Global Implications of Human Tendencies Towards Automated Driving and Human Driver Availability in Autonomous Vehicles

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Abstract. In the era of industrial revolution 4.0, an automotive industry flourished in a way that was never before. As different features added in the driver assistance systems time-to-time, hence, nowadays the driving process is not so much tedious as it seems before. This ensures the operation of hassle-free driving, which leads towards autonomous vehicles. Overall, it opens up many opportunities for researchers and business communities, but at the same time, raises concerns and issues for discussion that need to be analyzed before put the final product (here, in the sense of fully automated vehicle) on the road. We conducted an online-survey (N = 3139) with participants from 146 nations was participated and assembled their valuable feedback on the automated driving and human presence in the autonomous vehicles considering all the levels of driving automation. This paper explores the results in terms of useful implications, which highlights and implied us to re-examine the present regulations and policies in automated driving and autonomous vehicles.

Keywords: Automated driving · Autonomous vehicle · Implications · Survey

1 Introduction

Driving is a decision-making process by the humans and factors like stress can cause changes in decisions, reactions, and concentration capabilities [1–3]. And hence, it is substantial to know the people's opinions about what they are thinking about new technologies. We are fortunate enough that the 21st century is coming up with new advanced technology in the automobile sector, widely known as advanced driver assistance systems (ADAS), which has mainly four cognitive decision making tasks [4]: (a) assess the situation, (b) identify the available

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options, (c) determine the costs and benefits (relative value) of each, and (d) select the option of the lowest costs and highest benefits. The vehicles for today are equipped with these new technologies, and owing to that the stress on a human driver is reduced [5]. The levels of driving automation were provided for the first time in 2014 by the National Highway Traffic Safety Administration (NHTSA) [6], which is an operating body of the US Department of Transportation (DoT). It is quite obvious that with the continuous change in the various driving related operations, NHTSA published new driving automation levels in 2016 [7] and 2018 [8].

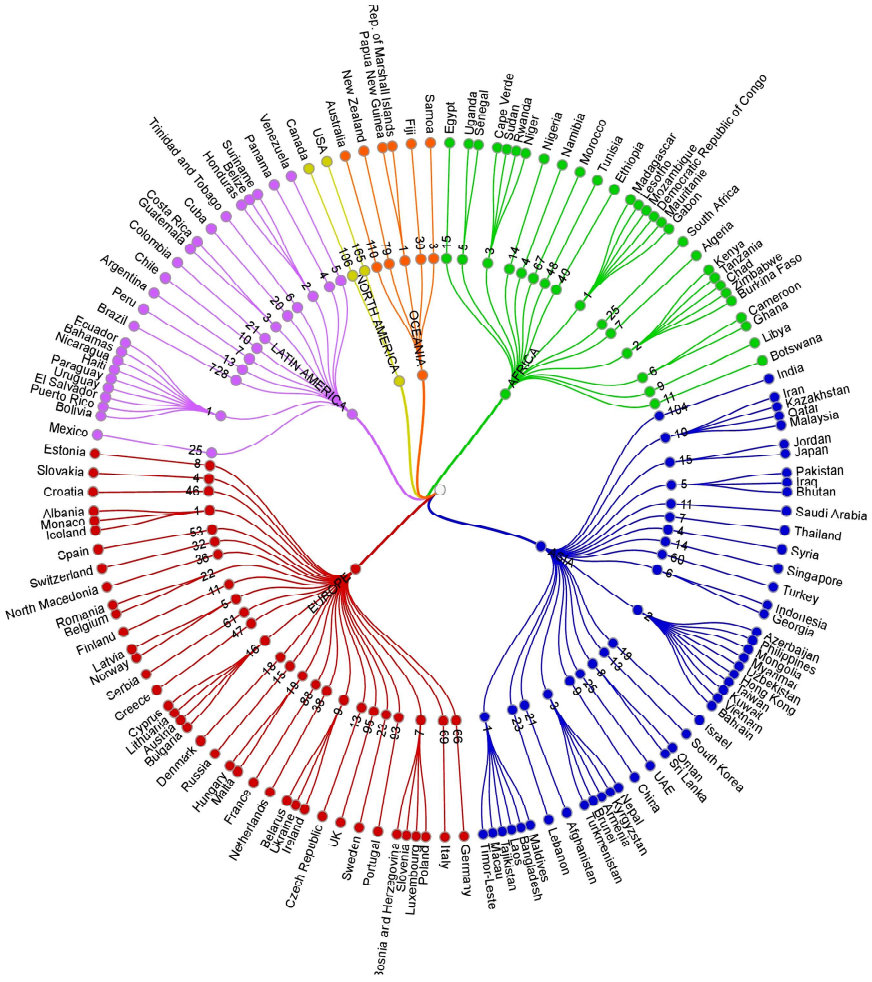

Fig. 1. Continent and nation-wise information of respondents.

