Ways for Safe Implementation of Autonomy: Preparation of Roadway Infrastructure and Mandatory Education for Drivers

Juyeon Hong

Abstract: This research paper will discuss about why autonomous vehicles being admitted on our roads should only be allowed once the implementation of roadway infrastructure (such as exclusive lane or roadway sensors which is solid enough to function well in any foul weather) and enactment of laws to mandate education of drivers of self-driving cars are done unless fully automated cars are developed, in order to prevent potential risks and problems. The paper explores the levels of self-driving cars defined by the Society of Automotive Engineers (SAE), pros and cons, experts' opinions, accidents, and any potential problems such as privacy, the responsible act of accidents, or the laws regarding autonomous vehicles, the methods to prevent those concerns, and the criticism on the suggestions. It highlights the necessity of implementation of infrastructure and legislation of mandatory periodic education for drivers in order to admit autonomous cars on public roads.

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I. Introduction

Autonomous vehicles, such as self-driving cars, were just a concept in sci-fi movies several years ago. However, now it is not only possible in your imagination. Most of the car companies are investing huge amounts of money in developing self-driving cars and the market size is growing every year that it is expected to reach USD 93.31 Billion in 5 years, where the market size is currently estimated at USD 33.48 billion [1]. We can also easily see the cars that support partially self-driving mode on the roads. But is it really safe enough to be admitted on the street? I would like to argue that self-driving cars are not yet ready to be on public road and should be admitted when the implementation of roadway infrastructure and enforcing mandatory education for self-driving vehicle drivers are done until fully automated vehicle is developed.

II. SAE's 6 Levels of Driving Automation (SAE J3016)

Autonomous vehicles are often classified into 6 levels that can be used by manufacturers, suppliers, and policymakers [2]. Levels of Driving Automation are defined by SAE(Society of Automotive Engineers) in partnership with ISO(International Organization for Standardization) [19]. This classification is not a mandatory regulation or legally binding, but it is adopted by NHTSA (National Highway Traffic Safety Administration), and widely accepted by the industry and government agencies [18], so I will use this level classification throughout the paper. There are 6 Levels of SAE J3016, from level 0 to level 5. From level 0 to level 2, the driver should monitor the driving environment, and from level 3 to level 5, the autonomous driving system monitors the driving environment.

A. 6 Levels of Automation

- Level 0 (No Automation): Human fully controls all systems. [3]

- Level 1 (Driver Assistance): The car can be operated by either a steering or acceleration/deceleration assistance system under certain conditions, but the driver performs all other functions and is responsible for monitoring and taking over if there is a failure of the system. [2, 3]

- Level 2 (Partial Automation): Vehicle controls steering or acceleration/deceleration assistance system. Driver must monitor the driving environment and have to change lanes or respond to traffic signals. [2, 3]

- Level 3 (Conditional Automation): The system monitors the driving environment from level 3. The system controls most aspects of operations. But the system might request to take over to the driver, and the driver has the responsibility for appropriate control. [2, 3]

- Level 4 (High Automation): The system can perform all operations without human input on a defined area. [2, 3]

- Level 5 (Full Automation): The car is always in charge of driving on any road and under any conditions. [2, 3]

B. Current Status of Development

The development of automobile cars has continuously progressed. Currently, "most mass-produced automobiles with self-driving capabilities are based on Level 2 technology of partial driving automation" according to KED Global [4] but in 2021, Honda and Mercedes-Benz managed to receive level 3 (L3) certification [5]. However, even if some L3 Pilot systems are legally approved, *Autocrypt* reported that "sensitive public reactions toward flaws in automated driving systems make OEMs more reluctant to introduce L3 [5]" so that potential risks should be addressed before introducing L3 vehicles on large scale. These risks will be discussed in more detail later in the paper.

III. Pros and Cons of Self-Driving Cars

A. Advantages

Self-driving cars have several advantages. First, it can assist drivers to drive safer and more efficiently. Autonomous cars have the benefit of removing human error, since driver error can cause up to 94% of all traffic accidents as stated by National Highway Safety Administration [6]. Second, self-driving cars have the potential to reduce traffic congestion. Third, autonomous cars can mitigate negative consequences associated with limited driving abilities due to decreased physical and cognitive capabilities for a growing number of older drivers [6]. Also, people with disabilities can benefit from autonomous cars.

