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A REVIEW ON IMPERATIVE FACTORS THAT AFFECT THE FEASIBILITY OF AUTONOMOUS VEHICLES IN INDIA

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Abstract— **In the recent times, the proliferation of the Autonomous Vehicles (AV's) is rapid. Autonomous Vehicles which were present on screens will soon become a reality. Autonomous Vehicles are being piloted in several countries and are being tested and running on public roads, even though only in a handful of locations. Autonomous Vehicles will fundamentally change the transportation scenario in a highly vehicle-populated country, such as India.**

The major milestone that the community of Autonomous Vehicle Technology in India facing was the inadequate literatures in this realm. Owing to this inadequacy, through this review paper, the exploration of few imperative factors – Political, Topographical, Economic, and Consumer Behaviorism, essential for the growth and development of AV's in India is put together.

Indicative results in the form of Likert chart and graphs have been developed through exploratory analysis to understand the feasibility of the AV technology in India in respect of the imperative factors mentioned. This study also touches upon the existing standards for the various factors and the introduction of Autonomous Vehicles in Indian market in comparison to other markets.

Keywords— **Autonomous Vehicles, Autonomous Vehicle Readiness Index, Smart Cities, Implementation Factors.**

I. INTRODUCTION

The world is witnessing rapid advancements in autonomous technology, with the integration of Artificial Intelligence (AI) based approaches, has further boosted self-driving vehicles to arrive at the forefront of public interest. The Autonomous Vehicle (AV) is also connoted as 'self-driving' or 'automated' or 'driverless' vehicle, is a recent advancement in automotive industry with the ability to steer vehicles in all predetermined situations without a human driver. [1]

The interest in this field of technology was brought to light in the year 2004 by Defense Advanced Research Projects Agency (DARPA), US, by launching a great challenge with the intention of exploring the viability of the autonomous technology by traversing approximately 150 miles in a gruesome desert, where no robot had ever traversed. [1]

This event developed gradually to a larger extent, with the launching of Self-Driving Car by Google, in the year 2007, which successfully was tested on the public roads and ran 15 miles without the mediation of a human driver. Up until 2014, the Google's 'Self Driving Car' has traversed more than 700,000 miles in the United States.

This boosted the tech enthusiasts all around the world to think that autonomous car and sustainable energy is inevitable for the fourth-coming generations. Even though this technology is currently driven by enthusiasm to an extent, it has far greater values in the fields of defense and military, mobility of the physically disabled etc.

History of Autonomous Vehicles

The idea of self-driving vehicles dates back much further than Google's research in the present days. In fact, the idea of Autonomous technology pertaining to vehicles dates back to 16th century, even before the invention of automobiles. In the early mid-1500s, Leonardo da Vinci designed a cart that could propel without being pushed or pulled by a human. Power to the cart was provided by springs under high tension, and steering could be set in advance so the cart could move along a predetermined path. A distant precursor to the car, this device is sometimes considered as the world's first robot.

In the mid-1700s, during the emergence of war weapons, Robert Whitehead's invention of a torpedo that could propel itself under water proved to be a game-changer for naval fleets around the world.

Fast forward to the year 1958, General Motors had designed a car with its front end embedded with pick-up coils, type of sensors that could detect the current flowing through a wire embedded in the road and using this current to manipulate the steering of the vehicle. Improvising this idea, the Japanese, in the year 1977, developed cameras to process the images of the road. As technology improved, so did the ability of the self-driving vehicles to detect and react to their environment.

The series of these innovations led to the beginning of the new era of Autonomous Vehicles are depicted in Figure 1.

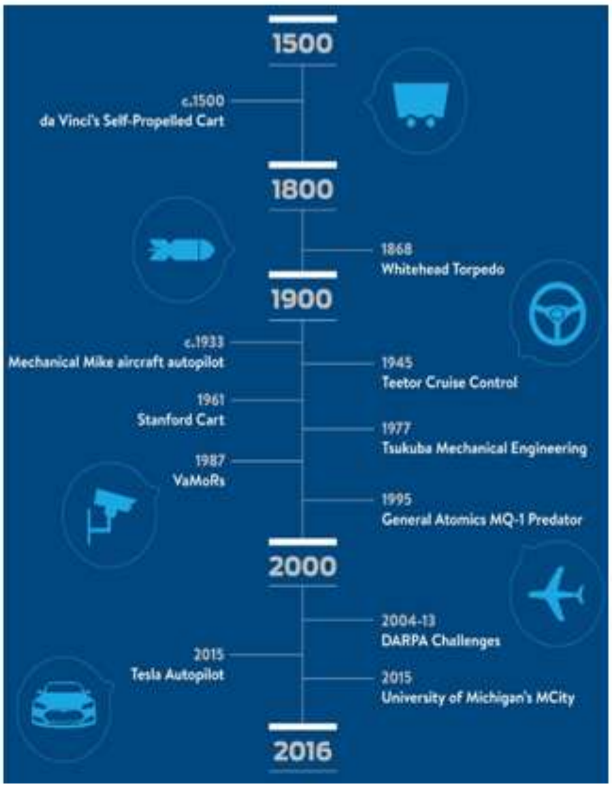

Figure 1: Timeline of Autonomous Vehicles.