This progressive rise of introducing new innovations in the automotive industry was more empowered when the first autonomous vehicle event held in California, USA in the year 2007 [9]. This opened up wings for the new development in the sector, especially as the autonomous vehicle has features like useful in traffic control (e.g. Management of traffic control in an effective way), manage the costs of congestion in urban areas, improve fuel economy, provide a new direction in the future city planning, a boon for people who are physically impaired, among others. The success of the autonomous vehicles will depend on the various factors of social-demographic environment, how the way people are accepted or rejected, whether the regulatory policies are enough to protect the rights of human or not. We should discuss such kinds of many obstacles on the way before putting autonomous vehicles on the road for common use and public transportation.

To date, there is no fully autonomous vehicle available on-road for the service, although the technology level reached a stage where the initial test is carried out by several OEMs. However, there are different acceptance criteria by the people around the globe, as it depends on the various factors. Considering all these modalities, we carried out an online survey (N = 3139, 146 nations worldwide (see Fig. 1)) from 14 February 2019 to 10 July 2019 with two key research questions, and to the best of our knowledge this kind of work is the first time combines the parameters of both automated driving and human driver presence in the autonomous vehicle (for the results of the survey, see Fig. 2).

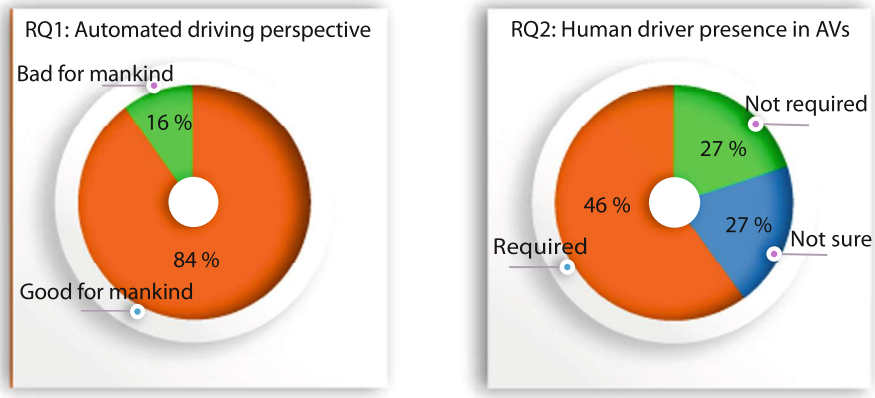

Fig. 2. Results of RQ1 and RQ2.

- **RQ1:** Whether automated driving is good or bad (in terms of reducing the driver stress, technological advantage, etc.) for mankind in a long run?
- **RQ2:** Whether the presence of a human driver is required (considering all levels of driving automation) in autonomous vehicles?

2 Data Analysis

As it is very clear that to investigate the research questions asked, the age and driving experience plays a key role. Hence, in this study we just consider the answers of people with driving experience and with age higher than 18 years old. Furthermore, double responses and in some cases the responses not appropriate (e.g. the difference between age and years of driving experience less than 18) were excluded. Hence, we only consider 2080 responses as useful for further analysis. The data were cross-tabulated and chi-square (χ^2) analyzes were performed to estimate the statistical strength of association between continents, and answers to the research questions. The level of statistical significance is set at *p-value* $< .05$.

