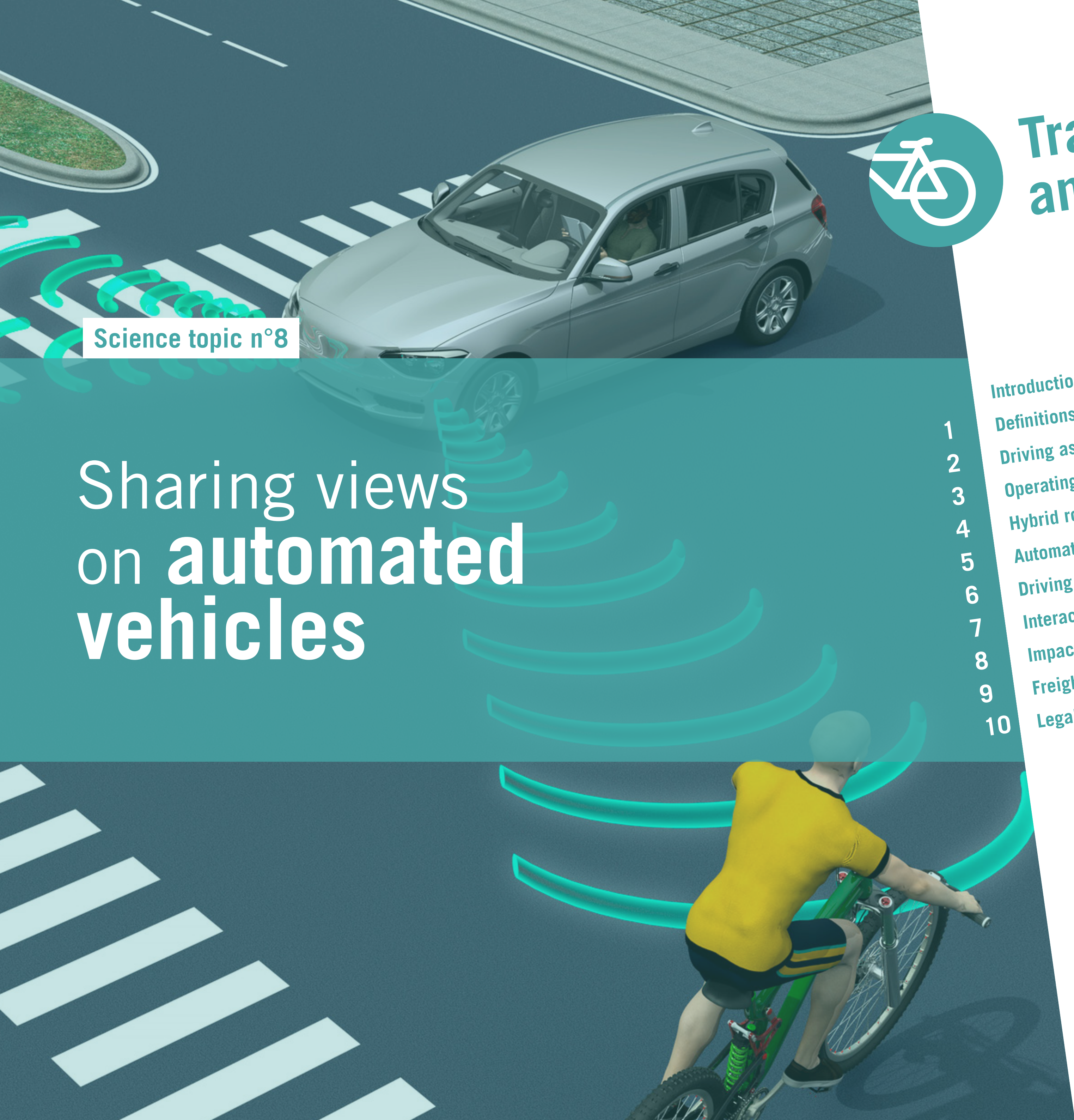

Sharing views on **automated vehicles**

Transport and mobility

Ifsttar has become Gustave Eiffel University
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Université Gustave Eiffel

SHARING VIEWS ON AUTOMATED VEHICLES

By Abdelmename Hedhli,
ITS[1] special adviser – COSYS[2] Department

New information and communication technologies have now become part of our daily lives as examplified in the field of transportation. Intelligent transportation systems (ITS) thus provide new solutions to remedy the consequences of the massive use of certain mobility modes. They offer a wide scope of application (road safety, traffic management, multimodal information, ticketing, driving assistance, etc.) and involve a large spectrum of technologies among which those related to the development of self-driving and connected vehicles.

A complex and cross-disciplinary topic

Often presented as a major technological breakthrough, self-driving vehicles hold the promise of far-reaching transformations for our societies. Their adoption by users will depend on how the four key fundamentals are taken into consideration: improving road safety, optimising infrastructure capacity, mitigating impacts on the environment and facilitating mobility for all. To address these overarching challenges, Ifsttar has for many years made this topic of autonomous vehicles a priority field of research. It has done so in a cross-disciplinary and systemic approach in order to address this complex topic which entails diverse technological, human, legal and societal issues dimensions.

A vehicle that is autonomous but also one that is connected

Whereas the self-driving vehicle is conceptually presented as a mobile robot, the connected vehicle refers to the capability to communicate and share information. Whether it is between vehicles, or between the road infrastructure and the communication infrastructure, these exchanges allow improving the safety and comfort of users as well as the management of infrastructures. Ifsttar, with projects such as SCOOP@F, is very much involved in this area.

