An Overview of Social, Economic, Environmental, and Safety Impacts of Intelligent Electric Vehicles

Dr. Muhammad Uzair,
Faculty of engineering, Islamic University of Madinah, KSA
uzair91@hotmail.com, muzair@iu.edu.sa
and
Saleh Hosain,
Faculty of engineering, Islamic University of Madinah, KSA
salehalhafiz@hotmail.com

Abstract: Internet of Things (IoT) can connect millions of devices, objects, appliances, sensors, and applications together to collect huge amount of data for multipurpose applications. It requires an efficient network to carry out these processes in a faster way which is accomplished with the help of 5G networking, i.e., ability to provide a very high data rate, etc. Autonomous vehicles (smart cars) are one of the applications of the IoT which integrates its components to make smart cars working as robots. Smart cars will have great impact on our society (like different driving experience, improving accessibility to urban opportunities to different groups of people, providing a convenient, comfortable, and flexible transportation, etc.), environment (like fuel consumption, gas emissions, land use, and urban spatial structure, etc.), economy (many current practices will close with new opportunities), and safety/security (software failures, denial of service, eavesdropping, hijacking, etc.). These impacts will be profound, particularly for level 5 automation smart cars.

This research analyzes key aspects of the autonomous vehicles with respect to these issues along with ethical dilemmas. This study clearly shows that lots of work still needs to be done by the manufacturers, the vendors, the industry, and the governments in order to make this technology adaptable. The study also describes that until now many aspects of this technology are also ambiguous, i.e., technology will have positive or a negative impacts, which group of the society will get more benefits, and which group might be affected negatively, etc.

Therefore, the study highlights the need of more empirical results from industry, and research community in order to make a conclusion of the impacts of the technology. Similarly, greater emphasis should be given to the safety and security because if this technology is not a hundred percent safe, it will not be widely accepted. An attack on a smart car does not only threaten the safety and privacy of drivers, passengers and everyone traveling on the road, but also has a big impact on the auto industry, i.e., millions of cars have already been recalled in many cases. Finally, the research also highlights different challenges/issues faced by this technology. The research also proposes recommendations and solutions in order to handle these current and future challenges keeping in view that the security/safety is one of the biggest challenges for the autonomous vehicles (AVS). At the end, the research also proposes a new comprehensive layered architecture for the AVS with particular focus towards security and safety of the AVs and making it safer and reliable as compared to the existing architecture.

Keywords: Autonomous vehicles, safety/security, social, economical, environment

نظرة عامة على التأثيرات الاجتماعية والاقتصادية والبيئية المتعلقة بسلامة السيارات الكهربائية الذكية

الملخص: يمكن لإنترنت الأشياء (IoT) توصيل ملايين الأجهزة والأشياء وأجهزة الاستشعار والتطبيقات معًا لجمع كمية هائلة من البيانات للتطبيقات متعددة الأغراض. يتطلب هذا شبكة فعالة لتنفيذ هذه العمليات بطريقة أسرع والتي يتم إنجازها بمساعدة شبكات الجيل الخامس (5G)، أي القدرة على توفير معدل بيانات مرتفع للغاية، وما إلى ذلك. المركبات المستقلة (السيارات الذكية) هي أحد تطبيقات إنترنت الأشياء الذي يدمج مكوناته لجعل السيارات الذكية تعمل كروبوتات. سيكون للسيارات الذكية تأثير كبير على مجتمعنا (مثل تجربة القيادة المختلفة، وتحسين إمكانية الوصول إلى الفرص الحضرية لمجموعات مختلفة من الناس، وتوفير وسيلة نقل عملية ومريحة ومرنة، وما إلى ذلك)، والبيئة (مثل استهلاك الوقود، وانبعاثات الغاز، واستخدام الأرض، والهيكل المكاني الحضري، وما إلى ذلك)، والاقتصاد (سيتم إغلاق العديد من الممارسات الحالية بفرص جديدة)، والسلامة / الأمن (فشل البرامج، ورفض الخدمة، والتنصت، والاختطاف، وما إلى ذلك). ستكون هذه التأثيرات عميقة، خاصة بالنسبة للسيارات الذكية ذات التشغيل الآلي من المستوى الخامس.

يحلل هذا البحث الجوانب الرئيسية للمركبات ذاتية القيادة فيما يتعلق بهذه القضايا إلى جانب المعضلات الأخلاقية. تظهر هذه الدراسة بوضوح أنه لا يزال يتعين القيام بالكثير من العمل من قبل المصنعين والبائعين والصناعة والحكومات من أجل جعل هذه التكنولوجيا قابلة للتكيف. توضح الدراسة أيضًا أنه حتى الآن هناك العديد من جوانب هذه التقنية غامضة أيضًا، أي أن التكنولوجيا سيكون لها تأثيرات إيجابية أو سلبية، وأي مجموعة من المجتمع ستحصل على المزيد من الفوائد، وأي مجموعة يمكن أن تتأثر سلبًا، وما إلى ذلك. تسلط الدراسة الضوء على الحاجة إلى المزيد من النتائج التجريبية من الصناعة ومجتمع البحث من أجل التوصل إلى استنتاج بشأن تأثيرات التكنولوجيا. وبالمثل، يجب التركيز بشكل أكبر على السلامة والأمن لأنه إذا لم تكن هذه التكنولوجيا آمنة بنسبة مئة بالمائة، فلن يتم قبولها على نطاق واسع. إن الهجوم على سيارة ذكية لا يهدد فقط سلامة وخصوصية السائقين والركاب وكل من يسافر على الطريق، بل له تأثير كبير على صناعة السيارات، أي أنه تم بالفعل استدعاء ملايين السيارات في كثير من الحالات. أخيرًا، يسلط البحث الضوء أيضًا على التحديات / المشكلات المختلفة التي تواجهها هذه التكنولوجيا. يقترح البحث أيضًا توصيات وحلولًا للتعامل مع هذه التحديات الحالية والمستقبلية مع الأخذ بعين الاعتبار أن الأمن / السلامة هو أحد أكبر التحديات التي تواجه المركبات ذاتية القيادة (AVS). في النهاية، يقترح البحث أيضًا بنية جديدة شاملة متعددة الطبقات لنظام AVS مع التركيز بشكل خاص على أمن وسلامة المركبات وجعلها أكثر أمانًا وموثوقية مقارنة بالبنية الحالية.

Introduction: Internet of things (IoTs) is a communication technology, which makes everything capable of communicating with other things existing in this world such as homes, cars, animals, humans, farms, and industry, etc. It uses low cost processors, i.e., Raspberry Pi and Arduino microcontroller, different protocols, and wireless networks to add digital intelligence in these dumb devices so that these devices can communicate with each other. In this way, it basically merges the digital and physical world [1]. In order to enable this merging and optimize the energy consumption, coverage, data rates, and security it requires next generation (5G) of the mobile networking system. Therefore, 5G is considered a driver for the Internet of Things (IoT) to connect different devices, sensors, and things together for data collection, and further processing [2].

Autonomous vehicles (AVs), or smart cars are one of the most trending researches in today's automotive industry. Smart cars are one of the great applications of the IoT which has the ability to connect the internet. Smart cars have the ability to send and receive data onto internet with other devices, both inside and outside of the car. The smart car is like a robot that uses its own intelligence to perform different functions. It encompasses cases such as telematics (i.e., fleet management or Geo-fencing), connected infotainment such as access to drive information (i.e., speed), and control functions (i.e., air conditioning), etc. Vehicle-to-Infrastructure (V2I) communication technologies will enable the drivers/cars to get information from the control station regarding parking, speed cameras, and real time information about traffic, etc. Vehicle-to-Vehicle (V2V) communication technologies will enable the drivers/cars to share information about each other regarding location, collision avoidance, traffic streamlining, etc. [3]. Figure 1 shows that how smart cars work [4].

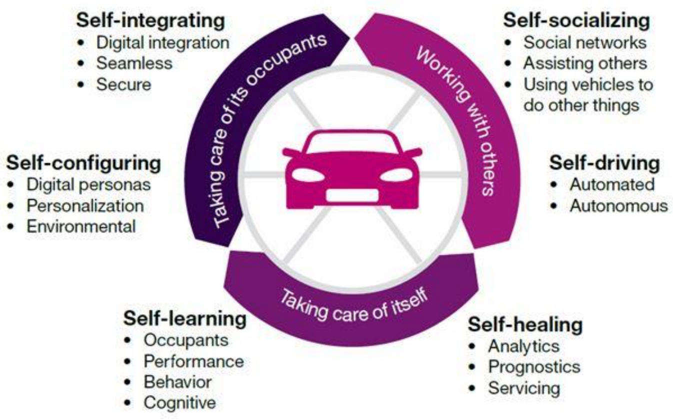

Figure 1. Smart Car [4]

The overall structure of the research is shown in Figure 2.

Levels of automation: Smart cars have two levels of automation, i.e., level 0 to 3 (low level automation), and level 3 to 5 (high level automation). Each of these automations provides an entirely different driving experience (especially level 5) by providing a completely different architecture and interfaces as compared to the today's cars. Table 1 shows the standard levels of automation [4].

