learning systems will also play an important role in manufacturing production lines and crash tests by reducing time and cost.

Original Equipment Manufacturers (OEMs): The wide-spread acceptance of Self-driving vehicles is accelerating the development of various new technologies such as advanced sensors, GPS positioning, computer vision and image recognition. Simultaneously there is the development of Robotics and drone technology as well. Henceforth, self-driving vehicles require a standard vehicle technical architecture and the stages of development for these are:

- (a) Multiple Sensor Technology
- (b) Sensor Fusion
- (c) Autonomous Engine

OEMs, therefore, need to start investing and acquiring the right technology expertise and also consolidate ventures which integrate hardware and software system. OEMs need to also incorporate the Advanced Driver Assistance System (ADAS) providers or tech providers for the efficient functioning of the autonomous vehicles.

Governments and Transport Service Providers: Autonomous vehicles have the capability to drive the development of 'intelligent' cities. As established, these vehicles are always collecting location, road and traffic data which can be used by government authorities to assess and analyse to assist in urban network planning. The data so derived can also be used to develop new road revenue models. Some cities in Europe and United States of America have already started using the technology to change the way they charge

for road usage. Because road usage requires accurate data, it is imperative to ensure that the smart cars collect the right data. For this purpose - governments, businesses and organizations, all need to come together.

Municipal authorities and transport service providers and operators can play an enhanced role by using smart technology to caution drivers of any potential hazards and crashes. Smart traffic signals could also be gaining traction and could potentially save up to 15% in fuel consumption. The transport authorities could also use the data collected by self-driving vehicles to schedule self-driving vehicles at off-peak times to enhance productivity and traffic throughput. In many ways, the data collected by the cars could, therefore, be used to mitigate traffic congestions by scheduling mail service providers, supermarkets and retailers so as to improve delivery times.

Global interest in self-driving vehicles is going to speed regulations up especially concerning smart roads, smart traffic signals, etc. Most countries have already aggressively started moving into the autonomous vehicle space. For instance, China is especially fast forward in defining regulations and setting standards to convert cities to driverless hubs with multi-year rollout plans. Many cities of United States of America are also already looking into establishing policy frameworks at the municipal, state and federal level.

The government can also play a fundamental role in the ecosystem by improving its public infrastructure. The public infrastructure which is important for self-driving vehicles are roads, pedestrian tracks, bridges, traffic lights, etc. The governments should play a defining role in establishing the need for infrastructure planning. Rough road conditions and broken traffic signals could be detrimental to sensor-driven cars – more than they would confuse a human driver. The government could either take up on itself to transform the public infrastructure that will support the driverless cars in the long run or it could implement laws – laws that would impose more liability on the cities. This in turn would make cities more responsible and pressurized to maintain streets and traffic signals.

Finance Service Providers: Banking and financial service providers need to play a defining role in autonomous vehicles to reshape ownership models and introduce new revenue streams. Foreseeing how autonomy is going to disrupt the finance industry, banks and other financial institutions will need to take the first step and boost their investments in machine to machine security. Simultaneously, the transformation of the traditional vehicle ownership models could alter the nature of car financing

and in turn stimulate the banks to create new lending projects for autonomous vehicles. This futuristic trend emphasises the role of banks and financial institutions to develop key relationships with service industries such as fleet providers and energy providers to drive up the revenue streams.

A radically reshaping of the insurance industry is also in question due to the potential widespread adoption of self-driving vehicles. Warren Buffet predicts that the need for insurance coverage by accidents is going to be less likely once fully automated cars are adopted. In such a scenario, new insurance models are expected to arise. Insurers will need to adapt to the new technologies. Profound changes are also expected in how insurers underwrite and sell insurance products. For example, the insurers could move from motor insurance to product liability insurance. In the United States insurance companies such as State Farm have already begun to examine and evaluate ways to understand the transformations that self-driving vehicles could bring.

Mobile Service Providers: According to Gartner by 2018, 20% of all new vehicles will need to be self-aware to capture systems status, positioning and surroundings in real time. This would lead to a significant increase in data consumption pattern and therefore create potentially attractive revenue models for mobile service providers. Mobile service providers will have to build new capacity, products and services. This shall benefit the telecommunications industry and the Original Equipment Manufacturers (OEMs) to take advantage by selling their products to consumers.

Energy Companies: Self-driving vehicles are disruptive, and they have the potential to disrupt the energy market as well. As these vehicles become globally prevalent, energy providers will soon have to start considering options of how to profit from them. Energy companies have to decide on:

- 1: Designing innovative service stations
- 2: In-road charging systems
- 3: Using alternate source of energy sources to generate power

The energy companies also need to start exploring options of partnering with car companies to understand the energy requirements of the car companies.

Roadway Contractors: The way to make self-driving vehicles safe is to make the infrastructure around the vehicles safe. Modest changes need to be made to the infrastructure so that autonomous vehicles can behave as predictably as

