NATIONAL PILOT COMMITTEE FOR DIGITAL ETHICS

OPINION 2

ETHICAL ISSUES REGARDING "AUTONOMOUS VEHICLES"

COMITÉ NATIONAL PILOTE D'ÉTHIQUE DU NUMÉRIQUE
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COMITÉ CONSULTATIF NATIONAL D'ÉTHIQUE
POUR LES SCIENCES DE LA VIE ET DE LA SANTÉ

ETHICAL ISSUES REGARDING “AUTONOMOUS VEHICLES”

Opinion unanimously approved by the members present at the CNPEN plenary session of April 7, 2021

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SUMMARY

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Automated driving vehicles are equipped with digital computational functions using sensors and on-board computers to replace the human driver. They are connected to a specific infrastructure. Their development is often motivated by the improvement of road safety through eliminating human failures, by a wider range of mobility options, lower emissions and environmental impact, and the renewal of the transport sector in general and the automotive industry in particular.

The CNPEN has analyzed the ethical issues raised by automated driving vehicles while examining the validity of these arguments. In this Opinion, it makes a number of recommendations concerning:

- the terminology used to describe these vehicles and the functions associated with their automation;
- road safety and system dependability;
- human control of the vehicle;
- personal freedom;
- social and environmental impacts.

These recommendations are the following:

Terminology

R1: Use the term "automated driving vehicle" in regulatory texts rather than "autonomous vehicle".

Road safety and system dependability

R2: Conduct realistic simulations and experiments on a representative scale in different types of environments in order to assess the impact of automated driving vehicles on improving road safety. Experiments should be conducted within an appropriate regulatory framework.

R3: Study the advantages of clearly identifying automated driving vehicles as such, based on the reactions of other road users.

R4: Future regulations concerning the design of critical onboard functions and the infrastructure needed for automated driving vehicles must require rigorous development, verification, validation and certification methods. Regulations must also require appropriate design transparency according to both users and certification authorities.

R5: Appropriate hardware and software protection must be assured for each component of the technical system formed by the vehicles, the infrastructure, their connections and the combinations thereof.

Note: The committee addressed the dilemma of decision-making in the situation of an unavoidable accident. It is dealt with in a section of this opinion but no specific recommendation is made.

Human control of the vehicle

R6: Make provision for remote operators to take back control at any time in the case of automated driving public transport vehicles or shared-use supervised vehicles, within the constraints of feasibility.

R7: Provide the users and remote operators of supervised automated driving vehicles with a communication and warning system in addition to on-site assistance and emergency services if necessary.

R8: Tailor driving training for users of unsupervised automated driving vehicles, based on research on the required skills, capacity for effective action, relevant information, appropriate human-machine interfaces and, more generally, on the design of the passenger compartment.

R9: Systematically make provision for both manual and automated driving modes in a private or shared vehicle.

R10: In automated mode, allow only predetermined standardized and certified driving modes in private or shared vehicles.

Personal freedom

R11: Study the mechanisms required to manage and protect personal data collected and processed by automated driving vehicles and their infrastructure (information provided to all those concerned, data anonymization, deadline for destroying the data collected, etc.), taking into account the possible transfer of data outside Europe.

R12: Ensure that the locking and movement of the automated driving vehicle are carried out according to the user's wish, unless otherwise requested by the public authorities within a specific legal framework and for a precise purpose.

Social and environmental impacts

R13: Submit decisions by local authorities on the deployment of automated driving public transport vehicles to public consultation concerning benefits in terms of the quality of mobility services, the environmental impact, and the impact on employment.

R14: Submit the decision to authorize the local circulation of automated driving vehicles for private or shared use to public consultation.

R15: Draw up a national plan for the equitable development of the connected infrastructure necessary for the deployment of automated driving vehicles.

R16: Allow for the necessary human assistance for people who need it to let them actually access and use automated driving vehicles.

R17: The impact of the deployment of automated driving vehicles on employment and jobs in each relevant sector should be assessed in order to develop appropriate training as part of strategic workforce planning, and to invest in emerging sectors.

R18: Submit the deployment of automated driving vehicles to a comprehensive environmental approval process, taking into account not only the vehicle itself but also the physical and digital infrastructure required by the different modes of use and operation.

R19: Take advantage of the possibilities offered by automated driving technologies for truck platooning on the road network to develop an environmentally-friendly multimodal freight transport policy, taking into account job transformation in each sector concerned as well as the impact on the use of the road network by different categories of users.