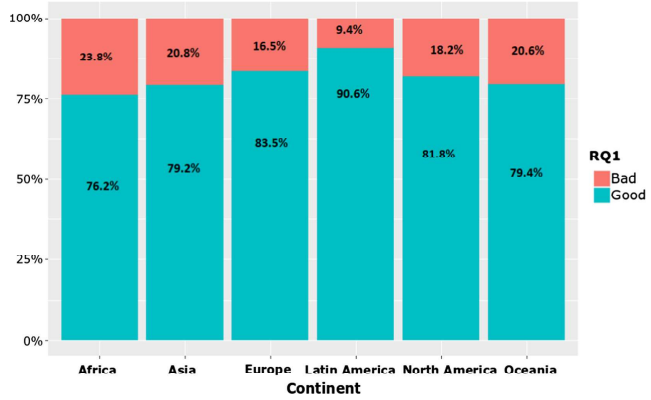

Fig. 3. Percentage of answers to each RQ1 option per continent.

For all continents the proportion of people who answered that automated driving is something good was high (greater than 76%, see Fig. 3). However, significant differences were found for the percentage of answers between the six continents ($\chi^2 = 32.79, df = 5, p < .0001$). While in Africa the percentage was about 76.2% in Latin America the percentage goes up to 90.6%.

Figure 4 presents the percentage of answers to each RQ2 option per continent in two different groups according to the answer in the RQ1("Good" and "Bad"). In the group of 'Bad' answers in RQ1, no evidence of the relationship between continents and RQ2 answer was bound ($\chi^2 = 10.97, df = 10, p = .360$). However, amongst the group of 'Good' answers in RQ1 significant evidence of the relationship between continents and RQ2 answer was bound ($\chi^2 = 60.56, df = 10, p < .0001$). While in Africa 64.9% answer 'Required' and just 14.9% answer 'Not Required', in Europe and Latin America the percentage of 'Required' and 'Not Required' were less than 40% and more than 30%, respectively. Comparing the percentage of answers to each RQ2 option between the group that answer 'Good' in RQ1 and the group that answer 'Bad' in RQ1

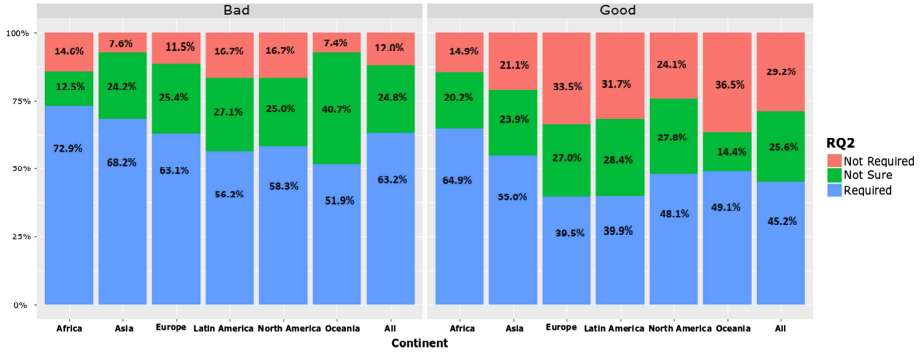

Fig. 4. Percentage of answers to each RQ2 option per continent in two different groups according to the answer in the RQ1 ('Good' and 'Bad').

for all answers, strong evidence of the relationship between RQ1 and RQ2 was found ($\chi^2 = 51.79, df = 2, p < .0001$). In fact, while 63.2% of the group that answer 'Bad' in RQ1 answer 'Required' in RQ2, just 45.2% of the group that answer 'Good' in RQ1 answer 'Required' in RQ2.

3 Implications

The focus of this paper is to explore the new avenues besides the RQ1 and RQ2 in terms of participant's implications (see Fig. 5). It is quite clear how these factors helpful in defining and developing new human-vehicle based technologies for the upcoming intelligent vehicles (or even future 'cognitive vehicles') that cope up with every situation. They also indicate knowledge gaps between diverse areas where future efforts should be carried out.

Our methodology was developed and adopted involving two steps. First, during the survey period, it is based on the discussion with the participants through online platforms, for example, LinkedIn, Facebook, WhatsApp, etc. And secondly, as a collection of viable feedback from the participants. We are quite conscious about not including any policy reports on automated driving and autonomous vehicles produced by the governments or any other organizations as a part of implication.

3.1 Infrastructure

Infrastructure is the entity where physical and digital worlds meet together. For the successful deployment of autonomous vehicles on the road, a dedicated infrastructure facility is needed, which also supports the levels of automated driving [10]. It is split into two categories: (a) physical infrastructure and (b) Information and Communication Technology (ICT) enabled infrastructure.