Current State of Technology:

Recently, many private companies such as Google's Waymo One, Tesla, Voyage, Uber, Aptiv, Toyota etc., are vigorously working in the race of Autonomous Vehicle Technology. Google's Waymo, in the year 2018, completed 10 million miles on the roads of United States. Tesla's Autopilot reached 1 billion miles mark, which is a huge achievement in this space.

Mobility Transformation Center- MCity hosted by the University of Michigan, has a development area of 32-acre launched in 2015 as a world-class test facility for autonomous vehicle technology. The first automaker to test their autonomous vehicle in the MCity was Ford, and in the harshest environmental conditions imaginable.

Perhaps, the most exciting part of the dawn of autonomous vehicle era is the collaboration between the private industries, Government, and the academia to adopt the technology at a faster rate and it is depicted in Figure 2.

Figure2: Most Influential Autonomous Vehicles Maker. [2]

II. LEVELS OF AUTONOMY

The possible fundamental changes in the transportation that the AVs could offer are yet incomprehensible. The AVs that roll out on the streets are leveled from 0-5 based on its functionality. These six levels, as shown in Figure 3, were standardized by SAE International in the year 2014. [3][4]

Level 0 (No Automation): The driver performs all the driving operations.

Level 1 (Driver Assistance): The vehicle has one or more control functions, assisting the driver in accelerating, braking. These functions are independent of each other and cannot work in tandem.

Level 2 (Partial Automation): The driver assistance system present in level 1 works in tandem in this level, with maximum of two functionalities at a time.

Level 3 (Conditional Automation): The vehicles can drive themselves, but only under ideal conditions only, and a human driver is required to take over if the road conditions fall below ideal.

Level 4 (High Automation): The vehicles can drive themselves. A human can take over the driving when he wishes, indicating that the vehicles at this level still have steering wheel.

Level 5 (Full Automation): The vehicles at this level will be able to monitor and maneuver through all road conditions and the steering wheel is possibly absent.

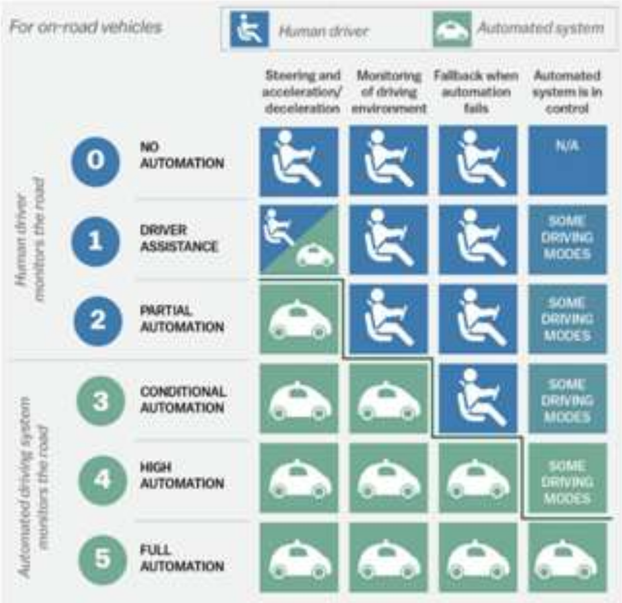

Figure 3: Levels of Autonomy [4]

III. TYPES OF AV BUILD APPROACH

A modern AV takes two generalized forms of build approach. The approaches are varied based on the manufacturers.

- **AVs with Vision Sensors and deep learning:**

This approach employs cameras as primary sensor to obtain the information of the surroundings. The data collected is then fed to a powerful processing unit capable of rendering the information and through machine learning produce response to drive the vehicle.

The advantage of this approach is that the cameras provide relatively higher resolution of information and use the collected information to learn and ameliorate over time. This approach is relatively cost efficient as well.

The biggest disadvantage of this build is that the cameras operate poorly in the low-light conditions.

- **LIDARs with maps:** This approach employs Light Detection and Ranging (LIDAR) and Radio Detection and Ranging (RADAR) as primary sensors along with the maps.

With this approach, the vehicle maintains relatively higher consistency in terms of predicting the surroundings. The distances, road edge detection, lane marking detection are more accurate in this build.

Although this approach is reliable to an extent, it has few limitations, starting off with the minimum to no improvements in the results since there is no machine learning involved, unless manually tweaked. This approach also comes at a higher cost as LIDARs are expensive.