ETHICAL ISSUES REGARDING "AUTONOMOUS VEHICLES"

Introduction

In a letter dated July 15, 2019, the French Prime Minister tasked the Chair of the National Consultative Ethics Committee for health and life sciences (CCNE)[1] with implementing a pilot project on the ethical issues associated with sciences, technologies, uses and innovations in the fields of digital technologies and artificial intelligence. Hence, the French National Pilot Committee for Digital Ethics (CNPEN) has been set up and placed under the CCNE aegis. The Prime Minister requested that the studies conducted as part of this pilot project focus primarily on "medical diagnosis and artificial intelligence", "conversational agents" and "autonomous vehicles', this last subject being coordinated with the mission concerning the national strategy for the development of automated road mobility, overseen by Ms Anne-Marie Idrac.

This Opinion of the CNPEN concerns "autonomous vehicles". It is based on the deliberations of the working group set up in December 2019 to study this topic. It involved hearings with stakeholders (see the appended group composition and list of people interviewed), as well as regular exchanges with the players involved in the mission relating to the national strategy for the development of automated road mobility[2] .The working group included a person from the Ministry of Ecological Transition assigned to the mission, and a number of working group members took part in the national seminar on the "societal aspects of the development of autonomous vehicles", held on November 19, 2020.

1. What is an automated driving vehicle?

Some road vehicles are equipped with driver assistance systems such as cruise control, stability control, safe distance warning, self-parking, obstacle detection and route planning. Although these functions make driving easier, they do not fundamentally change the action of driving or the status of the vehicle in its environment: it is the driver who controls the vehicle, who perceives and interprets the signage infrastructure (lights, signs, road markings) and who takes into account other users and any animals or miscellaneous objects that may also be present in the environment.

Unlike driver assistance systems, automated driving functions actually replace the driver in everyday driving on the open road or in the city[3]. They acquire and interpret information (perception) relating to the vehicle's environment and the vehicle itself, and make decisions on route planning and the actual act of driving (speed and steering control). These vehicles also include functions to communicate with the road infrastructure, with other vehicles, and, where applicable, with remote human operators. Through this communication function, the vehicle is able to receive information on road signage, traffic conditions and the local environment (e.g., other connected vehicles and users), even beyond the range of its own sensors. The infrastructure is designed and developed to enable this communication and ensure interoperability. It relies primarily on a system of digital signage that interacts directly with the vehicle.

Although these functions are currently the subject of a range of international research and development programs as well as many scientific and technical publications, they are not yet operational or available to buy, with a few rare exceptions. Vehicles equipped with these functions are currently deployed on an experimental basis only, within specific areas or cities, as part of a process of legal exemptions[4]. Given that manufacturers do not publish details on the operation, limits and state of progress of the systems developed, it is difficult to conduct an independent

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[1] *CCNE, Comité consultatif national d'éthique pour les sciences de la vie et de la santé* : French governmental advisory council on bioethics issues. https://www.ccne-ethique.fr/en/pages/presenting-national-consultative-ethics-committee-health-and-life-sciences.

[2] https://www.ecologie.gouv.fr/vehicules-autonomes (in French)

[3] "Levels of Driving Automation" set out in the SAE J3016 standard for consumers. https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic

[4] Decree No. 2018-211 of March 28, 2018, on trials of automated vehicles on public roads, https://www.legifrance.gouv.fr/loda/id/JORFTEXT000036750342/2021-01-25/

technical assessment of their real capabilities. If vehicles of this type are deployed on a large scale, international regulation will be necessary. Prior to this, the ethical issues raised must be addressed.

2. Ethical issues regarding automated driving vehicles

The main arguments put forward for the development of vehicles with automated driving functions—whether private or shared, for passengers or goods—concern the benefits to society and the environment. Automated driving vehicles represent a major economic challenge for the automotive industry as well as for digital players, leading to the emergence of many new companies[5].

The ethical analysis encompasses all the changes to the human condition associated with the development and deployment of this type of vehicle. Will these changes be as significant as when the automobile replaced the horse and carriage? The overall question is complex. It can nevertheless be addressed through several sub-questions relating to the design of the vehicle, its deployment and its use. Some of these questions have already been identified or addressed in the recommendations set out in the opinions of national or international committees or in policy documents.

For example, a report by the French Directorate General for Infrastructure, Transport and the Sea (DGITM)[6] draws attention to the lack of documentation and high level of uncertainty concerning the impact of vehicle automation on road safety, traffic flows, energy consumption, supply chain efficiency and access to mobility, particularly in rural areas.