B. Disadvantages and Challenges

However, there are still many unresolved issues to benefit from self-driving cars' advantages. First, the cybersecurity problem of self-driving cars can never be 100% solved. Since driverless cars rely heavily on the software system, they are always in danger of cyber threats such as remotely controlling the vehicle by hacking, stealing personal information about the driver and the driver's location or tricking the sensory of the vehicle [7]. For example, White hat hackers Amat Cama and Richard Zhu hacked a Tesla Model 3 in 2019. It only took a few minutes to take control of the car by exploiting the car's system [8]. Even if we solve known problems, there is always a possibility for malicious actors to develop new ways to attack. As another illustration, in a study conducted by researchers from the University of Florida, the University of Michigan and the University of Electro-Communications in Japan, they were able to hack a self-driving car to hide the pedestrian or other obstacle in its way [22, 23]. Self-driving cars have LIDAR sensors to detect the distance to the obstacles from the car so that the car can determine what actions to take [23]. However, by creating spoofed reflections to trick the LIDAR sensor, the scientists were able to delete not only the static objects but also the moving pedestrians. They even achieved a 92.7% success rate to remove 90% of target objects [24].

These vulnerabilities show the possibility of massive casualties if the automation system is not prepared for all kinds of attacks.

Also, people who work in the transportation industry such as bus drivers or delivery riders will be displaced. According to the Government of Canada, 130600 people were employed in the transportation industry in British Columbia province in 2021 [20]. That is around 5% of provincial employment [20]. So this job displacement will lead to unemployment of those people working in certain industries, and likely to encounter financial distress. Third, there are not enough laws related to autonomous cars which will cause huge confusion in case of accidents. That also leads to a question about who is responsible for the accident. Without firm regulations, individuals might not be protected from coverage of insurance in the event of accidents. Moreover, self-driving cars can encounter a trolley dilemma, meaning that when a car faces an unavoidable accident, the car has to either choose to sit back and save the driver while hitting 5 people, or choose to save 5 people but the driver. Of course, it is a question that has no correct answer for humans as well, but, the point is that designing such a program itself and the judgment are controversial [3].

C. Other Concerns and Potential Problems

There are many other potential problems, and one of these problems is regulation related to driverless cars. Legislation is still unclear "about who accepts responsibility when things go wrong with autonomous vehicles. [12]" Another problem is privacy. Since it is an autonomous car, sensors will keep track of the vehicle. It is true that traditional cars can indeed be tracked using CCTV footage, but with autonomous cars, malicious actors can check up on your location easily, in real-time. Furthermore, skepticism still exists toward driverless cars. The public's perception and acceptance is an important matter for the wide-scale adoption of driverless cars. However, according to the annual automated vehicle survey conducted by AAA, drivers who responded 'afraid' increased "to 68% in 2023, as compared to 55% in 2022 [21]" and drivers

who responded ‘trust’ decreased from 15% in 2022 to 9% in 2023 [21]. These problems should be addressed for increased reliability and to safely accept self-driving cars on public roads.

IV. Expert Perspectives

A. Positive Opinion on Driverless Cars

Experts have divided opinions on self-driving cars. Looking at the optimistic view about adapting autonomous cars, experts commented that humans are more error-prone than autonomous vehicles so that the transition to automation is inevitable [9, pp. 3-4]. The most common causes of car accidents are distracted driving, drunk driving, reckless driving, drowsy driving, drugs, etc. which are all human errors [11]. To prove if self-driving cars are safer than humans or not, Google’s self-driving unit Waymo conducted a simulated test to see which has better crash avoidance. Even though the study involved a virtual superhuman driver who “never gets tired or distracted [10]” “unlike normal human driver who experiences fatigue and distraction [10]”, the Waymo vehicle still did better. The Waymo vehicle managed to avoid 75% of crashes and reduce serious injury by 93%, while the superhuman driver avoided 62.5% of collisions and reduced serious injury by 84%, showing that the autonomous vehicle outperforms human performance [10].

