Abstract

Road safety statistics show a large number of casualties due to traffic accidents all over the world, which challenges the researchers and vehicle manufacturers to develop new technologies to reduce. In the last few years, vehicles that are capable of navigating autonomously (without a driver) have been developed and are expected to be released to the market in the near future. The testing of these cars is legally allowed in three American states, and some tests are also being conducted in some European countries. This new technology has many potential advantages; however, the use of such cars in public roads can raise many questions. In this paper, the legal, social, and ethical questions of self-driving cars are raised, in order to figure out to what extent the current applicable laws and regulations can answer them. The legal questions are sorted into six groups; reliability, insurance, regulations, behaviours, liability, and security questions, while the social and ethical questions are grouped into three categories; privacy, behaviours, and social impact. Moreover, some legal ideas and recommendations for the future laws are suggested. To achieve a better understanding of the topic, a brief description of the autonomous cars’ technology and components is also provided.

Keywords: self-driving cars; autonomous vehicles; regulations; liability
Introduction

Imagine yourself in the morning, getting into your car, but instead of driving it through the rush-hour traffic jam, keeping focused on the road, other cars, pedestrians, and traffic signs, instead of all that, you just ask the car to drive for you, while sitting down in your seat relaxing, drinking a cup of coffee and checking your email or reading the newspaper. And once you reached your work, instead of searching for a parking place to stop your car idly for eight hours, you simply ask it to make its way back home, so that other members of your family can use it.

Self-driving cars have long been a human dream that appeared in many science fiction stories, TV programmes and movies, such as KITT in the 1982 TV series; Knight Rider, Batmobile in the 1989 film; Batman, and many others. But in the last few years, as the technology has rapidly developed, this dream became very close to come true.

As this paper is being written, some automobile manufacturers, research groups, and corporations like Google are developing and testing fully autonomous vehicles that are expected to be available in the market within few years, which raises many legal and social questions and doubts regarding this new technology.

The main purpose of this paper is to raise these questions and to figure out to what extent the available laws and regulations can answer them. Moreover, some legal ideas and recommendations are suggested.

To achieve a better understanding of the legal, social and ethical aspects of the adoption and use of self-driving cars, a brief explanation of the need for this technology, its development with time, advantages, challenges, and how it works, is provided.

Road Safety Figures

Statistics show horrible numbers of human casualties; deaths and injuries, as well as large material losses, caused yearly by traffic accidents around the world.

In its mortality and global health estimates of 2011, the World Health Organization stated that road injury is the worldwide leading cause of death for young people of ages 5 to 29 years old (WHO 2011); their figures also show that the total traffic related deaths are more than 1,260,000 yearly. More than 50,000,000 injuries are yearly reported worldwide because of traffic accidents (PRB 2006).

Even in the leading developed countries, traffic accidents are considered as a serious issue; alone in the United Kingdom, a total of 195,723 casualties of all severities in road accidents were reported to the police in 2012, of these 1,754 were deaths (DfT 2013).

Furthermore, “the direct economic costs of global road crashes have been estimated at US$ 518 billion” in 2003 (WHO 2004, p.5).
Many studies have been conducted to study the causes of traffic accidents, e.g. in his study Rumar (1985) shown that 93% of car accidents in USA and the UK are related to human error.

**Historical Overview**

In light of the previous figures and facts, automobile manufacturers have invested more time, money and effort to provide their cars with safety means, table 1 below summarizes the main advanced driver assistance systems, the year when they were first introduced, and by which car manufacturer.