ACTIONS POINTS FOR THE AUTONOMOUS VEHICLE ECOSYSTEM

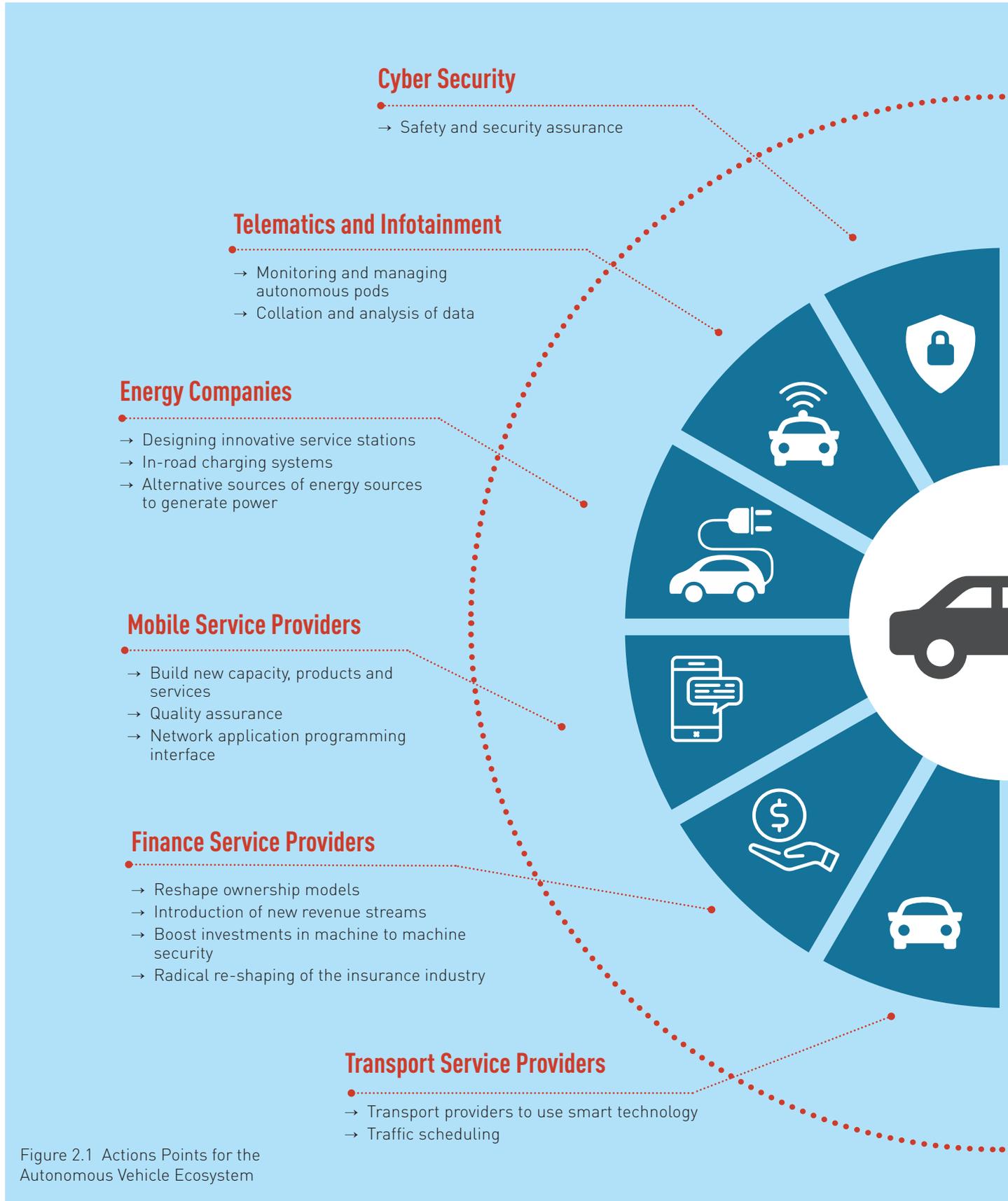
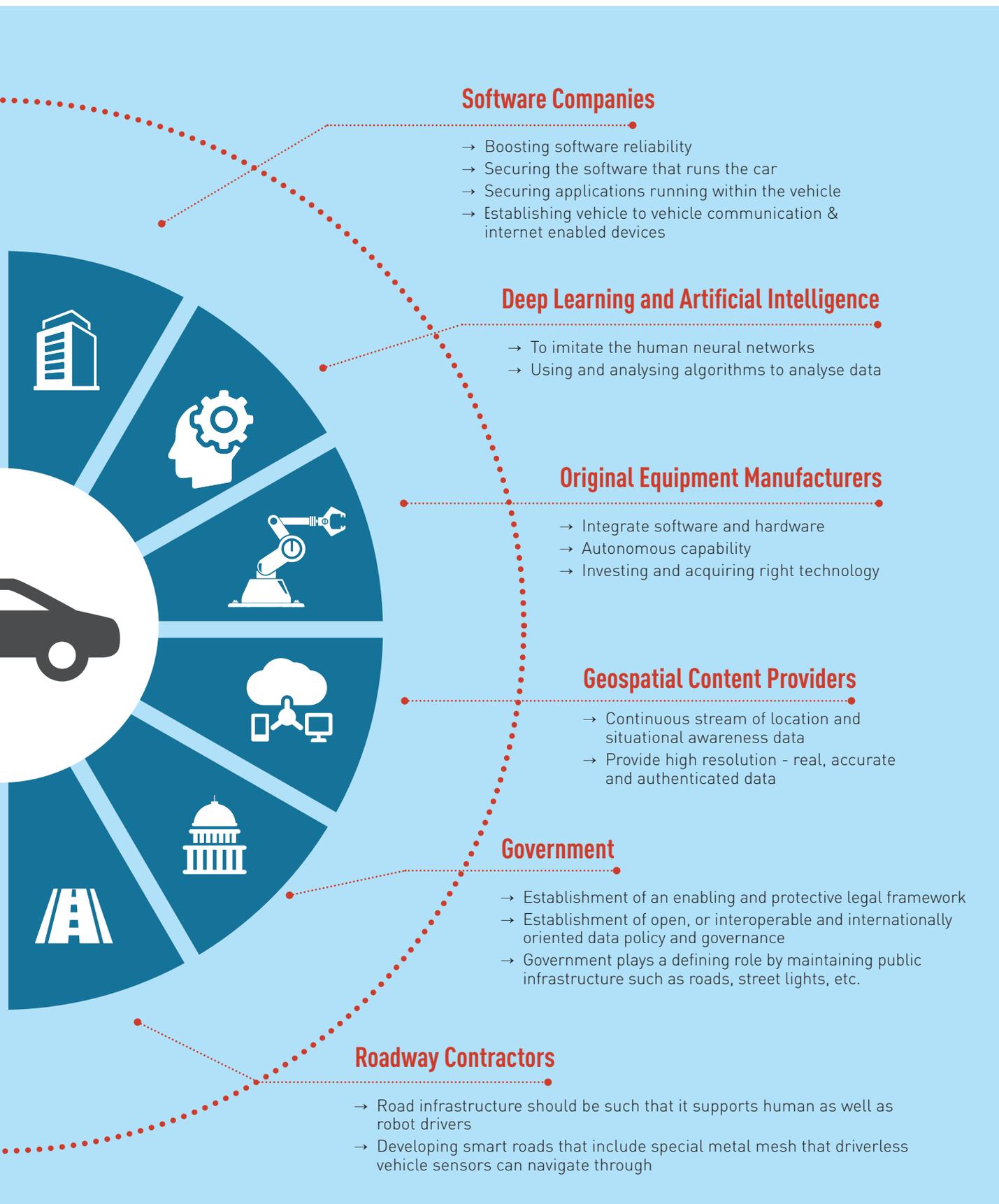


Figure 2.1 Actions Points for the Autonomous Vehicle Ecosystem



possible. Currently, the system of roads is built with human drivers in mind. The contractors responsible for public infrastructure such as roads and traffic lights, etc., need to start considering options for designing systems that are efficient, safe and effective transportation system. It has been found that the vehicles ability to communicate with smart road infrastructure is much more important than it seems. To develop the synergy of smart infrastructure the following have to be taken care of:

- The road lines need to be painted every year with reflexive paints so that the on-board sensors and cameras catch on to the road lines.
- Developing smart roads line that include a special metal mesh that driverless vehicle sensors can navigate through
- Building roadside sensors along the streets and highways so that cars can navigate them would allow the vehicles to 'see' activity far ahead on their routes
- Road infrastructure needs to be such that it supports human as well as robot drivers such that roads understand the technology used in the driverless vehicles
- Building several traffic signals at different intersections while ensuring that roads have clear land markings such that driverless cars can navigate safely

For instance, the United States National Highway Traffic Safety Administration (NHTSA) establishes that yellow turn signals are significantly safer than red one because they are easily recognizable. Similarly, well-maintained roads are also critical for driving predictability. Also, the contractors

can seek support from the local city government to network roadside infrastructure to enhance the vehicle to infrastructure communication such as traffic lights, cameras, road sensors and parking meters so that they can communicate with each other and the dream of smart cars on intelligent roads become a reality.

Telematics & Infotainment: Telematics play a key role in monitoring and managing a fleet of autonomous pods through collation & analysis of data and tracking malfunctioning's of the pods through software and hardware analysis. Telematics service provider may use a pay-per-use and premium subscription model to be sold on contractual basis for maintenance, diagnostics, infotainment and content streaming for autonomous transportation.

Cyber Security: As vehicles become connected and automated, concerns are going to rise over cyber security. As these cars will provide real-time accurate data – the fear that these systems can be hacked even by terrorists for massive damage is a major concern. Due to the recent successful hacking of Tesla Model-S, the autonomous vehicle ecosystem is venturing out to find solutions to this problem. It is crucial that it be decided early on by the government, the technology providers and the automobile makers on how to resolve the problem.

Now that we have established the action points for the self-driving vehicles ecosystem, let us dive deep into the core of what drives the self-driving cars – the geospatial component

GEOSPATIAL AND SELF-DRIVING VEHICLES

The self-driving vehicle industry has been growing at an accelerating rate and the geospatial industry plays a crucial role for this emerging technology relies heavily on geographic data. The technology requirements of the self-driving vehicles industry is largely based on geospatial technologies such as sensors, LiDAR, Radar, navigation, etc., the use of which can have a potentially disruptive impact on the geographic information industry. The idea of self-driving vehicles on road is only becoming a reality because of the advancements being made in positioning and sensor technologies. Thus, the whole array of geospatial technologies is at the core of the self-driving vehicles.