The report of the ethics committee set up by the German Ministry of Transport and Digital Infrastructure specifically on the topic of automated and connected driving[7] sets out twenty ethical rules. They put the emphasis on accident prevention, the need for a positive benefit-risk balance, the allocation of responsibilities, particularly when drivers or remote operators take back control, the risks associated with the infrastructure exercising general surveillance and control over the vehicles, the need for a data management policy, and the technical control of learning systems during operation. Regarding the issue of dilemma situations, the report recommends that they be prevented wherever possible and, if not, that the decision prioritizes people over animals and property, that no distinction is made between people, and that people who are not concerned by vehicle use are not sacrificed.

The report published by the expert group appointed by the European Commission to study the ethics of connected and automated vehicles[8] sets out twenty recommendations. They include the prevention of personal harm, the revision of traffic rules, a statistical risk distribution in dilemma situations, the possibility for users to select a number of consent options, the protection of the data collected, the prevention of discrimination in access to services, and the attribution of liability and accountability.

[5] Such as Tesla, Waymo, Cruise, EasyMile and Navya.
[6] *Développement des véhicules autonomes – Orientations stratégiques pour l'action publique.* [Development of autonomous vehicles - Strategic orientations for public action.] Directorate General for Infrastructure, Transport and the Sea (DGITM), May 2018 (in French).
https://www.ecologie.gouv.fr/sites/default/files/90p VDEF.pdf
[7] Ethics Commission Automated and Connected Driving – Federal Ministry of Transport and Digital Infrastructure, June 2017, https://www.bmvi.de/SharedDocs/EN/publications/report-ethics-commission.pdf?__blob=publicationFile
[8] Horizon 2020 Commission Expert Group to advise on specific ethical issues raised by driverless mobility (E03659). Ethics of Connected and Automated Vehicles: recommendations on road safety, privacy, fairness, explainability and responsibility. 2020. Publication Office of the European Union: Luxembourg.
https://ec.europa.eu/info/sites/info/files/research_and_innovation/ethics_of_connected_and_automated_vehicles_report.pdf

This CNPEN Opinion addresses ethical issues relating to:

- the terminology used to describe these vehicles and the functions associated with their automation;
- road safety and system dependability;
- human control of the vehicle;
- personal freedom;
- social and environmental impacts.

The report also discusses the relevance of the arguments put forward in favor of automated driving:

- *road safety*, i.e., fewer fatalities on the roads and, more generally, fewer accidents caused by deliberate or accidental human activity (speeding, drink driving, falling asleep at the wheel, poor driving, etc.);
- *social benefits,* for example, providing a means of mobility for people who are unable to drive; providing transport services in sparsely populated areas or in low-traffic time slots; saving time for drivers, relieving them of tedious or difficult tasks;
- *environmental impact and ecology*, i.e., reducing the environmental footprint of road vehicles through better route planning and a smoother traffic flow;
- *the economy*, i.e., the development of the automotive and transport industry.

3. Ethical issues regarding terminology

The widely used term of "autonomous vehicle" comes from the technical language of robotics: a robot is a mobile machine programmed to carry out various functions of perception and action. These functions may be based on machine learning methods. The robot carries out these actions in a complex and dynamic environment in compliance with precise specifications. It is described as "autonomous" if it is able to carry out its tasks without human intervention once it has been programmed.

The "autonomous vehicle" is therefore a robot of this type.

However, applying the term "autonomous" to the status and capabilities of these vehicles deployed in human environments is ambiguous since, for human beings, autonomy means being able to set your own goals and choose your own course of action.

This ambiguity is likely to inspire fear or misunderstandings or to give rise to unfounded expectations. Indeed an "autonomous" entity, in the etymological sense of the word, would be unpredictable by nature, taking "initiatives" by itself or making its own "decisions". For example, we sometimes hear narratives suggesting that the vehicle would "choose of its own volition" to run over one person rather than another. It is therefore more appropriate to adopt terms other than those used for human capabilities to describe the capabilities of computer systems based on artificial intelligence and robotics. In particular, we should use the term "automated driving vehicle" rather than "autonomous vehicle" or "self-driving vehicle".

Another example is the verb "to delegate", commonly used to describe the transfer of a decision-making capacity and the partial shifting of responsibility from one human being to another. Using the expression "delegated driving"[9] suggests that the human driver is transferring their decision-making capacity and some responsibility to a robot. This could then be seen as placing the machine on the same moral or even legal footing as a human. The use of this term is therefore inappropriate.

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[9] Act No. 2019-1428 of December 24, 2019, on mobility strategy, https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000039666574

Using terms such as “autonomy” and “delegated driving” suggests that the vehicle makes its own decisions and that users would not have to manage driving and to bear the associated responsibilities. In view of this ambiguity, we recommend the use of more appropriate terms.