<table>
<thead>
<tr>
<th>Driver Assistance System</th>
<th>Year (first introduced)</th>
<th>Manufacturer</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car GPS Navigation</td>
<td>1995</td>
<td>GM</td>
<td>(Lendino 2012)</td>
</tr>
<tr>
<td>Adaptive Cruise Control</td>
<td>1995</td>
<td>Mitsubishi</td>
<td>(Mitsubishi 1998)</td>
</tr>
<tr>
<td>Lane Departure Warning System</td>
<td>2001</td>
<td>Nissan</td>
<td>(JSAE 2001)</td>
</tr>
<tr>
<td>Collision Avoidance System</td>
<td>2002</td>
<td>Mercedes</td>
<td>(Daimler 2013)</td>
</tr>
<tr>
<td>Automatic Parking</td>
<td>2003</td>
<td>Toyota</td>
<td>(CNN 2003)</td>
</tr>
<tr>
<td>Lane Change Assistance</td>
<td>2006</td>
<td>Volvo</td>
<td>(Volvo 2006)</td>
</tr>
<tr>
<td>Traffic Sign Recognition</td>
<td>2008</td>
<td>BMW</td>
<td>(Snook 2008)</td>
</tr>
</tbody>
</table>

By a quick look into (table 1), it can be easily recognised that by the beginning of the 21st century, technology has evolved very closely to realise the dream of self-driving cars. The American military believed in this, in 2004 the US Defense Advanced Research Projects Agency organized the first long distance competition for fully autonomous cars in the world; DARPA grand challenge 2004, although no one of the participating teams succeeded in reaching the finish line, it can be considered as a significant milestone in autonomous cars development (Garza 2012).

In the second version of the challenge 2005, a fully autonomous robotic car; Stanley, developed by a team of Stanford University and Volkswagen Research Laboratory, has navigated the 212 km route through Nevada Desert, to become the first robotic car to win the $2 Million prize of DARPA grand challenge (DARPA 2005).

**Now and Then**

After the technological concept was successfully proven in DARPA 2005, the leading automobile manufacturers as well as the well-known web services provider; Google, announced that they are developing and testing autonomous cars, expected to be released to the market within the next few years;

- By 2016, Tesla expects to release cars that can operate autonomously for 90% of distance driven (Waters and Foy 2013).
- By 2018, Google expects to release their self-driving cars (Nichols 2013).
- After 2020, GM, Daimler, Nissan and BMW expect to sell self-driving cars (White 2013).
Autonomous technology is expected to be a standard feature included on most new vehicles by 2050 (Litman 2013).

**How self-driving cars work?**

In figure 1 below a brief description of the autonomous technology and its components is shown.

![Figure 1: Self-Driving technology main components](image)

To sum up, the autonomous car is controlled by a central computer using specific localization and path planning algorithms that can make all the driving decisions, plan the suitable routes, follow them, and respond to any possible road circumstances that may encounter it (Thurn 2012). To do so, it depends on:

1. Its accurate maps and street view images, such as Google Maps and Street View.
2. The data collected by sensors; Global Positioning System (GPS), Cameras, Laser Imaging Detection and Ranging (LIDAR), Radars and Ultrasonic.
3. As well as some data received via internet connection.
The Advantages

Based on the digital machine characteristics and capabilities, autonomous cars’ developers believe that their technology will have many advantages, such as:

1. Reducing traffic accidents (Eno 2013), e.g. the developers of Google Self-Driving Car believe that it can reduce traffic accidents’ casualties to the half (Thurn 2010), This belief is due to several reasons, including:
   a. Computers have faster reaction time than human drivers.
   b. They are not temperamental or emotional, and cannot be subject to psychological effects.
   c. They cannot be drunk or under the influence of drugs, and do not fall asleep.
2. Reducing traffic congestion, due to:
   a. Smaller safe gaps between cars will be needed.
   b. Cars Platooning (Iliaifar 2012).
3. This leads to more roadway capacity (Litman 2013).
4. Very useful for old or disabled people such as blinds.
5. Elimination of redundant passengers, which means more efficient use of cars.
6. Improving fuel efficiency, especially in cars platooning due to the *drafting* phenomenon. As well as environmentally friendly (Thurn 2010).

Legal Aspects

Any new technology is usually faced by legal questions and doubts, but when it comes to technologies that are much related to human safety, like self-driving cars, the challenges for lawmakers are more critical.