Table 1: Standard levels of automation in AVs

SAE Level	Definition	System capability
0	No Automation. Drivers perform all tasks	N/A
1	Driver Assistance. Vehicles assist some functions, but drivers handle accelerating, braking, etc	Some driving modes
2	Partial Automation. Vehicles can assist with steering or acceleration/deceleration functions, etc.	Some driving modes
3	Conditional Automation. Vehicles control all monitoring/functions, but drivers respond to request	Some driving modes
4	High Automation. Vehicles control all monitoring/functions even if drivers do not respond appropriately	Many driving modes
5	Full Automation. No human attention needed for any condition that can be managed by a human driver	All driving modes

Expectations from smart cars: In today's digital life, people have experiences of digital interfaces in every part of life, i.e., customer services, retail, etc. People are always interested in how to feel the use of interact with a product and about the company which provides it. Similarly, people who will use the smart cars in the near future, i.e., drivers, or passengers will have their own opinions towards the making, model, price, or the appearance of a vehicle. Both physical and digital developments will ultimately make the opinion of the driving experience. Therefore, the car-makers will need to develop such services and applications which offer the best personalized driving features. Software advancements will be the main factor in determining the popularity of certain vehicles over the others. With increasing understanding among the car-makers, developing reliable and user specific software in the smart cars will provide an opportunity to get more shares in the auto market [5]. Similarly, humans are giving the control of their lives to a robot, i.e., smart cars. This phenomenon is only possible when there is a good deal of trust which can only be achieved through reliability, security, and safety. Some recent accidents show that there are many severe shortcomings in the smart cars, and these smart cars are not trustworthy for a safer drive under all weather conditions. The safety and security solutions to level 5 automation are particularly important as it will have cutting edge effects on the society in every aspect. The concept of smart cities will also not be completed without smart cars. For a smart city, smart cars should have the ability to move through intersections without any delay, immediately self report of any accident, make ways for the emergency vehicles, and should know where to park safely, etc. [6].

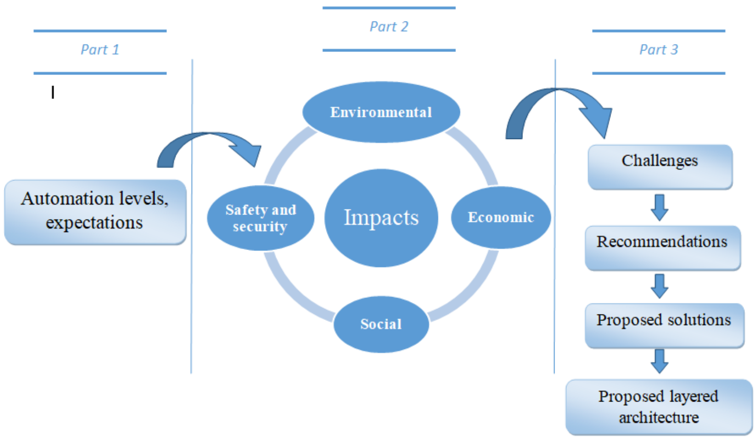

Figure 2: Overall structure of the research

The remainder of the paper is organized as follows: Section I, and section II describe the environmental and economic impacts of the autonomous vehicles. Section III, and section IV present the safety and social impacts. Section V presents the challenges to the autonomous vehicles. Section VI presents the recommendations and section VII presents solutionsto handle the existing and future challenges. Section VIII presents a new comprehensive layered architecture for the AVs. Section IX presents the conclusion.

In the following section, the environmental impacts of the AVs are being presented.

1. Environmental impacts

1.1. Radiation effects on humans, animals, and plants: With the rapid increase in the wireless technology and IoT, there will be an increasing number of devices around us, which will radiate high amount of radio frequency (RF). The smart cars will also be responsible for wireless radiations as they comprise of lots of numbers of IoT devices. In a recent study, the World Health Organization has classified wireless radiation as a Group 2B, i.e., possible human carcinogen [7]. The studies have also found that exposures to radio frequency radiation can also cause disruption of normal brain development in fetuses, learning disabilities, heart abnormalities, and electro hypersensitivities. The pregnant women, children, people with implanted medical devices, electromagnetically sensitive individuals, and the elderly people will particularly be affected by these radiations. Similarly, the sweat ducts within our skin act as an antennae. Due to this, the millimeter waves can penetrate up to 1 to 2 millimeters into skin tissue, and are also absorbed by the surface layers of the eye's cornea. The electromagnetic radiations also damage trees, and change the structures of the plants. The research studies also indicate that the wireless technology is another contributory factor to the decline birds, frogs, bats, and honeybee populations [8].

1.2. Gases emissions: Smart cars will have both positive and negative effects on the environment, i.e., motor vehicles can reduce transport energy consumption up to 90 percent, or increase it by more than 200 percent. According to the Environmental Protection Agency (EPA), the transport sector is at least responsible for a quarter of greenhouse gas emissions. Drivers will receive the advance information about traffic congestion by using smart cars, which will enable people to reschedule, postpone, cancel, or make their journey creating a fuel efficient and environmentally friendly environment. AVs which are powered electrically will reduce the carbon dioxide emissions. This would be a major positive effect on the environment, but it will only be true when we use the green energy sources of electricity production [9]. The net emissions are likely to reduce, but it is not clear that how much it will reduce. On the other hand, the total number of miles will be increased due to easy travel, and will encourage people to make an extra trip causing negative effects on the environment. According to the Eno-Center study, the emissions per mile could decline (if AV communicates well with the infrastructure) even if the vehicle mileage travel (VMT) increases. Therefore, AVs will have a significant impact on the environment, but good or bad will depend on the technological and policy options that are still evolving and are not certain [10-12].

1.3. Infrastructure: One of the most important limiting factors in the adoption of autonomous vehicles is the infrastructure. It will be easier to run the AV in any area if it is more understandable and predictable, i.e., traffic environment. This thing will also make AVs quickly adapted by the society. Therefore, the investment in the infrastructure will be a significant factor that will determine the success of AVs in the future. Moreover, when more numbers of AVs will be on the road; this technology will improve the infrastructure which will turn into a package of great societal benefits. This is particularly possible in highly congested areas where parking spaces are expected to disappear as AVs do not need to stay at the customer destination, i.e., either AV can return to the specified places or roam through the city. An average vehicle is parked 95 percent of the time and the lot of expensive urban space is dedicated to parking, especially in the busy areas. The study also shows that a reduction of 90 percent in parking areas is possible due to this technology [10].

1.4. Noise and light reduction: Electric engines can reduce the noise emissions at lower speeds. This noise reduction may increase the building of roads near the residential areas thus reducing the travel distance. But on the other hand, the cost of the land close to the highways may also be increased. Similarly, AVs depend on sensors which may not need light to see the surroundings as human drivers require. Therefore, it will be possible to build tunnels and similar structures without lights to reduce the light emissions and save electrical energy [12-13].

1.5. Fuel efficiency: The studies by the Eno Center for transportation have derived that self driving car technology could reduce fuel consumption of the cars by regulating the driving manner since everything is automated. The study finds that fuel economy from 23 to 39 percent is possible with smooth traffic, i.e., by minimizing braking on the highways, which is possible by integrating AV technology with V2V and V2I communications. This will also depend on the efficiency of the traffic smoothing algorithms. However, these and other analysis still do not have an exact measurement that how much fuel consumption will be achieved as it will really depend on the market share of this technology and number of other factors [12-14].

1.6. Congestion mitigation: AVs may reduce the energy wastage of the traffic by improving the traffic flow, and consequently also reduce accidents frequency. Schrank estimated the fuel wasted in the U.S every year due to traffic since 1982, and found that the fuel wasted due to traffic congestion rose steadily from 0.5 percent to 1.8 percent from 1984 to 2005, and it is expected to reach 2.6 percent by the end of the next year, i.e., 2020. Based on this study, if other factors remain the same, then approximately 4.2 percent of the fuel would be wasted due to congestion till 2050. Overall, a complete elimination of the congestion by using smart cars might decrease the energy intensity by about 2 percent today, and a little over 4 percent till 2050 [12].

1.7. Automated Eco driving: Eco driving teaches us how to reduce the fuel consumption without changing the vehicle design. The energy consumption can be reduced by running the engine at its most efficient operating points, i.e., high load and moderate speed. Another practice is to minimize braking as braking increases the energy wastage. Similarly, training the drivers is also the part of Eco driving. The study showed that driver's training, i.e., teaching optimal acceleration and deceleration brought a reduction in the energy consumption from 0 to

26 percent. However, without regular reminders, the drivers who took an Eco driving course stopped following efficient ways with the passage of time. Another study found that average savings are about 20 percent in the short run and about 10 percent in the long run. Similarly, another study found that in heavily congested conditions energy consumption can be reduced about 35 to 50 percent by using optimal driving. However, a driving cycle has to optimize keeping in view the legal constraints (e.g., speed limit) and maintaining the required travel time. More energy consumption can be seen especially in urban areas which have more frequent stops. AVs have the ability of Eco driving due to their ability to acquire current traffic and road conditions [12].