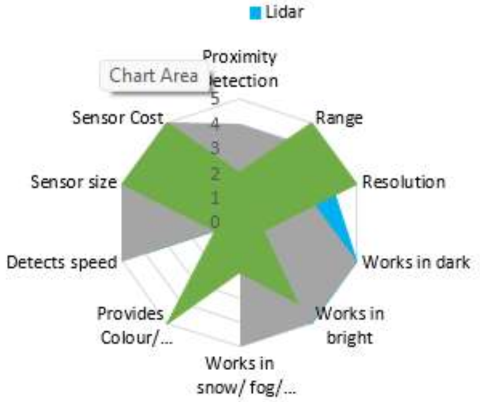

Figure 4: Fusion of AV Build Approach. [5]

Although both the approaches have advantages and the disadvantages over each other, a sensible solution would be to employ a fusion of both the approaches.

The graph shown in Figure 4 represents the cumulative scores of each approach differentiate by color. The combined build approach facilitates in the better performance of the AVs. To further improve the performance, ultrasonic sensors can also be incorporated to measure distances accurately. [5]

IV. IMPERATIVE FACTORS AFFECTING THE FEASIBILITY AND AOPTION OF AV'S IN INDIA

In developing nations like India, majority of the population suffer from unemployment, poor education access, inferior environmental conditions and mass death-toll owing to road crashes. In this context, queries might upsurge about the challenges entrenched in peoples' mind, their behaviorism and skepticism regarding AVs' safety issues and finally whether driverless vehicles would create or displace jobs.

The feasibility and adoption of the AV's in India is impacted by the prime factors- Political, Topographical, Economical and Consumer Behaviorism. Understanding these factors allows for faster implementation of the AV technology with the necessary amendments in the existing system to implement the AV's.

Topographical Factors

Topography refers to the study of the forms and features of land surfaces. The topography of an area could refer to the surface forms such as road infrastructure. The term 'road infrastructure' is understood to include all physical assets within the road reserve, including not only the road itself, but all associated furniture- signage, and all earth-works, drainage, physical structure- buildings, damns etc.

The existing road infrastructure is designed best for vehicles operated by a human driver, and the designers take timings of signals, lanes, parking lots, footpaths etc., into consideration while building the roads.

However, when the AVs are rolled out to the public roads, the current road infrastructure is inefficient for the AV's. Few parameters relating to the road infrastructure must be considered for the AV's to be in the zone of predictive effectiveness. The parameters- Electric Vehicle Charging Stations, 4G Coverage, Quality of roads. [6][7]

Electric Vehicle Charging Stations:
Autonomous vehicles are expected to be designed as ACES- Autonomous, Connected, Electric, Shared. The primary change in the vehicles would be the transition to electric motor drives from conventional internal combustion engines. Studies forecast that sales of electric vehicles will hit 41 million by 2040, representing 35% of new light duty vehicle sales. This projected change between now and 2040 will have implications beyond the car market.
The bottom line is that the integration of various advanced technologies is relatively simpler in Electric vehicles for the cleanest and safest operation of autonomous vehicles.[8]
With the advent of AVs, the increase in the electric vehicle charging stations is inevitable for seamless charging the AVs [24].

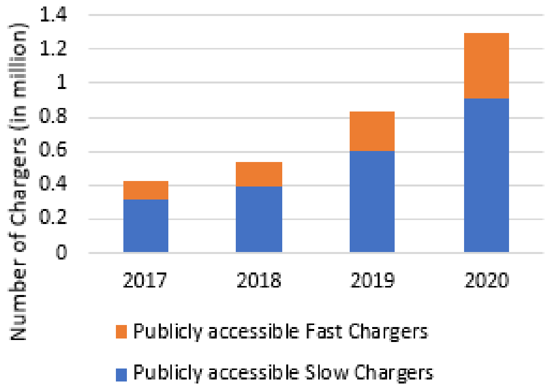

Figure 5: Growth of Global EV Charging Stations.[9] [10]

The electric vehicles running on the roads currently have the potential to be converted to Autonomous Vehicles. The graph shown in Figure 5 represents the increase in the global electric chargers in millions.
It can be noted that the establishment EV charging station is on the increasing trend [9]. The publicly accessible EV chargers were up by 45% in 2020, a slower pace than 85% in 2019, reaching to more than 1.3 million publicly accessible chargers, globally [9]. The slower pace was due to the interruption of the work in key markets due to the Covid-19 Pandemic outbreak [9].
The graph shown in Figure 6 represents scores of each country based on the availability of publicly accessible EV charging station per person [6].