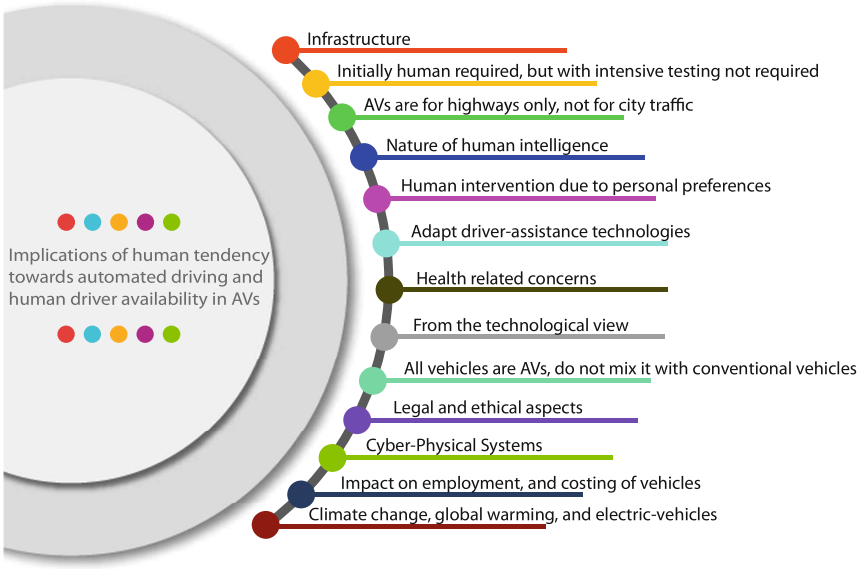

Fig. 5. Implications based on human tendencies towards automated driving and human driver presence in autonomous vehicles.

Physical Infrastructure: Currently available physical infrastructure is designed based on the conventional (non-autonomous) vehicles and somehow considering the human drivers' cognitive abilities. Also noted that building a new infrastructure that will support autonomous vehicles on the road is a little easy about the developing and undeveloped nations as they have to start with scratch compared to developed nations were already having heavy traffic on the road. The pace at which the autonomous vehicle technology developed and achieve the level of penetration will clearly indicate more investment to be needed in the physical infrastructure. Despite the fact that the nature of this infrastructure will be complex, who and how will maintain the infrastructure under which conditions? This means that whether the infrastructure will be maintained by the government agencies or by the vehicle manufacturers or by the other private organizations. A reformed infrastructure includes road markings and signs, enough charging stations in case of electric autonomous mobility, crash barriers, speed signs are among the others. It is also taking care that the visibility of the said steps has to be maintained in all the seasons.

Physical infrastructure must enable and support not only autonomous vehicles, but also different players including pedestrians and cyclists. A key challenge is to have dedicated areas for walking and cycling that will create a liveability, especially in urban spaces. By doing so, guarantees that the infrastructure will cope with the other traffic players and hence allow fleets more efficient along with socially acceptable and safer.

Information and Communication Technology (ICT) Enabled Infrastructure: In addition to physical infrastructure, we have to look after ICT based infrastructure owing to its features including to provide an accurate vehicle localization during the journey, assist a lane-keeping in the case of connected and automated vehicles (CAVs), managing traffic information flows between the traffic management center are among others.

To meet the requirements of rapid improvement and expansion of the current autonomous vehicle technology, a future ICT based infrastructure will be enabled by consistent connectivity between the vehicles and outside partners (e.g. Pedestrians, cyclists, other vehicles, etc.). With the emergence of 5G technology, which assures high-speed data connectivity and downloading facilities, is expected to resolve all the issues of connectivity in the ages of intelligent transportation.

3.2 Initially, Human Required, but with Intensive Testing Not Required

Autonomous vehicles will be a game changer in redefining mobility, at the same time requires a lot of development which ensures the safety at all levels and in all conditions. Just to switch from manual to an autonomous vehicle will solve all the current road problems related to safety is not yet guaranteed profoundly with the present development of technology, for example, the latest fatalities by Tesla [11], and Uber [12]. This will come with a new discussion, whether the reliability of autonomous vehicles defined by the number of miles traveled, and if so, how to calculate it [13].