The main legal questions can be summarized as follows:

1. **The Reliability Question**: How safety can be guaranteed?
2. **The Insurance Questions**: How the insurance laws and costs will be affected?
3. **The Regulatory Questions**: about the vehicle registration, driver license requirements, age limit, and tests.
4. **The Behavioural Questions**: about driving behaviours such as: speed limits, safe gaps and drunk driving. As well as the response to police officers.
5. **The Liability Question**: Who will be responsible when there is an accident?
6. **The Security Question**: What are the consequences if the technology is hacked?

In the next subsection, a brief summary of the existing laws is provided; in order to figure out to what extent they can answer these questions.

Self-driving cars in the current laws

In its 76th regular session in June 2011, the Nevada Legislature passed the assembly bill number 511 that authorizes the operation of autonomous vehicles on highways within the state (NELIS 2011). One year after, Florida became the second state to recognize the legality
of autonomous vehicles in July 2012, bill CS/HB 1207 (Florida 2012), followed by California in September of the same year, Senate Bill No. 1298 (California 2012).

Although “there is no UK legislation governing autonomous vehicles” (POST 2013), the government announced that driverless cars are tested on public roads by the end of 2013 (BBC 2013).

In Germany, Daimler and Karlsruhe Institute of Technology tested in September 2013 an autonomous prototype of Mercedes-Benz S-class for about 100 km from Mannheim to Pforzheim under a legal agreement with the government bureau (Grünweg 2013).

By studying the previously mentioned laws and references, the following notes can be concluded:

1. Traffic regulations in general are based on the Vienna Convention on Road Traffic (1968) that requires a driver to be in control of the vehicle at all times.
2. The current laws for autonomous cars try their best to comply with the convention.
3. They are made for prototypes’ testing purposes.
4. They direct to establish minimum safety standards for autonomous vehicles and their operation.
5. They require the following prerequisites to allow testing self-driving cars on public roads:

   **On the manufacturer:** to obtain an instrument of insurance, surety bond, or proof of self-insurance prior to the start of testing, for instance 5 million dollars are required in the American states (Florida 2012) (California 2012).

   **On the operator of the technology:**
   a. A driver to be seated in the driver’s seat, and to be capable of taking over immediate manual control of the vehicle in emergency cases.
   b. The driver should hold a car driving licence, in Germany an additional special license for autonomous cars is also required (Grünweg 2013).
   c. The driver should be solely of the employees, contractors, or other persons designated by the manufacturer of the autonomous technology.

   **On the vehicle (California 2012):**
   a. To have an easily accessible mechanism to engage and disengage the autonomous technology.
   b. To have a visual indicator for the autonomous made.
   c. To have an alert system, in case of technology failure, that requires the operator to take manual control of the vehicle, and if he cannot do so, it has to do a complete stop.
   d. Its autonomous technology has to meet safety standards.
   e. To have a separate mechanism to capture and store the autonomous technology sensor data for at least 30 seconds before a collision occurs while the vehicle is operating in autonomous mode.
f. The data shall be captured and stored in a read-only format, and shall be preserved for three years after the date of the collision.

Comments and Recommendations

Although these laws and regulations are designed for the vehicle’s testing purposes, they have very good points that can still be used in the permanent legal model of the autonomous vehicles.

Establishing safety standards for the vehicles and the technology can provide a partial answer for the reliability question. Similarly, the alert system for technology failures and the data storing consequences in the case of collisions can provide a partial answer for the liability question.

Except for testing purposes, the current laws do not provide clear answers for most of the insurance, regulatory, behavioural, and security questions.

In the remaining part of this section, some legal ideas and recommendations are provided for answering the six legal questions.

1st The Reliability Question:
The question of safety and reliability is mainly related to the worries of the technology failure, so it can be answered by eliminating the sources of this failure.

