Accelerating the Race to Autonomous Cars – A Case Study

Divya Kumari [1] & Subrahmanya Bhat [2]
[1]Research Scholar, College of Computer Science and Information Science, Srinivas University, Mangalore, India
Orcid ID: 0000-0003-4367-0891; Email: divyakumari.ccis@srinivasuniversity.edu.in
[2]College of Computer Science and Information Science, Srinivas University, Mangalore, India
Orcid ID: 0000-0003-2925-1834; Email: sbhat.ccis@srinivasuniversity.edu.in

Subject Area: Computer Science.
Type of the Paper: Review based Research Agenda.
Type of Review: Peer Reviewed as per |C|O|P|E| guidance.
Indexed In: OpenAIRE.
DOI: https://doi.org/10.5281/zenodo.5791958
Google Scholar Citation: IJAEML

How to Cite this Paper:
Divya Kumari & Subrahmanya Bhat, (2021). Accelerating the Race to Autonomous Cars – A Case Study. *International Journal of Applied Engineering and Management Letters (IJAEML)*, *5*(2), 219-231. DOI: https://doi.org/10.5281/zenodo.5791958

International Journal of Applied Engineering and Management Letters (IJAEML)
A Refereed International Journal of Srinivas University, India.

Crossref DOI : https://doi.org/10.47992/IJAEML.2581.7000.0114

Accelerating the Race to Autonomous Cars – A Case Study

Divya Kumari [1], & Subrahmanya Bhat [2]
[1]Research Scholar, College of Computer Science and Information Science, Srinivas University, Mangalore, India
Orcid ID: 0000-0003-4367-0891; Email: divyakumari.ccis@srinivasuniversity.edu.in
[2]College of Computer Science and Information Science, Srinivas University, Mangalore, India
Orcid ID: 0000-0003-2925-1834; Email: sbhat.ccis@srinivasuniversity.edu.in

ABSTRACT

Background/Purpose: *Every automaker is racing to generate self-driving innovations and some slew of fantastic tech firms and start-ups doing the same. The vehicle industry has a long history of implementing cutting-edge technologies to bring efficient, creative, and reliable vehicles to market, all while working to reduce production costs. Such innovations involve machine learning and computational intelligence, which are essential to automobiles progress. Machine learning (AI) technologies have made the innovative concept of self-driving vehicles an actuality. Today, global automotive rulers such as BMW, Volvo, and Tesla use intelligent automation to enhance production, raise production efficiency, and actually drive secure, extra relaxed, expanding, and increasingly enjoyable. This article provides a comprehensive analysis of Companies in the development of Autonomous vehicles and used ABCD analysis to examine the key parameters.*
Objective: *Analyses the technology and business strategies of the companies in the Race of Autonomous cars.*
Design/Methodology/Approach: *The information for this case study were gathered from various scholarly articles and websites.*
Findings/Result: *The technological details of Artificial Intelligence, Self-driving car companies, laws and restrictions of different companies for using Self-driving vehicles, Autopilot driving features, sales volume and financial expansion, Impact of COIVID-19 on Autonomous vehicles business are studied. The impacts of COVID-19 on the autonomous car business are analysed using the ABCD framework.*
Originality/Value: *The result provides a brief overview of different self-driving vehicle companies and self-driving technology building companies in the competitive race.*
Paper type: *A Research Case study paper - focuses on companies in a race of producing Autonomous vehicles and the growth of those companies*.
Keywords: Artificial Intelligence in autonomous car, Machine Learning, Autopilot, Autonomous Vehicles, Self-driving, driverless cars, Deep Learning, ABCD Analysis.

1. INTRODUCTION :

Deep Learning, Neural Networks, Big Data, Data Mining – every one of these innovations that are partly advanced in the internet finance and business worlds get a lot to offer production throughout overall, and the vehicle industry at large. Machine learning is among the latest key factors in the automotive sector, from facilitating driverless cars to converting study, architecture, and production technology. Machine learning is being used in almost every aspect of the car manufacturing process around the world. ML is shown performing miracles by robotic arms constructing the initial nuts and bolts of a motor or by self-driving vehicles that use artificial intelligence and vision to safely navigate traffic. Machine learning is among the latest best strategies in the automobile sector, from facilitating driverless cars to reshaping study, layout, and production technology [1].

2. RELATED RESEARCH WORK :

The following table shows the Related Research work in the area of Economic Impact, Public Awareness, and Pedestrians Awareness, Employee's Review, Customer Review, Deep Learning Techniques implementation and Impact of COVID-19 in the Automobile Industries.