AUTONOMOUS VEHICLES – AS DATA PRODUCERS

When it comes to self-driving vehicles, data is the oil. Data is at the centre of the functioning of the autonomous vehicles and without data, no driverless car can work. Automobiles are dependent on data and connectivity and therefore data has the potential to change the way driving is thought about. Autonomous cars are expected to engage a plethora of sensors, consuming lot of

real-time data for efficient driving. However, there is one other important aspect to the self-driving vehicles. They not only consume data but they act as 'super sensors' or 'on-the move data infrastructure' producing vast amount of data by themselves.

Autonomous vehicle is expected to exponentially increase the amount of data being produced. For instance, the driverless car from Google is a true data creator producing data on where to drive and how fast to drive. The self-driving vehicles are capable of producing 0.75GB data per second which means they would create 2 petabytes of data a year. It is foreseen that by 2020, an average autonomous car may be able to process 4000 GB or 4TB of data per day while the average internet user shall process only 1.5 GB. This means that one single autonomous car, loaded with LiDAR, sensors, etc., and shall be able to generate data approximately produced by 2666 internet users in a day. This also means that in 2020 when there are 3 million autonomous cars worldwide – automated driving shall be representative of the data of 3 billion people.

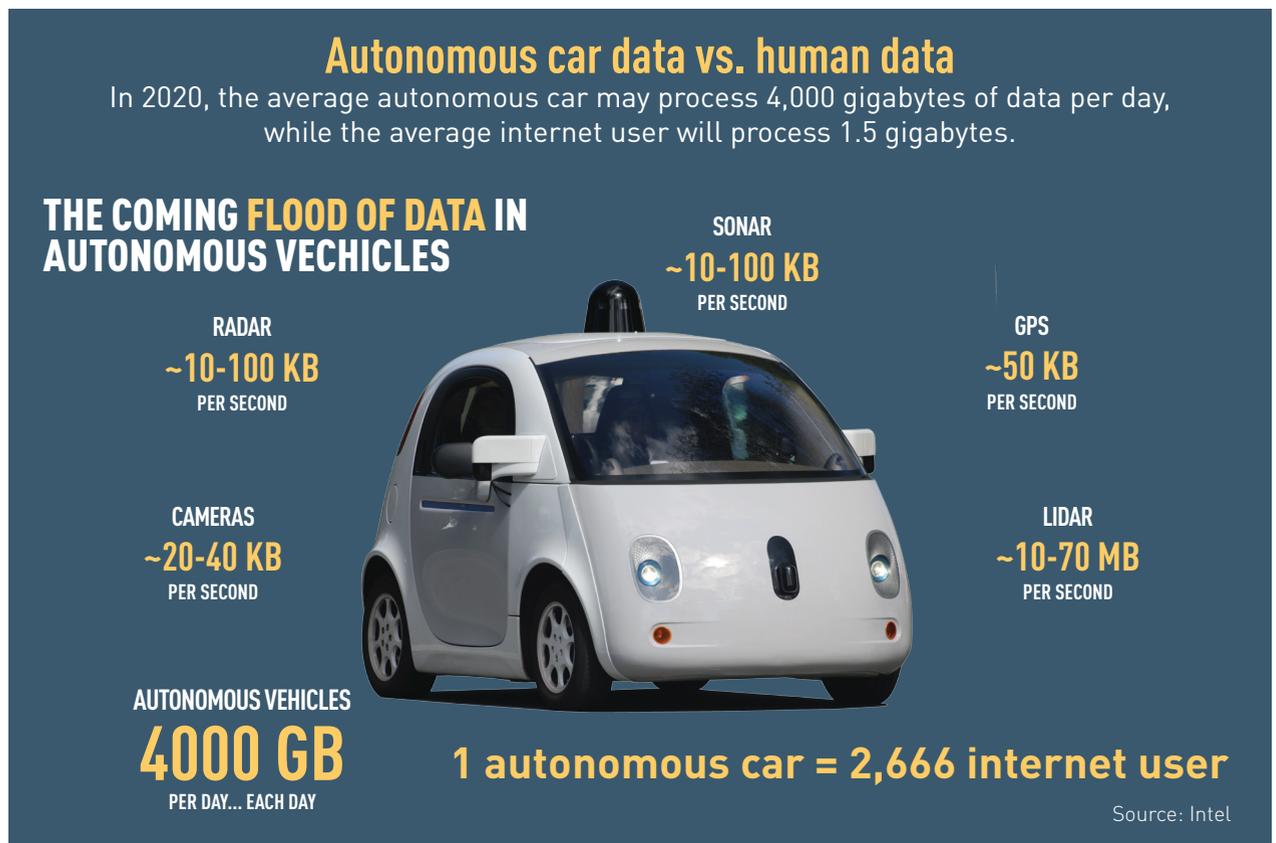


Figure 3.1 Autonomous Vehicles as Data Producers

Analysing the trends, self-driving vehicles shall send and receive information which will inflate the amount of data produced overall. This data may be location data, weather data, traffic data, navigation data, etc. Therefore, the data captured by the autonomous vehicle can be used for actionable items to derive full value. As it is understood, the driving force behind the technology is Big Data- autonomous vehicles are actually an extension of the same leading to almost unlimited data production. Countless sensors and cameras mounted on top of autonomous vehicles map the surroundings – spot lane markings, roadway edges, traffic signs and lights and identify pedestrians. The driverless vehicles are also fitted with other high tech gear such as altimeters and accelerometers to give more accurate positioning than would be possible on using GNSS. All this data that is produced by the autonomous vehicle during the drive could be stored in a centralized infrastructure from where it can be disseminated to the other stakeholders of data users after thorough analysis and processing. For instance, the data collected by self-driving vehicles may have to be shared with municipalities and the government. Road conditions, potholes, traffic light situations, etc., can be dealt with on an immediate basis because of the real-time data that the sensors in the car generate. In such a scenario, the self-driving vehicles may also be looked at as an important stakeholder of the ‘technology infrastructure’ of the geospatial industry. The data, thus, created shall be a powerful tool for touching the public sector goals.

Below are the important geospatial technologies incorporated inside the car that are primary to the success of the driverless cars and establish autonomous vehicles as data creators.

GEOSPATIAL TECHNOLOGIES: ‘UNDER THE BONNET’

Advanced Multiple Sensors

The most important part of self-driving vehicles is geodata and this data about the environment is gathered by using multiple sensors. These sensors are being used for mapping, localization and for avoiding obstacles. The main sensor used to gather geo-data and information is the LiDAR – Laser Illuminating Detection and Ranging, with ranges up to 100 meters. The LiDAR is used to build 3D maps and to allow the car to foresee any potential hazard by bouncing laser beam of surfaces surrounding the car to determine the distance and profile of the subject accurately. While LiDAR is being used to accurately map the surroundings, it is RADAR that is used to map and monitor the speed of the surrounding vehicles to avoid potential accidents, detours, traffic delays and any other obstacles by sending a signal to

the on-board processor to apply the brakes or to move out of the way. Modern self-driving vehicles rely on both LiDAR and RADAR to validate the data that is generated on what is seen and how motion is predicted.

LiDAR is currently seen as a premium option as Original Equipment Manufacturers (OEMs) figure out the cost structure of their self-driving vehicles. RADAR, on the other hand is a proven technology becoming more efficient for autonomous cars. At present, the technology is being introduced to fit smaller, low power and efficient sensors which are suitable for OEMs cost reduction strategy

High-Powered Cameras

All autonomous cars utilize high-powered cameras, but the actual camera technology and setup on each self-driving car varies. Some vehicles may have a single camera embedded in the windshield while others might require several cameras mounted to the vehicle’s exterior to give a composite picture of the surrounding world. A master of classification and texture interpretation, cameras are the cheapest and most available sensor. They use and create the maximum amount of data thus making processing a computationally and algorithmically complex task. Because cameras can sense colour, they are best useful for scene representation.