1.8. Impact on city planning: The increased automation will change the phenomena of planning and building the cities in the future. There will be removal of most of the traffic signs, lights, and parking spaces, etc. But on the other side, more parking spaces are needed for picking up, and dropping off customers especially during any public event. Therefore, connected cities will emerge by managing traffic data for the efficient flow of the traffic, i.e., intelligent traffic lights working with the current demand on the roads, automated crossings with no traffic lights, etc. There will also be mobile car charging facilities distributed all around the city, and/or charging the AVs by using electric field Street while driving [13].

1.9. Clean vehicle technologies: The reduction in the accidents will provide a cushion to the manufacturers to build lighter vehicles. With light weight vehicles, there is a possibility of weight reduction up to 20 percent in the vehicles, and every 10 percent reduction corresponds to a six to seven percent reduction in the fuel consumption. This reduction in weight can be further used to improve batteries or hydrogen fuel cells for clean vehicle technology, i.e., Nissan Leaf battery weighs 600 pounds. Therefore, with alternate fuel vehicles, i.e., able to self-charge, large climate benefits are possible [14].

1.10. Platooning: Running the vehicles together closely is called platooning, which also helps to achieve fuel efficiency due the cut down on air drag resistance. This is especially attractive for freight trucking on highways for long distances, which may be called as *road trains*. The total fuel efficiency can be from 10 to 20 percent depending on the type of vehicle involved, trip distances [14].However, tight vehicle spacing on roads could cause problems for other motorists.

1.11. Disposal of batteries: Lithium-ion battery waste management would be a great task for the manufacturers also. There should be possibility of re-using or recycling of components of batteries and other manufactured components for electric battery vehicle technologies to reduce the environmental impacts. It would depend on the technology advancement and advancements in membrane and fuel storage technologies [13].

1.12. Travel behavior patterns: The change in the travel behavior due to the AVs might have more effect on environment as compared to social or economical. The greenhouse gas emission might decrease due to the AVs on a functional unit bases, but, it may increase due to the more vehicle miles travelled [13].

Table 2 shows a high-level summary of the environmental impacts (qualitative) due to the AVs.

Table 2: High level summary of environmental (qualitative) impacts

Impact	Scale	Importance	Outcome	Advantages/Disadvantages
Gases emissions	Big	High	An overall decrease of the gases emissions	Reduction of the gases emissions, especially if AVs use other renewable energy sources
Congestion mitigation	Small	Medium	Possible decrease in traffic in big cities	Reduction in energy wastage by improving the traffic flow
Infrastructure	Medium	High	Increase in the overall required infrastructure	Extra money requiredto improve the current infrastructure or build new infrastructure
Fuel efficiency	Small to medium	High	Reduction of the use of fossil fuels	Advanced technology of electric machine can have more efficiency
Clean vehicle technologies	Medium	Medium	Ambiguous	Slow charging of cars by using clean energy sources, i.e., solar energy & wind, etc.

Tables 3 and 4 show a high-level summary of the environmental impacts (quantitative) due to the AVs [15].

Table 3: High level summary of environmental (Quantitative) impacts [15]

Aspect	Effect magnitude	Time	Notes
Fuel economy	+100% - +1000%	By 2050	Can be achieved by vehicle weight reduction
Fuel demand	-91% - +173%	90% AVs penetration	Based on different cases taking to account all possibilities
VMT	+9%	90% AVs penetration	That is also given for low market share
Fleet size	-42.6%		
Energy use	-12%	Fleet is all shared AVs	AV compared to the average light duty vehicle
GHG	-5.1%		
Fleet size	-66%	Fleet is all shared AVs	Does not depend on Energy only output

Table 4: High level summary of environmental (Quantitative) impacts [16]

Aspect	Decrease	Little decrease	No change	Little increase	Increase	Uncertain
VMT	1.3%	12.1%	17.8%	28.7%	29.3%	8.9%
Energy use	3.2%	41.0%	16.7%	28.2%	3.2%	7.7%
Walking and biking	0.0%	14.6%	53.5%	26.8%	0.6%	4.5%
Congestion	4.4%	34.2%	27.2%	19.0%	7.6%	7.6%
Pollution	5.8%	45.5%	26.9%	14.7%	1.9%	5.1%

Figure 3 shows a percentage of energy consumption changes due to the vehicle automation [12].

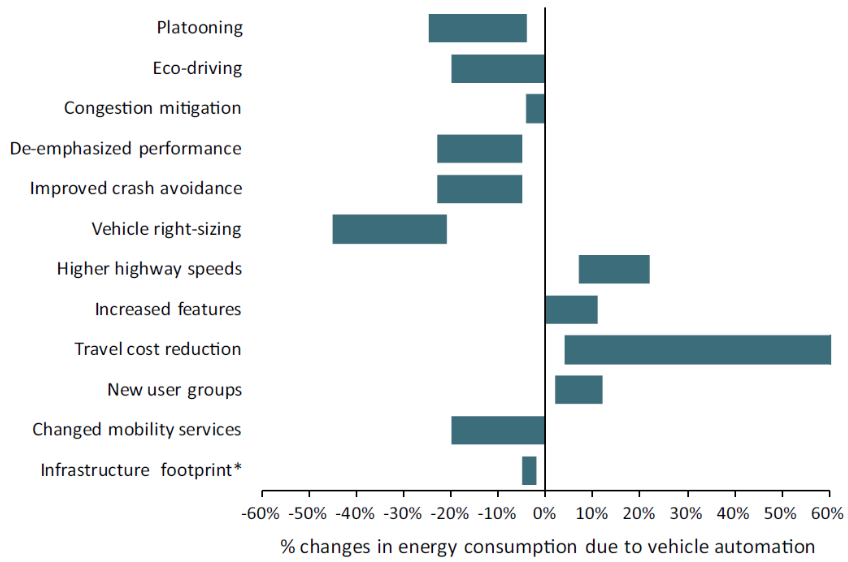

Figure 3: Percentage of energy consumption due to vehicle automation [12]

The economic aspects of the smart cars are described in the next section.

2. Economic impacts

2.1. Impact on car industry: Autonomous vehicles will have significant effects on auto industry due to the current developments, i.e., electric vehicles, increasing automation, artificial intelligence, car sharing, and on demand culture, etc. This technology will change the whole scenario that how cars will be manufactured, used, maintained, and how the legal issues (liability and insurance) along with the ethics will be answered. With this technology, the maintenance of the car would be done in traditional car workshops, or with a large scale service operator, or the car manufacturer has to provide the maintenance due to the complicated technology. As AVs will be able to discover the failures by themselves and drive the cars to a workshop, it will also cause the closure of the small garages. Therefore, the auto industry needs to do more accurate work in order to maintain a stable economic situation and keep its lead in the industry; otherwise any new company will take over the market [17].

2.2. Impacts on logistics: The autonomous vehicles can have a big impact on the cost delivery of goods. It is estimated that the current supply of goods will increase at least three times till 2050. The wages of the drivers generally contribute up to 30 percent of the total cost of the supply. By using AVs, this amount will be saved with an efficient and on time delivery of goods as AVs do not need rest like drivers. However, the number of jobs will be reduced in logistics by using this technology [10].

2.3. Changes in vehicle miles traveled (VMT): The study shows that VMT per AV will be 20 percent higher than regular vehicles when there will be 10 percent market penetration and 10 percent higher when there will be 90 percent market penetration. The additional VMT increase may be realized if travel costs and congestion is reduced. However, Fagnant and Kockelman undermine this analysis [18]. Another study finds that a fleet of shared AVs in Texas, serving more than 56,000 trips a day, was found to travel 8.7 percent more in the empty area. This number reduced to 4.5 percent and less than 1 percent when the demand rose by a factor of 5 and ride-sharing was permitted. Similarly, various studies show that each AV could serve the same number of trips as 10 privately owned vehicles if all traveling lies within the 12 to 24 miles Geofence. Although, the ratio from 10 to 1, may be too high, especially in rural areas and areas with longer distances [18-20].

2.4. Revenue collection and vehicle ownership: Smart cars have brought a revolution in the auto industry. Business Insider expects that approximately 380 million smart cars will be on the road till 2020 bringing total revenue of around 8 trillion dollars to the governments. This revolution has also brought different changes in the business market finishing the traditional concepts such as taxi business, i.e., even a blind person will be able to communicate by using hundred percent drivers less cars. Similarly, the study shows that till 2030 car ownership will fall by 80 percent in the United States, as AVs can be owned and used by the individuals, the families, the investors, or the public collectively [20].

2.5. Discount rate and technology costs: The technology is evolving rapidly, but many things are still not certain even the cost. A study found ten percent discount rate with respect to the net present value calculation, which is even higher than the 7 percent rate required by the federal Office of Management and Budget (OMB) for federal projects and TIGER grant applications in USA [19]. The research finds that an additional 10,000 dollars would be required to purchase AVs (around seven years) when there will be 10 percent market share. However, the research assesses that the price would be reduced to 3000 dollars when market penetration will reach up to 90 percent. The researcher also assumes that the return rate would be equal to 37, 500 dollars, which is closer to the added AV technology. Similarly, Shchetko (2014) finds that LIDAR systems are the most expensive parts of AVs. In order to make affordable, future AVs should use non-LIDAR sensors, or LIDAR prices must fall [18,20].