Table 1: Research Related Work

SI. No	Area of Study	Focus	Reference
1	Economic Impact	Study on Economic Impact of Autonomous Vehicles in a country	Alonso, E. et al. (2020) [2]
2	Exploratory Study	Transporting Children in autonomous vehicles	Tremoulet, P. D. et al. (2020) [3]]
3.	Public Awareness	Implications of autonomous vehicles	Pettigrew, S. et.al (2018) [4]
4	Pedestrians Awareness	Study Urban Traffic and Autonomous Vehicles	Millard-Ball, A. et al. (2018) [5]
5	Pedestrians Awareness	Survey of theory and practice	Rasouli, A. et al. (2019) [6]
6	Deep Learning techniques	Deep Reinforcement learning study	Lim, S. H. Sallab, A. E. et al. (2017) [7]
7	Reinforcement Learning	Deep learning techniques used in Autonomous Vehicles	Marina, L. et al. (2019). [8]
8	Employment Impact	Impact on Labour demand	Pettigrew, S. et al (2018) [9]
9	Customer Impact	Impact on the solution quality with increasing Customer demand	Hegner, S. M et al. (2019) [10]
10	Pandemic Impact	Study of stock markets of companies in pandemic	Liu, T. et al. (2021) [11]

3. OBJECTIVES OF STUDY :

(1) Understanding Artificial Intelligence and its subfields.
(2) Analyse the overview of self-driving car companies.
(3) Identifying the Companies in the race of Self-driving vehicles.
(4) To analyse self- driving vehicles sales volume and financial expansion.
(5) To know about the impact of Covid-19 to the Automobile industry using ABCD analysing framework.

4. UNDERSTANDING ARTIFICIAL INTELLIGENCE AND ITS SUBFIELDS :

Theorizing and developing information systems capable of conducting which often require human intelligence, such as visual perception, speech recognition, decision making, and language translation.AI is a technique for making machines work and behave like humans. Its subfields include Machine Learning, Deep Learning, Computer Vision, and Natural Language Processing [12].

Machine learning (ML) is a branch of Artificial Intelligence that teaches a device how to learn.AI and ML are closely related. These techniques are the most popular when it comes to developing intelligent machines.AI is a broader term that refers to the creation of machine intelligence which can imitate human brainpower and actions, Machine learning is a subset of AI that allows algorithms to gain knowledge from data besides being explicitly programmed.

A neural network is a type of deep learning that is influenced with how the nervous system functions. It is a computer system made up of interconnected units (such as neurons) that transmit data besides reacting components and sending data between themselves. Multiple passes through the data are investigated to obtain connections and draw conclusions from undefined data.

Deep learning employs huge neural deep networks of processing units, taking advantage of emerging computational technology and enhanced learning methods to learn complex patterns in large data sets. Voice and image recognition are two examples of common applications. Computer vision uses pattern

recognition and deep learning to recognise what is in a photograph or video. Machines that will perform, evaluate, and grasp images can collect and comprehend visual data in real time.

Natural language processing is the ability of machines to evaluate, perceive, and create natural speech, such as voice. The next stage of NLP is natural language conversation, which allows individuals to interact with computer systems by using normal speech to complete tasks. Machine learning is based on the idea that computers will be responsive through perception, whereas AI refers to a broader concept in which computers can perform tasks "smartly."

5. COMPANIES IN THE RACE OF SELF-DRIVING VEHILES :

Despite the fact that the concept dates back to the sixth century ad, when Leonardo Da Vinci planned a self-propelled trolley, it was not implemented until the twentieth century [13]. When Google announced in 2009 that it would begin researching self-driving cars, the concept gained a lot of attraction. In 2015, Tesla began monetizing 'Autopilot' functionality in its vehicles, and the race to be the leading driverless car company began. The race, however, was not limited to automobile manufacturers; technology and telecommunications firms also competed. Many large corporations are currently engaged in semi-autonomous and fully autonomous vehicle product development. Recent growth of people and enterprises in this domain will undoubtedly propel this business to the next level in the coming years. More than 250 driverless car industries are working hard to make self-driving or fully autonomous cars in actuality, along with car manufacturers, technology companies, network operators, and digital start-ups. Such an industry analysis divides automobiles into following four sections: car manufacturers and vehicle suppliers, tech firms, network operators, and innovation start-ups.