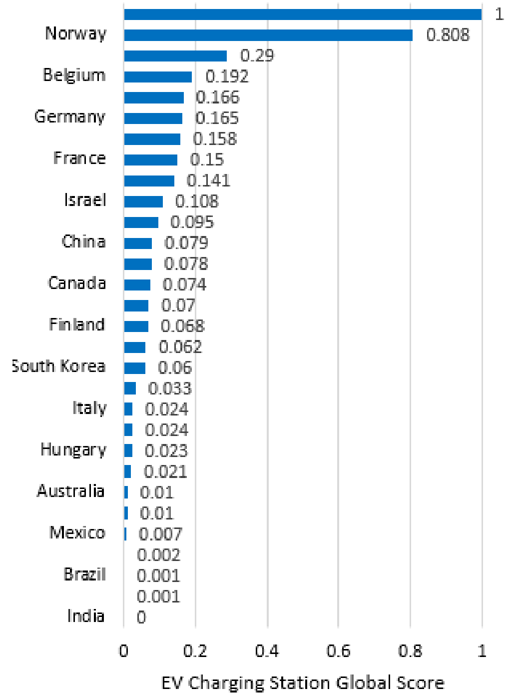

Figure 6: Scores Depicting Country-wise Standings in Electric Charging Stations [6]

In the Autonomous Vehicles Readiness Index (AVRI) issued in the year 2020, the Netherlands scored the highest in the EV charging station with 3 charging stations per 1000 residents [6]. India scored the least points emerging at the last place.
The government of India has highlighted the vision to boost the adoption and manufacturing of EV. The current Electric Vehicle policy framework is a mix of incentive-based policies accompanied by regulatory reforms, and public-private partnerships to encourage Electric Vehicle adoption, expand charging infrastructure and support domestic Electric Vehicles and supply equipment manufacturing capacity and battery manufacturing [20].
The Indian Government under Faster Adoption and Manufacturing of Electric vehicles (FAME)[12] program has decided to expand the charging infrastructure by allocating INR 1,000 crores (USD 130 Million)[11]. Figure 7 depicts the budget allotted to charging infrastructure under FAME-II.

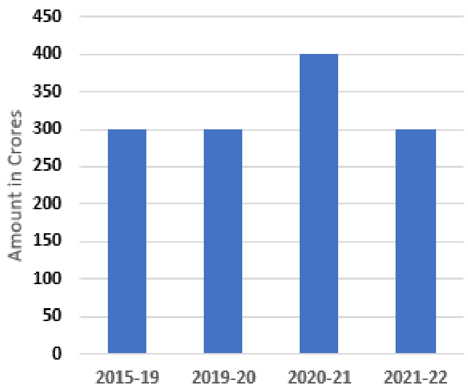

Figure 7: Budget Allotted to Charging Infrastructure under FAME-II (in Crores)[11]

4G Coverage: To support the Vehicle to Vehicle (V2V) technology and Vehicle to Infrastructure (V2I) Technology, the rate of data transfer in and out of the vehicle must be extremely quick for the vehicle to make quick and precise decisions. Enabling faster connection between these systems will open to new advancements in the Autonomous Technology. Based on this, the 4G network availability and coverage is crucial for the operation of AV's.
The countries have been scored based on the availability and coverage of 4G network, shown in Figure 8[13].

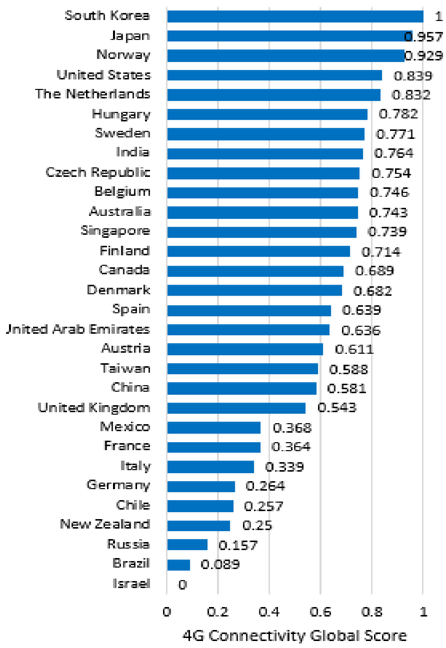

Figure 8: 4G Connectivity Global Score

In the Autonomous Vehicles Readiness Index (AVRI) issued in the year 2020, South Korea emerged in the first position in 4G Coverage [6].The 4G coverage in India is on par with some of the higher ranked countries, the reason being Jio telecommunication.

Quality of Roads: The usability of autonomous vehicles is largely dependent on the quality of the roads that the vehicles ride on [22].In the Autonomous Vehicles Readiness Index (AVRI) issued in the year 2020, Singapore has the best roads on this measure, followed by the Netherlands and Japan, while Brazil, Russia and the Czech Republic have the worst road quality.