2.6. Impact on travel cost: The study finds that shared AVs can be operated at a price of 0.42 to 0.49 dollars per mile which is almost the same as the today's car sharing services. Similarly, another study finds that shared AVs with at least 2 passengers will be competitive with mass transit till 2035. The same study shows that AVs are expected to become cheaper than other means of transportation as technology will grow. This will change the customer approach towards traveling mode, i.e., cost awareness will increase as per distance or per duration approach will evolve. This will also increase the understanding of the costs of travel as compared to today [10, 19].

2.7. Vehicle cost: Cost is always an important factor and it depends heavily that how much will be the cost of using an AV. The study shows that the average willingness to pay (WTP) for AV technology is 7253 dollars from 0 to level 3 automation. People are ready to pay another 5551 and 4589 dollars for additional level 4 and 5 automation. Mosquet (2015) finds that people are also ready to spend another 5000 dollars to add AVs features in their regular cars. With advancement in the AV technology and large scale productions promises will make AVs more affordable over the period of time [18, 20].

2.8. New business opportunists: It is worth to talk about the idea of not buying a car. With smart cars, new concepts of businesses are penetrating in the market and they might destroy traditional concepts. One of these ideas is to rent a smart car for some time using an application. The user can select a car with its specifications, and the car will come to the house door. Then the user can simply leave the car anywhere and it will go back automatically. This will create a new business concept and finish the others, such as taxi or Uber driver [10].

2.9. Employment issues: Highly skilled labor will be required in science and technology to design, build, and continuously improve the technology. On the other hand, low skilled workers and routine labor in the private sector will be highly affected, i.e., drivers and technicians, etc.

Table 5 shows a high level summary of the economical impacts (qualitative) due to the AVs.

Table 5: High level summary (Qualitative) of economical impacts

Impact	Scale	Importance	Outcome	Advantage/Disadvantages
Auto industry	Big	High	Ambiguous	Ambiguous
Other businesses	Medium	High	Ambiguous	Possible opportunities of new business
Employment	Medium	High	Possible reductions of employments in different sectors	High technology jobs will increase
Vehicles miles traveled	Medium	Medium	Ambiguous	Ambiguous

Table 6 shows a high-level summary of the economical impacts (quantitative) due to the AVs [21].

Table 6: High level summary (Quantitative) of economical impacts [21]

Aspect	Industry revenue ($B/yr)	Industry Impact ($B/yr)	% change in industry	$ per capita per year
Automotive Industry	$570	$42	7%	$132
Electronics and software	$203	$26	13%	$83
Auto repair	$58	$21	36%	$66
Traffic police	$10	$5	50%	$16
Infrastructure	$169	$8	4.4%	$24
Freight transportation	$604	$100	17%	$313
Personal transportation	$86	$27	31%	$83

Similarly, Figures 4 and 5 show different quantitative impacts on economy due to AVs [21, 23].

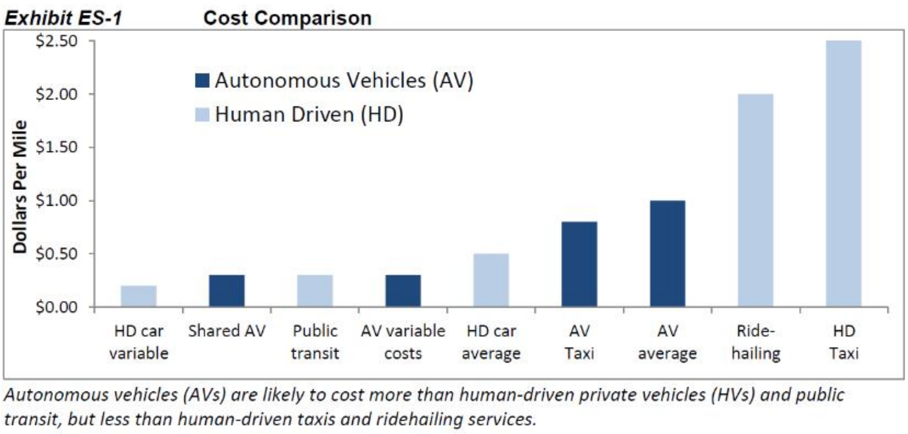

Figure 4: Cost comparison between AVs and Human driven vehicles (Dollars per mile) [22]

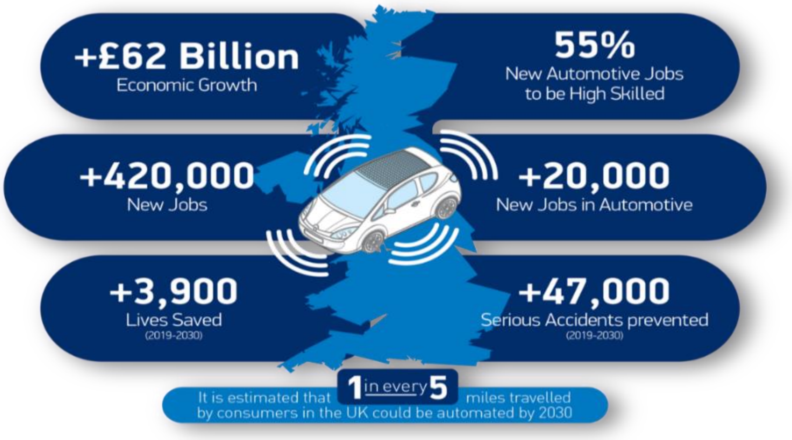

Figure 5: Different quantitative impacts on economy due to AVs [23]

The next section describes the safety/security impacts of this technology.

3. Safety and security impacts

3.1. Recent smart car accidents: In May 2016, a driver was killed while driving a Tesla Model S smart car on the autopilot system [24]. A truck was crossing the highway and the car crashed into the side of the truck. The investigation revealed that the Tesla autopilot system did not recognize the white side of the truck against the bright sky. It was also found that there was no defect in the design or performance of the Tesla autopilot system, but the sensor did not work under the bright sky. This accident highlighted that a constant attention of the driver is required, and the driver must be in a position to take control of the car in emergency situations. Similarly, a woman was killed by an Uber smart car in the street of Arizona [25]. This was the first accident between a smart car and a pedestrian in the US. The driver was inside the car, but the car never generated any alarm for the driver to take control. In other words, smart car failed to detect an object or moving object, or failed to distinguish between the stationary and the moving objects. Similarly, the Tesla smart car got another fatal crash when it failed to detect the stationary object and crashed into a concrete lane divider and burst into flames. The driver died in the hospital [26]. These accidents highlighted that these smart cars are still not ready for a safer drive under all weather conditions, so safer and more secure algorithms are needed.

3.2. Passengers and non-passengers safety: Road crashes cause nearly 1.3 million lives every year, along with 20 to 50 million injuries/disabilities. Since 2014, AVs have 34 reported accidents on the California roads. Auto experts believe that there will be at least 500 million smart cars on the roads till 2025. International study indicates that human error accounts for more than 90 percents of the crashes, including 10 to 30 percent user distractions or inattention.

This does not mean that drivers are the only cause of accidents, but it indicates that human error is one of the main dominant factors in road crashes. AVs have the ability to reduce or eliminate human errors, i.e., enhancing road safety, and minimize accidents. The safety benefits of AV also extend to other road users, i.e., pedestrians and cyclists, since level 4 and 5 AVs have the ability to detect the objects and take necessary safety actions automatically. Therefore, the social acceptance of this technology heavily depends whether AVs are safe or not [22, 27, 28].

3.3. Cyber security: AVs depend on a wide array of electronics, sensors, and software components which are vulnerable to cyber attacks. Cyber security vulnerabilities could not only risk physical safety, but also compromise sensitive personal data. There can be physical threats, software failures, denial of service, eavesdropping, hijacking, malicious code, identity fraud, etc. These threats can lead to smart car compromising with the users needs of security and safety.It is the responsibility of the governments, the industries, the public, and the private sectors to work together to protect the end-user from the cyber attacks. Many such attacks have already happened, i.e., Charlie Miller, and Chris Valasek made a remote attack by taking control of a jeep and sending it off the road and forcing 1.4 million cars to be recalled; the hackers hacked the BMW connected drive car and managed to remotely unlock cars with a recall of 2.2 million cars and attacks on the Volkswagen cars recalling about 100 million vehicles. Similarly, a recent attack on Tesla electric car resulted in software updates for the car operating system [29]. Therefore, the cost of cyber security is becoming a critical issue for the car manufacturers beside reputation damage. These threats have critical impacts on the security, safety and the privacy of the drivers, passengers, and everyone traveling on the road. With the advancement of technology, these attacks are also likely to increase [30]. Robust security measures are necessary to ensure public confidence in automated technology in order to provide confidence that cyber security risks are being controlled or mitigated.