Automobile Manufacturers Working on Self-Driving Vehicles

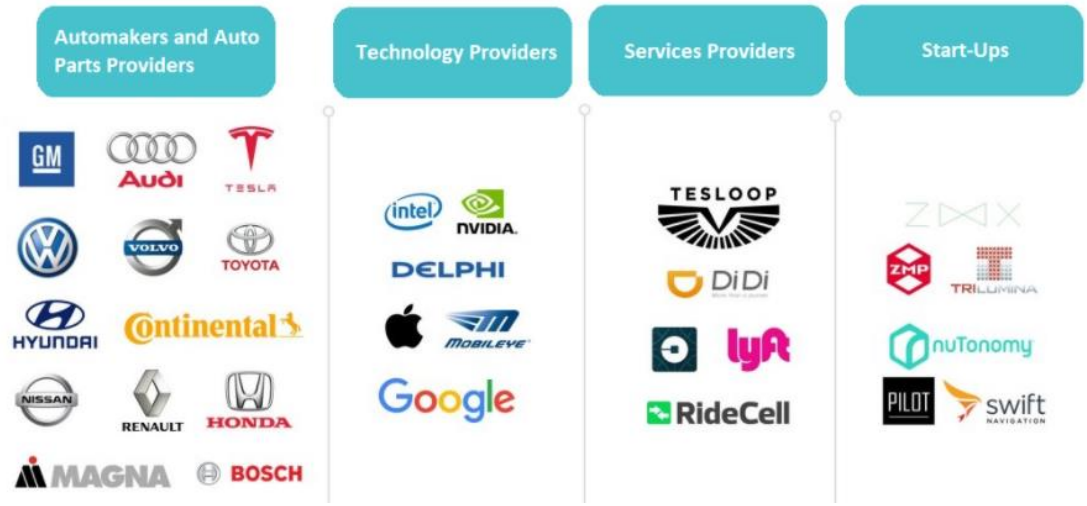

Fig. 1: Categories of Autonomous car Manufacturers working on Self-Driving Vehicles [13]

Ford: Ford is one of the most assertive self-driving industries, striving to release an extremely autopilot system as quickly as possible. It plans to introduce a completely self-vehicle by 2021. It has also taken multiple business strategy steps in this regard. Unlike other competing brands, which gradually increase autonomy from Level 2 to Level 3 to Level 4, Ford intends to skip several stages and go straight to Level 4. As per experts, the most important factor in this decision is the cost.

General Motors: General Motors is another company vying to be the first to initiate highly driverless systems, ahead of its competitors. It has the most combative test plans for driverless cars of any player. General Motors aims to test large numbers of self-driving electric Sports Car vehicles in 2018 through its ride-hailing subsidiary Lyft Inc. The only automaker has such combative testing plans ahead of 2020.

Audi: Audi announced in January 2017 that it plans to launch a completely autonomous car in 2019-2020, as well as a level 3 car by the end of 2017. The firm announced that it will use NVIDIA's technology in its driverless vehicles. Audi, which is owned by Volkswagen, launched a separate branch focused on driverless cars in 2017. This production order is known as Independent Artificial intelligence - based Car, and it serves the entire Volkswagen Group.

Renault-Nissan: Beginning in 2013, Nissan was one of the first companies to launch projects in the segment. It debuted its first general public working model in 2013 at the Nissan 360 event throughout California, and it has stated it will release a self-driving vehicle by 2020. Till now, it has been checking a self-driving Nissan LEAF on the streets of Tokyo and Detroit.

Tesla: Elon Musk, Tesla's CEO, stated in April 2017 that Tesla would be able to launch a Level 5 vehicle within the next two years, subject to design and development as well as governmental upgrades. This is the most aggressive timeframe offered by an automaker. Elon Musk as well stated that by the end of 2017, Tesla would have a vehicle capable of driving itself from Los Angeles to New York City without the assistance of a user [14].

BMW: BMW announced in April 2017 that it plans to launch Level 5 self-driving vehicles by 2021. BMW's primary aim is to acquire a market position in the interior by introducing a level 5 autonomous vehicle, whereas most industry competitors were also aiming for level 4 vehicles.

Technology Companies Developing Self-driving Vehicles

Apple: In 2016, Apple admitted that it is working on Autonomous cars. It announced plans to invest in deep learning and intelligent systems. This project, identified internally as Task Titan, began in 2014. The company has been less outspoken as to its self-driving car developments [15].

Microsoft: Microsoft's framework consists of self - driving technology is distinctive. It intends to work with automakers to put its self-driving technologies into action. Including the firm's top leadership, which has no measures to build on its self-driving car. The Azure cloud platform, Office 365, and the Windows operating system are examples of popular Microsoft strategies to be used in such vehicles. Ford, Kia, BMW, Nissan, and Fiat are among the businesses that use its application.

Intel-Mobileye: Intel has been eagerly entering the industry, getting whipped to the hit by businesses such as NXP and Nvidia in the production of auto parts silicon and fully independent computing power.

Waymo (Google): Waymo is the strong candidate for inclusion on the ranking self-driving industries. Since 2009, the group is working on self-driving car innovations. At first, the initiative was known as the Google autonomous car project. Waymo was established as a corporation of Google's holding company, Alphabet, in December 2016. Waymo's self-driving innovations have been put via long distances of testing in US cities. In 2016, Waymo cars drove 1 billion virtual kms. Even so, Waymo's attempts stopped on a constant schedule due to the defection of design consultants and rulers, along with part owner Chris Urmson.

NVIDIA: Nvidia is the major chipmakers in the self-driving cars. Numerous car manufacturers have stated that they will use Nvidia devices in their autonomous cars. They are Audi, Mercedes-Benz, Toyota, and Tesla.