GPS (Global Positioning Software)

Self-driving cars need a unique and detailed mapping system, and Global Positioning Software (GPS) is a vital part of the autonomous car’s large scale navigation. GPS software

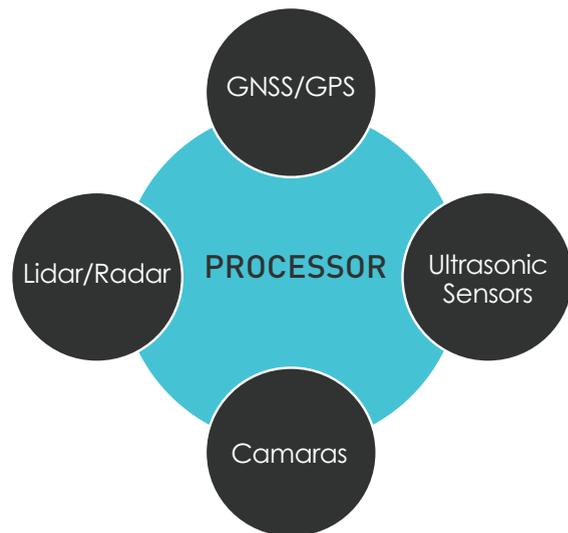


Figure 3.2 Sensor Integration in Autonomous Vehicles

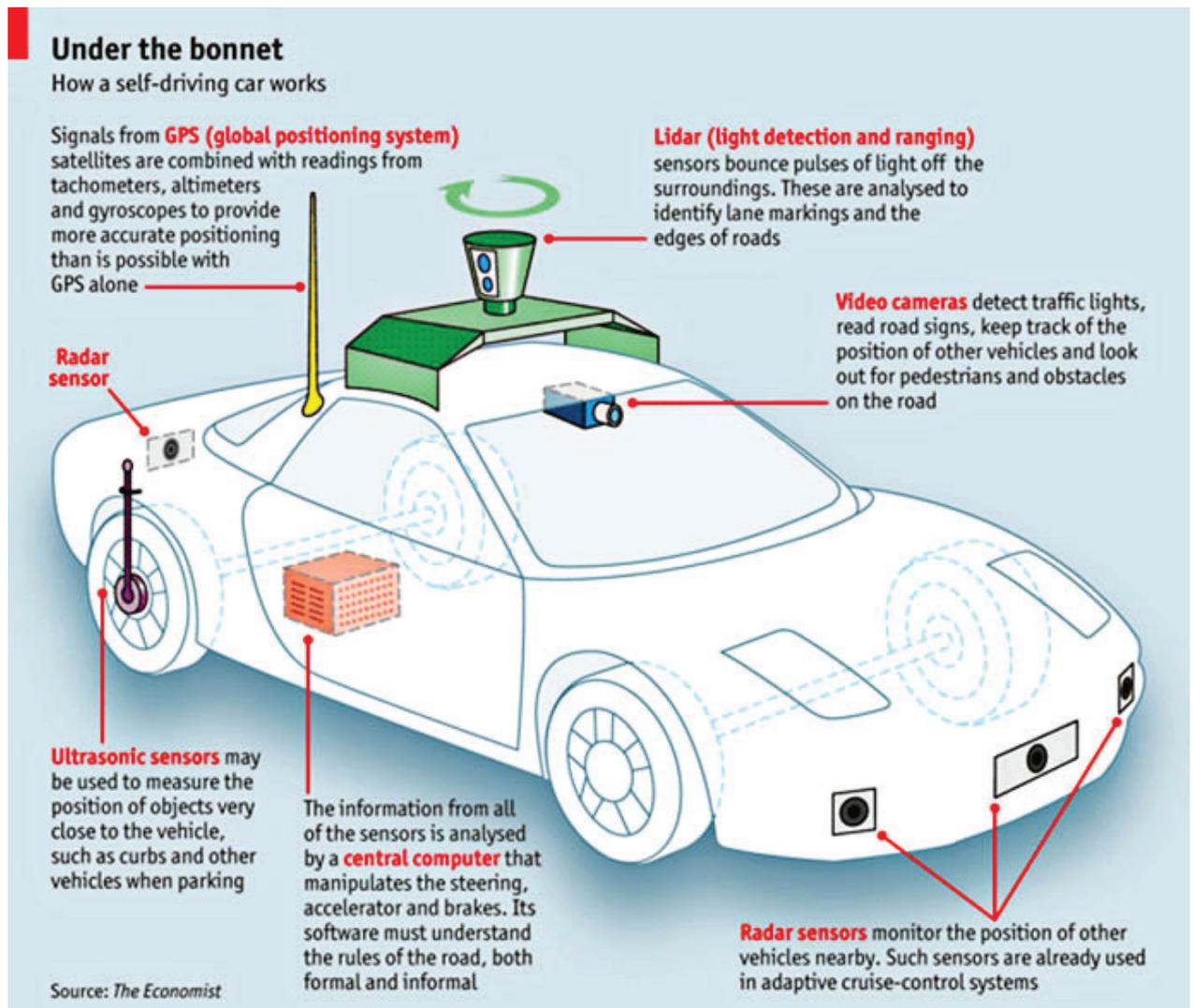


Figure 3.3 Under the Bonnet – How the Self-Driving Car works (The Economist)

is considered to be important because it defines the 'mission' of the autonomous vehicles by helping the car navigate successfully from the starting point to the end point of the drive by looking at all road and by choosing the path. A fully autonomous vehicle requires an accurate localization solution which can only be provided through high-precision Global Navigation Satellite System (GNSS) technology or GPS. This technology ensures that accurate and reliable data is available to ensure for a vehicle to stay in its lane or at least at a safe distance from other vehicles.

Ultrasonic Sensors

Ultrasonic sensors provide 360-degree visibility around the car for up to 250 meters of range. They allow for detection of both hard and soft objects very close to the vehicles. Ultrasonic sensors are also beneficial to the

self-driving cars for drifting around tight corners and are used extensively by parking aid systems.

Processors

All self-driving vehicles will have increased computing requirements for the data generated from the cameras, and the sensors will need to be processed in real-time. The processor is also necessary to model the behavioural dynamics of other drivers, pedestrians and objects around the vehicle. It is important to note that actions such as steering, accelerating and hitting the brakes are all controlled by the processed information.

All the aforementioned technologies mentioned above work in conjunction with each other to successfully and safely manoeuvre the vehicle to its final destination.

SPACE TECHNOLOGY

Space technology is defined as the technology developed by space science or the aerospace industry for use in spaceflight, satellites, or space exploration. Just like other technology domain, space technology too has a vital role to play in self-driving vehicles and is gaining importance slowly. Space technology can tackle the biggest problem that autonomous vehicles continue to face that is deciding the right moment to hand over control to humans. At present, Renault-Nissan, committed to self-driving vehicles is deploying the Seamless Autonomous Mobility system which uses artificial intelligence and is derived from NASA technology. Collaborating with NASA's Ames Research centre, the Nissan LEAF vehicle employs cameras, sensors and cellular data networking and robotics software developed for Ames' K-10 and K-REX planetary rovers to operate autonomously demonstrating the transfer of space technology to the autonomous vehicle industry.

GEOSPATIAL INFRASTRUCTURE

The food for self-driving vehicles is data. As is evident, to prepare food one needs a well established and an operational kitchen - similarly, to make use of available data, there is need of geospatial infrastructure unique to autonomous vehicles. Self-driving vehicles need a unique and detailed mapping system so that data is accessible to all stakeholders of the ecosystem as easily as possible. In such a scenario, geospatial infrastructure is of paramount importance for smart mobility.