It will be necessary for stakeholders to work together in order to change the vocabulary used to describe the capabilities of automated driving vehicles in such a way as to make a clear distinction between their capabilities and the human capabilities.

> **Recommendation for the authorities (R1):** Use the term “automated driving vehicle” in regulatory texts rather than “autonomous vehicle”.

4. Ethical issues regarding road safety and system dependability

4.1. Road safety

Global statistics by country show that the distribution of road accident victims is not uniform, and that it appears to be correlated with factors relating to economic development[10]. It therefore seems necessary to identify the precise causes of these accidents and to assess all the measures that could help to prevent them. Moreover, most of the automated driving vehicle deployment plans currently under consideration concern only a small number of countries, industrialized for the most part, and an equally small number of contexts in which accidents are rare: public transport, reserved areas, low-speed zones. As a result, the impact of automated driving vehicle deployment on the number of road accidents and fatalities has yet to be assessed by carrying out realistic simulations and experiments on a representative scale in different types of environments[11].

> **Recommendation for vehicle manufacturers (R2):** Conduct realistic simulations and experiments on a representative scale in different types of environments in order to assess the impact of automated driving vehicles on improving road safety. Experiments should be conducted within an appropriate regulatory framework.

Moreover, it could be necessary to identify automated driving vehicles in order to avoid their behavior surprising other road users and causing accidents. It is also true, however, that identifying vehicles in this way could cause other road users to react inappropriately, for example demonstrating exaggerated confidence in these vehicles and testing their behavior (blocking their way, tailgating them, etc.) or, on the contrary, showing excessive distrust of their behavior and taking risks to overtake or pull away from them.

> **Recommendation (R3):** Study the advantages of clearly identifying automated driving vehicles as such, based on the reactions of other road users.

4.2. Robust technical design

The onboard functions of perception and control in automated driving vehicles must be reliable.

A function is said to be “critical” if its failure jeopardizes the ability of the system of which it is a part to function correctly or if it results in catastrophic consequences (for example, failure of an automated braking function, or failure of the perception function to detect an obstacle)[12]. To ensure

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[10] World Health Organization (WHO), Road Traffic Injuries, February 2020 https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries#:~:text=Approximately%201.35%20million%20people%20die,road%20traffic%20crashes%20by%202020

[11] National strategy for the deployment of automated road mobility 2020-2022 https://www.ecologie.gouv.fr/sites/default/files/20171_strategie-nationale-vehicule%20automatise_web.pdf (in French)

[12] The first fatal accident involving a vehicle in autopilot mode was caused by a failure of this type. On May 7, 2016, a Tesla vehicle in autopilot mode collided with a white truck cutting across the road ahead because the sensor system failed to make a distinction between the white trailer and the bright sky behind it. https://www.straitstimes.com/world/united-states/tesla-car-on-autopilot-crashes-killing-driver. A similar accident occurred on March 11, 2021.

system dependability, critical functions are implemented as part of the software system architecture in order to minimize the probability of failure to negligible values. Explicit provision must be made for dealing with the failure modes of these functions.

Current regulations do not cover all the technologies developed for automated driving vehicles such as, for example, the use of machine learning in critical functions. Adapting or revising the regulations should not make them less demanding, but impose strict standards for the development, verification and validation of systems regardless of the technologies implemented. In particular, verification and validation of the machine learning algorithms (e.g., reinforcement learning, deep learning) that could be used must be achieved in order to ensure reliable operation. Continuous learning during vehicle operation must be ruled out, since it could cause the vehicle to behave unpredictably.

Furthermore, it is essential to provide protection against hacking, adversarial attacks and intrusions[13], and to ensure the integrity and confidentiality of data. At the same time, it is necessary to ensure the reliability of the embedded software itself and also of the networks and communication infrastructure.

Nevertheless, failures of onboard systems or of infrastructure are always possible as the result of breakdowns, design errors, or cyber-attacks. In this case, the automated driving vehicle should be able to function in fail-safe mode, hand over control to the user, or stop safely without endangering passengers or other road users. The vehicle should also be able to inform users of the type of failure and the functions concerned.

Recommendation (R4): Future regulations concerning the design of critical onboard functions and the infrastructure needed for automated driving vehicles must require rigorous development, verification, validation and certification methods. Regulations must also require appropriate design transparency according to both users and certification authorities.

Recommendation (R5): Appropriate hardware and software protection must be assured for each component of the technical system formed by the vehicles, the infrastructure, their connections and the combinations thereof.