Samsung: The South Korean Department of Land, Infrastructural facilities, Travel gave Samsung permission to verify driverless cars on Korean motorways since May 2017. Hyundai automobiles outfitted with sensors and cameras act as a foundation for Samsung's self-driving vehicles. Apple is Samsung's main opponent in the autonomous vehicle market.

Zoox (Amazon): Zoox is a collaborative group involved to assume as well as construct provides more detailed knowledge which will assist the potential demands of local transport between individuals and communities. This has several factors that distinguish apart from rivals like Waymo, Cruise, and others. That is competent of two ways steering as well as 4 steering, enabling this to switch direction without having to roll back or traverse in narrow areas. Moreover, each of its four seats is fully equipped with an airbag sensor.

Aurora (Uber): Aurora is a driverless car venture, and after gaining Uber's self-driving component, the company's current role was strengthened since it obtained the knowledge of the top driverless competitors. One of Aurora's features is its hardware or software, which can be modified to introduce non-autonomous automobiles and turn them fully autonomous vehicles. Apart from Zoox, Aurora does not intend to build a self-driving vehicle from the ground up. Its design and manufacturing combination can also be used to provide mobility and logistics services.

Rulers in Self-Driving Automobiles

Annually, Navigant Research submits a driverless car leaderboard.

Fig. 2: The Navigant Research Leaderboard Grid [16]

6. LAWS AND RESTRICTIONS :

USA: The government has specifically requested that driverless auto makers communicate a massive volume of information with the national govt. The administration also has mentioned it will approach security assessments such as when the vehicle's software will identify on the street during traffic incidents and socially responsible circumstances, and other simple facts like how such vehicles operate, how they track facts, what takes place if a crash occurs, what safety precautions will be in place against hacker attacks, and etc. Self-driving and semi-autonomous cars have positioned itself in the market, convincing the national government to enact legislation governing driverless cars. Tesla, for example, has managed to sell approximately 1 million hybrid cars equipped with a self-driving feature known as autopilot. Uber began testing self-driving car rides via their mobile application. Google and Apple, two of the world's largest technology companies, have been testing self-driving cars [16].

Europe: Given the benefits predicted, the legislation in Europe is shifting forward into the need for driverless cars. The most minimum element for driverless cars is a legal permit to use public roads. Any vehicle sold in an EU member country must have EC authorization.

Asia: Asia is among the most promising test platform for self-driving cars. Singapore and other established Asian nations are assisting such projects by found suitable, economic, and managerial assistance to replace by automation automotive shareholders. The administration has labelled driverless vehicles into 5 groups, including self-driving vehicles which do not demand a motorist or a wheel and help with several functions, like braking power, throughout automated cars. Car makers and the govt. are collaborating to develop a place for self-driving cars that would minimize car crashes mistakes or improve traffic flow.

7. DRIVER ASSISTANCE TECHNOLOGIES OF SELF-DRIVING VEHICLES :

The Society of Automotive Engineers (SAE) International and the National Highway Traffic Safety Administration acknowledge six levels of automated driving capacity in automobiles: Level 0 means zero autonomy; Level 1 means assistance support; Level 2 means Limited Driving Automation; Level 3 means Automation of Conditional Assistance; Level 4 means high automation; and Level 5 means full automation [17].

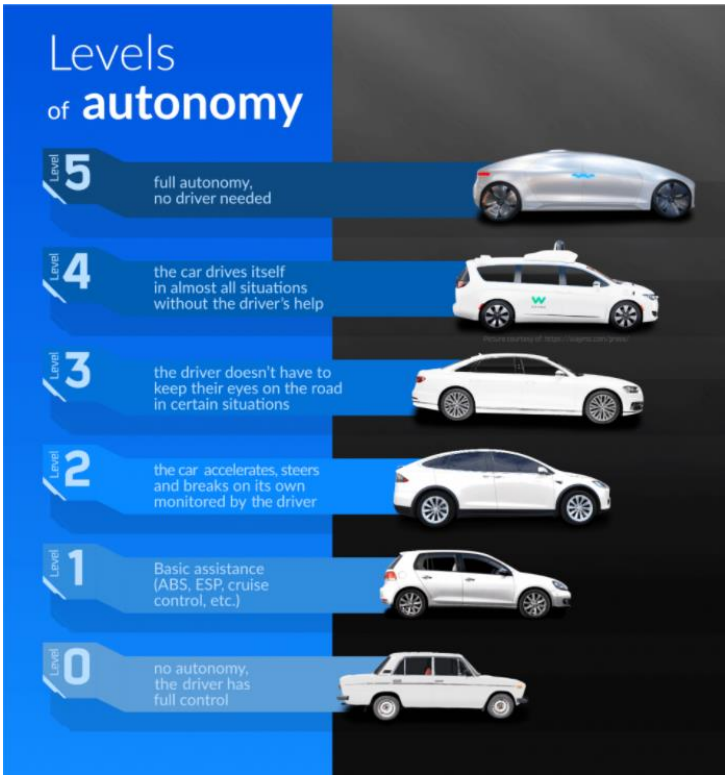

Fig. 3: Levels of Autonomy [17]

LEVEL 0: Zero Driving Automation

There is no automation here. The driver is in complete power of all road conditions and receives no help and support [18].