GNSS Infrastructure

Information technology is at the heart of the driverless vehicle ecosystem. GNSS infrastructure is at the core of localisation of data and positioning of self-driving vehicles.

Global Navigation Satellite System (GNSS) is a constellation of satellites that provide autonomous geo-spatial positioning with global coverage. They allow small electronic receivers to determine location in terms of longitude, latitude and elevation. The advantage to having a GNSS system is accuracy, redundancy and availability at all times. An integrated GNSS system is complementary and interoperable with other automotive technologies. By integrating sensor data and connectivity based information operators may reduce the need for expensive sensors and save money on infrastructure requirements. Therefore, GNSS is viewed as a fundamental enabling technology for autonomous vehicles – being at core of localisation of data and positioning.

An available and reliable GNSS is required to increase the safety, enhance the traffic flow and to provide better

public mobility. GNSS infrastructure is needed to convert the normal GPS signals into highly accurate navigation devices. Additionally, GNSS infrastructure can also be used to create highly precise reference frames for the vehicles by ensuring that high accuracy maps are tied down to real ground points. This helps the driverless cars to navigate by themselves. This also ensures that each vehicle on the road, irrespective of whether they are driverless or not, is in a universal frame of reference irrespective of who the automaker is and what is the sensor portfolio in use. GNSS infrastructure, therefore, is imperative to the success of the autonomous vehicle for it efficiently combines location information to actual physical objects and a corresponding digital map i.e. to a single reference frame.

For instance, WEpod, a completely automated vehicle currently in a testing phase in the Netherlands is utilising a combination of robust GNSS infrastructure, digital maps, radars, cameras, laser scanners and ultrasonic sensors. The localisation system used multi-constellation GNSS with network-based-real-time kinematics (RTK). Similarly the InDrive Project is developing a close to market solution that relies heavily on accurate and high-integrity satellite navigation based on European GNSS.

Data Infrastructure

Autonomous vehicles will be used as geospatial data collecting machines and, therefore, not surprisingly, these vehicles will be collecting a lot of data of their surroundings. Autonomous vehicles need to be aware of what is happening around them i.e. in their environment at all times, and that is why localisation of data is a fundamental concept. It is, however, important to consider that the data collected by these vehicles is only useful if it can be critically dissected in real time and processed accurately. Real-time data as gathered by autonomous vehicles could range from traffic patterns to delivery tracking, etc. This data is continuously gathered and will need a central repository for storage and further distribution. More so, the geographic information so collected will need to be processed to create accurate roadway maps which would too require an efficient infrastructure. Simultaneously, a robust data transfer pipe shall be the need of the hour to ensure that data that is collected and processed flows seamlessly. Therefore, the geospatial intelligence of driverless cars shall rely heavily on a well-established geospatial data infrastructure.

Challenges in Establishing Geospatial Infrastructure

While geospatial infrastructure is imperative to the success of self-driving vehicles, it comes with numerous challenges. The biggest problem that is foreseen is that it

is not going to be easy to map every terrain and link it to the same reference frame which could take a lot of time and involve high costs.

Also, there is a lack of uniform roll out of cellular technology which acts as the biggest roadblock for establishing an efficient geospatial infrastructure. While the United States and Europe are steadily moving towards the newer 5G standards, the rest of the world is still stuck in the older standards of 2G and 3G. Since most of the geospatial data generated are from data-heavy sensors, the need to have good cellular or Wi-Fi technology globally is paramount for conformity of self-driving vehicles.

GEOGRAPHIC INFORMATION: DATA

Data is at the core of the success of the self-driving vehicles (SDVs) industry. The on-going debate at present focusses on data and the legal quandaries that one may face with respect to data. It is imperative to realise that the geodata that is crucial to location information is going to an important aspect of the autonomous vehicle technology. Location information is critical because it shall determine the potential of the self-driving vehicles. Geodata, at present, is available for the surrounding environment and the more the data is available, the more 'automated' and convenient the decisions would become for these self-operating vehicles. Self-driving vehicles use geo-data to analyse their own location. The cars are fitted with sensors to monitor positional awareness, proximity to pedestrians, traffic signals and much more. The data is, therefore, collected at four levels which are:

- In-car sensor data
- Base map data for navigation
- Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I)
- Commercial datasets (also includes social networking sites)

In a way, it is Big Data that actually controls self-driving vehicles. Let's see how!

In-car Sensor Data

According to INVENT – a company dedicated to developing inter-vehicular networking, computing, and sensing technologies, autonomous vehicles or 'smart cars' of the future is an extensive data collection system of the environment. These vehicles have embedded cameras, sensors, computers (processors), short range wireless network interfaces and GPS receivers that can sync with a vast network that is continuously collecting data about the surroundings and that too in real-time. The data

generated from in-car sensors such as LiDAR and Radar is processed in software using algorithms to further make decisions on steering, braking, speed and route guidance.

For example, the self-driving car from Google is already a data creator in the truest sense. All the sensors in the car enable the car to drive without a driver generating nearly 1GB data every single second. If one driverless car collects approximately 1GB data (or more!) every single second, it can be only left to the imagination how much data can these in-car sensors generate over a period of time and with an influx of many such cars.

Base Map Data for Navigation

The base map is at the centre of the self-driving vehicles for efficient and easy navigation for even though sensors on the car detect things in real time, prior information is necessary to evaluate what exits. High precision base maps are being made by leveraging aerial imagery, sensors, mobile driven LiDAR, Aerial LiDAR data specifically for self-driving vehicle models and markets. The base map cannot be static and needs to be updated every second. Metre resolution maps are good enough for GPS navigation, but the accuracy of base maps need to be defined in the absolute ranges of 'centimetre' or even 'millimetre' for the SDVs. It is these high-precision maps that can smoothen the transition to a new technology. A highly accurate base map is needed to assert the stationary physical assets related to roadways such as road lanes, road edges, dividers, traffic signals, poles and all critical data required for safe navigation of road by the self-driving vehicles (SDVs).

For example, HERE is using satellite and aerial imagery for base HD maps. These maps incorporate data from GPS devices and from sensor systems that have been outfitted in the cars to collect datasets to make the base map. HERE has driven 1.2 miles in 30 countries on 6 continents in the last 15 months.

Connected Data – Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) Communication

The concept of V2I and V2V can be defined as the initiation of the term 'Internet of Cars', a play off on the term 'internet of things'. In the connected car discussion, Vehicle to Vehicle (V2V) speaks of all the communication happening between the vehicles on the road. V2V is still at a very nascent stage but could be the beginning of road safety. In this one vehicle can communicate with another directly which would allow cars to maintain an internal map of the surrounding vehicles. The idea is to employ a small radio transmitter and receiver on each