3.4. Legal issues (liability and insurance): The study shows that human mistakes were a definite or probable cause of more than 90 percent of vehicle incidents [31, 32]. The deaths on the road could be reduced by 90 percent by using this technology, as AVs do not drink, do not take drugs, do not use mobile phones while driving, and do not involve any other reckless activities like humans. However, technology is not perfect, and it is still likely that accidents will occasionally occur due to the failure of technology, human driver car interface, maintenance, or other factors, etc. There is a big debate in the case of accidents that who will be liable, i.e., drivers, or cars? Similarly, who will pay for an accident, drivers, or car manufacturers, especially when there is a system failure? This would ultimately create the ethical dilemma of finding out who is responsible for the accident, and moral decisions might be taken based on the information from the artificial intelligence based algorithms. Similarly, the smart cars are fuel-efficient, but insurance might be high as compared to today's cars especially for the electric version. Insurance rates for electric vehicles can be 21 percent higher as electric cars tend to be more expensive and have expensive repair cost, i.e., trained workers are needed to do work on expensive battery systems. Therefore, the concept of car insurance will change altogether from what we see today. Insurance rates will be decided more with respect to the risk profile of the vehicle than the risk profile of the driver, which is the reverse of what we see today [33].

3.5. Privacy and data: Due to the IoT, smart cars will generate lots of valuable data which will provide new information and services to consumers with a range of applications, e.g., travel information, planning and decision making for infrastructure, traffic management, remote diagnostics, maintenance, continuous improvement of automated driving features, accident investigation, and determining faults, etc. This data will benefit the consumers, the manufacturers, and the government agencies. Some of the data generated by an automated vehicle could be personal data. There are public concerns that who will collect/store this data, and how manufacturers, governments or other corporations will use this consumer generated data. One of the concerns is that the automated vehicles might have an accurate satellite positioning capability, and could also map the location history. There is also a risk that cyber attacks could expose personal data into malicious, or improper use if data reaches in the hand of terrorist organizations, hackers, disgruntled employers, and hostile nations, etc. In order to build the confidence of the public, the personal data must be safe in order to make it compatible with the community expectations [27].

3.6. Enhanced safety measures: Whenever a driver will lose his attention while driving, the risk of accidents will increase, which can be minimized by the use of fatigue detection system of the smart cars. The smart car analyzes the way in which driver uses the smart cars and performs certain functions, i.e., use of the steering wheel, accelerator pedal, brakes, etc. This enables the smart cars to understand that whether the driver is tired, distracted, drunk, and even nervous. Therefore, whenever there will be a change in the behavior of the driver, smart cars will activate an alarm for five seconds. If the driver does not take rest within fifteen minutes following the alarm, the alarm will be activated once again. It will ultimately minimize the risk of accidents [33].

3.7. Level 5 automation: Smart cars with Level 5 automation would eliminate driver stress, distractions, recklessness, and risk taking behavior which causes accidents. However, there will be accidents as smart cars will interact with other cars. The system failures and sudden breakdowns in smart cars would be the major cause of the road accidents. This thing is more critical as we are moving towards the deployment of level 5 automation. However, the safety of higher levels AVs on the road remains untested on a large scale, and may not be available immediately.

Table 7 shows a high level summary (qualitative) of the safety/security impacts

Table 7: High level summary (qualitative) of the security/safety impacts

Impact	Scale	Importance	Outcome	Advantage/Disadvantages
Safety/ security	Big	High	Ambiguous	Human error is reduced but still the abilities of the AVs for perfect driving is still low
Privacy	Medium	High	Privacy level will be reduced	More comfort but less privacy can be a good point for some people and bad for others
Legal issues	Medium to high	High	Complicated legal issues will arise & companies will be more responsible (product liability, etc)	Legal issues between people won't be only personal like before

Table 8 shows a high level summary of the safety/security impacts (quantitative) due to the AVs [17].

Table 8: High level summary (quantitative) of the security/safety impacts

Factors	Scale
Total Crashes per year in U.S.	5.5 million
% human cause as primary factor	93%
Economic Costs of U.S. Crashes	$300 billion
% of U.S. GDP	2%
Total Fatal &Incurious Crashes per Year in U.S.	2.22 million
Fatal Crashes per Year in U.S.	32,367
% of fatal crashes involving alcohol	31%
% involving speeding	30%
% involving distracted driver	21%
% involving failure to keep in proper lane	14%
% involving failure to yield right-of-way	11%
% involving wet road surface	11%
% involving erratic vehicle operation	9%

Similarly, Figures 6 and 7 show different quantitative impacts on safety/security due to the AVs [34, 35].

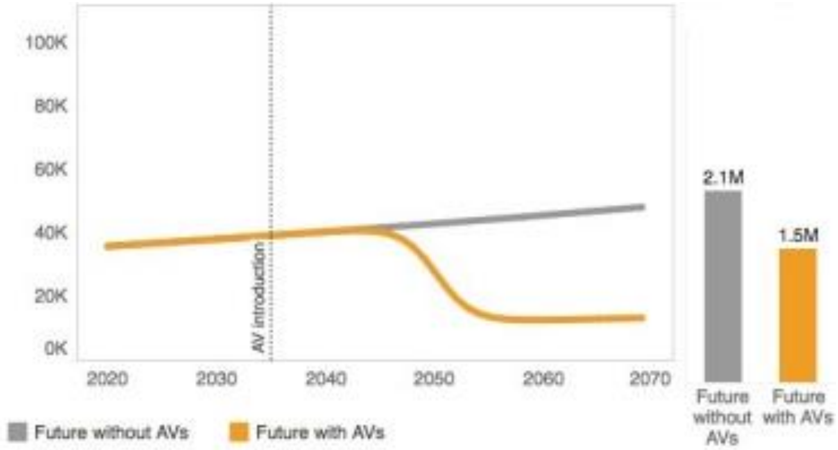

Figure 6: Number of fatalities comparison [34]

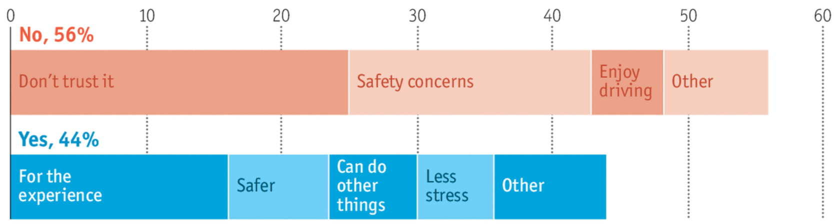

Figure 7: Trust on AV (a survey) [35]

The next section describes the social impacts of this technology.

4. Social impacts

4.1. Impact on mobility: Autonomous vehicles will have a huge impact on the mobility due to the comfort, convenience, and possibility of doing other activities while traveling. This will increase the number of trips which will turn into overall traffic congestion. Moreover, whenever there is an accident on the road, the flow of the traffic is disrupted, but AVs are expected to reduce the accidents up to 90 percent. With fewer accidents, it is also expected that the flow of traffic would increase. Similarly, the new developed infrastructure will provide more facility to the smart cars to travel easily and it will also increase the traffic. The public transport is also expected to vanish, or reduce as one bus will be replaced by many cars. The totality of many cars will also add to the flow of traffic. On the other side, an increase in the traffic might also cause the congestion and lower travel speed on the roads. However, it is still not clear whether all these things will really increase the traffic flow or will have adverse effects. It heavily depends on the characteristics of the AVs as it is not clear whether AVs will really drive faster as we expect or it will be slower. However, all studies generally agree that smart cars will increase the vehicle kilometer traveled [36].

4.2. Accessibility and commutation: The smart car technology will provide people new opportunities and huge ability to do many new things especially in cities. The technology will provide mobility to new user groups (blind, old, physically disabled, or people without driving licenses, etc.), will avoid fixed schedules, and will offer pick-up services at any location, etc. Therefore, AVs will provide an easy and independent access to those people who are always depending on others for commutation. Another major benefit will be the availability of transportation from the last stop of a public transit facility to people's homes, or work places especially for older and disabled people. This will ultimately increase the demand, but it might also slow down the traffic. However, an increase in the AVs would only be possible with advanced infrastructure which will be a great societal benefit also. The expected advantages due to the accessibility should be carefully examined keeping in view the expected loss due to congestion. Changes in behavior and decision making should also be considered due to increased accessibility [10, 19, 22].

4.3. Impacts on work organization: In today's fast paced life, allowing more flexibility in choosing work timings is another source of the connected society. With this technology work can also be done while traveling. This is particularly good for the business sector, which depends heavily on their employees who have to travel longer distances to reach the workplace. In this way, the number of workplace options for an employee is increased, and longer distances to the workplace are also tolerated. This facility can also urge upon the people to live far away from the urban areas, and also provide a facility for the companies to move out from the center of the cities to the suburban area to reduce their expenses [10, 19, 22].

4.4. Impacts on user profiles: One has the choice of high flexibility with his own non-AV private car, but he has to buy a car, pay insurance, bear garage expenses, parking costs, and fuel, etc. Even after bearing all these expenses, one cannot utilize his time in the car productively. Public transport offers more transparent pricing, i.e., weekly or monthly passes. However, the defined set of routes and fixed bus stop locations are also some of the major disadvantages. Therefore, the choice of a private car or public transport can always be seen as a question of availability. Similarly, an individual trip can be made by a car sharing facility with payment, but above mentioned problems can only be reduced in an urban environment. It is expected that car sharing would not produce great success in remote areas [10, 19, 22].