LEVEL 1: Driver Support

It is the most basic support. The driver is in complete power, but a solitary advanced driver assistance system (ADAS) provides some assistance with issues like speed, power steering, and low speeds. However, only one job can be done at a time.

LEVEL 2: Limited Driving Automation

The operator remains totally in charge and driving safely, but "assistance" seems to be more streamlined. The ADAS has coupled advance features, which implies could even possibly regulate both wheel and vehicle speed at the same time.

LEVEL 3: Automation of Conditional Assistance

Under certain conditions, the vehicle can operate on its own. Although processes such as navigation, decelerating, and speed control are automated, the operator must be willing to react at any time.

LEVEL 4: Top Levels of Driving Mechanization

At this level, the operator will undertake most tasks and respond when anything problem occurs. This is suitable for travelling through one place to another as well as returning.

LEVEL 5: Full automation

With completely automated driverless cars, users can essentially relax while the car accomplishes the required task in all conditions.

8. ALGORITHMS USED IN AUTONOMOUS VEHICLES :

Most impressive advancement of Artificial Intelligence is driverless vehicles. Machine Learning, in conjunction with several disruptive technologies such as IoT, is assisting in the upgrading of the capabilities of Autonomous cars. Machine Learning is an important element of a driverless vehicle's centralised electronic control unit (ECU), and steps are being taken to incorporate ML farther in self-driving vehicles in order to form them into cutting-edge designs. One of several main purposes of Machine learning algorithms in a driverless vehicle is regular review of the surroundings and prediction of possible changes to that environment [19].

ML algorithm performs the following 4 subtasks:

- Object detection
- Object identification/recognition

- Object localization
- Movement prediction

Global positioning system, radar, lidar, sonar, odometry, and gravitational measurement units are common sensors found in self-driving cars. They also have intelligent control devices which can perceive sensory data to determine barriers and determine appropriate routing paths.

The ML-based solutions which control a self - driving vehicle's operating system obtain data from connected ensemble learning devices to make estimates based on it. Such algorithms can also incorporate the driver's motion capture, voice recognition, and translation software into the vehicle's system.

ML algorithm types:

Supervised Learning: Algorithms are trained under supervision in the supervised learning approach. As a result, the selected information result can be fed into an algorithm, which identifies the type of results desired. The algorithm is fed both input and output data. The algorithm then starts creating norms which map the input to the output. The goal here is to train an algorithm to allocate or forecast output objects that it has not communicated with during the training phase [20].

Unsupervised Learning: Unsupervised learning feeds and trains algorithms solely on unlabelled data. Unsupervised learning is used to explore the inner structure of data and derive valuable insights from it. The above method attempts to discover such information and insight which can lead to improved outputs by sensing underlying patterns in unlabelled data.

Reinforcement Learning: Reinforcement learning aims to create self-sustaining and self-learning algorithms that can help in improving itself and by a constant loop of try and error based on the integration and interrelations of class labels and incoming data.

Autonomous vehicle ML algorithms are broadly classified into four types:

Regression Algorithms:

Regression algorithms are explicitly used to forecast events. Regression algorithms use repeated elements of a surroundings to develop a statistical study of the relationship among a specific image and the place of a particular object inside the image.

Pattern Recognition Algorithms (Classification):

Such algorithms aid in sorting sensor information by detecting object corners and fitting line segments and arcs to the corners. Line segments and circular arcs are coupled in a variety of ways by pattern matching algorithms to form the final characteristics for identifying an object [21].

Cluster Algorithms:

To find framework in data sets, cluster algorithms are used. If the images obtained are unclear due to their low resolution. Clustering techniques concentrate on utilizing the inbuilt patterns from data to finest structure the items into clusters with the most similarity.

Decision Matrix Algorithms:

Decision matrix algorithms are made up of various decision models that have been learned autonomously and whose forecasts are coupled to create the total forecasting while decreasing the probability of failures. The self-driving vehicle's moves are decided by such algorithms. As such, if the vehicle wants to turn rightwards, if it needs to decelerate or speed up, the exactness of such algorithms regarding classification, recognition, and prediction of the objects' next movement helps determine the response to certain queries.

9. SELF- DRIVING VEHICLES SALES VOLUME AND FINANCIAL EXPANSION :

According to Lux Studies, the Autonomous car economy is possibly worth $87 billion by 2030. Even in 2030, level 2 cars are expected to account for 92% of revenue, with level 3 automobiles reporting for the remaining. No Level 4 or Level 5 vehicles should be functional by 2030, as per their study. As per Allied Market Research, the industry is poised to increase at a CAGR of 39.47 percent from $54.23 billion in 2019 to $556.67 billion in 2026. Also, it predicts Europe to have the highest CAGR of 42.6 percent between 2019 and 2026 [22].

