Will Self-Driving Vehicles be a Reality By 2025?

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WHITE PAPER

A WAVE OF EVOLUTION IS CURRENTLY HAPPENING IN THE AUTOMOTIVE, MOBILITY AND TRANSPORTATION INDUSTRIES. THIS EVOLUTION, PERHAPS THE MOST CRUCIAL FOR THE 21ST CENTURY, WILL CHANGE THE WAY PEOPLE TRAVEL AND TRANSFORM THE WAY THEY LIVE. HOWEVER, THE QUESTION IS, WHEN AND HOW WILL THIS CHANGE HAPPEN?

There is a societal change in the way people function at present, as there is a growing need for faster, cheaper, and more convenient modes of transportation due to their changing lifestyle. People need to travel far and wide without wasting much time in transit. The rising fuel costs and maintenance charges for a personal vehicle are leading towards a steady decline in car ownership. Today, more cities are pushing for better public transportation facilities, and the public, especially the younger generation, is opting to use ride-sharing or car-pooling to save costs and increase their convenience of traveling.

Tighter emission targets have led to the highest sales for electric and hybrid vehicles in history. The advancements in sensors and software technology have brought in an age of autonomous and self-driving vehicles. Cities are being connected with high-speed modes of transportation, which will be accessible, enjoyable, and affordable for all. This advancement will affect various industries, technology clusters, and communities, allowing them to find new avenues of growth through the onset of this age of autonomous and self-driving vehicles.

There is a need to develop a plan to successfully usher in this change and prepare for a future with self-driving vehicles. In this report, BIS Research analyzes every aspect of disruptive trends in these emerging technologies in the mobility landscape.

Houdina Radio Control demonstrates a radio-controlled “Driverless” Car

The GM Firebird II is equipped with receivers for detector circuits embedded in roadways

1925 → **1956** → **1958**

The Chrysler Imperial is the first car with cruise control

The VaMP autonomous vehicle drives (almost) completely autonomously for 2,000 km

The Stanford cart uses video processing navigate a cluttered room without human input

1995 ← **1979** ← **1958**

The DARPA Grand Challenge is founded to incentivize autonomous vehicle development

The Google Self-Driving Car project begins

1995 → **2004** → **2009**

Google’s Self-Driving Car has its first accident

Tesla releases its Autopilot software update

2017 ← **2016** ← **2015**

Audi plans to launch its A8 which can be automated for Level 3 features using Audi AI

Waymo self-driving vehicles completed 10,000,000 miles during trials
Waymo became the first company to commercialize a self-driving robo-taxi service called Waymo One

2018 → **2019**

GM plans to include autonomous driving features in Bolt and Cadillac CT6

WHAT IS DRIVING THE TREND FOR SELF-DRIVING CARS?

NEED FOR VEHICLE SAFETY

Road accidents are currently a significant issue around the world. The U.S. accounts for 35,000 deaths every year due to road accidents, while deaths in China due to accidents are anticipated to be around 260,000. The number of fatal accidents in the U.K. and Japan every year is estimated to be approximately 1,700 and 4,000 respectively. As per the U.S. Department of Transportation, some of the primary reasons for the deaths due to these accidents are due to errors made by the driver, such as driving under the influence and drivers not wearing seatbelts. These crash injuries resulted in the U.S. citizens paying an amount of around $18 billion for medical bills and an estimated work loss of $33 billion in the year 2017. Likewise, the Motor Accident Commission South Australia reported drivers' distraction due to cell phone usage contributed 30% of the total fatal crashes and 45% of serious injury accidents every year, in South Australia.

Using autonomous vehicles equipped with features like forwarding collision warnings, autonomous emergency braking, lane departure warning, and blind spot detection, among others can lower down the number of fatal accidents.

GROWING CONGESTION IN URBAN AREAS

Cities are choking up with an increasing population rate every year. By 2030, the urban population of the world will increase by more than 1 billion people. This creates a crunch for resources, jobs, and space in these cities. Traffic congestion is one of the most common phenomena in major cities around the world. Drivers searching for parking spaces are one of the primary reasons for traffic congestions, which results in greater commutation time and more fuel consumption. For instance, according to the U.S. Department of Transportation on an average, a U.S. citizen spends five days in a year being stuck in the traffic. Moreover, the highway congestion problem in the U.S. costs $121 billion every year in wasted time and fuel, i.e., more than $800 per commuter. There are similar road crunch situations in other major cities such as Istanbul, London, Tokyo, New Delhi, and Moscow, among others.

Automated vehicles are equipped with vehicle to vehicle (V2V) connectivity features; therefore, these vehicles can be connected to each other can fully optimize the road network, as these connected vehicles can drive closer to the other vehicles and lower down the chances of the vehicle colliding with the surrounding obstacles, hence vehicles could be made without using heavy protective safety features. This enables manufacturers to make lighter but safer cars. This may increase roadway capacity without affecting safety since automated vehicles can maintain shorter minimum distances between themselves, as compared to human drivers and still be safe, resulting into better traffic flow, reduction in travel time and therefore reducing emission levels.

Moreover, with the advancements in the autonomous vehicles, the number of zero-emission electric vehicles are expected to increase. In addition to this, various other features like self-parking (park pilot) assistance feature enabling the car to drop/pick the users and park itself at designated parking spaces will further ease the flow of traffic.