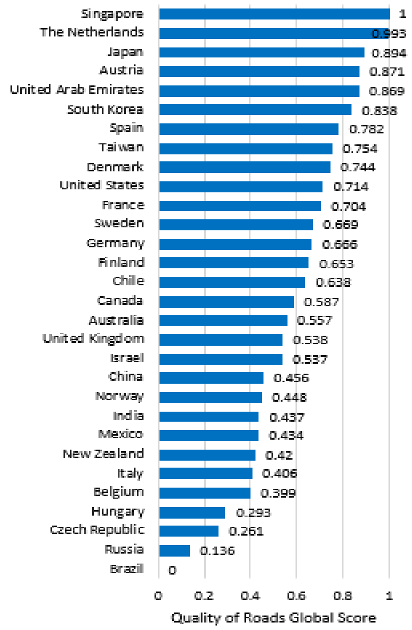

Figure 9: Quality of Roads Global Score [6]

The graph shown in Figure 9 represents scores of each country based on the quality of roads as reported in the Global Competitiveness Report [14].
In terms of road quality, India stands at 23rd position. The poorly constructed roads in India are etched in its core problems. Potholes, roads under construction, poorly concreted speed breakers and down-and-out drainage system on the roads are a cause of increasing accidents, deaths, and health problems in the country [15].

Political Factors
The political factors are generally the actions of the government and its conditions in the location where these vehicles operate in the physical world. The likings of the Autonomous vehicles simply cannot operate on public roads without the government foreseeing the operations. The primary reason is the safety of the public and their properties.
Political factors, in the context of Autonomous vehicles, are a type of external constraints acting on the technology. The meaning of this is that the implications of the political factors on an Autonomous Technology does not have its role in the

core working principles of the technology but rather its operations on the public roads [20] [21].
The most prevalent political factors related to the activities and administrative practices of the Government concerning the Autonomous Vehicles are- Government Regulations on AV, Government Funded AV's Pilot.

Government Regulations on AV: Both regulations and standards are important in the emergence and development of AV Technology.
Before laying out the regulations, the Government must understand the following questions to know the impact of AV's:

1. How should the AV's be regulated if adopted and what level of Autonomy is better suited?
2. What kinds of AV's should be allowed on the road, and who is responsible and allowed to operate them and who should be blamed in an event of accidents- Man or the machine?
3. How should the safety of AV's be tested, and by whom should the testing be done?
4. To what extend should the consumers be encouraged to adopt AV?

Understanding these questions to an extent, few countries have regulated the operation of AV's on public roads.
The graph in Figure 10, depicts the ranking of countries based on the regulations on AV's in those countries and have fewer restrictions on when and where the operations of AVs are done [6]

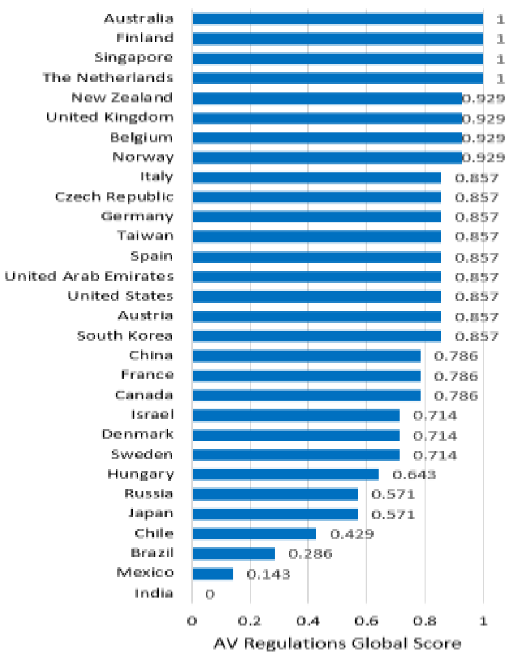

Figure 10: AV Regulations Global Score [6].

It can be observed from the graph, that India scores 0 in terms of AV regulation due to absolutely no regulations set by the government to allow Autonomous Vehicles of level 3 and higher to test and function on public roads.
Government Funded AV pilots: The research and development of AV's require huge amount of funding. The benefit of increased R&D means having better technological capacities.
The Figure 11 represents in the graph scores of countries in based on AV funded by government.