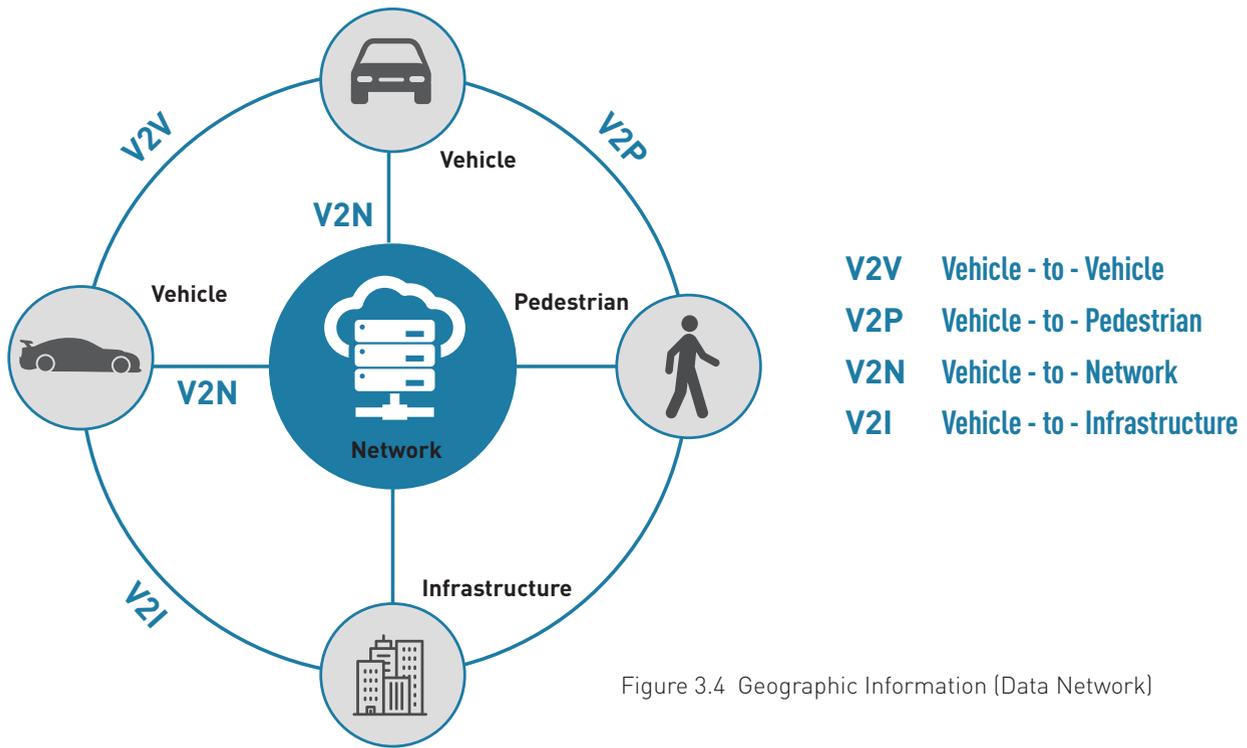


Figure 3.4 Geographic Information (Data Network)

vehicle that broadcasts information about location, speed and direction to other vehicles within several yards. This will help provide driver warnings to guide the driver about when it is safe to change lanes, speed and merge thereby helping electronic safety systems work safely.

Once V2V is successfully established the next step would be to develop the Vehicle to Infrastructure (V2I). The idea behind V2I is an integrated data network between the vehicle and the roadside infrastructure such as traffic signals, roadway sensors, pedestrians (V2P), etc. It is predicted that the first V2I systems will be developed and employed by 2020.

Commercial Data Sets

At present, many private companies are collecting data for use in self-driving vehicles. Social networking sites such as Facebook, Twitter, etc., also collect data pertaining to 'location', traffic, etc., which can be made available for the real time functioning of the autonomous vehicles.

An interesting data source for autonomous vehicles is telematics or weather data that can also to some degree be used to evaluate and monitor driving behaviour to improve the driving experience. In such a scenario, all the data can be combined with the socially available public

data such as geographic locations, housing, and demographics to give a 360-degree view to the customers.

AUTHENTICITY AND RELIABILITY

Self-driving vehicles or now commonly known as intelligent vehicles are a complex system in which data plays a crucial role. Data in such a case needs to be reliable for a safe and secure autonomous vehicle that can by itself analyse complex environment in real time. Passenger vehicles are complex issue in general and the involvement of data to majorly drive autonomy can be a challenge. The geographic information so required needs to be of high definition, industrial class reliability, authenticated by the supreme authority and true to real time. The whole technology is that is why based on data-centric connectivity.

Data is already central to a thousand of applications such as defence, power, medical, communications, construction, transportation, etc. Therefore, data, a strategic asset integrates all the other components of the autonomous vehicles and helps them to operate better. It is understood that the autonomous system cannot stop, even if for a few micro-seconds. Henceforth, it is imperative that the data – which is a food to the whole of the autonomous system in the self-driving vehicles – be reliable, flexible, real time and secure.

To ensure data integrity, reliability and accuracy, advanced data encryption techniques that are used in the current financial and banking system could be leveraged for autonomous driving and associated data flow. Enhanced integrity techniques that are often found in safety of life applications such as Aviation can be leveraged to form primary data exchange standards that provide security and integrity. Data encryption is a method that aims to reduce risks, however, not acting as a substitute for data protection controls. Autonomous vehicles should be able to leverage data collected by the smart gateways and the smart sensors and cameras on-board the car in encrypted format i.e. the binary vectors and submit the encryption of the vectors to the data servers/infrastructure. This shall make the encrypted data unreadable, thus ensuring the accurate and reliable data to be safeguarded till the software managing the algorithm is presented the appropriate credentials and keys to unlock the encrypted data. In such a scenario, data remains accurate and reliable for the original binary vectors remain uncorrupted. The only drawback that exists in encryption of data is the loss or corruptions of the authentication credentials would result in loss of the entire system or if managed by an application, could result only to loss of data managed by the applications, per say. However, in the long run, encryption of data would ensure authentic and reliable data for driverless cars. It is also important to note that encrypted data will ensure safety from cyber hacking.

Understanding the importance of data, automakers are taking a step forward to control maps and navigation and that explains the acquisition of HERE by the German consortium of automakers consisting of Audi, BMW, Daimler and others. While the autonomous vehicle shall have sensors and cameras to collect real time data – the data in the infotainment system needs to be pre-installed and therefore needs to be reliable especially in necessary times. For instance, in a bad weather, the camera or sensors may only be able to deliver information to up to 300 meters ahead and for more information it is important to see further. In such a case, the pre-installed data comes into play and helps the autonomous vehicle to be 'aware' of its surroundings. In conclusion, the data so available needs to be reliable, consistent and accurate according to the set standards and structure.

STANDARDS AND STRUCTURE

As discussed, while reliable data is important, this data needs to be authenticated on the basis of set standards and structure. As the autonomous technology comes to the forefront, it is necessary for the government to get involved so as to analyse and address the issues of standards

and structure of the data to be used. A central unification process is needed worldwide with respect to data for self-driving vehicles. It is not fundamentally possible to use different formats and structures for datasets because that complicates the autonomous driving further which is not in the best interest of the autonomous vehicle ecosystem.

While setting a data unification standard, it is important to consider the standards laid down by established standard development organizations like Open Geospatial Consortium, Industrial IOT, OMG, etc. Road maps need to be set which shall lead to the development and implementation of the standards needed. As per the technology ecosystem, best standards need to be defined which is, for instance, standards for change detection and standards for interfacing. These standards need to be available in a format used by all autonomous vehicles is the same or easy to interpret. Lessons can be learnt from Europe, China and Japan. While in Japan, three major automakers are struggling to agree on standards, in China, standards are being set for vehicle to vehicle to communication. China also aims to establish a national data standard by 2020 which would speed up the implementation of self-driving cars in the auto market. Safety

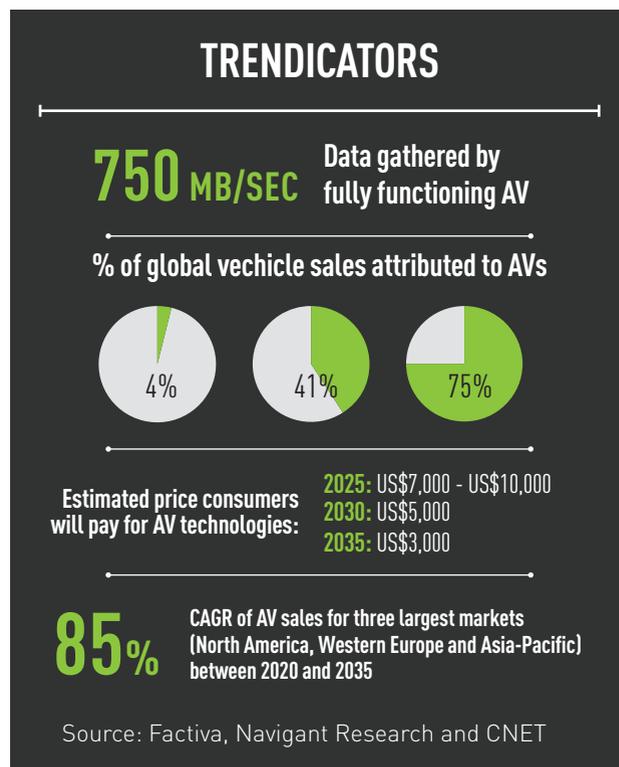


Figure 3.5 Trends on Autonomous Vehicles

and insurance are also two important facets of setting standards. Self-driving cars have unique safety demands and therefore with the emergence of the new international standards. While ISO 26262, sets the standards for developing such systems – it is imperative to set standards for safety requirements.