4.3. The dilemma question

Many studies and recommendations have focused on the question arising from the dilemma[14] that automated driving vehicles could face: “If a collision is unavoidable, which victim should be chosen?”[15]. This question is in fact a thought experiment concerning the moral choices made by humans. It is transposed in the real world to critical situations in which the vehicle software would be programmed to make a choice between several options, all of them with negative consequences for people. In these real-world situations, the vehicle’s behavior depends on several technical parameters (availability and interpretation of data, degree of uncertainty, decision time, time to collision).
The dilemma question, as a thought experiment, focuses exclusively on human moral choice and does not factor in all these technical constraints.

Discussions often focus on this specific type of situation: the answer to the dilemma should be foreseen at the vehicle design stage so that it can be programmed—unlike the spontaneous and unpredictable reaction of a human driver facing the same situation. It should be noted, however,

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[13] For example, one experiment showed that a traffic sign recognition system could be tricked by displaying a speed limit sign on a digital billboard for a split second. The system considered this sign to be legitimate information and displayed the wrong speed limit on the on-board display. By briefly projecting images of vehicles or pedestrians onto the road, researchers were also able to trigger the emergency braking function of the latest versions of Tesla's autopilot. https://www.nassiben.com/phantoms

[14] Philippa Foot. Moral Dilemmas and Other Topics in Moral Philosophy. Clarendon Press; Oxford University Press, 2002.

[15] See in particular the German and European reports mentioned in notes 7 and 8.

that unexpected situations will always arise on the road, and programming will inevitably be incomplete, no matter how exhaustive.

As the perception and decision-making algorithms are designed in advance, the situation assessment and the actions computed in real time are based on programming. Two ethical issues arise in a dilemma situation. First, the criteria used to identify the entities present on the scene and the distinction that the algorithm would make between them. Second, the method applied to select the action, necessarily defined in advance, the consequences of which will be harmful for one or more of these entities.

The debates around dilemmas are based on the idea that the automated calculation of a decision can be modeled on the moral reasoning of a human being. However, reasoning and calculation are not the same: a dilemma situation, presented as leading to a "decision to kill" made by the machine, resulting in human casualties, is meaningless for automated driving vehicles. The vehicle's actions are determined by the designer's predefined algorithms; this does not make the vehicle a moral agent. However, as mentioned above, adopting vocabulary used to describe human traits (e.g., "decision to kill") is likely to project a sense of morality onto the vehicle. The CNPEN highlights the need to avoid projecting this type of reasoning onto automated driving vehicles by adopting a narrative that is explicitly different from the one used to characterize accidents involving human drivers.

As has already been pointed out, the dilemma question is a thought experiment concerning human moral choices. Should this question represent a real decision-making issue in a real driving situation, several non-exclusive possibilities can be contemplated:

- ***with regard to preventing the situation:***

a. Restrict the use of automated driving vehicles by some local authorities in specific conditions. For example, ban these vehicles in some urban areas.

b. Segregate automated driving vehicles in specific lanes in order to limit dilemma situations. This option would require manual driving outside these lanes.

- ***with regard to vehicle programming:***

c. Implement random behavioral choices in the programming of automated driving vehicles. This would break the causal chains leading to harm or damage, thereby ensuring that morality is no longer projected onto automated driving vehicles.

d. Design explicit rules on the behavior of automated driving vehicles in dilemma situations. This choice should be informed by considerations relating to the algorithmic feasibility of the chosen solution. Furthermore, the rules should be enshrined in legislation.

e. Do not distinguish the dilemma situation as such in the control algorithms governing vehicle behavior.

5. Ethical issues regarding human control of the vehicle

Human control is one of the ethical principles highlighted in the international debate on autonomous systems and artificial intelligence[16]. In the case of automated driving vehicles, human control is clearly not exercised at all times during the journey, but rather concerns the selection of the driving modes—manual or automated.

5.1. Remote operator

Some automated driving vehicles projects, especially for public transport or fleet usage, involve professional operators. They would supervise the vehicles remotely and take back control in certain situations. Like air traffic controllers, these remote operators would manage several vehicles assigned to them at the same time. It should be noted, however, that situations tend to change more quickly on land than in the air and that controllers do not currently fly the aircraft.

The remote operator could either deal with driving as planned in pre-established situations, for example on portions of road where automated driving is impossible, or they could intervene in the event of incidents, that are by nature unplanned.

In the second case, the operator could experience long quiet periods requiring no action on their part, during which they could become less attentive. Or, in contrast, they could be faced with a situation in which several incidents occur at the same time, requiring them to make a rapid assessment in order to take action and, where applicable, take back control of one or more vehicles. If the operator has not been able to continuously monitor the situation, they could take inappropriate action owing to a lack of understanding of what is actually going on.