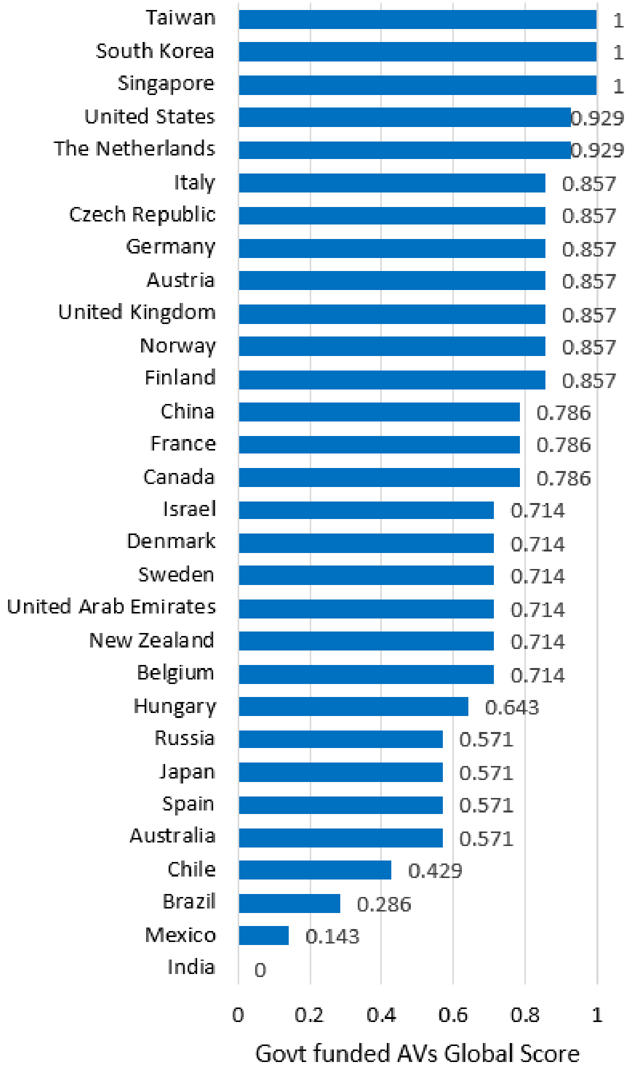

Figure 11: Govt. funded AVs Global Score [6].

Some sort of buzz around Autonomous vehicles is created around the entire globe but apparently not in India due to the noble cause to avoid unemployment due to this technology.

Economic Factors
Economic Factors are the factors that affect the economy, and include interest rates, tax rates, law, policies, wages, and

governmental activities. India has developed into one of the international performers in the automobile market.

Foreign Direct Investment (FDI) inflow to Indian automobile sector is increasing year by year due to significant cost advantage that attracts the FDI in this sector. India became the fourth largest market for automobiles in 2018, with sales increased more than 8.3% year-on-year to 3.99 million units [16].

Currently, Indian automobile sector in a growing stage and five megatrends that are expected to be transform the Indian automobile sector in the future.

The Make in India program has played major role in the automotive sector. As per this program Government of India allows 100% of FDI toward the automotive sector [43].

Industry Partnerships: With all the enthralling movements, India is trying to attract the global automobile industries, but when it comes to the AV industries' tie ups, the performance of India is on the poorer side. With no support from the government to adopt AV technologies in India, very less to no industries' tie ups are observed [42].

Having a good industry partnership index directly co-relates to stronger FDI possibilities.

The industry partnership index is scored based on the reviews of news coverage from global and local media, research from consulting firms and blogs that the AV industries experts maintain.

The swift nature of AV technology has made partnerships between automobile makers and AV technology suppliers essential, and many have been formed recently [44]. The graph as shown in the Figure 12 represents the scores of countries that are home to companies with larger number of partnerships with the AV industries [6].

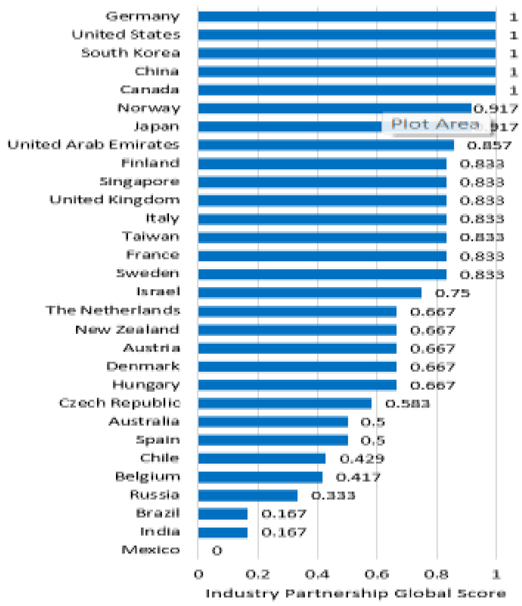

Figure 12: Industry Partnership Global Score [6]

It can be observed from the graph that Germany, US, South Korea, China, and Canada have companies with excellent partnership with the AV industries.

Industry Investment in AV: The investments made by the industries allows for a raise in the standards of the financial markets [45]. This allows for efficient allocation of resources in the economy.

The graph represented in Figure 13 indicates the scores of countries investing in the AV technology, scaled by national population.