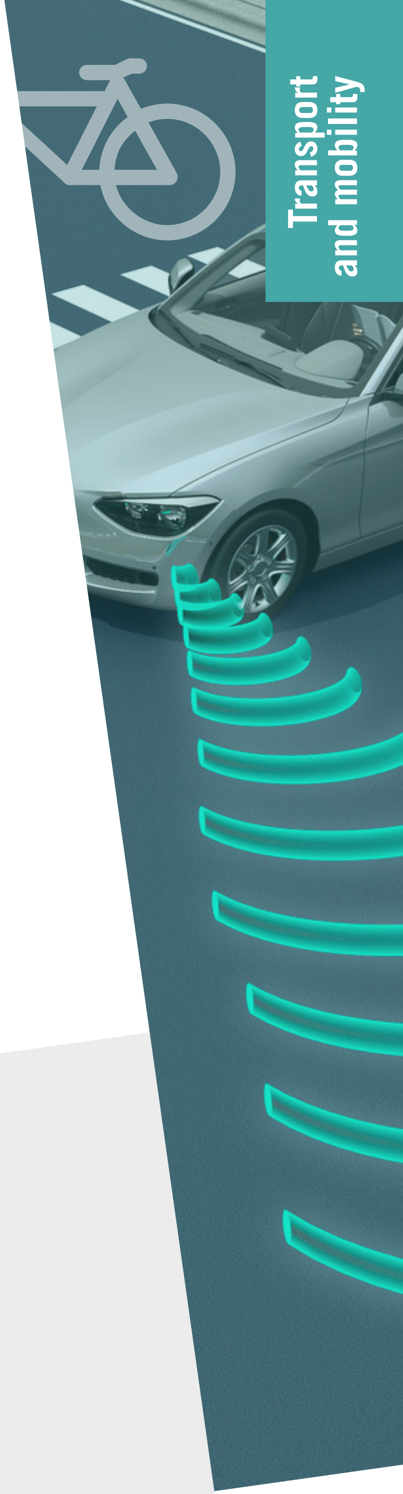
Although at the present time the research approach and concepts on which self-driving and connected vehicles are based are different, the two will soon become complementary. Indeed, in order to enhance its environment perception capacities, overcome the problems found on a given itinerary and improve safety, the autonomous vehicle will have to be connected to the infrastructure and to the other vehicles.

And what about the human driver?

Before these vehicles can be commercially available, i.e. in 2020 according to several French auto-makers, a number of obstacles and technological, regulatory, legal and social hurdles remain to be cleared, in which the human component plays a paramount role. It is also important to bear in mind that the development of autonomous vehicles will be a gradual process and thus entail a transition phase during which roads will be shared by vehicles with and without drivers. In addition, human intervention will remain necessary for as long as vehicle automation is only partial (for instance, level 3[3] refers to phases where the human driver is requested to resume control).

1. ITS intelligent transportation systems
2. COSYS: Components and systems Department
3. There are six levels to qualify vehicle automation or autonomy as defined by the American Society of Automobile Engineers (SAE)

"In the following papers, we have chosen to use indifferently «autonomous vehicles», «self-driving» or «driverless vehicles» although in the main title we opted for "automated vehicles" which seems to be the most widely used."



"This special feature offers an insight into the complex topic of "autonomous vehicles", the problematics involved and the way they are being studied at IFSTTAR."

Credit: Epictura

1 WHAT IS AN AUTONOMOUS VEHICLE?

By Sébastien Glaser,
Researcher in automation,
COSYS[1] Department, LIVIC[2] Laboratory

A vehicle performing a complex mission in interaction with its environment and with no intervention of a human driver was long seen as belonging to the realm of science-fiction or that of artists' imagination. And yet, driving automation, whereby parts or all of the driving tasks are delegated to an automated system, has now become a reality, gaining public attention through the experimentations of Google's automated vehicle (in 2010).

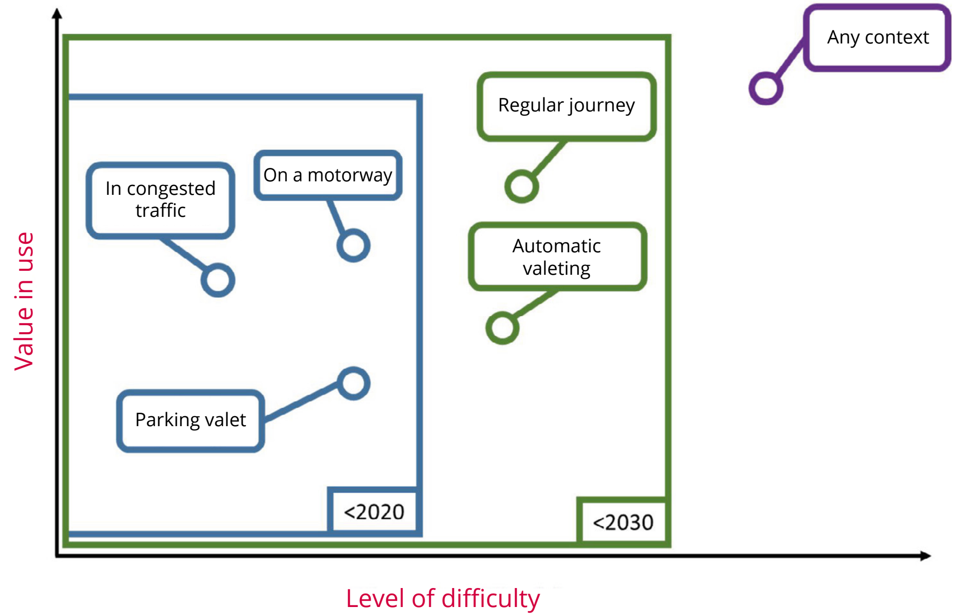
The word "autonomy" comes from the Greek roots "Auto" for self and "Nomos" for rules. An autonomous vehicle should therefore be able to react by itself based on pre-defined rules. In order to perform the tasks assigned to it, such a vehicle should be able perceive the environment and understand it, decide on a manoeuver and plan how to undertake it.
To this end, it is equipped with various sensing technologies (laser scan, radar and camera). The signals captured by the sensors are then translated by algorithms into data liable to be processed by the machines and essential to the driving operations (road markings, signalling, buildings, vehicles, pedestrians, etc.).
In this respect, SAE[3] suggests several levels of automation and autonomy, reflecting these systems' respective impact on the driving function.
Autonomous vehicles will allow us to tackle a number of societal challenges such as road safety, traffic fluidity, energy savings and mobility for all. This latter point is crucial in the context of our ageing societies and for disabled persons, for indeed such mobility is an enabling factor and allows the people concerned to recover part of their autonomy.

