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Critical features of autonomous road transport from the perspective of technological regulation and law

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Abstract

Autonomous vehicular technology significantly stresses the issue of safety. Although the use of driverless cars raises considerable expectations of a general improvement in safety, new challenges concerning the safety aspects stem from the changing context. On the one hand, the paper addresses regulatory issues raised by the impact of technological changes, particularly standardization problems. On the other hand, the issue of liability questions is investigated as it might cause today's main legal obstacle for the wide spreading of autonomous cars, especially as autonomous cars might jeopardize the existing approaches to vehicular liability. The aim of this paper is to scrutinize the basic problems in both fields. We provide what, at the current state-of-the-art, appear to be reasonable recommendations from the perspective of technological regulation and law, in order to deal with the main problems that might hamper the development of autonomous transport technology.

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Keywords: autonomous vehicle; standardization; law; liability

1. Introduction

In recent years, the technological innovations of road vehicle industry have been coming up with spectacular developments concerning autonomous and connected cars. Autonomous cars are currently in a testing phase, but in a future not far away they are expected to bring dramatic changes to today's society, with impacts on the technological, economic, social and legal domain. Automated vehicles open up a series of opportunities, due to safer roads, travel time reduction, more personalized services, and energy efficiency (Fagnant and Kockelman, 2015).

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The main issue that will be tackled by the widespread presence of autonomous cars is that of road safety. As the human error has been identified as the main cause of car accidents (Stanton and Salmon, 2009), taking that factor out of the scene is supposed to drastically reduce the number of accidents and the costs associated with them.

Of course, there are some obstacles that can hinder the expansion of autonomous cars. In particular, two constraints have been identified (Greenblatt, 2016), and in both cases the problem is that the perspective is fully centered on the human driver. The first problem is the current legal framework for road transportation, which does not easily fit in a context where the car is a self-driving system, and lacks a comprehensive and uniform approach to autonomous vehicles. The other is the existing huge network of road infrastructures that are designed to allow human drivers to drive, taking into account their ability to see, their reaction times, and so on. The development of these two domains will have to progress in parallel with that of autonomous cars, which in turn will face different stages of evolution as the context in which they are designed to operate slowly adjusts to them.

The development of autonomous vehicles face several challenges from a radical change of transportation modeling (Tettamanti et al., 2016) to the coordinated adoption of technologies to support an interconnected infrastructure (Bansal and Kockelman, 2017). Ethics in decision-making (Goodall, 2016; Lin, 2016) is also a major source of questions, such as the well-known trolley problem (Thomson, 1985). The solution to these problems is not straightforward and will necessarily emerge over time, based on a collaborative interaction between industry, academy and legislators. Manufacturers' associations and consortia, legal studies, and standardization bodies will also play a significant role in this field (Anderson et al., 2014). This paper tries to conclude major regulatory and legal barriers that driverless cars will have to overcome prior to the mass market take-up.

The paper is structured as follows. In Section 2, the concept of driverless cars is introduced. Section 3 focuses on international regulation about driver's responsibility and standardization issues for autonomous road transport. In Section 5 civil and criminal liability problems are investigated. The paper ends up with a short conclusion.

2. Concept of autonomous vehicles

The concept and definition of autonomous road vehicles must be clarified in order to investigate their legal problems. Basically, road vehicles with the ability of high-level environment sensing and controlled movements without human driver can be called as autonomous vehicles. They are also designated as driverless, self-driving, or robotic cars. The Society of Automotive Engineers (SAE) determined the terminology and the taxonomy for autonomous vehicles in a standard (*J3016*, 2016). Accordingly, levels of autonomy are tabulated into Table 1.

Table 1. Levels of driving automation according to the standard of SAE International (source: SAE International (2014)).