4.5. Smart assistance: Smart cars will gather all information about every driver. It will identify the driver using smart camera and will adjust the settings, i.e., seating, air conditioning, radio frequency, routes, and mirrors to the driver preferences, etc. The driver can also authorize the vehicle for another individual. Furthermore, the smart assistant will also organize the calendar and timetable, determine the optimized routes and stops according to the current traffic, and so on. In this way, smart cars will minimize the risk of the loss of attention and will reduce the accident risks by storing the data about habits [17].

4.6. Better travel management: Through connected vehicles, drivers will receive advance information about traffic, which will enable people to reschedule, postpone, or cancel their journey, etc. Travelers may decide to avoid busy roads, take alternative routes, or use public transport or reschedule their journey. All these options will make the travelers become more fuel efficient and environmentally friendly. People can also move to the public transport, which will reduce greenhouse gas emissions resulting in a significant reduction of fuel consumption, reduced traffic congestion and improved air quality [37, 38].

4.7. Tax issues: Government revenue would decrease by less collection of money for different penalties, i.e., speedy tickets, towing fees, etc, which happens due to human error. The government may impose additional taxes on auto sector, insurance, operators, manufacturers and aggregators to recover the lost revenue opportunities [48].

4.8. Land use patterns: Due to the car sharing and a decrease in the travel cost may reduce the population burden on the cities. People who can afford to buy AVs would prefer to live in suburbs, which may also increase their commutation. However, whether the urban density would increase or decrease would be realized exactly over the longer period of time. [17]

4.9. New driving experience and Public transport reduction: Smart cars will have the ability to interact with the drivers to understand their feelings, and analyze how they are behaving based on some patterns, facial expressions, way of braking, acceleration, drifting, and even the type of music the driver is listening to, and let the car act based on these inputs. Therefore, a smart car will be a secretary for the driver, arranging his appointments, listing his groceries, and driving the car on his behalf while he is not willing. The smart cars will also provide health supervision and safe drive. These things will not only increase the comfort, but will also affect the quality of the lifestyle and the driving experience will be different. Similarly, if huge investment is done in this sector, it can also have a negative effect on the other transport services especially the public transport. AVs may replace the public transport, and it would have an immediate effect on the people with low income, and having no personal transport [39].

4.10. Trust: AVs cannot get a widespread adoption until unless it is assured a trustworthy technology. As many complex systems are involved in the operation of an AV, i.e., GPS, map data, external devices, other vehicles information other than sensors, hardware, software, etc. The question is that how much trustworthy are these different systems?

Table 9 shows a high level summary (qualitative) of the social impacts

Table 9: High level summary of social impacts

Impact	Scale	Importance	Outcome	Advantage/Disadvantages
Mobility	Big	High	Mobility will increase	More comfort, convenience, and possibility of doing other activities while traveling.
Work organization	Medium	Medium	Good for the business sector	Work can also be done while traveling. More choices for time investment
Better travel management	Medium	Medium	Travel management will improve	Will enable drivers to reschedule, postpone, or cancel their journey, etc., based on advanced information's
Land usage	Medium	Small	Ambiguous	Due to the car sharing, and a decrease in the travel cost may reduce the population burden on the cities.

Table 10 shows a high level summary of the social impacts (quantitative) due to the AVs [16].

Table 10: High level summary (quantitative) of social impacts

Aspect	Decrease	Little decrease	No change	Little increase	Increase	Uncertain
Employment (overall)	0.6%	6.4%	52.9%	26.8%	1.3%	12.1%
Employment (transportation)	7.1%	29.5%	30.1%	24.4%	0.6%	8.3%
Cars on road	3.2%	32.3%	25.9%	22.8%	9.5%	6.3%
Segregation	0.6%	12.8%	53.2%	17.3%	4.5%	11.5%
Transit ridership	5.1%	35.7%	27.4%	18.5%	1.9%	11.5%
Equity (mobility)	2.6%	21.8%	28.2%	32.7%	7.1%	7.7%

Similarly, Figures 8 and 9 show different quantitative impacts on social due to the AVs [40, 41].

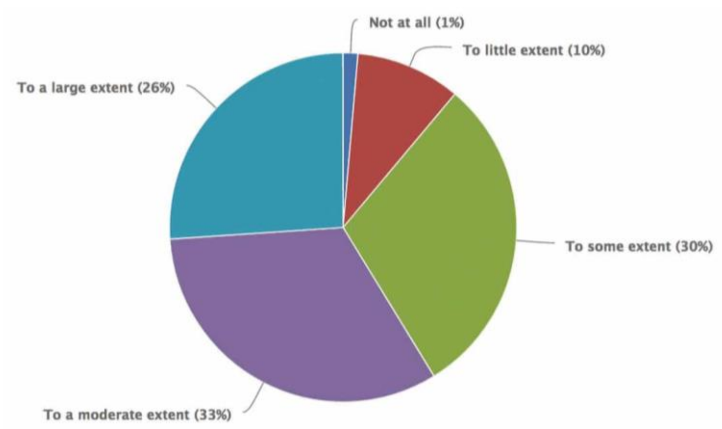

Figure 8: People trust on AVs [40]

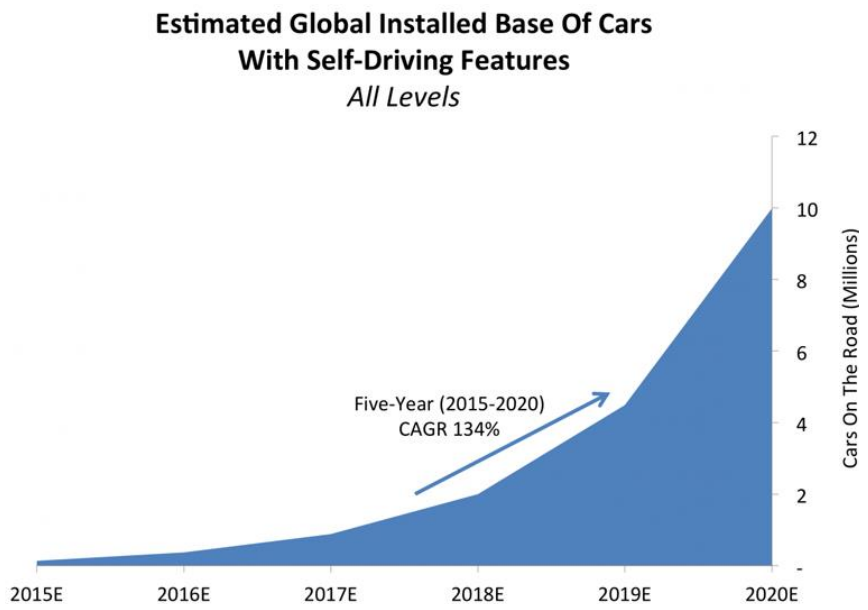

Figure 9: Number of cars with AV features [41]

Previous sections have shown clearly that the autonomous vehicles will have huge impacts on our life and society. There are still many areas in which the outcome of the AVs is also ambiguous. The next section discusses about the challenges and issuesof the AVs.

5. Challenges/barriers of the AVs

5.1. Hardware technology (current developing pace and issues): Hardware technology will determine how quickly the smart cars will be on the road especially level 5 AVs. The innovations in this technology will deliver the required computational power, i.e., graphics and central processing units (GPUs/CPUs). In fact, the hardware technology is already approaching the levels required for well optimized AV software to run smoothly. With the current advancements, the vehicles that adhere up to level 4 automation will probably hit the market in next five years. Sensors have the required range, resolution, and field of vision, but still have significant limitations in bad weather conditions. Radar technology is ready, and has the capability of detection in rough weather and different road conditions. Similarly, the LIDAR system is offering the best field of vision at high levels of granularity. Currently, these equipments are expensive, but inexpensive devices will be commercially available soon after the technology improves. Several high tech companies are claiming to have developed less expensive LIDAR, i.e., within 500 US dollars, but companies still need to understand the optimal number of sensors required for commercial purposes especially for level 5 automation. The technology has been tested in certain feasible conditions, but verifying it under every kind of situation/condition (unmapped areas, or with significant infrastructure/environmental features, etc.) might take years to ensure complete security and safety. Tuning the system, especially for level 4 and 5 automation to operate successfully in any given situation needs more time and technical expertise [3, 42]. Finally, which technology will be used in the automated vehicles for perception, localization, and mapping is also one of the critical aspects. One approach uses radars, sonars, and camera systems to observe the environment. These devices require less processing power, but they do not assess the environment on a deep granular level. The second approach uses LIDAR system with radar and camera and it is more robust in heavy traffic situations, i.e., provides granular, and high definition (HD) maps, but needs more data processing and computing power. Therefore, experts believe that LIDAR technology will be the technology of the future AVs [44].

5.2. Software technology: One of the major issues is the development of the reliable software. This is also very important as the normal logic, i.e., IF Then statements are not applicable to smart cars as it will take a lot of time and computational resources to handle millions of conditions (data) that the smart car faces. Machine learning needs lots of data to perform different functions (also shows high performance when a lot of data is available), and smart cars (IoT) deal with huge amounts of data. Therefore, one of the best applications to use machine learning is the smart cars which use huge amounts of data. In order to have a secure, safe, and reliable driving experience, and build a high level of trust in the AV users, the industry must develop and employ highly efficient artificial intelligence based algorithms [45].