B. Negative Opinion on Driverless Cars

On the other hand, some experts raised concerns about security and the possibility of hacking. One expert expressed concerns that they are “skeptical about whether AV technology would ever reach sufficient levels of safety and sophistication to replace manually operated vehicles [9, p. 7]” and it is also pointed out that “verification of the technology is near-to-impossible [12]”. Also, Lohmann commented that “security issues will predominantly concern software bugs as systems will never be 100% safe [14]”. To suggest a counterexample from the

positive opinion's argument that autonomous cars are safer than human drivers, Robbie Miller, the former Uber executive, said that the industry has created the illusion of safety, instead of actually delivering safety, and also the industry metrics are misleading [13]. Few days after Miller warned of such problems as if to prove his argument, a self-driving car operated by Uber struck a pedestrian to death [13]. Moreover, Miller published a study claiming that self-driving cars actually have higher accident rates than non-autonomous cars [13]. The study compared the data from the Strategic Highway Research Program (SHRP) and the California DMV and demonstrated that "autonomous test vehicles created more injuries per mile than the average human motorist with a few years of practice [13]".

V. Accidents caused by Autonomous Cars

In March 2018, autonomous Uber struck a pedestrian to death in Arizona. There was a driver in the car and no passengers. The backup driver did not hover his hands above the wheel even though the drivers are instructed to do so in case of emergency [16]. However, apart from how the driver behaved, the car should have detected the pedestrian. Experts claimed that it was a situation that could have been avoided as machines in self-driving cars can collect more sophisticated information using lidar sensors (light detection and ranging systems) unlike humans [3]. Later in the same year November, the investigation revealed that the software was not designed to recognize pedestrian jaywalking [3]. Even before the accident, there were people expressing mistrust about autonomous vehicles, but after this first dead on record where a pedestrian actually died because of the autonomous car, it caused more controversy than before.

Similarly in the same year, the driver of a Tesla SUV driving in self-driving mode was killed in Silicon Valley [17]. The crash occurred because the car turned in the direction and slammed into a concrete barrier that separates exit lanes and the freeway from the highway [17]. The collision of the car did not warn the driver, and its automatic emergency brake also was not activated [17]. In addition to the malfunction of the self-driving car system, it was found out that the driver was playing a video game on his smartphone so that he did not brake to avoid the

crash. Robert Sumwalt, the chairman of The National Transportation Safety Board (NTSB), said "partially automated driving systems like Tesla's Autopilot cannot drive themselves, [17]" meaning that "when driving in the supposed 'self-driving' mode, you can't read a book, you can't watch a movie or TV show, you can't text and you can't play video games [17]".

In both of the cases, although there were primary issues with the software in car companies, the drivers also lacked attention on the road and did not hold the steering wheel, unconditionally relying on the technology. The accidents highlight the necessity for compulsory driver education that even drivers of self-driving cars should not neglect their duty to keep an eye on the road and need to be ready to take over the steering wheel at any time, unless it is fully (level 5) autonomous vehicle.

VI. Solutions to Prevent Accidents Due to Self-Driving Cars

Driverless cars offer many advantages such as efficiency, reducing traffic congestion and removing human errors. However, as real-world cases such as accident where a pedestrian was killed by a self-driving car or researches from expert warn, there still exist many vulnerabilities and problems regarding autonomous vehicles. If self-driving cars are allowed on the roads without any measures, it might lead to great confusion for both human drivers and autonomous vehicles. Therefore, I would like to argue that in order to safely deploy autonomous cars, roadway infrastructure should be prepared in advance, especially exclusive lanes for self-driving cars should be introduced, and the law to require drivers of self-driving cars to get regular mandatory training must be enacted, prior to adapting autonomous cars, in order to mitigate the confusion and prevent potential risks.

A study by Shantanu Chakraborty at the University of New South Wales was conducted by developing a computer simulation model [15]. The study team simulated different scenarios involving autonomous cars and non-automated legacy vehicles [15]. They proved that the dedicated lanes for self-driving cars significantly improved safety where there is a hybrid

network of autonomous cars, regular cars, pedestrians and cyclists [15]. Also, according to [15], the scientists also found that "since machines in autopilot do not have to rely on driver attention and reaction time to traffic conditions," self-driving cars would improve the overall flow of traffic. In addition, the people who oppose to autonomous cars can use separate lanes so that the objection to self-driving cars can be quelled.