First a collective experience to start with

With the new mobility capabilities now within reach, self-driving cars are often likened to mobile phones and the revolution they brought about. If the autonomous transport object is primarily seen from the angle of the vehicle, then it may benefit many other areas such as freight transport, autonomous taxis or collective transportation.
In this latter case, a number of experimenta-tions, or even integrations, have already been performed (driverless shuttles serving airports such as OrlyVal and Navya Arma, or automated metros). The common feature of these transport modes remains the context within which the vehicle is operating: it is highly protected. The environment perception step indeed remains a complex aspect and requires being performed with a great level of performance and reliability. Thus, to simplify the decision-making and plan-ning step, the vehicle's reactions should remain limited: lateral control is thus constrained (by rails or by walls strongly restraining the guidance system) and only longitudinal control may vary within extensive ranges.

Motorways, the way forward for individual vehicles

Stakeholders have thus replicated this roadmap for individual cars. First to be targeted will be the motorway network, with two main applications: high-speed driving over long distances and low-speed driving in congested traffic situations.
The motorway environment shares many similarities with the above-mentioned protected environments: guidance is simplified (standard markings available), limited interactions with other users (few pedestrians and obstacles, trajectory of other vehicles both comprehensible and easily predictable), and potential reactions are constrained.



▲ Excerpts from the research objectives of *Nouvelle France Industrielle* (new industrial France) for autonomous vehicles – usage roadmap of the autonomous vehicle, case of the passenger car. http://pole-moveo.org/appels/plan-nfi-objectifs-de-recherche-vehicule-autonome/

Credit: Ifsttar and Nouvelle France Industrielle

WHAT IS AN AUTONOMOUS VEHICLE? (END)

This development also echoes one of the major demands of drivers concerning high-speed motorway driving. Today, Tesla and high-end automakers promote automated systems for this type of usage, which is very popular among users.

A matter of implication

Driving delegation is nevertheless still quite limited thus far. First from a technical point of view, the functions available, or soon to be, are only found at level 2 of the SAE[3] ranking. The driver still is under the obligation to supervise the system and the environment and to take immediate action in the event of a failure. Besides, misuses have already been identified, in particular as the driver builds up confidence in the system and starts indulging in other activities, as was the case with the TESLA accident. Thus, what we would need as from now is a level-4 system capable of supervising itself, the vehicle's environment, and of taking self-prompted action in case of a failure.

The autonomous vehicle, such as we can imagine it, will take a few more years before it becomes a reality. Until then it will have to position itself precisely with respect to its environment and learn to make decisions in order to plan its trajectories while minimising constraints for other users.

1. COSYS: Components and systems Department
2. LIVIC: Laboratory for Vehicle Infrastructure Driver Interactions
3. SAE International is a worldwide association of over 128,000 engineers and technical experts working together with the aerospace, automotive and commercial vehicles industries. https://www.sae.org/
4. VEDECOM: French Institute for Public-Private Partnership Research and Training dedicated to individual, carbon-free and sustainable mobility.

Credit: VEDECOM

2 FROM DRIVING ASSISTANCE SYSTEMS TO VEHICLE AUTOMATION

By Dominique Gruyer,
Research Director for environmental perception and multi-sensor data fusion
Head of LIVIC[1] Laboratory, COSYS[2] Department

The last three decades have seen the rise of so-called Advanced Driver Assistance Systems (ADAS). These systems enhance the "safety", "energy", "mobility" and "comfort" aspects. However, they do not in any way replace drivers in their task as such but rather provide them with informative and active assistance. More recently, these ADAS systems have emerged as a preliminary step before the implementation of semi- or fully-automated mobility systems. These new driving assistance systems will help better address the challenges by ensuring a high level of reliability while taking into account users' comfort for broader acceptability. At Ifsttar and in particular at the LIVIC laboratory, these aspects have been tackled in many French and European research projects.

Driving assistance systems gaining recognition

Comfort features are meant to make driving easier and more pleasant for the driver. Examples of these are cruise control (ACC[3]), parking assistance (ParkingAssist), automatic windshield wipers and headlight control (orientation, zone, intensity). Drivers have shown to particularly welcome these functions: in 2015, the best-seller applications were parking assistance, visual perception and cruise control.
On the safety side, following ABS[4] in the 1960s, came ESC[5] in 1995, the ACC cruise control in 1997, enhanced night-time vision in 2000, followed by lane departure alert in 2001 and emergency braking in 2003.

▲ CARLLA: the Ifsttar prototype dedicated to driving automation (ABV, Have-it, eFuture, and other projects)

Environmental issues are not overlooked either, with the emergence of information to mitigate consumption (eco-driving) and the development of alternative mobility systems (electric, hydrogen, hybrid). A last societal challenge concerns users' mobility. For the latter, solutions are yet to be found in order to significantly and efficiently improve mobility-related systems. To this end, there is a need to develop specific adaptations to infrastructures and relevant multimodal mobility systems. The variable message signs (PMV), most of which installed on motorways, were among the first systems rolled out. More recently, new cooperative and communication-enabled systems have looked to mobile technologies in order to optimise the dynamics of a fleet of vehicles (capacity, convoy management, lane insertion or departure, etc.).

On track for autonomous driving

Most of the above-mentioned systems are now available on a wide range of vehicles. The current state of research clearly indicates that we are very close to partial automation of low-speed driving in situations of dense traffic.

1. LIVIC: Laboratory for Vehicle Infrastructure Driver Interactions
2. COSYS: Components and systems Department
3. Adaptive Cruise Control
4. Antilock Braking System (from the German "Antiblockiersystem")
5. Electronic Stability Programme providing electronic assistance for the antilock braking system, distribution, emergency braking assistance, anti-skid, etc.