5.3. 5G: 5G technologies are expected to highly improve the capacity and data speeds of the wireless networks. It will also enhance and develop the technology of the AVs which needs a high speed network to acquire and process the huge amounts of data. 5G networks have already good coverage in urban areas, but recent studies show that dead zones in rural areas may reduce the smart cars to cities only. Therefore, if there is less investment in the rural areas, than AVs will not be able to travel through highways and in rural areas. This situation will be more prominent, i.e., around 2025, when the number of smart cars will increase in rural areas. Therefore, telecom sector would need to ensure that they can provide reliable connections between the most trafficked highways and rural areas [46].

5.4. Power consumption issue: Power consumption is also a big issue with smart cars. A car with just cameras and radar generates 6 gigabytes of data for every 30 seconds. This data will go higher with additional devices, i.e., LIDAR, cameras, etc. For higher level automation, all available data needs to be processed which will ultimately consume huge computing power, i.e., around 2,500 watts which is enough to light 40 incandescent light bulbs. For lower level automation, on board power requirement increases from 2.8 to 4.0 percent [47]. A smooth and efficient traffic flow will only be possible when autonomous vehicles do not need to recharge themselves after a short interval of time, especially for logistic purpose and highway travel. Therefore, devices should be able to perform data processing quickly and efficiently with less power consumption. Smart cars driving systems provide Eco driving facility, but the computers and sensors can consume enough electricity to negate this green benefit also.

5.5. Regulations: There are civil, criminal, moral, technical, and operator liabilities associated while using AVs. If two self-driving cars crash into each other, then who is liable? Is it the operator sitting idle inside the car or a passenger? Or the manufacturer or supplier or network provider is liable? Similarly, does a special driving license needed for autonomous driving? Does AV have to follow all traffic rules? Or different rules will be needed for AVs? There are a lot of other legal questions around the driverless cars along with these questions, but there are no clear answers. Therefore, lot of legal and legislative work still needs to be done in order to address liability, data ownership and other novel AV problems [43].

5.6. Cost: The hardware technology used for AVs, i.e., sensors, radar, camera, etc., is not very cheap at the moment. Similarly, other high tech experts who are involved in the development of this technology, i.e., software programmer, are also expensive. The auto companies will only be able to sell the AVs at mass level, if it is cheap and affordable to the public, especially to those who need it, i.e., older people, etc. Otherwise it can result into a situation creating a socioeconomic inequality on the roads. Similarly, If the cost drops too slowly, the benefits of the AVs will also not have long lasting effects. Auto analysts believe that the cost premium of an AV should drop by at least around $10,000 to become commercially viable to the end users. At this price, AVs would also be able to make 10 percent market penetration as well, but it may take up to ten years[44].

5.7. Infrastructure: The driverless cars are just only a part of the big picture. This technology needs an established infrastructure to run on it. The auto industry is in dilemma whether to design the driverless cars for existing infrastructure or ask governments to build infrastructure first and then build cars accordingly. Current infrastructure can only handle driverless cars on few designed roadways or changes have to be made, i.e., placing sensors on lane dividers or creating special driverless car lanes, etc [44].

5.8. Ethical problems: Who should be held responsible for the accidents from a moral stand point of view is another aspect of autonomous cars. AVs must make good decisions even in the extreme emergency situations. Is this always possible? It is worth to notice that the engineering problem is substantially different from the hypothetical ethical dilemma. An engineering problem can always differentiate between better and worse solutions, while an ethical dilemma is an idealized constructed state that has no good solution. Therefore, driverless cars need to be designed to be able to differentiate between life and death without human intervention. What a car should do if it has no choice but to decide between killing a rider or a pedestrian? Currently, this kind of situation is rare, but, as the number of driverless cars will increase, these issues will occur on regular basis [17, 43].

5.9. Public acceptance: Public attitude towards AVs are still in the formative stage. It is not yet clear that how much public desire for the AVs. However, the acceptance of the public is directly related to the safety/security, trust and transparency, privacy, better infrastructure, developed regulations, and the cost of the AVs. It is very difficult that a technology is adopted in a widespread manner, especially if it is not safe and secure to use along with other issues. In one of the survey conducted by the Pew Research Center and Smithsonian magazine in USA found that only 48 percent of American would ride on AVs, if they get a chance [17].

5.10. Social challenges: The technology will really effect different occupations and job markets, i.e., taxi/truck drivers, insurance agents, car mechanics, low skilled labor, etc. Similarly, there will be a change in different business, i.e., car manufacturing, etc. Therefore, the government and other organizations must be ready for this kind of situation.

In the next section, this research proposes recommendations in order to address the current and future challenges faced by this technology as mentioned in previous section.

6. **Proposed policy recommendations**

6.1. Funding required at government levels: Car manufacturers and others have already invested heavily for the research and development of this technology. But, still there are many areas in which the effects of the AVs are ambiguous. Therefore, now it is the time for the governments, transport research agencies, planning organizations, and other stake holders to contribute/fund for the research and development of this technology, so that maximum benefits can be taken from this technology [12].

6.2. Regulations required for liability and security/safety: Liability (civil, criminal, moral, technical, and operator liabilities, etc),and safety/security are the substantial barriers towards the wide spread acceptance of this technology. The manufactures and investors will start pursuing this technology more aggressively, if clear regulations regarding these issues are available as early as possible. Liability regulations should be able to assign responsibility in case of accidents. Countries around the world should work together to deal with these legal issues.At the same time, policy makers should also weigh the effects of extra regulatory actions on AVs, which may be harmful to technological advancement[12].

6.3. AVs certification required: There should be a standardized AVs certification process at least at the government level, and efforts should be made to enhance it to the world wide level. Although, the countries like America has already developed broad principles for

AV testing. But, these testing are currently at the state level only. But, there should be a single document for the adoption by all the states, with the possibility of modifications to suit specific local needs. With such standardized rules, AV manufacturers will be better able to meet national and even international requirements. Moreover, such AV certification will also likelyhelp limit AV product liability [12].

6.4. Understanding AVs impacts: There should be contributions (financial, technical, academic, awareness programs, etc)from organizations, auto industry, local and federal governments, and other stakeholders for the better understanding of this new technology to the public. By creating such awareness, maximized benefits can be obtained from this technology, i.e., climate benefits, energy consumption, land use models, etc [12].

6.5. Managing social effects: The governments and policymakers should have a smooth plan for the coupling of this technology with the society. Therefore, there should be clear and strategic solutions from the governments to handle different social effects of the AVs, i.e., providing alternatives to people losing jobs, taking measures to minimize the negative impacts of AVs on the society, etc [12].

6.6. Developing end user trust: The governments/industry should come up with such standards/regulations to provide high level of transparency and make sure that the privacy of the end user will not be sacrificed at any cost.

6.7. Quality assurance process/programs: New quality assurance processes should be developed in order to monitor the quality of smart cars at all level. The quality of components must be checked from hardware to software and during the process of design and development, ethical aspects must be included. How the decisions are made during critical condition must be given a high importance, i.e., quality of decision making, rules following a certain guidelines, ethical principles, etc. Similarly, how the quality will be maintained during life time must be assured for safety and reliability [17].

6.8. Stakeholders and public interests: In order to take care the interests of all stakeholders and public (all groups, i.e., young, old, working disable, etc), their opinion must be taken into account in the process of design and developments. This will make sure that how much freedom can be provided in decision making process, especially in case of critical conditions. This will determine that how much control a human has in context of the self-driving car. Moreover, the dialogue between automakers and public will decide the priorities and choices of future smart cars [17].

The research has highlighted that the safety/security is the biggest issues in the AVs. The society will not adapt this technology until unless this deficiency is not over. Therefore, in the next section, this research proposes new ideas to for the security/safety of the AVs.

7. Proposed solutions for improvements of safety/security of the AVs

7.1. Regulations for beaconing: It is always difficult to understand the behavior of the surrounding, i.e., vehicles, pedestrian, appearance cues, brake lights, or human behavior (moves right while giving a left signal), etc. We propose an idea of using regular beaconing messages to handle this situation. A regular beaconing should be used at all times for communication (V2V, V2N, V2I, V2X, etc) informing others about the current AV location, speed, heading, etc, along with other messaging. Although, AVs are still using beaconing messages, but, existing vehicles and many newly made vehicles do not have any capacity to send and receive beaconing messages. Therefore, these vehicles do not get any kind of alarm in case of any emergency. We propose a solution to this issue that the governments should make such regulations that all newly made vehicles (whether AV or not) and all existing vehicles must install necessary hardware/software to receive and transmit beaconing messages. The cost of beaconing device is usually less than 50 US dollars [44].

7.2. Fusion based sensor technology: AVs fail to perceive the environment, especially, when there is snowstorm, mirrored reflections, fog, rain, fast moving objects around blind spot, etc. Individual radar, Lidar, sensors, and computer vision system, etc., do not work well to perceive environment under complex conditions. The only safest, easiest, and lowest cost solution is to use the fusion based sensor technology (combination of multiple sensors and deep learning artificial based algorithms) to provide a high level safety in the AVs [47].