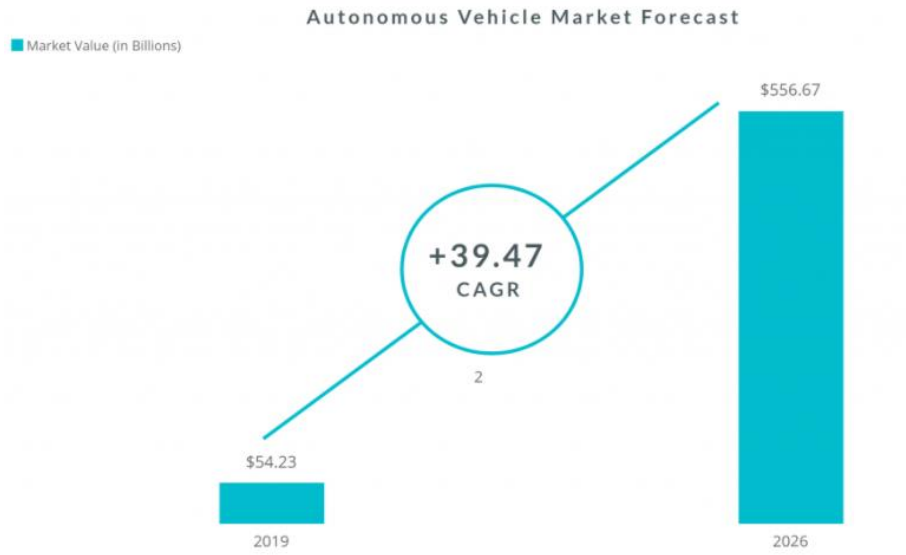

Fig. 4: Autonomous Vehicles Market Forecast [22]

Driverless cars are expected to account for 25% of overall auto sales in 2035, with 15% being partly independent and 10% being self-driving [6].

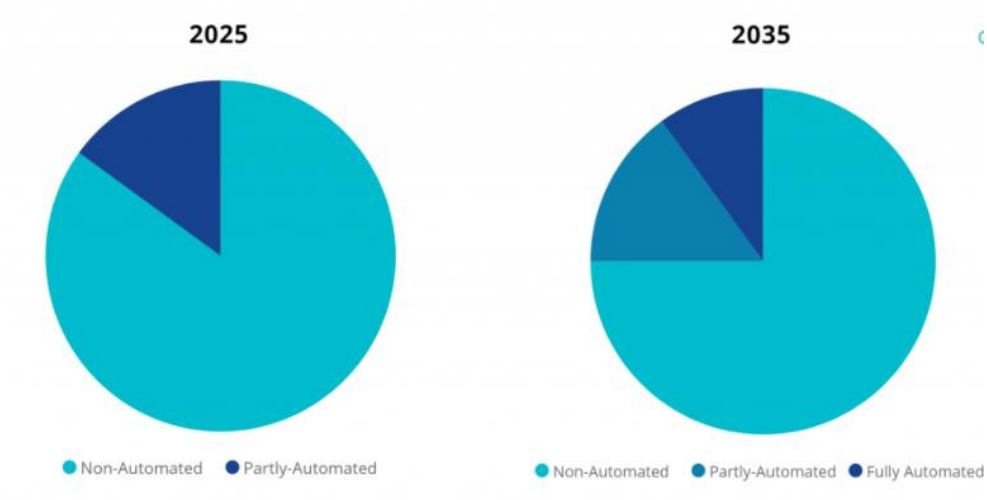

Fig. 5: Self-driving Vehicles Sold as a Percentage of the Overall Economy (2025 vs. 2035) [22]

10. SELF -DRIVING CARS IN CHANGING THE ECONOMY :

Autonomous vehicles have the potential to conquer the motor industry in the near future. When Self - driving cars are adequately efficient and cheap, they will enter industries, causing economic spill over effects across businesses [23]. Transportation exchange may decrease the number of cars and trucks acquired every year, but increasing transit times could raise auto sales. The ability for heavily loaded motorists doing other tasks or relax during road trips could decrease cargo expenses and higher potential. Private public transport could transition to common driverless car ships use, lowering the use of cabs, public transport, and other types of travellers. Lesser accidents and further legislation cars would then lead to lower sales for car maintenance, traffic cops, healthcare, health coverage, and legal assistance. Self - driving cars also will lead to future strategies for reducing tourism as well as the reusing of trash and recycling and off-street car parks, and also good returns from efficiency gains during hands-free journeys and diminished death and misery expenses from accidents. As per the scientist Mr. Morgan Stanley (MS), as per his studies on self-driving vehicles, those who would save

market $488 billion in value obtained by reducing the number of accidents and $158 billion by lowering fuel usage.