Therefore, smoother traffic flow and decreased travel time due to the usage of autonomous vehicle is expected to drive the global autonomous vehicle market.

COST OF OWNING A CAR

In 2017, the vehicle sales in the U.S. slumped by 1.8%, with various forecasts suggesting that it will fall further in the next few years. Many in the industry are wondering the ways to tackle the declining sales projections for vehicles. Amidst this, many OEMs have now begun to find new business models by investing in new modes of transportations which will replace the need for owning a vehicle. One factor for this is the increasing external and internal costs of owning a car. In its lifetime, a car is only utilized for 4% of the time, while the rest of the time it is parked or in maintenance. New services such as Mobility-as-a-Service, shared vehicles, and robo-taxis are expected to replace the need to own a car in urban cities.

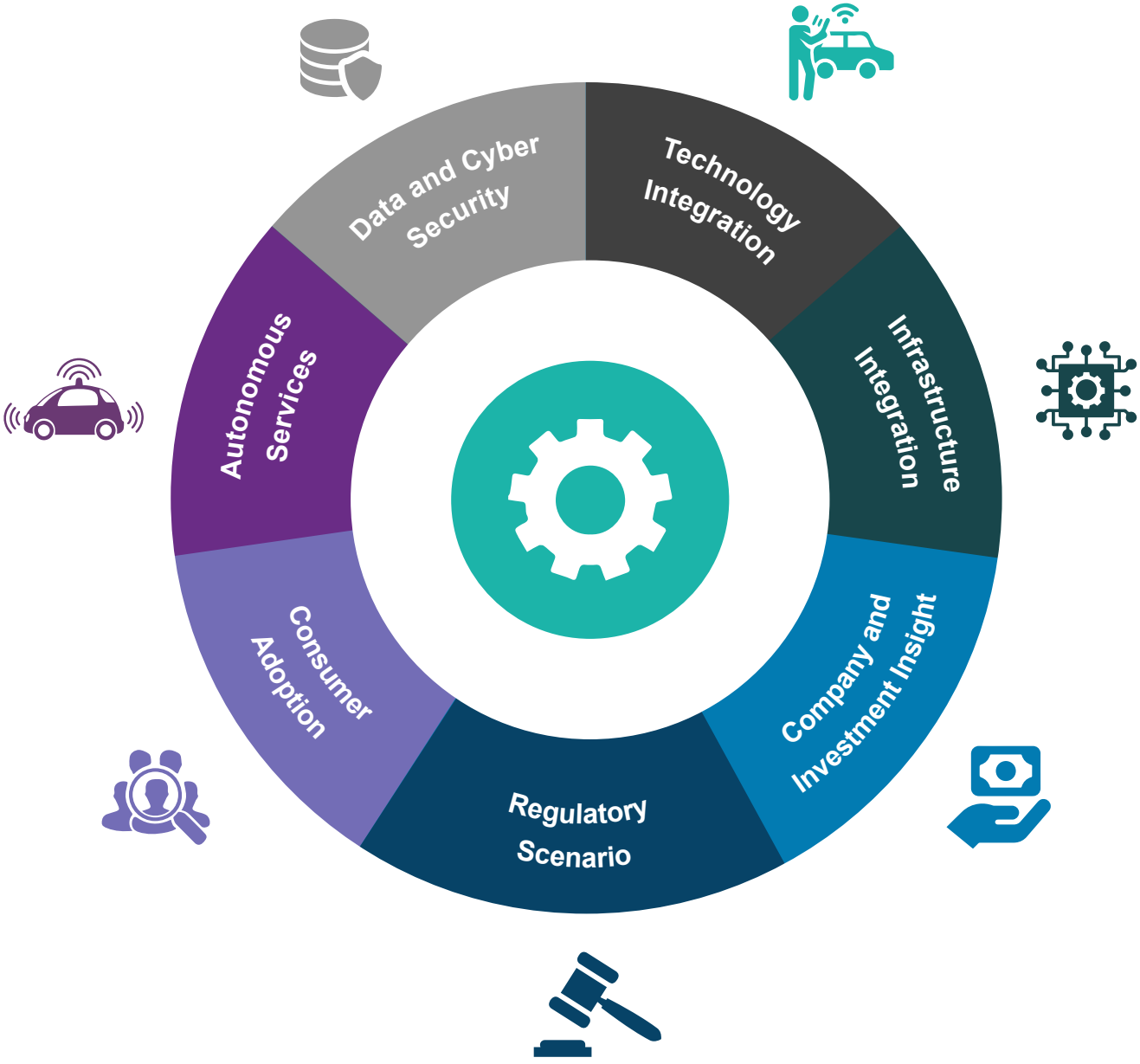
NEED FOR AN ACCESSIBLE AND RELIABLE TRANSPORTATION

Many people in urban areas face a lot of challenges in their daily travels. Hindrances such as missing trains or buses scheduled at fixed timings, and not finding any ride options during huge traffic congestions or odd hours of the day, among others, are common for city-dwellers. There is a need for a more reliable and less stressful mobility solution which autonomous vehicles will be able to fulfill. Also, these vehicles increase the mobility of people who are unable or unwilling to commute on their own such as the disabled or the elderly. Autonomous vehicles can be accessible and cost-effective solution for them.