Research projects

> French national research projects:
– **LOVe** (detection of vulnerable road users);
– **ABV** (low-speed automation);
– **SCOREF** (deployment of transport-dedicated communications).

> European research projects:
– **Have-it** (automation in the motorway environment);
– **eFuture** (automated electric vehicle);
– **ecoDriver** (ecomobility).

> International research projects:
– **CooPerCom** (perception and cooperative communication for vehicle automation).

Amongst these ongoing projects are:
– **SINETIC** (multi-level simulation platform for cooperative ADAS systems);
– **GameEcar** (eco-driving);
– **C-ROADS** (cooperative systems);
– **CARTRE** (Cooperative Support Action on vehicle automation).

Credit: Ifsttar

1/2>

FROM DRIVING ASSISTANCE SYSTEMS TO VEHICLE AUTOMATION (END)

From a more global perspective, these applications and services are still be fitted separately and independently. Even if several of these ADAS systems can be found in a given vehicle, they are still regarded as driver assistance mechanisms.
However, with the growing number of these in-vehicle systems and their increased capabilities, reliability and robustness, the trend is towards fully-automated driving. Now, in the event of a system failure (sensors, actuators, electronic equipment, applications, etc.), the system must be in a capacity to promptly and efficiently warn the human driver for him/her to take over control. To mitigate risks in the man/machine transition situation, it should be possible to predict and anticipate critical situations. At present, this transition stage is a genuine scientific and technological challenge which is currently being investigated, etc.

Up to six levels of driving automation

SAE[1] recently proposed a definition of the six levels of driving automation identified so far. The first 3 are only concerned with the assistance provided to the driver who maintains the task of observing the environment and acting on the vehicle. The next 3 levels define potential automation modes ranging from partial and shared automation to full automation without human driver.
More specifically, level 3 allows reproducing the driving task with the human driver taking over control in the event of a problem. Level 4, more complex, should warrant a high level of safety. This level therefore implies that the system should understand the driver's behaviour and develop substitution strategies, even under critical conditions for the automation system. The last level is that of full automation where the human driver has no possible scope for intervention.

1. SAE International is a worldwide association of over 128,000 engineers and technical experts working together with the aerospace, automotive and commercial vehicles industries. https://www.sae.org/

Automation levels (as per the Society of Automotive Engineers, SAE International)[1]

SAE level	Name	Narrative definition	Execution of steering and acceleration/ deceleration	*Monitoring* of driving environment	Fallback performance of *dynamic driving task*	System capability *(drivin modes)*
Human driver **monitors the driving environment**						
0	No automatisation	The full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhance by warming or intervention systems.	Human driver	Human driver	Human driver	n/a
1	Driver assistance	The *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*.	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial assistance	The *driving mode*-specific execution by one or more driver assitance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*.	System	Human driver	Human driver	Some driving modes
Automated driving system **("system") monitors the driving environment**						
3	Conditionnal automatisation	The *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*.	System	System	Human driver	Some driving modes
4	High automatisation	The *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*.	System	System	System	Some driving modes
5	Full automatisation	The full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*.	System	System	System	All driving modes

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3 OPERATING DEPENDABILITY AND SAFETY OF AUTONOMOUS VEHICLES

By El Miloudi EL KOURSI,
Researcher in the field of railway safety and security
ESTAS[1] Laboratory, COSYS[2] Department

Automation of transport systems, whether individual or collective, has always been a major challenge in ensuring safe and efficient mobility for citizens. Genuine technological and performance leaps have been achieved at different levels of automation to enhance socio-economic, functional and security performance. Self-driving vehicles should be capable of operating in fully autonomous mode under real traffic conditions and on non-specific infrastructures, without requiring human driver intervention. Their proper operation will depend on the equipment's safety level, software quality and reliability of the information used by the onboard intelligence.

Navigation system, a risk not to be overlooked

Car manufacturers and OEMs[3] have made extensive efforts to develop an optimum ecosystem for the safety of self-driving vehicles. Their automation has been made possible through the use of geo-tracking technologies via GPS[4] and in the near future Galileo. It is however possible to deceive a GPS receiver by misleading it to believe it is in another physical location than where it actually is. The risk then would be that self-driving vehicles be diverted to other locations than the users are targeting. This type of attack should be taken into consideration in analysing the security of hardware and software components as well as at system level.

Complexity of the road system, a point to be taken into consideration

Unlike driverless metro systems, full automation of on-road vehicles, which operate in a complex urban context, requires uncompromising demonstration of equipment safety, both onboard the vehicle and as built into the infrastructure. Such demonstration shall be carried out in detail and in reliable conditions, covering both normal and complicated situations so that all dangerous situations be factored in. Safety is therefore a major challenge for the future of self-driving cars and should be able to satisfy the zero-accident requirement at a reasonable cost.

Knowledge transfer to ensure users' safety

For many years, Ifsttar has developed expertise in driving automation and in the area of certification for automated safety systems in track-guided transports. The Institute's teams have been working in the fields of signalling, command-control (hardware and software) and systems safety and security to contribute to the commissioning of TGV high-speed trains and driverless metro systems. Ifsttar was thus called upon for almost all of the automatic track-guided transport systems implemented in France. This synergy between competences in on-road vehicle automation and the safety expertise for driverless metros will contribute to the safety of automated road vehicles.

1. ESTAS: Evaluation of Automated Transport Systems and their Safety Laboratory
2. COSYS: Components and systems Department
3. OEMs: Original equipment manufacturers
4. The GPS global positioning system is an American satellite-based navigation and position-tracking system.
Galileo is its European counterpart.
5. LIVIC: Laboratory for Vehicle Infrastructure Driver Interactions

Transport and mobility

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4 TOWARDS A HYBRID ROAD INFRASTRUCTURE

By Nicolas Hautière,
R5G © Project manager at Ifsttar and researcher within the COSYS[1] Department

Being used on roads, self-driving vehicles will continue to physically interact with the infrastructure, whether it be urban or interurban roads. However, unlike conventional vehicles, they will almost exclusively rely on sensors to decipher the environment they operate in.
The traditional road, which currently takes into account the driver's environmental perception capacities, should further evolve to adapt to this new type of transport. The whole challenge is to be able to assess the nature, scope and timeframe of such evolutions, so as to measure their social and economic acceptability.
In this perspective, Ifsttar is developing an infrastructure liable to support autonomous vehicles. The latter is a component of R5G ©, the 5th Generation Road.