7.3. IEEE 802.15.4 MAC protocol: For the MAC layer protocol, IEEE 802.11 and IEEE 1609.4 have been used. We propose the use of another low power, less complex, and low data rate protocol, IEEE 802.15.4 MAC (*added and written in red after modification of the original stack*) for less bandwidth hungry applications for communications, i.e., monitoring and control, remote sensing, etc., as compared to those applications which require a high data rate protocol such as IEEE 802.11. In this way, many low data rate applications can be realized efficiently to further improve the safety by deploying IEEE 802.15.4, which has not been exploited so far for the AVs.

Keeping in view of the challenges, the next section proposes a comprehensive layered architecture for the AVs.

Figure 10 shows the protocol stack for AVs [50].

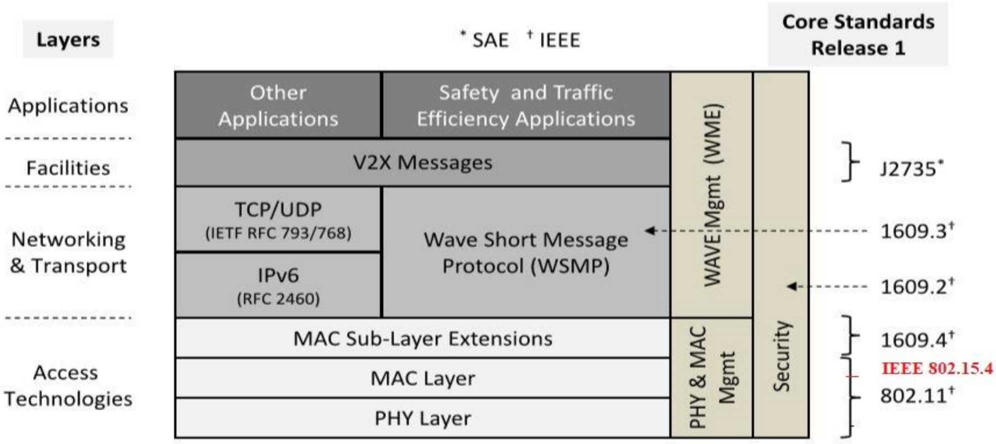

Figure 10. Protocol stacks and core standards for Dedicated Short Range Communication (DSRC) [50].

Proposed comprehensive layered architecture for AVs

Figure 11 shows a proposed comprehensive layered architecture for the AVs [51].

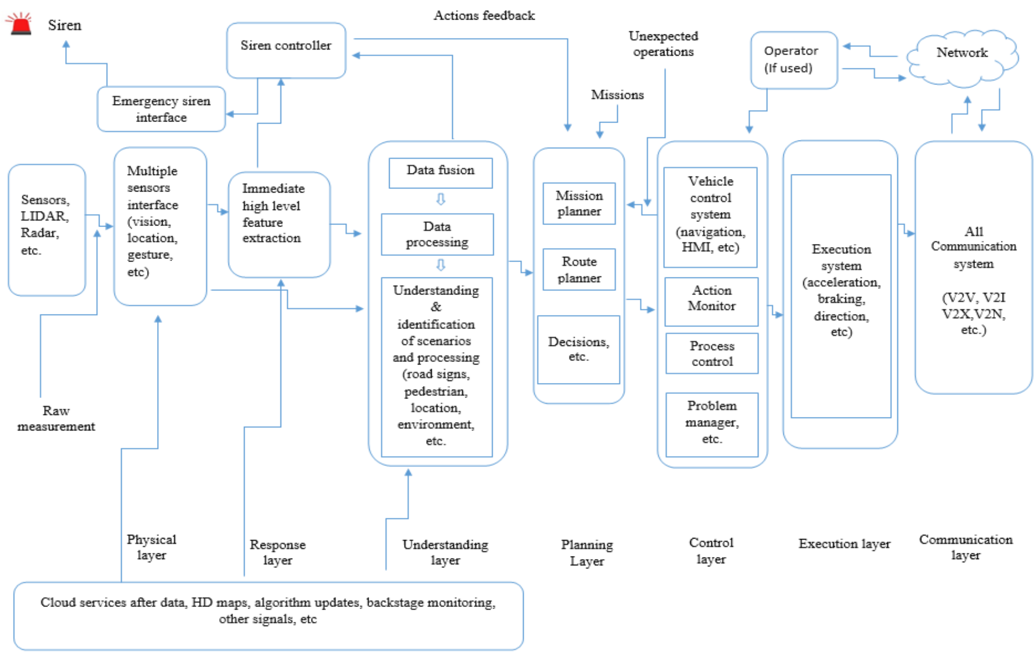

Figure 11. Comprehensive layered architecture for the AVs [51]

According to the architecture, different components can be classified as:

(I) **Physical layer:** This layer will provide a hardware interface with multiple kinds of sensors, i.e., vision sensor, location sensor, gesture sensor, radar, Lidar, and siren interface, etc.

(II) **Response layer:** High level feature extraction will be done at this layer for any emergency action. Deep learning algorithms must be applied at this layer.

(III) **Understanding layer:** Raw data from multiple sensors, and extracted features from the response layer will be fused and processed in this layer to understand the environment, i.e., road signs, pedestrian, location, terrain, environment, etc.

(IV) **Planning layer:** All kind of planning will be performed at this layer, i.e., mission, route, decisions, actions, etc.

(V) **Control layer:** Components in this layer will supervise and control all other integrated systems so that the AV is actually making progress according to the plan and will react in case of any unexpected problem, i.e., faults, obstacles, etc.

(VI) **Execution layer:** Based on the decision from the control layer, this layer will execute the desired actions, i.e., acceleration, braking, direction, etc.

(VII) **Communication layer:** This layer will be responsible for maintaining all kind of communications, i.e., V2V, V2N, V2X, etc.

(VIII) **Similarly,** there can be an operator whether sitting inside the car or outside to control the AVs.

In this proposed architecture, along with fusion based approach, an additional measure has also been proposed for the extra safety/security of the AVs at the response layer. The siren controller at the response layer will receive feedback from the extracted features, and understanding layer, and it will initiate an emergency siren in case of any unusual situation to inform the surrounding vehicles to avoid any accident. This is especially very important in the situations where the time difference between getting watchful of the situation and taking control of the vehicle becomes fatal at certain occasions.

9. Conclusion

This research presents a review of the key impacts of the autonomous vehicle on the society, the environment, the security, and the economy along with recommendations, solutions and a layered architecture. In the first part, the research briefly discusses IoTs, i.e., how IoTs and 5G have enabled the industry to manufacture AVs, and then talks about the working, level of automation, and expectations from the AVs. Secondly, the major impacts of the AVs on the economy, the society, the environment, and the safety are described in detail. The study shows clearly that this technology will have a deep effect on different aspects of our lives, i.e., environment (city planning, gas emissions, fuel consumption, etc.), economy (car industry, logistics, revenue collection, etc.), safety/security (recent accidents, cyber security issues, privacy and data, etc.), and society (accessibility, transportation, jobs, etc.) along with ethical dilemma issues. The study shows that although the technology will have many advantages, there are still definitely many issues with respect to socioeconomic effects. Similarly, in many areas, the impact of AVs is ambiguous. In the final part of this research, current and future challenges/issues of the AVs have been described. Keeping in view that the security/safety is one of the biggest challenges; the research also proposes new recommendations and solutions in order to handle this challenge. The proposed recommendations and solutions provide a comprehensive approach towards the safety/security. With these solutions, the society will be able to adapt the AVs much quickly with full confidence. At the end, the research also proposes a new comprehensive layered architecture for the AVS. The proposed layered architecture provides further special features to provide high level safety and security of the AVs which makes it more safe and reliable as compared to the existing architecture.

Human life is very important, and the study clearly shows that this technology needs a lot of improvements in different aspects, particularly safety/security before humans can have full trust in the AVs. These cars are still not able to predict human movements accurately; the sensors do not work under all conditions, i.e., bright sky (Tesla white truck accident), bad weather conditions, (Uber cyclist night crash), and handling unexpected situations, etc. In order to handle these challenges, the research provides solutions through proposed recommendations, solutions and layered architecture.

The study also highlights the issues with respect to liability and legal challenges to the government and insurance companies. Liability and legal challenges should be defined with respect to both low and high level automation. Similarly, safer and more secure algorithms are needed before these cars can become fully safe to run on the road. Therefore, the research proposes the safest, easiest, and lowest cost solution by using fusion based sensor technology (combination of multiple sensors and deep learning artificial based algorithms) to provide a high level safety in the AVs.

How much this technology will really affect the society is still unclear and uncertain. This is due the fact that the current research is not empirically oriented. Empirical based research will really be able to tell the true impact on the society, the economy, the environment, and the safety, i.e., jobs, social services, emissions, potential shifts in travel behaviors, data management and privacy issues regarding data generation and sharing, gender dimension of autonomous transport, assigning autonomy to artificial intelligence in critical safety situations, and moral dilemmas, etc. Based on the detailed analysis and impacts of the smart cars, it is very clear that until the smart car manufacturers, the vendors, the industry, and the governments do not improve information among themselves, improve exchanges with security researchers, clarify liability among industry actors, and other legal and environmental issues, it will be very difficult for the rapid widespread adaptability of this technology in the society.

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