This raises questions about the feasibility of remote control and fast action on a large number of vehicles, the number of operators that would be required, their roles and the means they would need to be able to monitor situations and take appropriate action. Procedures to compensate for a possible lack of reaction by an operator must be defined, as described in paragraph 4.2, to manage fail-safe modes or vehicle stopping while ensuring the safety of both vehicle passengers and immediate surroundings.

Recommendation (R6): Make provision for remote operators to take back control at any time in the case of automated driving public transport vehicles or shared-use supervised vehicles, within the constraints of feasibility.

5.2. Vehicle user

Concerning the user of an automated driving vehicle, a distinction must be made between the user of a public transport vehicle (such as a shuttle or a shared taxi), which would be supervised by a remote operator, and the user of a private unsupervised vehicle.

User of a supervised vehicle

Driving is managed by the automated functions and by the remote operator, so the user is not involved. However, the user could notice abnormal or dangerous situations, or even inappropriate behaviors by other users, that would not be perceived by the automated functions or the remote operator. This raises the question of a warning system through which the user could communicate with the remote operator.

[16] Independent High Level Expert Group on Artificial Intelligence - Ethics Guidelines for Trustworthy AI. European Commission, April 2019
https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai

Recommendation (R7): Provide the users and remote operators of supervised automated driving vehicles with a communication and warning system in addition to on-site assistance and emergency services if necessary.

User of an unsupervised vehicle

Driving is managed by the automated functions and there is no remote operator. The automated functions can be designed to give the control back to the user in specific situations (e.g., freeway exits). Conversely, the user may want to take back control in some situations (e.g., stopping because a passenger is suffering from travel sickness). This raises questions about:

- the skills that are compulsory for the user to drive the vehicle, requiring a special license;
- the user's actual ability to take control of the vehicle if they are otherwise busy;
- the design of the passenger compartment to allow the user to take back control.

Recommendation (R8): Tailor driving training for users of unsupervised automated driving vehicles, based on research on the required skills, capacity for effective action, relevant information, appropriate human-machine interfaces and, more generally, on the design of the passenger compartment.

5.3. Freedom to choose the operating mode of the automated driving vehicle

The principle of human control presupposes that users of personal or shared automated driving vehicles are free to choose between automated and manual driving modes. It also implies that users are free to choose their destination and their route (e.g., fastest route, scenic route, etc.).

However, users cannot be left entirely free to choose the driving style that best suits them (e.g., sporty driving, economical driving, etc.) in view of the consequences for safety and traffic. These modes should be included in vehicle software so that the vehicle remains predictable in terms of both its behavior and its interaction with other automated driving vehicles in the vicinity.

Recommendation (R9): Systematically make provision for both manual and automated driving modes in a private or shared vehicle.

Recommendation (R10): In automated mode, allow only predetermined standardized and certified driving modes in private or shared vehicles.

6. Ethical issues regarding personal freedom

Automated driving vehicles perceive their environment continuously by means of visual and range sensors, for their navigation needs. They also collect data on their users as well as on other road users. Their algorithms analyze the perceived scenes and interpret situations. The vehicles are geolocated. They exchange information with the infrastructure on road signs, traffic conditions, or the behaviors of other vehicles nearby. This processing of data raises questions relating to privacy, personal data protection and respect for personal freedom (freedom of movement, freedom of demonstration, freedom of assembly, freedom of expression).

6.1. Data collection

Data collected by automated driving vehicles concerning both the users of the vehicle and its surroundings (other vehicles, pedestrians, homes, etc.) may be made accessible to private or public operators[17]. This creates a conflict between the fundamental freedoms of the vehicle user, particularly freedom of movement, and the fundamental freedoms of others, as well as their privacy. The user also experiences a conflict between the choice to use an automated driving vehicle and the collection of their personal data implied by this choice. More generally, the collection of data relating to automated driving vehicles could contribute to the implementation of a technological system (vehicle data recorder, environmental sensors, etc.) that could lead to the gradual development of permanent, widespread surveillance. Developing a legislative framework specific to automated driving vehicles as part of a global approach could contribute to reinforcing the protection of personal freedoms and privacy[18]. In particular, the findings of research on how the presence of a vehicle data recorder impacts the behavior of vehicle users will be useful in informing the legislative framework concerning data access.

> **Recommendation (R11):** Study the mechanisms required to manage and protect personal data collected and processed by automated driving vehicles and their infrastructure (information provided to all those concerned, data anonymization, deadline for destroying the data collected, etc.), taking into account the possible transfer of data outside Europe.