Constraints to anticipate

Roads are designed on the one hand to support the various rolling loads and on the other hand to enable drivers to adapt to traffic conditions. The self-driving car will have to be aware of all the characteristics of the infrastructure it is using in order to operate safely.
But the vehicle may also affect the specificities of such infrastructure. For instance, by driving in numbers and always at the same place, a large number of heavy self-driving trucks could damage the roadway. Likewise, if they are too close to one another they are liable to impact the engineered structures they run across.

Road assets are also concerned. For instance, road markings, initially designed to be visible to the human eye, will also be used by self-driving vehicles so they may precisely locate themselves on their respective traffic lanes. This means that we also need to look into the potential link between the performance of onboard cameras and the visibility of said markings.

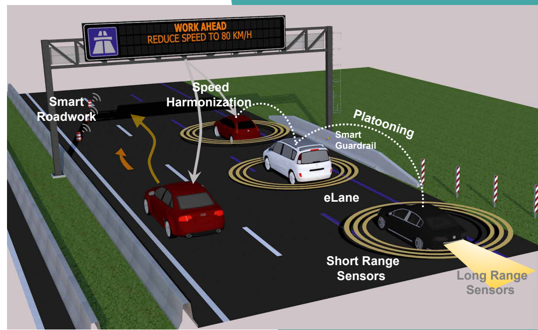
The role of digital technologies

The sensors present onboard every autonomous vehicle are responsible for analysing the road. If they cannot read it, an onboard digital mapping system will take over to gather the missing information. The physical infrastructure will thus become increasingly digital.
The challenge is then to conceive this digital infrastructure and to keep it up to date, which raises the issue of data exchange standards and formats. Not to mention scientific issues. For if the geometry of roads shows little change over time (except in roadworks areas), what about the skid resistance of road pavements or the visibility of markings which are highly sensitive to weather conditions?

To ensure the power-supply of this digital infrastructure and keep it up to date, it will have to be connected not only to vehicles but also the management centres in charge of maintenance, traffic and weather forecasts.

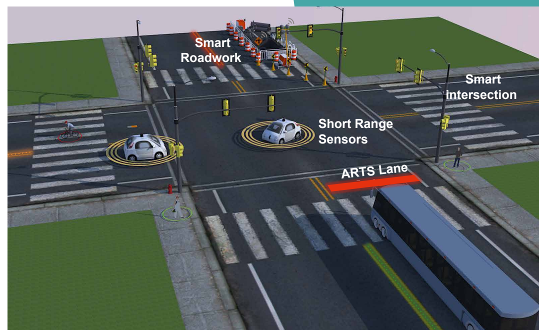
A necessarily hybrid infrastructure

The infrastructure supporting self-driving vehicles will thus be hybrid, i.e. both physical and digital. The roads connectivity will make it possible to constantly refresh the digital infrastructure thanks to the roadside units[2] (G5 technology) or via cellular networks (3G or 4G).
Besides, this infrastructure may support vehicles featuring different levels of automation (0 to 5) as well as vulnerable users. The interactions will have to unfold in full safety without compromising traffic flow.



▲ Hybrid motorway equipped with a dedicated lane for the traffic of autonomous vehicles

1. COSYS: Components and systems Department
2. The function of roadside unit is to coordinate all of the connected objects across the covered area, whether they are static or mobile. See paper on connected and cooperative roads.



▲ Hybrid urban intersection adapted to the traffic of autonomous vehicles

Learn more about

> **5th Generation Road,**
aka R5G ©, thematic paper consult on https://reflexscience.univ-gustave-eiffel.fr

> **SCOOP project on connected vehicles and roads**

Further readings

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5 IMPACTS OF CONNECTED AND AUTOMATED VEHICLES ON TRAFFIC, SAFETY AND POLLUTANT EMISSIONS

By Nour-Eddin El Faouzi,
Researcher in traffic modelling,
Head of the LICIT[1] Laboratory
and Deputy director of the COSYS[2] Department

Connected and Automated Vehicles (CAV) are about to revolutionise the mobility of goods and people while also increasing its safety. These vehicles not only help to streamline the use of infrastructures but also to uphold mobility and self-reliance for an ageing population. The most promising benefit, and most looked forward to, concerns the potential safety improvements that would result in reducing, if not altogether eradicating road accidents.
Besides, the connected – or smart – vehicle can help reduce traffic congestions and thereby curtail associated pollutant emissions. To this end several technologies are being used such as "targeted traffic and real-time" information and the capacity for traffic to organise itself through the information exchange mechanism (vehicle-to-V2V-vehicle and vehicle-to-V2I-infrastructure communications).

Assessing the impacts of Connected and Automated Vehicles on traffic

Ifsttar[3] is currently conducting new research projects on the impact of these vehicles on road traffic and more specifically on congestion[3]. It has been observed that the presence of even just a few Connected or driverless vehicles could significantly mitigate the shockwaves due to the stop-and-go phenomena and reduce their energy consumption.
Moreover, thanks to their connectivity and automation, these vehicles are thus becoming both mobile sensors and actuators. This in turn makes it possible to rethink existing traffic management strategies and give rise to new control strategies (e.g.: speed smoothing, dynamic speed limit, platoon management, departure into/from a lane).