Figure: Motor Vehicle Cost Distribution (Italics = Non-market)

	Variable	Fixed
Internal (User)	Fuel Short term parking Vehicle maintenance (Part) *User time and stress* *User crash risk*	Vehicle purchase Vehicle registration Insurance payments *Long-term parking facilities* *Vehicle maintenance (part)*
External	Road maintenance Traffics services Insurance disbursements *Congestion delays* *Environmental impacts* *Uncompensated crash risk*	Road construction Subsidized parking Traffic planning Street lighting *Land use impacts* *Social inequity*

WHAT ARE THE MAJOR FACTORS FOR ADOPTION OF AUTONOMOUS VEHICLES?



There are several significant factors that will be important for successfully ushering in and effectively implementing the changes in the ecosystem for autonomous vehicles.

THE PATH TO AUTONOMOUS VEHICLES

TECHNOLOGICAL INTEGRATION

Artificial intelligence (AI) technology is the brain that enables AV capabilities, attracting R&D efforts from many tech companies, from startups to tech giants, as well as automotive OEMs and suppliers. These systems analyze the incoming data on the driving environment and use deep learning to recognize threats and learn to react accordingly. The challenge is that human drivers have highly unpredictable and often irrational judgment while driving and learning to navigate in this chaotic environment requires extensive testing and simulation. Processing power must also improve so that the system can handle the vast amount of data collected and still act in a timely fashion. These components must be integrated into a seamless operating system and continuous testing will determine when the technology is ready for commercial release. The level of investment in AI research and progress from leading players like Nvidia has created an optimistic backdrop for AV developers regarding release timelines, but ultimately, consumers must be convinced to facilitate adoption.

Actuation

This element handles the steering, braking, accelerating, and maneuvering the vehicle

Cloud

This element is transmit data and update the car's system knowledge via IoT and vehicle connectivity systems

Driving Decision

This element acts as the brain of the vehicle, enacting decision making into drive signals for the actuation elements

Mapping

This element is used for vehicle localization and detecting the environment of the vehicle

Hardware & Software Systems

This element consists of the hardware such as system-on-a-chip, and software such as the operating system

Sensors

This element has multiple crucial sensors required for autonomous vehicles such as LiDARs, RADARs, and camera sensors

INFRASTRUCTURE INTEGRATION

Cities need to be ready with adequate infrastructure to support autonomous vehicle. These vehicles will rely on signages and data inputs from its surroundings to control the vehicle without any human intervention, but without proper roads, the vehicle's functionality will be limited. Cities and regulating bodies need to determine gaps in the existing infrastructure and what type of roads would be the most suitable for autonomous vehicles. In the short term, there needs to be repainting of roads and installing RFIDs along the road to help the vehicles to operate. Cities also must solve the challenge of operating mixed stream roads for both autonomous cars and vehicles with drivers. In the long term, there need to be sensors not only in the vehicles but in the surrounding environment too, for the vehicle to process the path better and with more clarity. There will also be a need to restructure roadways, for concepts such as kinetic energy road harvesting, for autonomous vehicles. More optimal data that vehicles gather from the infrastructure will assist in building a more effective transportation model. For example, a vehicle can send a signal to transportation agencies whenever any pothole detected on the road. This will provide information to these agencies about fixing the problem and building better roads.