Considering these situations, currently, a human driver is required for testing and safety point of view, however, as the technology grows up the need for a human driver will subside. A completely cloud controlled traffic system would be much safer and more efficient than any system involving human control. The hard part is the transition phase, in which human drivers are inevitable, but autonomous vehicles need to be able to cope with these factors. It is common knowledge that more than 90% of accidents have been occurring today due to human error. The push for autonomy is to focus on the reduction in the number of Killed and Seriously Injured (KSI) and reduce road-related fatalities. There are multiple other benefits such as reduction or elimination of driver fatigue, freeing up of time spent driving, which could increase productivity or free time, more efficient traffic flows through the cities and optimization of the use of road infrastructure. It is also true that correctly developed and deployed autonomous vehicles could reduce the number of vehicles required if shared use and ride-sharing is promoted in an effective way.

When looking at autonomous vehicles, where we are still in the phases of adapting and learning. Before adopting this vehicle to be a part of our routine life, the software and hardware are well-tested for many levels to avoid any malfunctions. However, in the short-term, there may be a need to build trust, which is one of the challenging parts for the successful deployment of vehicles on the road in a mass volume. Thus, human presence may be seen as a good

way to win trust. Still, how long a human driver required is not cleared yet, and hence it is quite early to tell about the absence of the human driver in the AVs in the near future. Altogether, in the coming time, it is a challenge for the vehicle manufacturers to develop layouts that support both human driver and driverless configurations at least for the next few decades.

3.3 AVs are for (Motorways) Highways Only, Not for City Traffic

The key question with respect to autonomous vehicles is that they occupy the same space as today's conventional vehicles. If so, then it is highly recommended that autonomous vehicles are deployed firstly only on motorways with stronger rules, for example, no human driver car quickly coming on the motorways. This is because of future city centers might be very limited with vehicular transportation in order to give more space for pedestrians and other road users. In these limited-access centers, AVs can be used as a complementary service to some specific areas and tasks. The implementation of fully autonomous vehicles in an urban environment is highly unlikely to occur to a wide scale because of the complexity which lies in the interactions between vehicles for busy city streets, pedestrians, other modes of transport as well as unpredictable behavior of different road users.

3.4 Nature of Human Intelligence

There is no doubt that technological innovations increase productivity, but are they enough mature to compete with human intelligence in all conditions, especially, in the case of road accidents. Despite numerous similarities between accidents, it is not possible to find even two identical events (accidents) in which their parameters are exactly the same. Human intelligence should never be replaced by machines, as there are situations where algorithms are not capable of learning as a human can. Hence, automation is great progress and opportunity to improve drivers' skills, however, that has to enhance the drivers' capabilities not to replace them.

3.5 Human Intervention Due to Personal Preferences

Apart from other technical modalities, people want the control of a vehicle for their hands and not to the machine (here, an autonomous vehicle). This is due to their mentality, routine habits, and at the same time raise questioning the current regulatory and infrastructure concerns. If the system is totally automated and works as a boss, but in some uncertain situations where machines are not capable to anticipate the situation correctly, hence human intervention is necessary to regain the smooth and safe travel as a supervisory agent.

3.6 Adapt Driver-Assistance Technologies

While autonomous vehicles have enormous potential to benefit society, care will need to be taken to optimize these benefits of the whole transport system. Nowadays, automotive majors are rushing into filling the streets with autonomous vehicles predicted to be in the near future, where they compete with each other to prove their technological superiority, rather than cooperating to overcome the existing challenges that still lay ahead. Effort should be spent on driver-assistive technologies, where there is a huge potential to improve and save human lives. We have seen in the last decade that the rapid development and the speed of deployment of different driver-assist technologies in the vehicles is astonishing. This is not only due to only safety concerns, but provide comfort to the driver in day-to-day driving operation, and control the vehicle in an indeterminate state. Today drivers use more than 90% of automatic technologies, in the case of in-vehicle infotainment systems (IVIS) to automatic lane changing and braking systems, while driving to manage the conscious and unconscious state. This way one can travel through quite long periods of time for minimal risk and an optimal amount of mental workloads. It is also observed that the accessibility of the driver-assist systems is increasing day by day, and will continue until the fully automatic vehicles developed which will work in all conditions. We should give surety to make a balance between automation and human intelligence with the effective integration of human factors in the process of design and development of such systems.