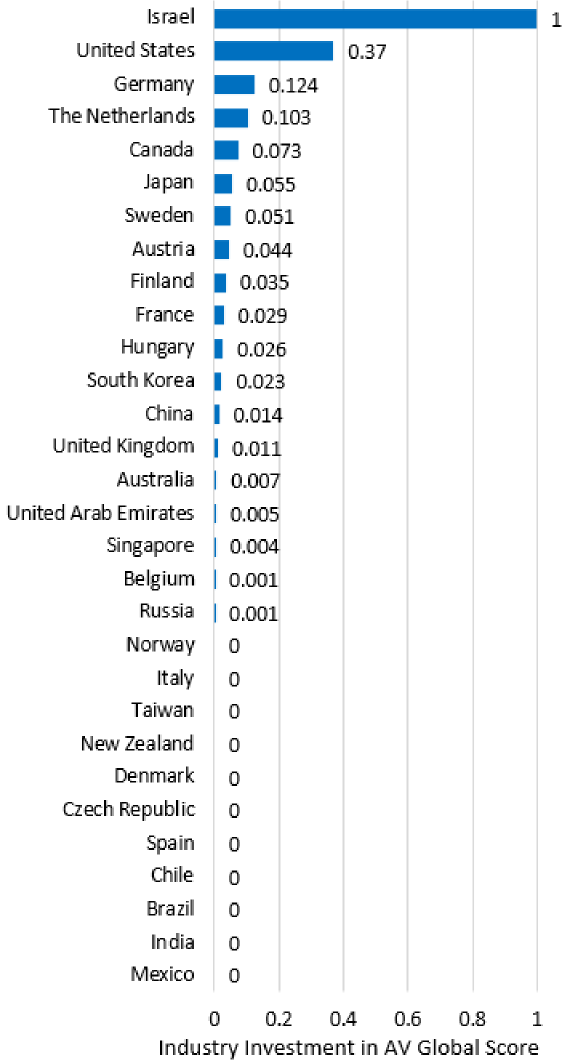

Figure 13: Industry Investment in AV Global Score.

The countries have been scored on the basis of investing organization, rather than where the investment is made. Israel is the leading country for investments on per capita basis. Eight countries including India receive no score [6].

Cost of AV's: AV's are technologically advanced machines, and the price of an AV is extremely high. Most of the AV's use LIDAR based build, and the price of lidars is extremely high and can cost up to 10,000 USD which translates to INR 7.5 lakhs. The price of the LIDAR is nearly the same as the average cost of a new car in India. This difference alone can make the autonomous vehicles uneconomical and unreasonable to the Indian market.

Consumer Behaviorism

This factor analyses the users' degree of interest towards existing AV's by conducting and procuring results from some of the online surveys for the people under different ages, genders, organizations, qualification etc. Through these surveys the generalized idea of how much the people are comfortable with the AV's is predicted.

Reviewing various literatures, the common interpretation that can be arrived is the Indian are keener towards this technology than the rest of the neighboring countries and also with other higher ranked countries on AVRI [6].

The graph in Figure 14 shows interest of consumers from various countries. The values are colored to differentiate the surveys conducted by ANSYS and Statista.

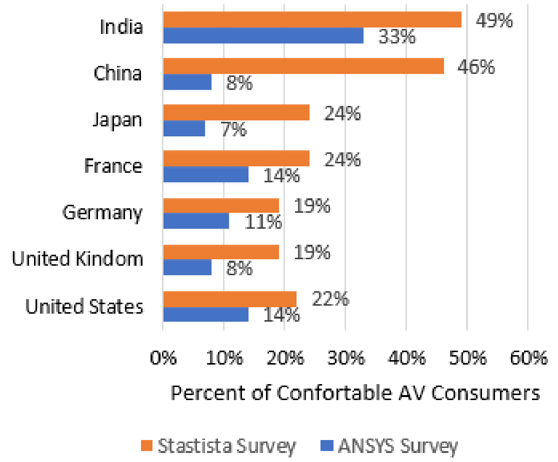

Figure 14: Percent of Comfortable AV Consumers Country wise. [17] [18]

It can be noted from the graph that the percent of consumers comfortable to ride AV is higher in India compared to the other countries.

In a different research conducted [19], the perception and acceptance of AV's among probable future AV users of India were investigated. Exploratory analysis were conducted to understand the users' degree of interest in AV's, knowledge regarding the socio-economic variables such as cost of the AV's, benefits concerning the AV's, overall safety issues. [19]

The results of this research were that 91.1 percent of the respondents had prior knowledge regarding the AV technology. The research respondents were categorized based on gender, age, educational level, monthly income, ownership of vehicle. [19]

The graphs shown in Figures 15 and 16 depicted the results that were obtained in the survey conducted.

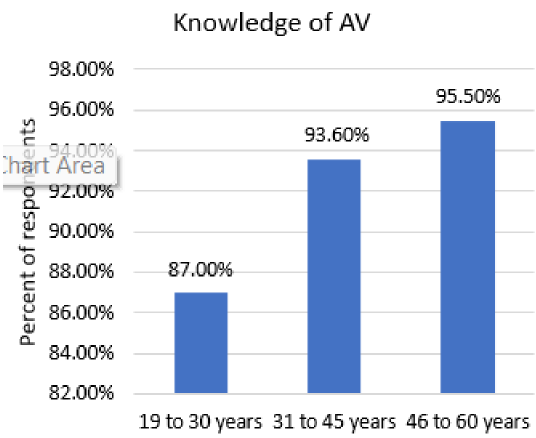

Figure 15: Percent of users have knowledge regarding AV [19]

It was observed the younger generation respondents had the least knowledge regarding the AVs, although the expected results were that the younger generation respondents would have higher knowledge regarding the AV technologies.

It was observed that 50% of each category was moderately concerned regarding the AV.