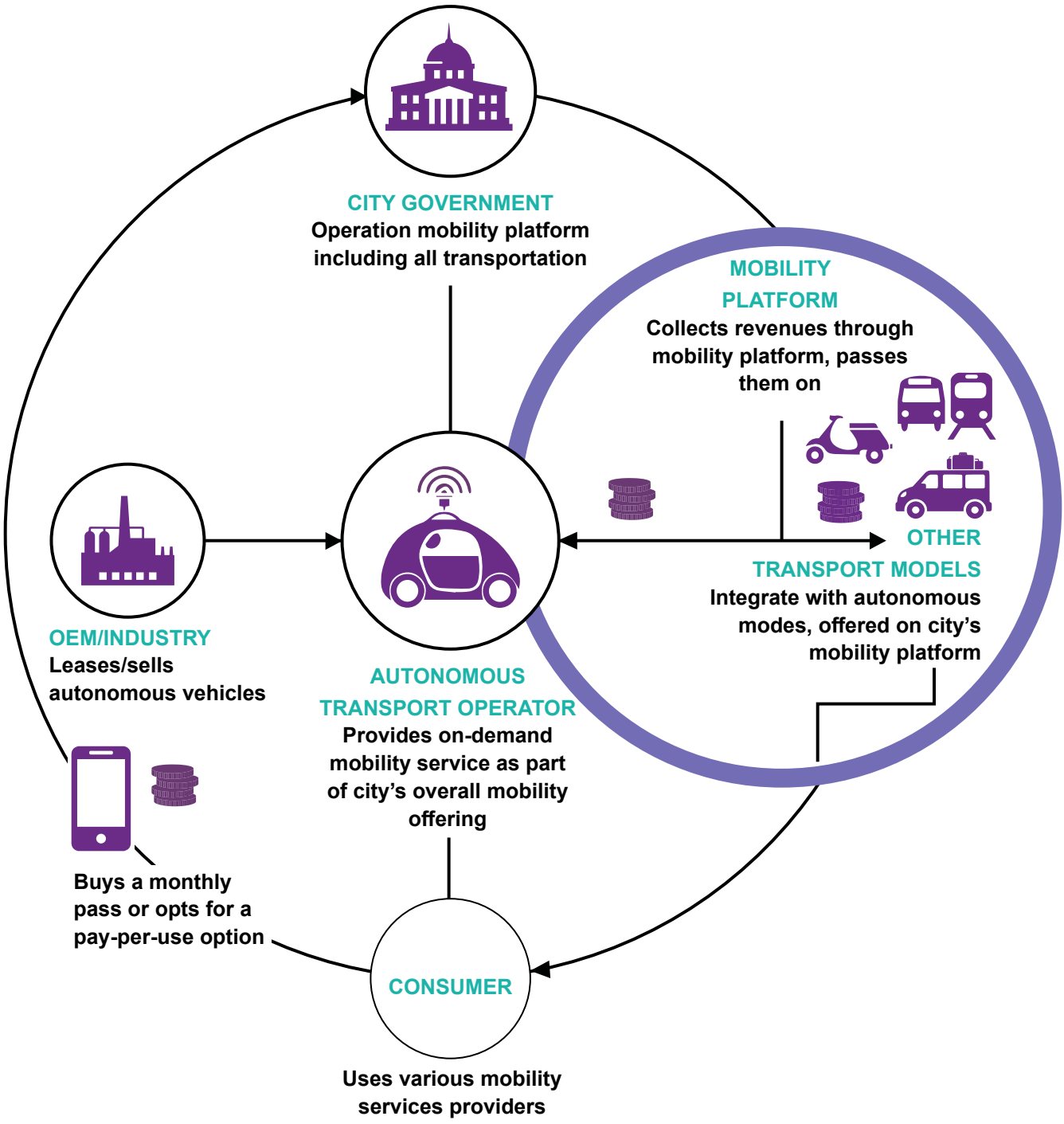
COMPANY AND INVESTMENT INSIGHT

In recent times, the number of investments in the autonomous vehicle vertical has increased manifolds, as disruptive technologies and trends are reshaping the investing scenario. There has been some prominent acquisitions, investments, and partnerships in the autonomous vehicle ecosystem too, for subcomponent suppliers, tech developers, sensors manufacturers, and OEMs. The number of investments and government support for research and development should increase with time, as the autonomous vehicle industry is projected to be a multi-billion-dollar industry in the next few years, and returns will be high for this. Software, connected vehicle, and ancillary services are some of the areas where there needs to be further investment in the future. The amount of investments will create confidence in the industry and in public about the developing tech in this vertical. Also, there need to be government subsidies for its manufacturing and purchasing process, as these vehicles will be helping in decreasing traffic congestion and road accidents, and saving the government billions of dollars in that process.

AUTONOMOUS SERVICES: MaaS AND PRIVATE VEHICLES

People need on-demand and affordable rides, so they can travel without the need to buy and maintain a car. There also needs to be an integration of different modes of travel to ease the travel time and complexity, especially over long distances. Shared vehicles will facilitate the rise of intelligent transportation systems, where people can avail on-demand and affordable rides for their daily travels, without the need to own and maintain a personal vehicle. These concepts are being developed to become a reality, and in this highly disruptive and emerging market, it will be important for all players in the automotive ecosystem to have a track and in-depth knowledge of the market developments, to be able to tap into this multi-billion-dollar industry.

In urban cities, the Mobility-as-a-Service ecosystem will consist of a transport operator, working together with the city government, vehicle providers, and ancillary service providers, among others, to provide the consumers with bundled mobility services, consisting of various forms of transportations and with coordination with public transport systems.



TRADITIONAL MOBILITY SOLUTIONS	TYPE OF USAGE	NEW MOBILITY SOLUTIONS
Personal Cars, Rental Cars, Private Taxi		Peer-to-Peer Car Sharing, Robo-Taxis, Self-Driving Cars
Motorbikes, Cycles		e-Mini Shuttles, e-Scooters, Bikes, Hoverboards
Bus, Metro Train		Autonomous Shuttles, Extensive Subway Systems, Flying Taxis
Minivans, Trucks		Autonomous Electric Trucks, Autonomous Delivery Pods, Drones
Trains, Airplanes		Hyperloop, Bullet Trains, Maglev Trains

CONSUMER ADOPTION

Consumers must have a positive perception of autonomous vehicles for the growth of the industry. Currently, there is a mixed response, with many people being either afraid or reluctant to use self-driving vehicles, or many people who don't find any incentive or cost benefit of using these vehicles. There needs to be a gradual change for the public, from ADAS functionalities to autonomous vehicles. Proper safety records along with time and money saving benefits should be marketed by autonomous vehicle manufacturers and mobility service providers to increase the public perception.

REGULATORY SCENARIO

The fast growth of this autonomous vehicle industry, has made many different players in the ecosystem to increase their capacity building and product development efforts, to capitalize on this surge in the self-driving car market. Observing this change in technology, governments across the world are taking a pro-active approach towards formulating short-, mid- and long-term policies for the inevitable domination of automated and connected vehicles on the road. Many countries currently do not have any specific regulations related to automated vehicles, while in many countries laws and bills are still being researched and discussed upon for the implementation of guidelines about monitoring driverless cars.