6.2. Freedom of movement

The technical possibility for a public or private body to remotely control the locking or movement of the automated driving vehicle may infringe on freedom of movement if it is exercised outside a legal framework.

> **Recommendation (R12):** Ensure that the locking and movement of the automated driving vehicle are carried out according to the user's wish, unless otherwise requested by the public authorities within a specific legal framework and for a precise purpose.

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[17] Act No. 2019-1428 of December 24, 2019, on mobility strategy, Article 32, https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000039666574

[18] European Data Protection Board, https://edpb.europa.eu/

7. Ethical issues regarding social and environmental impacts

The deployment of automated driving vehicles raises new questions relating to social and environmental ethics in the four main modes of use: private use, shared use, public transport and logistics.

7.1. Social ethics

Regarding the deployment and operation of automated driving vehicles for private or shared use, or public transport systems, a number of issues must be addressed concerning public acceptance of the principle of automated driving vehicles and their deployment in different modes of use and operation. This concerns, for example, the quality of public transport services, or the impact on employment and businesses.

> **Recommendation (R13)**: Submit decisions by local authorities on the deployment of automated driving public transport vehicles to public consultation concerning benefits in terms of the quality of mobility services, the environmental impact, and the impact on employment.

> **Recommendation (R14)**: Submit the decision to authorize the local circulation of automated driving vehicles for private or shared use to public consultation.

In addition, one of the main arguments put forward for developing automated driving vehicles is to help people who are isolated or unable to drive, for example, to enjoy increased independence. This type of vehicle could be used to provide dial-a-ride services for people living a long way from main transport routes at a lower cost than a vehicle with a driver. However, the actual access to automated driving vehicles as a means of transport will depend on the existence and capacity of the required infrastructure: in the absence of any specific infrastructure in these areas, automated driving vehicles might need to function with degraded capacity since they would be solely reliant on their own perception of the environment. For the sake of equity among regions, the infrastructure investments required for the deployment of automated driving vehicles in areas that are a long way from major roads should be anticipated.

> **Recommendation (R15)**: Draw up a national plan for the equitable development of the connected infrastructure necessary for the deployment of automated driving vehicles.

For people who are not able to get into the vehicle independently or who need assistance (e.g., elderly people, children, people with disabilities), the advantages of automated driving vehicles must be weighed against the need to provide human support to give these people effective access to the vehicle and its use.

> **Recommendation (R16)**: Allow for the necessary human assistance for people who need it to let them actually access and use automated driving vehicles.

Another argument frequently put forward in favor of automated driving is that it frees up the time normally devoted to driving and reduces the cognitive load. This could be of advantage to vehicle users, and it is also likely to improve the working conditions of professional road users[19].

Finally, the development and deployment of automated driving vehicles are a major economic challenge for the automotive and transport sectors, but also indirectly for other sectors such as telecommunication and road infrastructure industries. While promoting the creation of new activities, the deployment of automated driving vehicles could also threaten others, particularly

[19] https://www.ecologie.gouv.fr/temps-travail-des-conducteurs-routiers-transport-marchandises (in French)

professional transport services (public transport drivers, taxis, ride-hailing, commercial vehicles, trucks, etc.).

> **Recommendation (R17):** The impact of the deployment of automated vehicles on employment and jobs in each relevant sector should be assessed in order to develop appropriate training as part of strategic workforce planning, and to invest in emerging sectors.

7.2. Environmental ethics

The connectivity of automated driving vehicles should contribute to a smoother traffic flow, thereby reducing energy consumption. We might also expect a fall in the ownership of private vehicles[20,21] following the development of shared transport services or local public transport, encouraged by lower operating costs. This would bring down the overall number of vehicles and the parking space occupied.

However, the intrinsic energy consumption of an automated driving vehicle is currently significantly higher than that of a manual vehicle, primarily because of the electrical power required to run the onboard sensors and computers. The increase of consumption has been estimated at between 3 and 20%. This compares to the possible average reduction of 9% obtained by combining all the benefits offered by vehicle automation and connectivity (eco-driving, platooning and junction management)[22,23]. Moreover, the intrinsic power consumption of the communication infrastructure required to run automated driving vehicles must be considered (5G base stations[24], roadside units). Yet digital technology currently accounts for between 3 and 4% of greenhouse gas emissions worldwide and is increasing its electricity consumption by 9% every year, so its global environmental footprint is not sustainable[25,26,27]. Digital sobriety is therefore a major challenge for the deployment of automated driving vehicles[28].