3.7 Health Related Concerns

In light of the transition to conventional to autonomous mobility, we should have to take care of health-related issues while and after deployment of the system. If a driver is in a passive role or having no role in active driving due to automated driving, especially considering SAE Level 3–5, over the time he/she forget how to drive a vehicle and will cause numerous health-related issues. The use of autonomous vehicles by very ill people along with their pets will increase illness in the cities. Individual autonomous vehicles are not solutions to all these kinds of social trouble, the solution is to aware people to use more and more public transport, which is autonomous in nature.

3.8 From the Technology Point of View

If we explore the autonomous vehicles for the technological advancement point of view, of course, there are two sides of the coin, (a) Trust in technology, and (b) Is the technology mature enough to trust?

Trust in Technology: In the era of the fourth industrial revolution where the growth of computational power and sensor data is tremendous, hence, automation and artificial intelligence (AI) are inevitable. Where manpower has to be

used for other productive purposes to make society more livable and responsible. A person is smarter than a machine, but it depends on a case by case basis. When we are doing repetitive tasks, we generally tend to become easily distracted or tired. Autonomous vehicles are able to maintain the same level of alertness all the time, if well designed. For example, in the military application, it is proven that automation and artificial intelligence-based weaponry system works well, with or without human presence for a long time. Altogether, machines are definitely behaving better than a human if we trained to learn them in all the situations as well as improve them to take the foolproof decision providing the design are trustworthy.

Is the Technology Mature Enough to Trust? No machine can rival human judgment, especially if it is based on emotions and values. The judgment on an autonomous vehicle is only based on data given by sensors that are not comparable to human senses in terms of quality, reliability, trust, and self-assessment. There will always be an indistinct case which will be vague to interpret. For example, a fully autonomous system may get troubled or even failed by wrong inputs and create dangerous situations. Artificial intelligence is still in the learning phase (e.g. To recognize road signs, obstacles, the difference from a bike rider and a pedestrian crossing the road, etc.) and mistakes may still be made. The technology is not yet matured enough to work in case of heavy fog, snowfall, bad weather, and hence to adhere to all these will take time depends on how the automation and AI develop over the years.

3.9 All Vehicles are AVs, Not Mix It with Conventional Vehicles

It is a nightmare to give a 100% guarantee that no accident will occur with adopting autonomous vehicles for the roads of the future having mixed traffic conditions. Therefore, if all the vehicles on the road are autonomous (considering SAE Level 5) then there is no human driver really necessary. In such a condition, there will be no interaction of driver behaviors (as no human driver presence on the road in any of the vehicle) and the autonomous vehicle will remedy all the safety and operational issues. And hence, great potential for passengers to use their time productively, as all the AVs on the network can produce system having optimal solutions with regard to travel time and energy consumption too.

3.10 Legal and Ethical Point of View

Legal Matters: In the realm of safety and digitization of the transportation system, for example, intelligent traffic management systems and effective tracking systems, require the establishment of specific legal backgrounds and strict regulations. As of now, the deployment of autonomous vehicles for mixed traffic systems is not studied well due to a lack of legal framework. There are still, some open questions that pointing out legal liability include, (a) Who will be

accountable in case of malfunctions? Be a software provider? Be the manufacturer? Be the owner of the vehicle? (b) How to handle different contexts? Are manufacturers enabling to develop a different vehicle for different countries owing to infrastructure, traffic regulations, driver habits, etc.? (c) How to adopt autonomous vehicles to match with the mindset of pedestrians and drivers in different geographical aspects? (d) Who is liable in case of an accident of fully autonomous and non-autonomous vehicles? Answers to such questions are not clear yet and to be discussed or to be considered before framing any legal roadmap and deployment of an autonomous vehicle on the road.

The development and deployment of autonomous vehicles are going to change the nature of the insurance service sector. Decision making in extreme and unavoidable cases that end with a fatal accident is the key question of the time. While human beings are judgmental and condemnable subjects, the decision on a pre-programmed algorithm does not work all the time. Cases like this where insurance plays a vital role and in which the algorithm developer will predetermine the collateral damage in case of an accident and this will generate a different insurance coverage.