Simulating Cooperative and Automated Traffic

More precisely, recent research conducted at Ifsttar's COSYS department (Components and Systems) has resulted in the proposal of a "multi-agent modelling" of partly cooperative and automated traffic. This proposal describes traffic flow by a so-called "microscopic" traffic model that computes the exact trajectory of each vehicle (agent). This model reproduces the major driving behaviours such as car following, lane change or insertion, route choice.
The cooperation is provided by a multi-agent model whereby each vehicle receives information about its surrounding environment and accordingly adapts its kinematics based on a perception-decision-action process. The system's response has also been studied according to the percentage of connected and automated vehicles but also the agents' confidence level in the information they receive from other agents. A simulation platform named MASCAT (Multi Agents for the Simulation of Cooperation and Automation of Traffic), was developed in this framework.

Self-organised Vehicles to Better Traffic Control

The findings of these research projects highlight the capacity of connected vehicles to organise themselves in order to homogenise traffic characteristics, enhance safety and reduce traffic-related environmental impacts.
These impacts become visible from a fairly low penetration rate to the extent that a mere 10% of connected vehicles amidst the traffic will suffice to significantly improve its fluidity.
This is a good indication of the case for deploying these vehicles, even during a transition phase (more or less long) that will see a mix of non-equipped and partially equipped vehicles (phase known as "fixed traffic situation").

Transport and mobility

MASCAT project

MASCAT simulation platform video
Investigating the impact of the introduction of cooperative vehicles

▲ Traffic homogenisation (Traffic view and spatial temporal diagram)

1. LICIT: Transport and Traffic Engineering Laboratory
2. COSYS: Components and systems Department
3. Accumulation of vehicles on roads causing traffic disturbance. Congestions are commonly called "traffic jams" or "gridlock".

Further readings

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Credit: LICIT, ENTPE-IFSTTAR 2017

6 IMPACTS OF AUTOMATION ON THE DRIVING ACTIVITY

By Hélène Tattegrain,
Researcher in artificial intelligence
and Head of the LESCOT[1] Laboratory, TS2[2] Department

In terms of road safety, autonomous vehicles chiefly rest their case on their ability to reduce the number of road accidents. Indeed, the engineers' central idea is that by removing the human driver from the loop and thereby the human-factor related risks too, systems will perform better than with human intervention.

This argument however should not be taken for granted as many problems remain to be evaluated. For instance, full automation (SAE level 5[3]) is not yet available for light vehicles. A transition phase should therefore be provided between the manual (vehicle driven by the human driver) and autonomous (vehicle driven by means of its automatic onboard control systems) modes. Depending on the various levels of automation (as suggested by SAE[3]), expectations vis-à-vis the drivers will differ, and accordingly the problems they might be faced with.

In this framework, Ifsttar is working on the anthropocentric design[4] of driver assistance systems, the identification of critical scenarios, the monitoring of drivers to adapt man-machine interactions and on the virtual design of assistance systems.

Driver assistance

The first level is currently being deployed with the advent of various control systems that are only active on part of the driving functions. This allows the driver to momentarily resort to occasional assistance (acceleration, braking, etc.) and correspondingly diminishes the amount of attention required to handle the driving task. If such reduction can be beneficial in highly complex situations, it may inversely entail dangerous side effects. Thus, inattention phenomena resulting from excessive lack of activity (e.g. drop in vigilance levels, wandering thoughts, etc.), or mind being distracted by other asks (e.g., phone calls, eating, etc.), could be observed. These phenomena basically result in problems with the intake of information pertaining to the road environment.

The role of driver-supervisor

In the level-2 case, the system takes on board new functions but the driver, who controls his/her environment, should be able to resume control on the vehicle at all times. But then, the risk related to the above-mentioned phenomena may be compounded by the fact that the driver no longer has any active driving task when all longitudinal and lateral controls are taken over by the system. This level would however still require the driver to be attentive to his/her environment to be capable of resuming control at all times. This rather worrying obligation means that in terms of road safety nothing ensures that the human driver is indeed in a supervision posture, from a cognitive point of view, even if his/her physical position is indeed correct.

From supervisor to passenger status

For levels 3 and 4, the driver is authorised to execute other tasks during the driving delegation phases. S/he must however remain in a capacity to resume control at the system's request. If the driver fails to resume control, it is provided the vehicle may be called to a halt (level 3) or parked to safety (e.g. on an emergency stopping lane for level 4). In both cases, transition phases are quite critical.

Indeed, when the driver delegates his/her driving task to the autonomous system (manual transition to self-driving), the system must be ready to take over control. Should the system not be able to ensure self-driving, it is important that the driver fully understands that the vehicle cannot do so. The same observation applies for phases of control resumption by the driver (self-driving transition to manual). It must be ascertained that the driver is in such physical and attentional condition that s/he may resume control and be well aware that the vehicle no longer is in self-driving mode.

Whatever the level of automation, the need for the driver to take into account the system's status is a well-known issue in cases of man-machine cooperation. It is nevertheless of even greater importance in the case of automated vehicles where mistakes can be fatal.

1. LESCOT: Laboratory Ergonomics and Cognitive Sciences applied to Transport
2. TS2: Transport, health, safety Department
3. SAE International is a worldwide association of over 128,000 engineers and technical experts working together with the aerospace, automotive and commercial vehicles industries. https://www.sae.org/
4. Human centered

Credit: Epictura

7 ANTICIPATE ON THE INTERACTIONS BETWEEN PEDESTRIANS AND SELF-DRIVING VEHICLES

By Aurélie Dommes,
Researcher in cognitive psychology and
and Jean-Michel Auberlet,
Researcher in artificial intelligence – COSYS[1] Department, LEPSIS[2] Laboratory

Recent technological breakthroughs will soon turn delegated driving, so-called autonomous, vehicles into full-fledged players in the French road traffic landscape and across other industrialised countries. These sensor-packed vehicles will amongst other things be capable of detecting the presence of a pedestrian at some distance and their algorithms will compute the engine controls required for any appropriate action (braking, deceleration, pulling out, etc.). These technological and scientific advances should therefore make it possible to reduce the number of accidents involving pedestrians through safer interactions. Self-driving vehicles could indeed make up for human mistakes, whether drivers or pedestrians.