System failures can occur due to:
1. An internal error in the technology; software and/or hardware. (can be eliminated by setting high quality standards, and using backup systems)
2. Inappropriate roads or surrounding conditions. (can be solved by executing a surroundings preliminary check)
3. Running out of power. (can be solved by preliminary and frequent fuel checks)

Standards:
- As mentioned clearly in the current laws, common high standards for both the hardware and software should be applied on the manufacturers.
- For example, the instrumentations and sensors should be proved to withstand tough conditions of temperature and pressure etc.
- Standards on the program codes and algorithms should also be enforced.

Backup systems:
- The concept of backup systems is commonly used in the aviation industry. In their report, the UK parliamentary office of science and technology, suggested the application of this concept in the self-driving cars as a safety factor to compensate any system failing. (POST 2013)
- For applying this concept, three system types are suggested to be used:
  1. The main active system (system in operation).
  2. Spare backup systems working in parallel, capable of taking control in failure scenarios.
3. Monitoring System; continuously watching the active system to detect any failure, and store the sensor information.

Preliminary checks:
1. As a preparatory step for the technology release, a comprehensive study of all the roads in terms of their readiness, capability, and appropriateness for the new technology is suggested to be done. After that, the self-driving mode can only be enabled in the capable roads. This should be enforced in the software.

In other words, an updateable list of the allowed roads, in which the self-driving mode can be used, should be generated by the motor vehicles and safety departments. When the operator selects the self-driving mode, the car computer shall first read the GPS data, determine the current position, look it up in the allowed roads list, and decide whether to enable the self-driving mode or not.

Moreover, for increasing the reliability of this technology, the road-related rules -such as speed limit and other traffic signs- should be included in the car maps, and the path-planning algorithms should read these signs internally from the maps, rather than using the camera and the image processing algorithms.

This can lead to the idea of smart roads, which are interactive with the autonomous cars, e.g. the traffic lights transmit wireless signals that can be received and understood by the car’s computer.

2. In the software: the car should perform a preliminary scan for the surrounding environment; including, but not limited to, the light intensity, visibility, and the cleanliness of the sensors surfaces.

3. In the software too, when selecting the journey route, the algorithm should take into consideration the actual fuel levels, which should be checked prior to enabling the self-driving mode, and frequently during the journey. And if the fuel level goes under specific limit, an alternative route -includes stopping in a gas station - should be chosen.

2nd The Insurance Questions:
A comprehensive insurance for the self-driving car and its operator should be obligatory by the law. Moreover, the manufacturers of the self-driving technology should also be obliged to pay a specific ratio of the insurance expenses that cover the vehicle in its autonomous mode of operation.

“The insurance industry would need to update their processes as current risk modelling is based on the behaviour of a human driver” (POST 2013).

Predicting insurance costs changes is quite difficult. “In theory, robocars should drive the ‘insurance’ costs down because of the reductions in collisions. However, if the cost per collision is much higher even though the number of collisions drops, there is uncertainty over whether autonomous vehicles will save money for both parties.” (Pinto 2012 cited Templeton 2012).

3rd The Regulatory Question:
Additional to the normal licences for both cars and drivers, a special type of licences should be applied for robotic cars and their users. To obtain a robotic driving or vehicle license,
special tests have to be passed, for example, drivers should have the ability of responding to system failures and dealing with sudden control transfer while operating (POST 2013).

Each car should undergo functionality tests for its technology. This should be done yearly in order for the vehicle license to get renewed.

The developer of the autonomous technology has to add a feature to automatically disable the autonomous mode once the robotic car license expires.

After passing the safety and proper functionality tests, the licensing department will re-enable the autonomous mode of the vehicle for a new period.

4th The Behavioural Questions:
Most of the behavioural regulations, such as speed limits and safe gaps, should not be changed, at least in the first stages of adoption, since the majority of the cars on roads will be non-autonomous (driven by humans).

Even drunk driving should still be forbidden in the early stages of adoption, to make sure that the driver can take control of the car in system failure. After the new technology proves its safety by practical experience on the public roads for a reasonable period, a built-in Breathalyzer should disable the manual driving mode and activate the autonomous mode, when the driver is drunk.