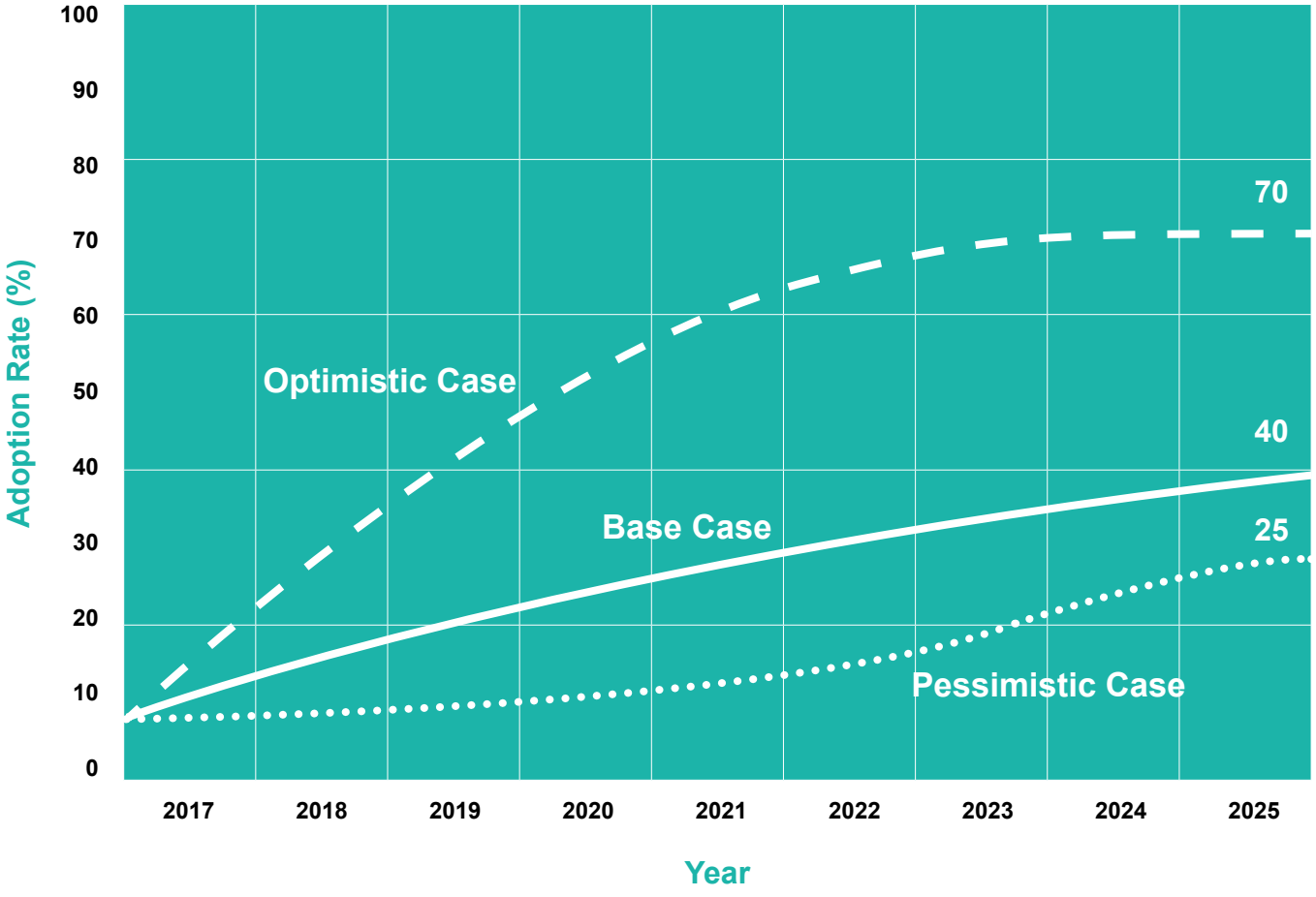
Some of the barriers to formulating any guidelines related to autonomous vehicles have been:

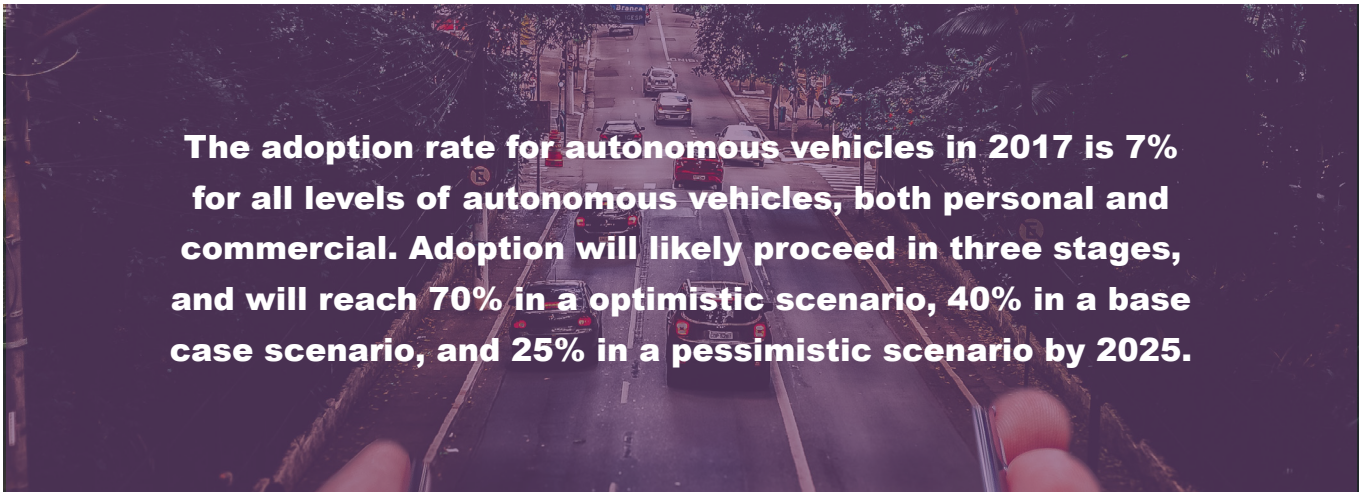
- The ambiguity over terminologies such as "driver", "driving" and "control", among others. These terminologies have different definitions in many countries and changing their meanings often is difficult for jurisdictions and insurance companies, and any change might conflict with other existing road-laws
- There are certain potential liability issues with the introduction of self-driving vehicles. There need to be separate guidelines for civil, criminal and product liability and many countries have not yet found a uniform provision for liability and insurance guidelines related to these automated vehicles
- The developing and emerging technologies related to driverless vehicles makes it difficult for governments to track and make laws related to them instantly, as any change has wide implications in the country's road and vehicle laws