SAE level	**SAE name and definition**	**BASt level**	**NHTSA level**
0	No Automation: The human driver constantly controls all aspects of the dynamic driving task. There is no direct system intervention, only warnings for the driver.	Driver only	0
1	Driver Assistance: The autonomous system is able to take over the dynamic driving task partially (steering or acceleration/deceleration) in defined use cases with the expectation that human driver constantly monitors the drive and will be ready to resume control immediately if needed.	Assisted	1
2	Partial Automation: The autonomous system is able to take over the entire dynamic driving task (steering, acceleration/deceleration) in defined use cases with the expectation that human driver constantly monitors the drive and will be ready to resume control immediately if needed.	Partially automated	2
3	Conditional Automation: The autonomous system is able to take over the entire dynamic driving task in defined use cases with the expectation that human driver will be ready to resume control in a given time frame if system requests to intervene.	Highly automated	3
4	High Automation: The autonomous system is able to take over the entire dynamic driving task in defined use cases with the expectation that human driver will be ready to resume control in a given time frame if system requests to intervene.	Fully automated	3/4
5	Full Automation: The autonomous system is able to take over the entire dynamic driving task anytime and anywhere. This level represents the real driverless operation.	-	

The last two columns of Table 1 represent the cross-compliance of SAE levels compared to the levels of the German Federal Highway Research Institute (BASt: Bundesanstalt für Straßenwesen) as well as that of the National Highway Traffic Safety Administration (NHTSA) of the USA. As an interpretation to Table 1 SAE phrased the following: "*These levels are descriptive rather than normative and technical rather than legal. They imply no particular order of market introduction. Elements indicate minimum rather than maximum system capabilities for each level. A particular* *vehicle may have multiple driving automation features such that it could operate at different levels depending upon the feature(s) that are engaged*" (*J3016*, 2016).

Basically, the defined levels indicate the balance of the dynamic driving tasks between human and machine from zero level (no automation) to fifth level (full automation). Two paths are possible to achieve the full automation (*Automated and Autonomous Driving: Regulation under uncertainty*, 2015): the concept of "something everywhere" or "everything somewhere". The first variation means that automated driving systems appear gradually in the traditional vehicles according to the levels of Table 1, i.e., the drivers give more and more driving tasks to the automated systems. The second evolution concept assumes that the fully automated cars could be applied in driverless mode immediately together with traditional vehicles until a total market penetration is achieved. Whichever scenario of penetrations will be finally realized, serious legal and policy questions have already been emerged concerning the application of autonomous vehicles in road transport.

3. Regulation and standardization issues for autonomous road transport

In 74 countries of the world the standard road traffic rules are regulated by the Vienna Convention on Road Traffic of 1968, and its predecessor, the Geneva Convention of 1949. In practice, similar regulations are in force in Europe, USA and China, with strong development trends of autonomous driving technologies already underway. This is important as the above treaties also provide a legal definition of the road traffic driver. According to those sources, the driver is a responsible person being charged with vehicles or animals on the road, and drivers must be at all times able to "control their vehicles (or guide their animals)". Therefore, the main legal challenge emerges: can driverless vehicles drive?

The current regulation therefore might hinder the evolution and the fast spreading of self-driving cars. Several solutions have been proposed (Bradshaw-Martin and Easton, 2014). One is to define the concept of robo-pilot of autonomous car, i.e., the driving software of the vehicle would be considered as "driver". This would allow to designate the software systems that control autonomous vehicles as persons. Another recommended solution would be to rephrase the Vienna convention, encompassing non-human drivers as well. Of course, this would open up further questions concerning liability and ethical responsibility, especially in complex driving situations or accidents when non-human drivers are in use. An answer to these critical questions can be given by the application of "ethical proxies" (Bradshaw-Martin and Easton, 2014), where autonomous cars are programmed to behave with a predefined ethics appropriate to the vehicle users. Thus, car owners retain the ability to choose a given ethical theory. This approach would be convenient as its liability concept is close to the current liability system of human drivers.

Moreover, it is also important to note some other important suggestions (Hamilton and Teare, 2015). On the one hand, the rules for autonomous vehicles should be agreed as a new treaty at international level similarly to the Vienna convention. On the other hand, it must be realized that the legal system of our days only try to follow the development process of autonomous technology instead of leading it and keeping pace with it.