Furthermore, it could be possible to reserve specific lanes for automated driving vehicles, which would increase the vehicles footprint. Last, deploying automated driving vehicles is likely to lead to an increase in the number of cruising empty vehicles in order to provide a faster response for possible users. Private vehicles could also drive around empty if the cost of moving is lower than the cost of parking. This could lead to permanent congestion on city streets[29].

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[20] Jeremy Webb, The Future of Transport: Literature review and overview, Economic Analysis and Policy (Elsevier) (2019), 61, pp. 1-6

[21] Jeremy Campbell Webb, Clevo Wilson & Max Briggs: Automotive modal lock-in: a theoretical framework for the analysis of peak car and beyond with special reference to Australia, Australasian Journal of Environment Management (2017), 24/7, p. 406-422

[22] James H. Gawron, Gregory A. Keoleian, Robert D. De Kleine, Timothy J. Wallington, Hyung Chul Kim, “Life Cycle Assessment of Connected and Automated Vehicles: Sensing and Computing Subsystem and Vehicle Level Effects”, Environ. Sci. Technol., 2018, 52/5, pp. 3249–3256.

[23] The benefits are greater in the specific case of trucks platooning on freeways.

[24] The Shift Project, Environmental impact of digital technology: 5-year trends and 5G governance, Analysis Note, March 2021 (in French).

[25] ARCEP (French regulatory authority for electronic communications and postal and print media distribution), *Pour un numérique soutenable* [For a sustainable digital future], Progress report (in French), summary of the work platform and 11 proposals combining developments in the use of digital technology with a smaller environmental footprint, December 2020, https://www.arcep.fr/uploads/tx_gspublication/rapport-pour-un-numerique-soutenable_dec2020.pdf

[26] French senate, For an ecological digital transition, Information Report No. 555, June 2020, http://www.senat.fr/rap/r19-555/r19-5551.pdf

[27] The Shift Project, *Déployer la sobriété numérique* [Towards Digital Sobriety], October 2020, https://theshiftproject.org/article/deployer-la-sobriete-numerique-rapport-shift/ (in French)

[28] M. Taiebat, A.L. Brown, H.R. Safford, S. Qu, and M. Xu. A Review on Energy, Environmental, and Sustainability Implications of Connected and Automated Vehicles. Environmental Science & Technology 52 (20): 11449-11465, 2018. https://doi.org/10.1021/acs.est.8b00127

[29] Jooyong Lee, Kara M. Kockelman, “Energy implications of self-driving vehicles”, Proceedings of the 98th Annual Meeting of the Transportation Research Board, Washington D.C., January 2019, https://www.caee.utexas.edu/prof/kockelman/public_html/TRB19EnergyAndEmissions.pdf

The real needs in terms of mobility must be assessed in the light of ecological objectives and of the preservation of social ties[30]. Is it a matter of being more mobile or, on the contrary, less mobile, while rebuilding local economies? In any case, the environmental impact of automated driving vehicles in terms of energy consumption, life cycle, and physical and digital infrastructure must be comprehensively assessed, taking into account their utilization rate (number of people on board, occupation of infrastructures) and the possible rebound effects.

In particular, deploying automated driving vehicles for reasons of technological innovation and to boost the automotive sector must not encourage laxity concerning the environmental approval of these vehicles. The approval approach must be comprehensive, extending to the physical and digital infrastructure, unlike the current approach, which focuses exclusively on the vehicle itself. Approval must be carried out on standardized cycles representative of the onboard sensors and computers in conjunction with a communication test infrastructure. It must be based on a multi-criteria analysis of the life cycle, factoring in the different modes of use and operation.

> **Recommendation (R18)**: Submit the deployment of automated driving vehicles to a comprehensive environmental approval process, taking into account not only the vehicle itself but also the physical and digital infrastructure required by the different modes of use and operation.

The deployment of automated driving vehicles could have an impact on freight transport activities. For example, automated driving technology enables to consider the platooning of freight trucks with a corresponding automated driving mode controlling the distance between trucks and vehicle speed. The environmental benefits of this approach have been demonstrated[31] in freeway tests. Results show that platooned trucks consume less fuel, since their aerodynamic drag is lower. This approach would be even more efficient if it were part of a broader context placing the emphasis on environmentally-friendly multimodal transport and a commitment to sustainable development. These changes will clearly have an impact on the work of truck drivers. They will also have an impact on the use of the road network by other users, since some lanes will be occupied by platoons.

> **Recommendation (R19)**: Take advantage of the possibilities offered by automated driving technologies for truck platooning on the road network to develop an environmentally-friendly multimodal freight transport policy, taking into account job transformation in each sector concerned as well as the impact on the use of the road network by different categories of users.

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ANNEXES

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