11. JOBS CREATED BY SELF-DRIVING CARS AS TECHNOLOGY ADVANCES :

Just a years back, self-driving cars seemed a sci-fi dream, but they are rapidly being an actuality as car manufacturers, cruise assistance, and tech firms compete to create a secure and easy driverless car[26].As per a latest survey by Boston Consulting Group (BCG) and Detroit Mobility Lab, the growth in Autonomous cars will generate about 1 million United States transport jobs in the next ten years, such as the profession of professionals with computer science related graduates and Machine learning expertise [24].

12. IMPACT OF COVID-19 ON AUTONOMOUS VEHICLES USING ABCD ANALYSIS FRAMEWORK :

The pandemic had a negative impact on not only self-driving cars, but also on the auto parts and cruise industries. Pilot study was also halted for over than six months [26-27]. During the disease outbreak, as families lived inside all day, cab companies experienced a significant decrease. Even though individuals are able to venture outdoors, the majority of them preferred to travel by private transportation. The ABCD approach is used to explore the key parameters as well as the potency of the business cases that are to be executed in societal structure [28]. The process and its attributes are studied from customers point of view and significant issues are discussed using four constructs : Advantages, Benefits, Constraints, and Disadvantages.

12.1 Advantages:

i. AV innovation offers great ability to significantly change how shipments are transported from storeroom to retail shop
ii. Dishes are served from food places and our front doors, and parcels are supplied from retail outlets to our inboxes.
iii. Pandemic has had an effect on the functioning of many OEMs, from manufacturing to R&D. Since market players could experience small period disturbance in AV growth and slide, a certain instability could open new possibilities for AV innovation adoption inside segmentations and speed up implementation in different manufacturing sections, as AV innovation is seen as a vital part of replying in case of calamities and ambiguity.

12.2 Benefits:

i. While COVID-19 may have slowed the advancement of AV innovation, it has also raised the possibility of its use in many areas.
ii. The Epidemic highlighted the uncertainty of the production process and substantiated the growth of international production methods.
iii. Traditionally, the auto sector had also created a fairly close distribution network focused on the area in which the business is located.
iv. It is indisputable that today's modern car production foundations were converted into "metanational" businesses which safeguard worldwide supremacy besides creating international operations as well as utilising managerial skills gathered in nations [24], that has ultimately been a drawback to global epidemic response.

12.3 Constraints:

i. Pandemic have even halted the growth of AV innovation and delayed buying intention of modern cars, but has expanded the possibility for this innovation to be used in other areas.
ii. COVID-19 have also decelerated the growth of AV technology and halted purchase behaviour of cars, it has also increased the potential for this technology to be used in other areas.

12.4 Disadvantages:

i. Since Autonomous car manufacturing companies spending more on Research and development cost of the Vehicles also high. Only selected group of people can afford autonomous Vehicles.
ii. In pandemic since airways and waterways are closed this slowdown, the import and export of vehicles.

13. CONCLUSION :

Industries must meet the goal in way to sustain shareholders hopeful. As even large corporations including Amazon and Google cannot spend hundreds of billions annually. Participants would require significantly

external resources to keep the research going. Whatever future holds for the AV sector, it's indeed clear that driverless shipment makes better sense in some sectors, like logistics and groceries & food stores delivery, due to the post globe. There was a high demand between all automotive companies in generating key aspects in their domestic markets in the period leading up to COVID-19. The escalation of import tariffs via appropriate economic exchange controls framed a direct and tangible risk to large corporate carmakers which had to be addressed.

REFERENCES:

[1] Shapiro, D. (2016). Accelerating the race to autonomous cars. In *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, *1*(1), 415-415.
Google Scholar ↗

[2] Alonso, E., Arpón, C., González, M., Fernández, R. Á., & Nieto, M. (2020). Economic impact of autonomous vehicles in Spain. *European transport research review*, *12*(1), 1-17.
Google Scholar ↗

[3] Tremoulet, P. D., Seacrist, T., Ward McIntosh, C., Loeb, H., DiPietro, A., & Tushak, S. (2020). Transporting children in autonomous vehicles: An exploratory study. *Human factors*, *62*(2), 278-287.
Google Scholar ↗

[4] Pettigrew, S., Fritschi, L., & Norman, R. (2018). The potential implications of autonomous vehicles in and around the workplace. *International journal of environmental research and public health*, *15*(9), 1876-1876.
Google Scholar ↗

[5] Millard-Ball, A. (2018). Pedestrians, autonomous vehicles, and cities. *Journal of planning education and research*, *38*(1), 6-12.
Google Scholar ↗

[6] Rasouli, A., & Tsotsos, J. K. (2019). Autonomous vehicles that interact with pedestrians: A survey of theory and practice. *IEEE transactions on intelligent transportation systems*, *21*(3), 900-918.
Google Scholar ↗