Another strong obstacle that autonomous vehicles face is the nonexistence of standardization for autonomous road transport. Although terminology and levels for autonomous vehicles exist as an international standard (SAE International, 2014), it only concerns the automated road vehicle itself and not the autonomous road transport as a whole system. This problem, however, could be handled by exploiting the already-existing standards for other means of transportation. Automated transport systems (e.g., railway, subway or even elevator systems) are plainly accepted and have already been working since decades in many parts of the world. The first automatic train operation started at the Victoria line in London in 1967. Also, automated technologies of air passenger transportation (e.g., auto-pilot, automatic baggage sorting) have been in place for a long time.

Accordingly, the standards of automated railway systems could be considered as a starting point to create a common regulation for driverless road vehicle transportation. The IEC 62290-1:2014 international standard for automatic train operation (*IEC 62290*, 2014) also applies five Grades of Automation (GoA) as automation levels. The standard summarizes the principles for urban guided (track-based) transport management and control systems. By using this standard analogically, the autonomous public transportation criteria could be directly derived. Although this applies to track-based vehicles, autonomous public buses with fixed routes (especially on bus lanes) could be considered as "rail" vehicles. Therefore, the same standard can be used in general as a basic requirement.

ISO also provides a basic regulation for functional safety concerning all automotive electronic and electrical safety-related systems (*ISO 26262*, 2011). It concerns the possible hazards related to the malfunctioning of electrical systems, providing regulations and recommendations throughout the development of the product. Therefore, this standard is largely applicable to autonomous road transportation.

In the European Union the High Level Group GEAR 2030 was launched on the basis of the Commission Decision C(2015) 6943 in 2015. The group will reveal and discuss the main challenges for the automotive industry in the next 15 years. Gear 2030 aims to formulate a harmonized and competitive European vision for the connected and automated driving. Obviously, the Union is committed to support the autonomous technology through jointly agreed roadmaps and milestones. This work could be accelerated by considering the analogies with other transport modes as suggested above as well as by ensuring a clear and harmonized standardization background.

In conclusion, the international regulation for autonomous road transport is extremely important. Best practices from related domains should be utilized in the absence of an *ad hoc* standard. Moreover, the clear technological potential of autonomous technology must be justified through tests and validation prior to regulation. This can be fulfilled mostly by testing and proving actions. As a fresh example, the new automotive test track of Hungary (Zalaegerszeg) is mentioned, which is underway and especially designed for autonomous road vehicle proving ground (Szalay et al., 2017). Such initiatives can lay the ground for fast and successful standardization process.

4. Liability

Autonomous cars significantly stress the issue of liability. There are three main types of liability concerning road traffic: civil (e.g., reimbursing the value of damages caused to third parties), criminal (e.g., being accountable for the death of the injury of a person), and administrative liability (e.g., driving in absence of the required authorization). The problem of liability in autonomous means of transportation has already emerged in the past, in particular with respect to elevators and airplanes (Colonna, 2012; LeValley, 2013). However, autonomous cars pose a brand new challenge from the perspective of liability (Marchant and Lindor, 2012).

Elevators are vehicles, but elevator liability is not generally governed by any specific law. In the United States, accidents by elevator fall into the category of torts based on the premises liability law, whereas administrative liability is generally governed by State laws, and partly by federal laws. The European Union has recently adopted a Directive[1], which supersedes previous Directives, but it does not concern liability. The Directive is focused on the manufacturer's duties of conformity and the rules for conformity assessment, and the Article 43 on penalties does not introduce any specific sanctions, leaving them to Member States. In general, in case of personal injury caused by elevators, courts place liability on the manufacturer, both from a civil (Cour d'appel de Paris, 1985) and a criminal (Cassazione penale, Sezione 4, 2016) perspective, unless the manufacturer is found compliant with all required standards and maintenance procedures (*Pridgen* v. *Boston Housing Authority, 308 N.E.2d 467 (Mass. 1974)*, 1974). For an ample survey of U.S. decisions concerning liability in unmanned vehicles, see (Wu, 2011).