Behaviours and reactions yet to identify

Beyond the heavy technical constraints (e.g. sensors detection capacities, predictability, robustness and flexibility of the algorithms, etc.), this objective may only be achieved if self-driving vehicles and pedestrians can live and interact together in all safety.
Unfortunately, we are still lacking knowledge, be it only experimental, on the way pedestrians could behave in front of a self-driving vehicle. The question is particularly acute in situations of street-crossing, a key moment of these interactions and with the highest risk. Indeed, as the pedestrians are positioned on the roadway, or intending to do so, they are potentially in an imminent situation of collision with an approaching vehicle. Some work has been conducted abroad (e.g. Rothenbücher et al., 2016), but not yet sufficient to draw solid conclusions as to specific pedestrian behaviours (imprudent, more prudent, etc.).

Technologies to anticipate the pedestrian's intentions

Another challenge to tackle is the capacity of sensors and algorithms of the autonomous vehicle to detect a pedestrian's intention to cross the street. More precisely, the matter is to know the criteria and variables to be used in determining whether the pedestrian imminently intends to cross the street while at the same time taking into account the applicable highway code in France (art R415-11[3]) "Any driver shall give way, if needed by halting the vehicle, to a pedestrian proceeding to cross a roadway, as authorized, or clearly indicating his/her intention to do so, or moving about in a pedestrian zone or meeting area".

Studies liable to be conducted in virtual environment

Thanks to the developments of simulators and populated environments such as Lepsis, virtual reality may help addressing, at least partly, the challenges related to the integration of self-driving vehicles into road traffic. It would thus be possible to place a pedestrian subject in an environment populated by non-playing characters (NPCs) and self-driving vehicles.
In order to start answering some of these questions about the prediction of pedestrians intentions and behaviours vis-à-vis self-driving vehicles, a joint study by Ifsttar (LEPSIS and LBMC[4]) and Institut Vedecom is currently underway on a large-scale street-crossing simulator.

1. COSYS: Components and systems Department
2. LEPSIS: Laboratory for road Operations, Perception, Simulators and Simulations
3. Article R415-11 of the French highway code
4. The Biomechanics and Impact Mechanics Laboratory (LBMC UMR_T9406) is a joint research unit between IFSTTAR (Institut Français des Sciences et Technologies des Transports de l'Aménagement et des Réseaux) and Université Claude Bernard Lyon 1 (first French university in medical sciences).

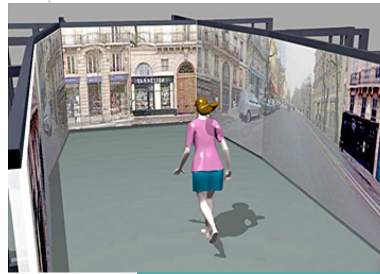
Further readings

Rothenbucher D., Li J., Sirkin D., Mok B., & Ju W. (2016). Ghost driver: A field study investigating the interaction between pedestrians and driverless vehicles. In 2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN) (pp. 795–802).

Transport and mobility

Learn more about (FR)

> The various simulators in operation at LEPSIS



▲ Street-crossing simulator developed by Ifsttar

Learn more about

> Thematic paper on Pedestrian safety

8 IMPACTS OF SELF-DRIVING VEHICLES ON TERRITORIES AND LIFESTYLES

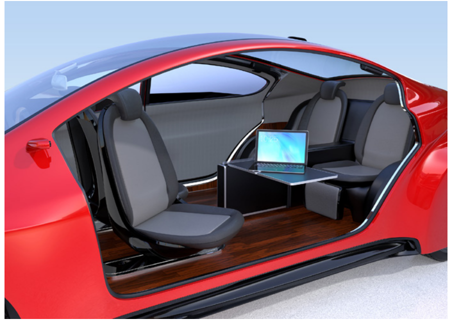
By Olivier Bonin,
Researcher in geography and Deputy director of LVMT[1], AME[2] Department

As seen from its function and usage, the self-driving car is a conventional vehicle with a robotised driver. Whether for individual or mass transport (taxi and bus), this type of vehicle will provide the services as before. For Ifsttar, self-driving vehicles are not very likely to drastically change people's lifestyles.

Can self-driving vehicles alter lifestyles?

If the fleet of individual cars is gradually replaced by evermore autonomous cars, the impact on mobility practices will remain limited. In the longer run however, we may envisage consequences on users' modal choice (turning away from mass transportation if individual cars ensure more safety and comfort), the way they organise their daily activities (shopping in particular), telecommuting (working while on the road) and the mobility of young people and seniors.

If the vehicle becomes fully autonomous and shared, it will partly or completely come to be substituted for the public and private collective transport offering, e.g. school bussing. Such driverless shuttles are already being deployed over short urban routes. They will initially operate on fixed itineraries and on dedicated lanes so they can be safely tested. In the longer run, these shuttles may become very flexible in their routes and timetables in order to further optimise the transportation offer.



Echoing the industrial transformations of our times

By replacing the private taxi or bus driver by machines, the self-driving vehicle reflects the heavy mechanization trend witnessed in industrial production. By giving up part of their free will to the benefit of a machine, men will be fundamentally challenged in their relation to technology. Industrial players, for their part, will introduce new business models and new services (e.g. playing advertisements aboard the vehicle to cut down the price of the journey). As a result, the relationship to the driverless vehicle will not be the same as with a conventional vehicle (c.f. research on breakthrough business models in the ITE Efficacity – Energy Transition Institute).

New perspectives arising from the waning interest in the notion of individual property

Unrelated with vehicle automation, households are seen to be less and less motorised in the centre of large towns. They tend to favour collective transportation modes such as car rental, sharing or pooling[3]. The mainstreaming of robotisation will then make it possible to imagine vehicles that are used more. The fleet in operation will be better managed and used more. More recent, and better maintained vehicles will mean less pollution and less emissions of greenhouse gases (GHG). The gains, however, may be mitigated, if not altogether cancelled out by a possible rise in mobility (for people and also goods) and longer distances covered.