[7] Sallab, A. E., Abdou, M., Perot, E., & Yogamani, S. (2017). Deep reinforcement learning framework for autonomous driving. *Electronic Imaging*, *2017*(19), 70-76.
Google Scholar ↗

[8] Marina, L., & Sandu, A. (2017). Deep reinforcement learning for autonomous vehicles-state of the art. *Bulletin of the Transilvania University of Brasov. Engineering Sciences. Series I*, *10*(2), 195-202.
Google Scholar ↗

[9] Pettigrew, S., Fritschi, L., & Norman, R. (2018). The potential implications of autonomous vehicles in and around the workplace. *International journal of environmental research and public health*, *15*(9), 1876-1888.
Google Scholar ↗

[10] Hegner, S. M., Beldad, A. D., & Brunswick, G. J. (2019). In automatic we trust: Investigating the impact of trust, control, personality characteristics, and extrinsic and intrinsic motivations on the acceptance of autonomous vehicles. *International Journal of Human–Computer Interaction*, *35*(19), 1769-1780.
Google Scholar ↗

[11] Liu, T., Hai Liao, Q., Gan, L., Ma, F., Cheng, J., Xie, X., ... & Liu, M. (2021). The role of the Hercules autonomous vehicle during the covid-19 pandemic: An autonomous logistic vehicle for contactless goods transportation. *IEEE Robotics & Automation Magazine*, *28*(1), 48-58.
Google Scholar ↗

[12] Zmud, J., Sener, I. N., & Wagner, J. (2016). Self-driving vehicles: Determinants of adoption and conditions of usage. *Transportation Research Record*, *2565*(1), 57-64.
Google Scholar ↗

[13] Companies in the race of self-driving vehicles and Laws and Restrictions from https://www.greyb.com/autonomous-vehicle-companies/ on 11/10/2021

[14] Maslin, E. (2020). A subsea space race: The race is on to introduce advanced robotics and autonomy into subsea oil and gas production operations. *Engineering & Technology*, *15*(3), 72-75.
Google Scholar ↗

[15] Shapiro, D. (2016, August). Accelerating the race to autonomous cars. In *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining* ,*1*(1),415-415.
Google Scholar ↗

[16] Liechtung, J. (2018). The Race is On! Regulating Self-Driving Vehicles Before They Hit the Streets. *Brooklyn Journal of Corporate, Financial & Commercial Law*, *12*(2), 6-18.
Google Scholar ↗

[17] Driver assistance technologies of self-driving vehicles retrieved from https://www.csail.mit.edu/news/explained-levels-autonomy-self-driving-cars on 11/10/2021

[18] Ramos, C., Augusto, J. C., & Shapiro, D. (2008). Ambient intelligence—the next step for artificial intelligence. *IEEE Intelligent Systems*, *23*(2), 15-18.
Google Scholar ↗

[19] Hashimoto, D. A., Rosman, G., Rus, D., & Meireles, O. R. (2018). Artificial intelligence in surgery: promises and perils. *Annals of surgery*, *268*(1), 70-81.
Google Scholar ↗

[20] Kohl, C., Knigge, M., Baader, G., Böhm, M., & Krcmar, H. (2018). Anticipating acceptance of emerging technologies using twitter: the case of self-driving cars. *Journal of Business Economics*, *88*(5), 617-642.
Google Scholar ↗

[21] Gusikhin, O., Rychtyckyj, N., & Filev, D. (2007). Intelligent systems in the automotive industry: applications and trends. *Knowledge and Information Systems*, *12*(2), 147-168.
Google Scholar ↗

[22] Self-Driving vehicles sales volume and financial expansion retrieved from https://www.greyb.com/autonomous-vehicle-companies/ on 19/11/2021

[23] Clements, L. M., & Kockelman, K. M. (2017). Economic effects of automated vehicles. *Transportation Research Record*, *2606*(1), 106-114.
Google Scholar ↗

[24] Jobs created by self-driving cars as technology advance retrieved from https://builtin.com/artificial-intelligence/artificial-intelligence-automotive-industry

[25] Puneeth, B. R., & Nethravathi, P. S. (2021). Bicycle Industry in India and its Challenges–A Case Study. *International Journal of Case Studies in Business, IT and Education (IJCSBE)*, *5*(2), 62-74. Google Scholar↗

[26] Aithal, P. S. (2017). ABCD Analysis as Research Methodology in Company Case Studies. *International Journal of Management, Technology, and Social Sciences (IJMTS)*, *2*(2), 40-54.
Google Scholar↗

[27] Aithal, P. S., Shailashree, V. T., & Kumar, P. M. (2015). A new ABCD technique to analyze business models & concepts. *International Journal of Management, IT and Engineering*, *5*(4), 409-423.
Google Scholar↗

[27] Impact of covid-19 on autonomous vehicles. Retrieved from https://www.foley.com/en/insights/publications/2020/08/covid-19-adoption-autonomous-vehicle-technology on 14/12/2021

****