Ethical Issues: Transition to fully automated driving will require regulations that will restrict some personal freedom and it is not clear if that is balanced by the benefits. There are many parameters to be considered and taken into account for this to be acceptable to every user, especially in complex situations involving the ethical factor as a prime [14]. Yet moral choice solutions not made available, for example, in case of an emergency situation (a) Whether a vehicle ended up on a wall or to the person on the road? (b) Would the death of children be more important than an elder? (c) Should a pregnant woman count as two lives? Lastly, in the case of an accident which causes only injuries, but no fatalities, whether the pre-programmed algorithms are enough to define the priority of the decisions by severity, types of injuries as well as life affected by it?

3.11 Cyber-Physical Systems (CPS) Concerns

We all know that driving is a complex task and to make it easy or smoother will need plenty of programming capability in case of the autonomous vehicle. By doing this, the system has the issue of vulnerability. The efficiency and reliability of autonomous vehicles totally depended on the computing power, competency and network effectiveness, which can fail or even hack by the hacker. In the context of malware and ransomware putting into the system during the upgradation of software, how to protect the vehicle? Intelligent vehicles have several electronic control units (ECUs), which are connected with an internal network of the fulfillment of various tasks. Attacking these ECUs and breaching the data line will cause numerous unknown complications which never happened before. On the way of deployment of such vehicles issues related to the infringement of data is not resolved yet. Broadly, the open questions related to data privacy include, (a) Who will keep the data? (b) What is the size of data storage (e.g.

Daily, weekly, etc.)? (c) Who provides security to store data? (d) If data is stolen, by which law one can be punished?

3.12 Impact on Employment, and Costing of Vehicles

Driving is a socioeconomic entity, and hence, by the implementation of an autonomous vehicle on the road will create serious employment issues in many countries. If so, it will push out some sort of criminal activity and increase the poverty level in society. In particular, developing nations will face drastic changes in their political domain as a number of people are going to unemployed suddenly. Deployment of an autonomous vehicle for the developing nations is not feasible due to infrastructure facilities, and especially they have already fought with a higher unemployment rate. In light of these, the governments have to find some suitable way of employment before adapting an autonomous vehicle.

Although, there is a tremendous development during the recent time for the autonomous vehicle technology, still, the costing of a single unit is not predicted well enough. There are lots of factors affecting the costing, include what kind of the infotainment system provided, what level of security provided, where the unit is manufactured, and what is another extra package demanded by the customer.

3.13 Climate Change, Global Warming, Electric-Vehicles

Autonomous vehicle technology came up with the revolutionary change in the day to day life. Of course, it comes up with a profound effect on the environment, but whether it is good or bad will depends on the regulatory authorities that how they will manage and/or define the rules and regulations. In the midst of various driver-assist and autonomous vehicle technology development, one of the greatest challenge comes across is global warming. This is because yet not clear whether the greenhouse gas (GHG) and emission reduction guaranteed by adopting autonomous vehicles. It depends on how many AVs are on the road, nature of congestion on road, and fuel efficiency per mile traveled by the AVs are among the other prime factors. One of the solutions is to prepare the future road to electrical autonomous vehicles (EAVs). EAVs should be integrated with the vehicle sharing and public transport system to ensure the reduction in the level of emission.

4 Limitations of the Survey

As the survey was conducted via different web-based platforms, hence, there are no specific participatory restrictions imposed on participants. That's why it has seen that we recorded a high number of responses from one part of the world, while it is not true for the rest, for example, the total number of respondents counted from Brazil was 728 and at the other end only single respondents from counties like Ecuador, Paraguay, Haiti, etc. which may affect the results of whole Latin America. Furthermore, it was assumed that adequate information provided

with the survey page was enough for the participants to understand the concept of automated driving and autonomous vehicles. Although, we were available online for any kind of help throughout the time of the survey period. It may be observed that findings from the survey conducted are largely based on descriptive and qualitative. Hence, future research is needed to comprehend and investigate diverse analyses based on the near real-time or simulator-based study to ensure the facts presented.

5 Conclusions

The way in which it portrays the usefulness of automated driving and the importance of autonomous vehicles for the society as a next-generation intelligent transportation system, there is no doubt that it will work largely for the benefit of a common man. But, in a journey of driver-assistance to driver replacement, we should not forget the key player "human". By considering these implications, it will help to the policymakers and regulatory authorities to put autonomous vehicles in more acceptable and meaningful ways.

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