The main problem concerning autonomous cars is that most countries have adopted an intense legislation concerning vehicular traffic, but this legislation is based on the traditional paradigm, i.e., the driver is human and the car is a "thing" operated by him/her. Liability therefore weighs on the human being, with the additional consideration that car driving is considered a dangerous activity (Harper and Kime, 1934) and therefore subject to stricter rules. In general, the legal framework for vehicular traffic includes: manufacturing requirements and product liability (Stapleton, 1994); administrative requirements for car ownership and liability of car owners; mandatory insurance for car owners; and administrative requirements for car driving and liability of the driver (Pascàud, 1908).

The existing legal framework collides with driverless cars, where the car occupant is not a "driver", and therefore the normal rules for driver's licenses and liability are jeopardized (Vladeck, 2014). As autonomous cars take over the market and the roads, the rules for vehicular traffic will need to be rewritten. As mentioned, liability exists under several different perspectives: administrative liability for failing to comply with regulations; civil liability for damages

[1] Directive 2014/33/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to lifts and safety components for lifts.

caused to third parties; and criminal liability for violation of imperative norms.

The administrative perspective is not significantly affected by autonomous vehicles. Both the driving and the owning of a vehicle are generally subject to administrative requirements. Unless a legal framework is modified with the introduction of specific provisions for autonomous vehicles, the requirements are unchanged. In particular, two situations are eligible to occur. If a legal framework does not include any specific requirement for autonomous vehicles, then the owner, the driver and the manufacturer will be subject to the same legal requirements as per traditional vehicles. On the other hand, if the legal framework introduces specific provisions for autonomous vehicles, then the requirements of all the three aforementioned stakeholders might be changed. Most of the existing regulations affect the production of autonomous cars, in particular the testing phase. However, regulatory changes might also affect owners and drivers: for example, it is possible that specific driver's license is introduced for autonomous vehicles; or that the insurance requirements for the owner of an autonomous vehicle are modified with respect to ordinary vehicles. Laws and regulations introducing such requirements will also determine the sanctions for their violation, so little doubt is likely to arise concerning liability from administrative requirements.

4.1. Civil liability

Civil liability aims at restoring damages suffered in consequence of an accident. In particular, civil liability for damages caused by the circulation of vehicles is a complex topic, which is severely jeopardized by the autonomous vehicle revolution. In case of damages caused to third parties (mostly people and other vehicles), the liability is placed on the car driver. As autonomous vehicles normally don't have a "driver" in the strict sense, the remedies might be charged upon someone else. The introduction of driverless cars is already causing a shift from the paradigms of tort liability (Colonna, 2012) and insurance (Sloan et al., 1994) to product liability (Villasenor, 2014). Negligence will still be one of the perspectives under which vehicle liability is viewed, but with a significant shift: from the driver for being inattentive or in conditions not suitable for driving, to the car owner (Duffy and Hopkins, 2013) or the manufacturer (Gurney, 2013) for defects in maintenance or in the manufacturing process.

According to general liability principles, the car occupant is not eligible to be held accountable in case of damage to third parties, because he or she was not actually controlling the vehicle. When the vehicle is operating autonomously, there is no room to hold the occupant accountable, as he or she is actually a passenger, no more and no less than a passenger of an elevator or a bus. As the passenger of a bus is not liable in the case of an accident in which third-party goods or people suffer damage, the same can be said for the passenger of an autonomous vehicle.

Concerning the liability of the owner, it does not seem that the introduction of autonomous vehicles significantly impairs it. As current legal frameworks place the liability on the owner for objective reasons (i.e., the mere ownership of the car, which allows to easily identify a natural or legal person to hold liable), there is no reason why this should not be maintained for autonomous vehicles. In general, the owner cannot be held liable if he or she took adequate precautions concerning the custody of the vehicle and its maintenance (normally in the form of periodic check-ups prescribed by laws and regulations).