For instance, to bring the promise of automated vehicles to reality, an European Intelligent Transport Organization, ERTICO, is defining a standardised interface known as SENSORIS to share information between the in-vehicle sensors and a dedicated cloud. The cloud is also expected to warrant broad access, delivery and processing of vehicle sensor data will enable location based services which are key for automated driving. Developed by the location cloud company, HERE, SENSORIS standards is expected to be universal and will enable driverless vehicles to prepare for changing conditions well before the vehicle can see them. A universal data language will

initiate communication will all the vehicles on the road to live route conditions in real time.

In summary, the world is moving towards making fully autonomous vehicles a reality and setting data standards and defining a structure of data is important. Therefore in this context, open data standards, interoperable standards, policy standards and technical standards – all need to be defined beforehand. If the data is available in a uniform format and structure – the benefits of autonomous driving shall be far more than the risks and the costs associated with it.

The government too has a significant role to play in setting up standards and structure for geo-information data. In our next chapter, we identify the crucial role that the government plays in establishing an enabling and legal framework for driverless cars and for open and interoperable data policy.

GOVERNMENT AND SELF-DRIVING VEHICLES

Autonomous vehicles embody great potential and can yield a wide array of benefits for citizens, organisations and governments. However, cashing in on those will require numerous framework conditions to be met, which are typically 'governmental'. Accordingly, there is no doubt that governments, both at the national and international level, will have a major role to play. The role of the government will emerge and re-emerge in different forms and shapes over time and may, in fact, differ from continent to continent, country to country and even from region to region. These roles are closely linked to a wide variety of factors, including technical know-how, technical and data infrastructure, the economic structure of the main enabling technologies, size and character of demand for driverless cars, legal constituency, policy objectives, just to mention a few.

Interestingly, the world of geo-community can play a small but crucial role in the sound development of driverless cars. We can define and cluster the universal key requirements that are conditional for the prosperous development of autonomous vehicles as:

- (a) Establishment of an enabling and protective legal framework
- (b) Establishment of open, or interoperable, and internationally oriented data policy and governance

ESTABLISHMENT OF AN ENABLING AND PROTECTIVE LEGAL FRAMEWORK

It has been accepted that autonomous cars are going to be arriving soon and smart vehicle technology is advancing with or without legislative and agency actions at the federal level. Governments worldwide are realising the need for changes in legislation required specifically for self-driving vehicles. These legislations are not only needed for the vehicles but for the entire automobile ecosystem. At present, changes in legislation are currently only occurring for testing driverless cars. However, change can still be expected to define the ownership, importation and use of autonomous cars in the near future.

There is a wide range of issues that necessarily need to be addressed by the governments through legislation, which include:

(a) Safety

It is necessary that the government leads the charge in the establishment of data safety standards for autonomous vehicles. Also important is to define the rules

and regulations and specific standards pertaining to the manufacturing, vehicle design. The government also needs to establish the standards and legislations necessary for road management and traffic signal management to ensure safety on the roads. Policies need to be set for setting infrastructure for data and communications networks necessary to maintain safety. To establish the necessary guidelines to ensure safety, it is imperative that the governments take a proactive approach.

(b) Privacy / Data Sharing

Autonomous vehicles are referred to as a dynamic data collection system, and because apart from making use of the available data, they will be gathering a large volume of data to operate, there is a growing concern about data ownership, collection and use. It is here where the government should create guidelines for the driverless car industry to be transparent with consumers about data ownership and sharing. Simultaneously, the government needs to provide clear rules and regulations with respect to the private information that will be collected by these smart cars of its passengers. Because privacy is a concern, the government has to play a defined role by developing policies to further its cause.



Figure 4.1 Establishment of an Enabling and Protective Legal Framework

(c) Cyber Security

Autonomous vehicles are seen to be an easy target for terrorists. Since the technology is going to be digitally driven, any cyber-attack carries the risk of coordinated traffic disruptions and collisions. Also, because the car is generating humongous amount of data every second, this data in the wrong hands could cause much bigger security threats around the globe than imaginable. It is vital that the governments develop a framework to improve critical infrastructure and develops policy frameworks to encompass the risks associated with the autonomous vehicles.

(d) Liability

To define Liability is going to be a major issue in autonomous vehicles. How do you divide the blame between a human driver and a car's automated system? Is it the software? Or maybe it was the hardware? Or perhaps it was due to the hardware and software interacting in unexpected ways. According to an article in the San Diego Union-Tribune, "if the issue of liability is not solved, it could delay or even wipe out the vision of driverless cars gaining widespread consumer use." Therefore, an important question that continues to persist is who is liable when an autonomous car crashes. Complex systems in the self-driving vehicles are like any other technology system is not immune to software failure. A sense of responsibility aka a sense of liability must be established with respect to these vehicles. While a few of the automobile manufacturers are willing to assume full responsibility in case of a highly automated system failing – the other manufacturers are taking a cautious view. Therefore, liabilities need to underline the assurance and resilience predominantly in the stakeholders that deliver highly automated driving functions.

A developing area of policy and legal framework, as the use of autonomous car technologies increases, the incremental shifts in the liability and the responsibility of driving also increases. In the case of an accident – who does the plaintiff sue is an important question. In a typical case, the plaintiff would assign the blame to the driver or the car manufacturer, but in the event of self-driving vehicles, it is tedious. The plaintiff may have to consider the operator of the self-driving vehicle, the car manufacturer, the software provider or the autonomous car technology creator or the automobile manufacturer. Also, it is necessary to question that if software in the vehicle stops working or if it misinterprets a worn down sign and an accident occurs as a result of it – who is going to be held liable. Will it be the department of transportation or the government for the poorly maintained signage or will it be the company that

produced the self-driving software? The answers to these questions need to be established beforehand for the realm of self-driving cars to grow.

ESTABLISHMENT OF OPEN, OR INTEROPERABLE, AND INTERNATIONALLY ORIENTED DATA POLICY AND GOVERNANCE

For the rapid and prosperous development of the self-driving vehicles, data is crucial. Data being both the fuel and output of the autonomous vehicles– must be available, accessible and re-usable. Clearly, this applies to its own data – in particular (systems of) reference data, which should feature high-quality standards and free and open access. The data is foreseen to bridge the information gap across the autonomous vehicle ecosystem, thereby enhancing the sharing of benchmarks and standards that shall raise the efficiency. It is up to the government to realise that the open government data is crucial and the benefits so derived need to be understood and be conferred to the government and stakeholders of the self-driving vehicles.

While flawless data exchange is crucial, the autonomous vehicle will lead to the establishment and elaboration of data standards. The role of government may well be just to define the functional requirements i.e. in relation to the legal provisions set (road safety, liability, etc.) - and follow the market forces. In such a scenario, the government would rather not step into the actual market. However, the government will need to take a proactive role to monitor the process preventing de facto monopolies from arising once single standards emerge.