The two accidents mentioned in previous chapter *VI*. *Accidents* both occurred while the human driver on the wheel wasn't keeping an eye on the road. First and foremost, the car and the software itself must be safely designed taking consider every possible situation the autonomous car can face. However, self-driving car is still in development. Even though we can see many self-driving cars on the road, that does not mean they are flawless and able to trust completely. Therefore, unless a fully automated level 5 vehicle, which can be "operated without human involvement [21]", is developed, I argue that there should be legislation of obligatory periodic education for drivers to keep reminded of the possibility of danger when riding on partially automated vehicle and enforce drivers to keep their visual attention on the road to always ready to take over the control.

According to [3], on the ranking of self-driving car companies conducted by Navigant Leaderboard, Tesla was ranked at the bottom as they commercialized autonomous cars too hastily which resulted in many casualties. This suggests that along with the car company's intensive experiments, constructing road infrastructure that can improve safety, and making clear regulations to minimize uncertainty should be prioritized over introducing self-driving cars hastily.

VII. Criticism

While the suggestions provided in the previous chapter can help mitigate the problems of self-driving cars, there might be criticisms against those suggestions.

One might argue that implementing roadway infrastructure is too expensive and time-consuming. It is true that it indeed requires a large amount of investment cost and time. Nevertheless, nothing is more important than safety. With the preparation of roadway infrastructure, we can prevent and reduce potential accidents which can save numerous people. Also, if we consider the long-term benefits, the recovery costs of accidents and insurance cost will eventually outweigh the initial investment cost of infrastructure.

It is also possible to be criticized that forcing drivers to maintain their visual attention on the road would limit the benefits of autonomous cars and such regulations will slow down the innovations made for cars. One of the advantages the self-driving cars provide is that the driver doesn't have to be involved in driving tasks and can stay relaxed, but if a driver is obliged to stay alert, there is not much difference compared to traditional vehicles except that the driver is handling the steering wheel. Even so, as the precedent accidents show, self-driving cars are still in the experimental phase. As long as it is a partially automated car that we are driving, we cannot fully trust the automation system. This is to protect not only the pedestrians but also the drivers as well.

VIII. Conclusion

In this study, we analyzed the 6 levels of SAE J3016, the current level of automation development, the advantages and disadvantages of self-driving cars, how experts view autonomous cars, accidents caused by autonomous cars, and how to address and prevent the problems we have seen in the previous chapters, and the possible oppositions to the suggested solutions. As the self-driving car market is growing rapidly, it is an important task to adopt autonomy safely.

The degree of development of self-driving cars is often interpreted with 6 levels defined by SAE J3016. Driver observation of the driving environment is required from level 0 to level 2, and the autonomous driving system monitors the driving environment from level 3 to level 5. We

are currently in level 3, and heading towards level 4. While self-driving cars offer drivers convenience and remove human errors such as drunk driving or drowsy driving, it can be a new method of attack by exploiting the autonomous system. Many researchers and white hat hackers managed to find such vulnerabilities that can possibly be used for attacks, indicating that partially automated systems cannot be fully trusted. The real-world accidents where autonomous car killed driver and pedestrian also emphasize the unreliability of automation. Even though it is hard to provide technical solutions for the uncertainty of automacy, as a driver, we can protect both pedestrians and drivers by staying alert to be ready to take over the steering wheel at any time when autonomous is malfunctioning. Also, as the simulation from the University of New South Wales showed, autonomous vehicles having exclusive lanes can help autonomous cars for improved safety.

In conclusion, autonomous vehicles can bring increased efficiency and convenience. But for safer implementation, having separate lanes for autonomous cars and drivers' oblige to keep an eye on the road are needed. One might argue that it is too expensive and time-consuming to build a dedicated lane and limit the benefits to stay alert, but the safety of both pedestrians and drivers is the priority. By balancing the acceptance of developing technology and efforts to improve safety, it will open the way to better integration of autonomous vehicles on our roads.

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