The liability of the manufacturer is based on product liability. In particular, this can happen if the damages were caused by a malfunctioning of the vehicle. The manufacturer can be held accountable based on defective product liability if the damage occurred because of a defect in the ability of the vehicle software to prevent the damage. "Defect" is a wide concept, embracing both situations where the vehicle used to function properly and at some point starts operating in the wrong way, and those where the vehicle features do not allow it to avoid the damage (e.g., accidents that the vehicle was not programmed to prevent). This distinction concerns both internal and external liability. In other words, it does not only affect who, between the owner and the manufacturer, will ultimately suffer the consequences of the damages, but also who will face the procedural consequences and refund the damages, although with some slight differences. In particular, the owner should be held liable *prima facie*, and condemned to refund the damages, with the possibility to be refunded in turn by the manufacturer if the damage was caused by production defect. That is, unless the defect is particularly evident, thus excluding the liability of the owner and allowing the plaintiff to complain directly against the manufacturer. On a different perspective, the liability of the manufacturer might be limited or excluded in case it did everything possible to make the defect known to its customers and offer to remove it, and the owner did not take action to remove the potential source of damage.

Recent experiments where autonomous cars were trained by means of artificial intelligence (AI) and machine learning techniques present challenges that are even more significant (Ackerman, 2017). In AI-based systems, it is hard to identify the exact reason that led to a certain decision. As the training of the AI involves configuring millions of connections by means of a training phase, backtracing the decision to the exact training set of inputs that stimulated those connections is considered an almost impossible task, and this has implications on assessing the liability of the manufacturer.

If this legal context can be expected in a future, when damage from a car will be treated just like damage from a microwave oven, the current transition phase presents challenges that are even more complex. There are still some reasons to refer to the car occupant as a driver: on one side, there is a significant role in setting the course; on the other side, as the technology behind driverless cars is undergoing extensive testing and refinements, existing driverless cars have a dual mode, allowing the human occupant to take manual control of the vehicle. Such a situation calls for the combination of the two approaches, the one based on the drive's responsibility for damages and criminal offences, and the one based on the manufacturer's liability for defective products. For example, if there is an evident malfunctioning of the vehicle, the driver-passenger might be required to take manual control of the vehicle. Failure to do so might lead to him or her being held accountable for damages, at least in those cases where it can be proven that there was a reasonable time to react and take manual control between the malfunctioning and the occurrence of the damage. In those cases where the human occupant's reaction in taking control of the vehicle would be deemed to have the potential to avoid an accident, he or she might be held liable for negligence. In other words, liability for the driver-passenger may occur in any situation where an ordinarily able driver could have avoided an accident but the vehicle failed to avoid properly, and there would have been enough time to allow a duly attentive driver to take manual control and avoid the accident.

Additional questions arise from the interaction between driverless and human-driven cars, which is inherently dangerous as has been shown by several accidents, even with fatal consequences (Singhvi and Russell, 2016). The legal remedies call for an investigation of the degree of liability that can be placed on the driver of the human-driven car and of the product liability of the driverless car, although some authors deem it possible to approach liability in a homogeneous way, i.e., using negligence for the driverless car as well (Greenblatt, 2016). Determining the degree of liability that can be placed on the human driver or on the car manufacturer will be a major challenge in courts, as the increasing adoption of autonomous vehicles will also increase the accident rate.

Finally, it is evident that this shift will also have implications on the insurance system. Today, most countries require cars to be provided with insurance. As the emphasis shifts from driver liability to product liability, a similar shift in insurance will accommodate the change (Thierer and Hagemann, 2015).