While specific proprietary data and standards may become an 'essential facility', concepts of 'universal access' and 'must carry' should be applied (legislatively also), ensuring a level playing field and the need for ensuring fair competition. In such a scenario, where needed, agile procedures will need to be established upfront so that market deficiencies and abuse of dominance can be recognised early and addressed efficiently.

It is, therefore, becoming imperative that standard policies are formulated for both standards and data which shall create a predictable and inclusive ecosystem. Appreciating the international context of the autonomous vehicles, governments, in particular, those of the power players in the value chain (car producers, platform owners, analytics companies) should aim to establish an international coalition going beyond the short-term national economic interests.

Therefore, in this respect, the role that the geospatial community could play will be pivotal as (real-time) location data will be crucial in realising the potential of the self-driving cars. Location data is the linking pin that could solve the international vacuum that appears to exist. Appreciating and leveraging on this position, the community should help to set the policy agenda, set roles and responsibilities and suggest priority areas for action. Also, being 'in the middle' it should aim to pull together industry leaders and policy makers and key data and infrastructure holders, including those from the public sector like road authorities. Short term actions could involve connecting to neighbouring communities like ITS communities.

Open government spatial data for autonomous vehicles will bring significant social, environmental and economic benefits. The data shall bridge the information gap across the entire eco-system, thereby enhancing the sharing of benchmarks and standards that shall raise efficiency. At the forefront of the benefits of open, interoperable data for self-driving vehicles is, therefore, transparency, commercial value and participatory governance.

CONCLUSION

In conclusion, 25 years from now, roads globally shall be filled with millions of autonomous vehicles. According to research conducted on auto industry, it is forecasted that 94.7 million vehicles with self-driving capabilities will be sold annually globally by 2035. As more automobile makers race to launch the fully automated self-driving vehicles, legislators and decision makers, are taking initiatives to include autonomous driving in their legal and policy frameworks. The technology is evolving – geospatial industry is realising their role in the autonomous vehicle domain and is exploring viable opportunities to contribute.

Data, as discussed, is a strategic asset for the autonomous vehicles and therefore the data ecosystem is also reaching a defining maturity. Data from in-car technologies such as vehicle technical sensors, environment sensors, location/navigation platforms, high definition satellite imagery receptors, etc., is the fundamental enabler of self-driving vehicles. The role of geographic data is critical to the proper functioning of the smart car. Not surprisingly, data along with software platforms and infrastructure technologies (cloud, big data, etc.) will transform the entire landscape of future mobility.

ANNEXURE

[A] Participants to the session 'Autonomous Vehicles' (AV) that was held at the Geospatial World Forum Conference in Rotterdam (The Netherlands) on 25 May 2016

Moderated by: Rob van de Velde and Arnoud de Boer, Geonovum

NAME	ORGANIZATION
Denise McKenzie	Open Geospatial Consortium, UK
Kumar Navalur	Digital Globe, USA
Andy Wilson	Ordnance Survey of Great Britain, UK
Sandeep Singhal	Google, India
Chris Gibson	Trimble, USA
Michiel Beck	Ministry of Infrastructure and Environment, The Netherlands
Robert Voute	CGI Nederland, The Netherlands
Marije de Vreeze	Connekt, The Netherlands
Marc De Vries	Geonovum, The Netherlands
Frans Jorna	Hiemstra, The Netherlands
Theo Thewessen	Geodan, The Netherlands
Hans Nobbe	Rijkswaterstaat, The Netherlands
Harald Kraaij	Kadaster, The Netherlands
Hans Nouwens	Smart Data City, The Netherlands
Noud Hooyman	Ministry of Infrastructure and Environment, The Netherlands
Heide, Jene van der	Kadaster, The Netherlands
Rob Bieling	Mapcreator, The Netherlands
Rob Huibers	Andes, The Netherlands
Taner Kodanaz	Digital Globe, USA
Jean Pierre Krause	Msc ETH & MA HSG, Switzerland
Anamika Das	Geospatial Media and Communications, India

(B) Participants to the session 'Autonomous Vehicles' (AV) that was held at the Geospatial World Forum Conference in Hyderabad (India) on 24 January 2017

Moderated by: Rob van de Velde and Marc de Vries, Geonovum

NAME	ORGANIZATION
John Renard	Cyient EMEA, UK
Kumar Navulur	Digital Globe, USA
Sundara Ramalingam Nagalingam	Nvidia, India
Rajendra Tamhane	Genesys International, India
Vijay Kumar	TCS, India
Bengt Kjellson	National Land Survey, Sweden
Ivan Deloatch	Federal Geographic Data Committee, USA
Alessandro Annoni	Joint Research Centre, European Commission
Rob Beck	NEO BV, The Netherlands
Alan Smart	ACIL Allen Consulting, Australia
Andreas Gerster	FARO, Germany
Dan Kruimel	AAM, Australia
Anand Murthy	Symtronics Automation Private Limited, India
Ashok Gupta	National Technical Research Organisation, India
Paomesh Menon	Genesys International, India
Kariappa	SECON, India
Arya Bhattacharya	Mahindra Ecole Centrale, India
Vinod Mishra	MapmyIndia, India
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Louis Nastro	Applanix Corporation (Trimble), Canada
Briad Ysseloyk	Applanix Corporation (Trimble), Canada
Ad Bastiaansen	ILOC Group, The Netherlands
N.D. Gholba	Indian Air Force
Vivek Saxena	Defence Terrain Research Laboratory (DTRL) of Defence Research and Development Organization (DRDO), India
Pankaj Dahiya	National Remote Sensing Centre, India
Robin Jiss	National Technical Research Organization, India
George Lukes	Institute for Defence Analyses (IDA), USA
Akshay Bandiwdekar	Swift Navigation, USA

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ABOUT GEONOVUM

Geonovum is the National Spatial Data Infrastructure (NSDI) executive committee in the Netherlands. The organization devotes itself to making the government perform better with spatial data, by developing and managing spatial data standards. Geonovum is a public organisation, supported by the Ministry of Infrastructure and Environment, the Ministry of Economic Affairs and The Dutch Cadastre and the Geological Survey of the Netherlands.

ABOUT GEOSPATIAL MEDIA AND COMMUNICATIONS

Geospatial Media and Communications, with its vision of Making a Difference through Geospatial Knowledge in World Economy and Society, works to build the geospatial industry in all its facets. It is a catalyst organisation pursuing business objectives towards promotion and facilitation of growth of Geospatial Industry through creating awareness, policy advocacy, business development and by connecting stakeholders and communities worldwide. Since 1997 Geospatial Media has invested its energies and resources in developing geospatial market globally and has provided a leadership role in promoting geospatial tools to several stakeholders with a thrust on prospective industries. Headquartered in India, it has regional offices in USA, UAE, Brazil, South Africa, Malaysia and The Netherlands.

Geospatial Media achieves its objectives by publishing content on geospatial technologies, trends, policies and applications. It also undertakes policy advocacy, business consulting and produces industry reports on market behaviour, requirements, challenges and prospects of geospatial information and applications for society and economy. In addition, it is one of the few professional organisations that organises many national, regional and international conferences on the domain.

ACKNOWLEDGEMENTS

Our appreciations to the efforts put in by the GEONOVUM Team:

Rob van de Velde

Marc de Vries

Arnoud de Boer

Our appreciations to the efforts put in by the Geospatial Media and Communications' Research Team:

Anamika Das

Ananya Narain

for preparing a comprehensive report &

To our Graphic Team for creating visual concepts

Pradeep Singh

Subhash Kumar

Manoj Kumar