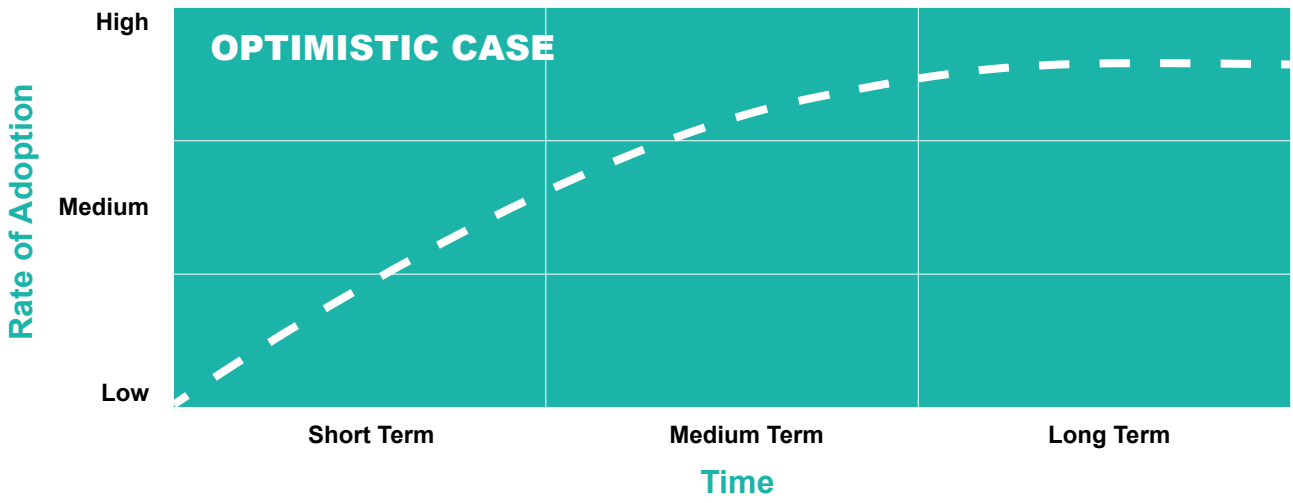
DATA AND CYBER SECURITY

Autonomous vehicles would need immense data transmission and connectivity networks to communicate and operate with various sensors internally and other vehicles and infrastructure externally while driving. There would also be a need to protect these data from cyber-attacks for the vehicle's safety. There is a need to create data security frameworks and guidelines, which can be applied to autonomous vehicles. Companies would need to create ways for a secure path for data connectivity and storage, which can be used by the OEMs and service providers to improve their vehicle systems.

WHAT ARE THE THREE ADOPTION SCENARIOS?







NOTE: Optimistic Case - Compound Annual Growth Rate for autonomous cars for the period 2018-2025 is considered >20%
Rate of adoption of autonomous vehicles is 60%-70%

Short Term (1-2 Years)