4.2. Criminal liability

Given its function as a penalty, criminal liability is bound to the behavior of the agent. Therefore, in the absence of a causal bond between the behavior of the driver and the event, no liability can be placed on the driver. The very basis of criminal liability is seriously impaired when autonomous vehicles are involved. Criminal liability is based on the strict personality of the crime. This assertion is not belied by the fact that some countries include provisions concerning the criminal liability for legal persons and corporates, because that phenomenon essentially resolves in a distinct separation between the legal entity and the natural persons who acted on its behalf. In other words, depending on the legal system, liability may reside on the legal person, on the natural persons who acted on its behalf, or both, but such liability criteria are not incompatible with the principle of personality of the crime.

In general, laws hold the driver liable for accidents involving criminal consequences. Additionally, criminal liability in case of vehicular accidents may be heightened, since cross-border opinions consider car driving to be a dangerous activity, although not as dangerous as to imply strict liability (Boston, 1999; Cigolini, 1963; Pascàud, 1908; Prosser, 1977). In other words, the car driver is held personally accountable for criminal, but he or she can prove the absence of liability depending on the circumstances. This principle is highly at stake when autonomous vehicles are concerned. As there is no "driver", the criminal liability of the car occupant is excluded.

Mitigations to the principle of the criminal liability of the car occupant already emerged in the past. In particular, in those situations where no driver can be held criminally accountable, it is possible that a criminal liability is placed on the car manufacturers (Fleming, 1965). Although the liability of the manufacturer is certainly a viable legal solution in any case where the car occupant cannot be held liable, the real issue is whether there are still situations in which the occupant can be held liable. The issue is particularly problematic, because the occupant might be oblivious to the operation of the driverless vehicle, such as sleeping or reading (Douma and Palodichuk, 2012).

The relevant question, then, is whether the occupant is allowed, on a general basis, to be oblivious to the vehicle operation and its surrounding context, or he or she is supposed to be attentive and ready to react in case an accident becomes likely. Preliminarily, it should be noted that current legislation does not operate any distinction concerning the liability of the driver of an ordinary car and the passenger of an autonomous car. Therefore, at the current state of the art, it is quite safe to assume that the passenger of an autonomous car cannot be exempt from liability for the sole reason that the car is autonomous.

It can be argued that even the attention of the passenger might not be sufficient to prevent an accident involving criminal consequences. However, in the case of an autonomous car, such an attention may be required to be exempt from liability, whereas a lack of attention would probably be sufficient to incur into criminal liability.

In 2016, there have been at least two reports of autonomous car accidents involving the death of a person. One in particular was confirmed by the car manufacturer Tesla (The Tesla Team, 2016), and it appears that the investigators are trying to determine whether a portable DVD player was operating at the time of the accident (Liston and Woodall, 2016). This detail could be significant in establishing that the passenger can be held liable due to negligence in case he or she is not attentive, exactly like the driver of an ordinary car.

With the current state of the art, as autonomous vehicles are still undergoing an extensive testing phase, the correct solution certainly lies in requiring attention on the passenger's part, at least in the perspective of avoiding the liability. Future legislation in a stable environment of autonomous vehicles could include provisions that exclude or limit the liability even in case the passenger is inattentive. Possible mitigations between the two extremes could include some sort of alarm to snap the passenger's attention in case the traffic conditions start to get worse, requiring him or her to be ready to take manual control of the vehicle. Then again, the occupant might be exempt from liability (which might then be placed on the manufacturer) in case of a "failure to warn" issue on part of the vehicle, as has been recognized by courts in the past (Wu, 2011).

5. Conclusions

In this paper, the critical features of autonomous road transport have been investigated from the perspective of technological regulation and law. The results are twofold. On the one hand, standardization issues were concerned concluding that the international regulation for autonomous road transport is inevitable and the analogies from other transport means should be utilized as best practices. On the other hand, administrative requirements and liability issues were discussed with recommendations. The proper definition of liability put on human driver and on the car manufacturer will be a critical problem in the near future. Moreover, future legislation concerning autonomous vehicles should include provisions that exclude or limit the liability even in case the passenger is inattentive.

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