Obedience to traffic policemen can be guaranteed by adding new feature to the police radar; enables it to send wireless stop order to the autonomous car, this procedure should be monitored in the police records.

5th The Liability Question:
It will be hard for manufacturers to avoid liability for safety problems with their robotic cars (Pinto 2012) (Gurney 2013), how will they find justification for legislative protection? (Brown 2013).

The existing traffic accident liability rules in the European countries can be classified into three types of accident compensation regimes; fault liability, strict liability and road traffic insurance (Van der Heijden and Van Wees 2001).

The road traffic insurance regime, used in Sweden, seems to be the most suitable for autonomous cars; when an accident occurs, the damages will be automatically compensated by the insurer of the involved vehicles.

The storing of pre-collision data, as introduced in California (2012), can provide a very clear method for determining the responsible party for the accident.

Remote retrieving of the accident data via internet - or the mobile phone network by inbuilt SIM card (POST 2013) - should be done by police under certain regulations, to save time, efforts and traffic congestion due to accidents’ investigation.

If this investigation finds that the responsibility lies on the autonomous car, the technical details and conditions of the accident should be sent to the technology manufacturer to search for the source of the problem and fix it within a specific period set forth by the lawmakers. If
the manufacturer was not able to update his technology within that time limit, he will be obliged to withdraw the product from the market.

6th The Security Question: 
This question is mainly about hacking and cyber-attacks. Since autonomous cars are controlled by computer, and can be connected to the web or the mobile phone network, such attacks seem to be possible.

Security experts see very low probability for it. “It would take too much time, expertise, money and hard work to hack into the multitude of computer systems.” (Krisher 2013)

In case of any cyber-attack, the same liability procedure of system failure should be applied.

Social and Ethical Aspects

These aspects can be summarized in three groups:

1. Privacy Issues.
2. Behavioural Issues, such as cars without driver inside, allowing children to ride it alone, or its use by disabled people (e.g. blinds)
3. The Social Impact: on driving careers (taxis, buses, driving schools etc.)

Some good answers for the privacy and behavioural issues are introduced in the California (2012) law. For example it forces the technology manufacturer to provide a written disclosure to the purchaser of an autonomous vehicle that describes what information is collected by the autonomous technology.

Moreover it declares that “the department shall hold public hearings on the adoption of any regulation applicable to the operation of an autonomous vehicle without the presence of a driver inside the vehicle” (California 2012).

Since the new technology will need long time before it fully replaces the human drivers, its behavioural as well as social impact issues are expected to be solved gradually over time. Each new technology replaces some human careers, but it usually creates many new others.

Conclusion

Self-driving cars will be on our roads in few years, raising many legal, social and ethical challenges, for which the lawmakers should provide reasonable answers.

Benefiting from the current laws as well as the manufacturers testing experience on public roads, more comprehensive laws should be issued, taking into consideration all the adoption and using aspects of the new technology; starting from standards level, insurance, licensing, behaviours, liability, and ending with privacy and cyber-security issues.

Proper regulation as well as successful experience will hopefully open the door for this technology to be used in wider applications that will definitely improve the traffic safety, and might shape a new future for roads and transportation planning.
Glossary

**Autonomous Car**: (also known as driverless, self-driving, or robotic car) is a vehicle that can navigate without the active physical control or monitoring by a human operator (California 2012).

**Breathalyzer**: a device for estimating blood alcohol content from a breath sample.

**Drafting (Aerodynamics)**: the reduction of the overall effect of drag on a moving object due to the slipstream of a larger lead object.

**Fault Liability**: “a type of liability in which the plaintiff must prove that the defendant's conduct was either negligent or intentional” (Hall 2002)

**Public hearings**: the opportunity for the public members to voice their opinions and provide input to the board on a particular issue.

**Strict Liability**: the imposition of liability on a party without a need of proof of fault (such as negligence or tortious intent) (Cantú 2002).
References


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