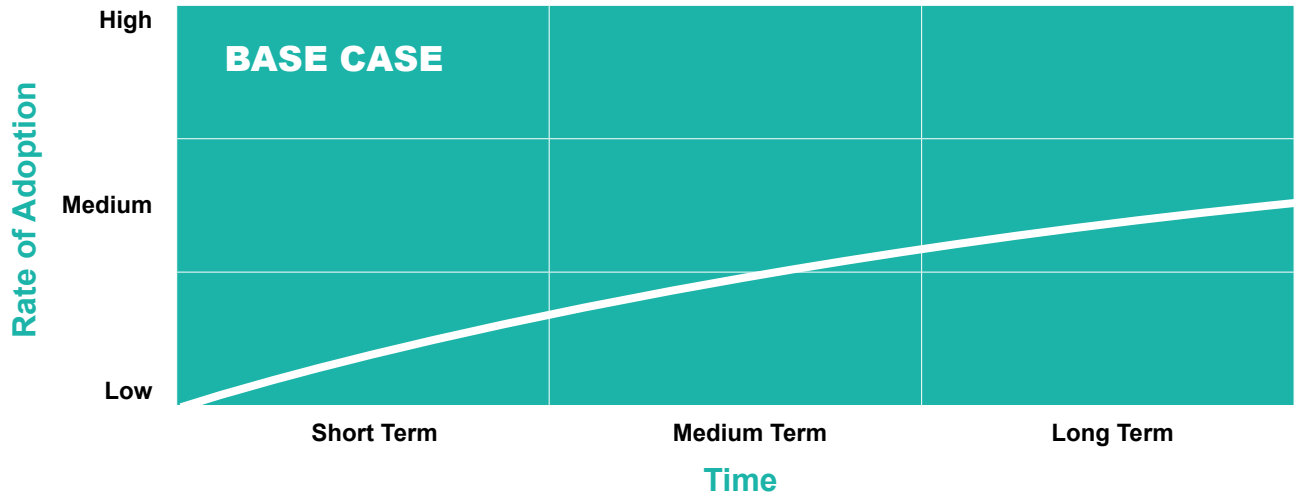
- Initial adoption is quick due to successful early applications and positive public perception
- Rapid technological developments have been able to solve the problems of the traditional mobility model, as various regulatory bodies issue notice for regulatory intent related to autonomous vehicles
- Many new companies are established related to Mobility-as-a-Service, with investments from almost all the traditional vehicle OEMs

Medium Term (3-4 years)

- Adoption rises as aftermarket retrofit for autonomous vehicle components
- There is a seamless transition for most of the cars produced from Level 0 vehicles to autonomous vehicles of Level 3 and onwards
- New business models are created as OEMs diversify their business from being a hardware provider to service providers and integrators

Long Term (5 years +)

- Adoption density of autonomous vehicles increase in urban areas, gradual increase in rural areas
- Extensive network of public multimodel transportation is established in many major and tier 1 cities
- Services related to mobility are diversified, with customers being able to buy bundled offers according to their usage
- Mass usage has rendered autonomous driving as an affordable and widely accessible mode of transportation
- Policies related to autonomous vehicle manufacturing and driving support environment friendly goals
- Urban areas become more favorable to live due to the ease of transportation
- Suitable infrastructure required for autonomous vehicles, and fast charging methods such as kinetic energy road harvesting are being created



NOTE: Base Case: Compound Annual Growth Rate for autonomous cars for the period 2018-2025 is considered between 10%-20%
Rate of adoption of autonomous vehicles is 30%-40%

Short Term (1-2 Years)

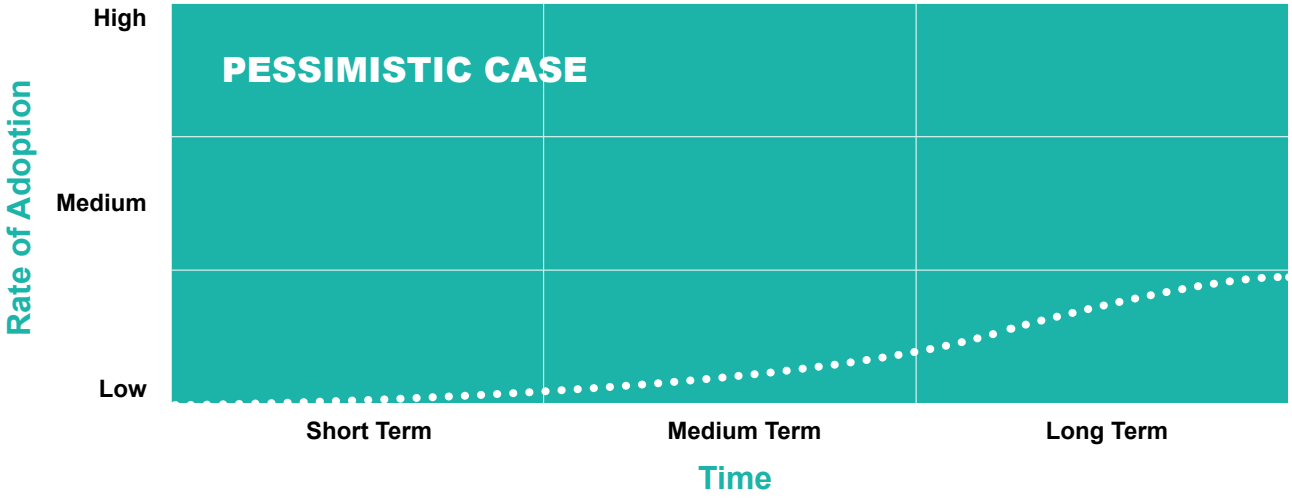
- Initial adoption is at a moderate rate, with some cities showing strong better adoption rates
- The strong difference in public perception for the safety of autonomous vehicles between younger and older generation

Medium Term (3-4 years)

- Tangible benefits and additional services at reduced prices are able to attract people to use autonomous vehicles
- Public transportation to be promoted by governments, consisting of a mixture of traditional and autonomous modes of transport, to ease the needs of the growing population of cities
- Number of companies related to autonomous vehicle development to increase, as more experiment permissions are issued for trials across cities

Long Term (5 years +)