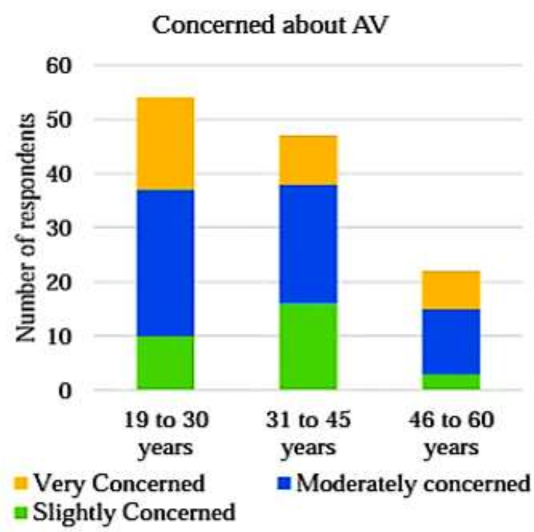

Figure 16: Number of respondents having concerns regarding AV

Considering the entire above factor, the graph depicted in Figure 17 is plotted to represent the improvement in mentioned factors to an extent by India, each year from 2018-2020 on the AVRI.

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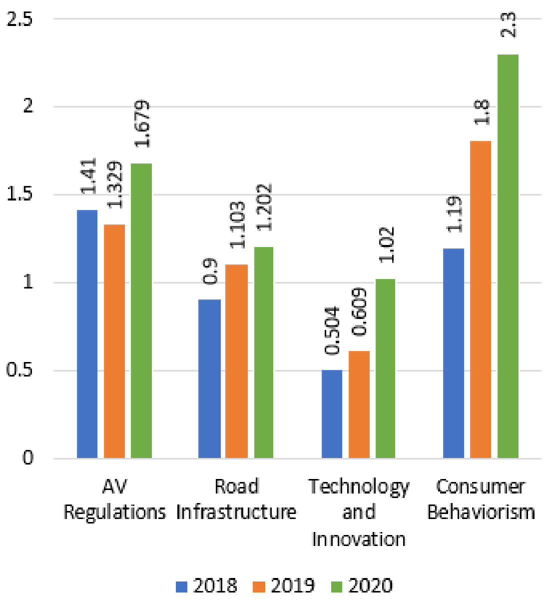

Figure 17: Year-wise comparison of AV factors of India.

V. RESULTS

Based on the analysis of the factors consider for the study, indicative results have been plotted in the form of a Likert chart as shown in the Figure 18.

Each factor is considered on a scale of 0 to 10, '0' representing that the implementation of AV in India is not feasible and '10' representing the opposite i.e., the implementation of AV in India is feasible. The feasibility of the AVs in India is based on the factors independent of other factors.

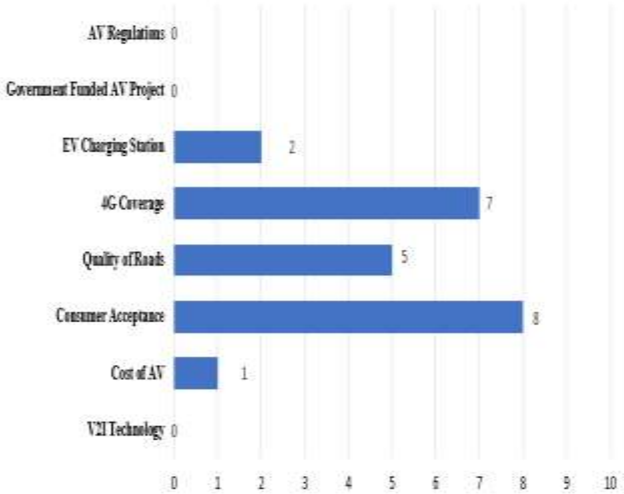

Figure 18: Likert chart representing feasibility of AV in India based on each factors independently

VI. CONCLUSION

Quality of roads being the paramount importance in transportation, majority of the Indian roads suffer from standardizations limiting its effectiveness to human drivers let alone the Autonomous Vehicles. Lack in infrastructures to accommodate electric vehicles is slacking the advent of Autonomous Vehicles.

In the Political sense, no regulations have been implemented in bringing the Autonomous Vehicles to the public roads by the Government, owing to the noble cause of unemployment induced by this technology.

The cost of an autonomous vehicle is extremely uneconomical and unreasonable to the Indian market. The gradual decrease in the cost of components used on the autonomous vehicle will shed some light on the decreased price of the whole Autonomous Vehicles, but the rate of decreased pricing is slow.

The positive attitude of Indians towards the Autonomous Vehicles will have impact on the faster adoption of the technology. The growing network of internet connectivity has shed optimistic hopes in the faster adoption of the technology.

The Indian Government is keen on adopting the Electric vehicles in lieu of the infant Autonomous Vehicles, focusing towards more sustained and cleaner environment rather than elevating the better transportation experience.

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