- Private enterprises will start producing aftermarket solutions related to autonomous vehicles
- Regulatory bodies will begin to issue notice for regulatory intent related to autonomous vehicles
- Investments in autonomous vehicle-related business models increases as the adoption rates also increases in cities
- Many urban areas have introduced multimodal modes of transportation, as cost of traveling decreases
- Many of Level 3 and above features become a norm in the latest models of vehicles being manufactured by OEMs
- Companies try to improve adoption rates by focusing on better data management, transportation network, and pricing structures
- Positive public perception brings a gradual adoption of higher autonomous vehicle systems, especially in ride-sharing and robo-taxis



NOTE: Pessimistic Case: Compound Annual Growth Rate for autonomous cars for the period 2018-2025 is considered <10%
Rate of adoption of autonomous vehicles is 15%-25%

Short Term (1-2 Years)

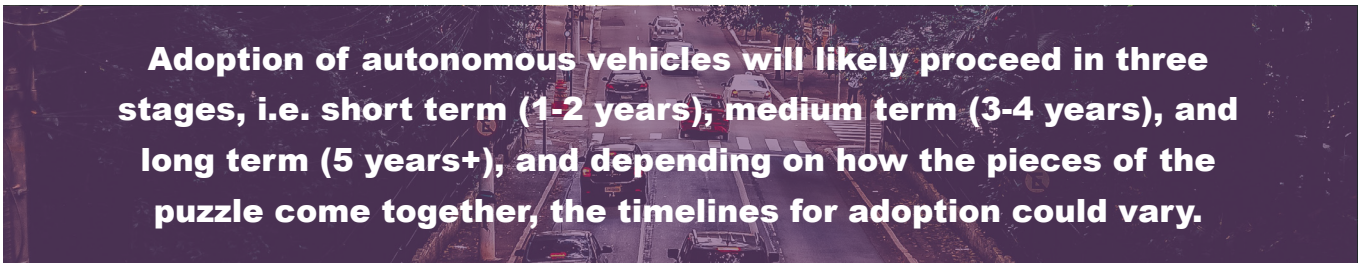
- Initial adoption is slow due to low consumer enthusiasm for early ADAS and autonomous vehicle systems
- Technological progression is slow due to unsuccessful initial trials and low investment in this sector
- High cost of sensors and retrofit technologies deter OEMs from using them in their vehicles

Medium Term (3-4 years)

- Alternative modes of transportation, such as car-sharing and car-pooling, among others are preferred instead of robo-taxis
- Some models of Level 3 autonomous vehicles are introduced in the high-end range with moderate sales, mainly marketed as luxury vehicles
- Governments began work towards improving public transportation and last mile connectivity with conventional modes of transportation
- Some cities allow public trials for robo-taxis and autonomous shuttles in selected locations such as campuses and commercial areas, plying mostly on fixed routes
- Heavy regulations are put on manufacturing and using autonomous vehicles, as public perception is still low for the safety of autonomous vehicles

Long Term (5 years +)

- Adoption level of autonomous vehicles, mainly of Level 2 and 3 improves due to decrease in sensor pricing and advancements in technologies
- Commercial usage of autonomous vehicles such as shuttles, drones, and robo-taxis are seen as more viable than self-driving personal cars



CONCLUSION

THERE IS A FERVENT ZEAL IN ALL STAKEHOLDERS FOR A BETTER TRANSPORTATION SOLUTION. THE WORLD IS EXPECTED TO HAVE 70% OF ITS POPULATION LIVING IN URBAN CITIES BY 2050, IN AN ECOSYSTEM OF INCREASING POLLUTION AND SCARCE ENERGY RESOURCES. THE NUMBER OF ROAD ACCIDENTS DUE TO HUMAN ERROR CAUSED MORE THAN 1.35 MILLION FATALITIES IN 2017, AND WILL ONLY INCREASE WITHOUT ANY CONCRETE SAFETY REGULATIONS FOR VEHICLES. BY 2030, PASSENGER TRAFFIC IS EXPECTED TO INCREASE BY 50% AND FREIGHT VOLUME WILL GROW BY 70%, CREATING MORE CONGESTION IN URBAN CITIES. FOR THIS, THERE IS AN IMMEDIATE RUSH FROM ALL STAKEHOLDERS TO INNOVATE AND WORK TOWARDS MAKING AUTONOMOUS VEHICLES A REALITY SOON.

Many companies have development to bring self-driving vehicles on road by as soon as 2020, while producing numerous prototypes for different applications of self-driving vehicles, opening new divisions specifically for autonomous vehicle development, acquiring or partnering with major subcomponent and technology providers, and investing significantly for research in this vertical. This surge of interest has helped in creating a congregated ecosystem, where many major companies are partnering with each other and functioning in a complex supply chain and "who-supplies-whom" scenario. This would help further improvise these self-driving cars and have an edge for others for the changing dynamic of transportation in the future. The next whitepaper will focus on the new players in the autonomous vehicle ecosystem, and how OEMs and suppliers will be able to win the market.

In the coming decade, by 2025, it is expected that level 3 vehicles to have majority of the market share, with many vehicles, both personal and commercial, to have basic ADAS and autonomous vehicle functionalities. The public would be initially introduced to completely autonomous vehicles through robo-taxis, and not personal self-driving vehicles. Models similar to that of airplane industry may be followed, where after a period, the cost came down and the public acceptance increased. Fully autonomous self-driving vehicles will become a reality for the public if the factors mentioned in this paper are worked upon by both the government and the companies in this ecosystem.

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