Public space to be rethought anew for all users

Automobile traffic significantly impacts the public space: roads, parking places, petrol stations, etc. The robotisation of vehicles will not diminish the impact of cars on public space, apart from the smaller parking footprint needed. But it will call for urban amenities to be rethought so as to incorporate those facilities indispensable to the guidance of vehicles or the management of passengers in full safety.

This is a good opportunity to reconsider the public/private space divide and the resulting strong segmenting that is usually enforced (sidewalks for pedestrians, cycling lanes for cyclists, dedicated lanes for busses, remainder of the roadway for other motor vehicles).

A new factor of urban spread?

Access to car ownership in the middle of the 20th century was a decisive factor for urban spread and peri-urbanisation. Private cars made it possible for people to settle down further away from cities, where access to individual housing is an option and less costly and with a quality of life meeting the aspirations of French people. If robotisation can be a source of even greater comfort, for instance by offering users the possibility of professional or leisure activities during their journeys, self-driving vehicles could again further promote urban spread.

1. LVMT: Research Laboratory addressing the City and Transportation
2. AME: Planning, Mobilities and Environment Department
3. ANR MoDe project (Motives for Demotorisation) steered by LVMT

9 AN OPPORTUNITY FOR FREIGHT AND LOGISTICS?

By François Combes,
Head of the SPLOTT[1] Laboratory, AME[2] Department

Logistics covers the whole scope of operations concurring to deliver the right product at the right time and in the right place. The transportation of goods, known as freight, plays a key role in the supply chains and self-driving vehicles could in the long-term reshuffle the cards.

New opportunities for freight transport

As an economic activity, freight transport involves a number of fundamental resources: vehicles, drivers and energy. Personnel costs account for a significant share of the budgets and put constraints on operation[3].

A driverless vehicle which does not necessarily require staff aboard does not imply the same costs, nor the same constraints. It can be used for longer hours in one day thus providing a quicker return on investment. If used at night it accordingly reduces daytime traffic, be it partly only, to the benefit of the other users, in particular at rush hours.

To address operational constraints, vehicle automation offers several solutions conducive to the productivity of road hauliers. From this standpoint, the economic benefits of self-driving vehicles in the area of freight transportation are far from negligible. If it is not hampered by unsurmountable technical difficulties this technology will probably establish itself in due course.

The supply chain activity strongly impacted

There will be many different impacts on the supply chain. Lorries not requiring additional space for the staff will thus offer extra payload, they will be able to run at all times, day and night. For shorter distances, smaller, perhaps electrical, vehicles will be able to deliver parcels all the way to individual customers.

Although it is still difficult to anticipate all the potential impacts of these technologies, it is quite likely that non-road shipping modes will be affected by these new practices. Whatever the case may be, the supply chains will adapt to the new configuration of freight transportation if there is significant cost-saving to be expected.

Human and social consequences to be anticipated

Beyond the technical hurdles to be overcome, using driverless vehicles for freight transport raises a number of social and economic challenges: What about the customer relationship and how can you make sure the goods have indeed been delivered? What about daily maintenance tasks (checking vehicle condition, refuelling, making small repairs, securing the goods aboard the vehicle, etc.)?

If this technology is to stay for the long-term, it will probably require a long transition phase. This transition will have to tackle the question of the relationship between man and an increasingly automated vehicle, the drivers' jobs that will disappear, when today there are several hundred thousands of them.

For new jobs and new functions to emerge, these changes must be addressed properly.

1. SPLOTT: Production Systems, Logistics, Transport Organization and Work
2. AME: Planning, Mobilities and Environment Department
3. For example, a lorry driver is not allowed to stay at the wheel over 9 hours a day – and up to 10 hours twice a week maximum – and should make several breaks on the way. The driver needs to rest in appropriate places such as roadside laybys, and should be able to go back home regularly.

Credit: Epictura

Transport and mobility

Learn more about

› What urban supply chain in the future?
A thematic paper consult on https://reflexscience.univ-gustave-eiffel.fr

› The European project www.mobility4eu.eu

10 LEGAL CHALLENGES FOR CONNECTED AND AUTONOMOUS VEHICLES

By Michèle Guilbot,
Research director in Law and Deputy director of the LMA[1] Laboratory TS2[2] Department

In 2016, the Commission for the enrichment of the French language defined the autonomous vehicle as "a connected vehicle which, once it has been programmed, travels on public thoroughfares automatically and without any intervention from its users"[3]. But full autonomy requires the presence of artificial intelligence capable of handling its interaction with the environment and taking action without automatically responding to a pre-programmed situation[4]. The French law proposes the notion of "partial or total driving delegation"[5]. This alternative helps better assessing the functional features that will lead to autonomy and is suitable to legal analysis as it identifies the delegated tasks: to whom (or what), at what time, under what circumstances.

Combined with the automation levels put forward by SAE[6], this concept offers a reading grid for the analysis of new risks and responsibilities of the stakeholders in the design, manufacturing, maintenance and usage of the autonomous vehicle, its specific components and its environment (software, algorithms, mapping, digital platforms, road infrastructures, etc.).
Autonomous vehicles indeed raise new challenges to which the law must now bring adapted responses in view of the new risks and liabilites.

Legal tools for protection against new risks

The execution of tasks entrusted to the vehicle requires using a large amount of data, often shared with third parties. Law and technique must therefore concur to address the risks generated by the multiplication of connected objects. This is particularly true for the capturing and usage of personal data; violations of privacy and of the freedom to move anonymously; illegitimate, if not malicious, intrusions into the systems to alter their operation. To prevent such risks the law has two arrays of tools.

> Regulations, including EC regulations. In 2018, the General Data Protection Regulation (GDPR) will strengthen the protection of users' personal data across the territory of the European Union[7]. Cybersecurity[8] and the deployment of cooperative intelligent transport systems (STI-C)[9] have also been placed under the scrutiny of the European regulator.

> The "soft law" with standardisation (ISO[10] and ETSI[11]), recommendations, charters and best practice guidelines (G29[12] and CNIL[13] for advice and recommendations concerning the protection of personal data, ENISA[14] and ANSSI[15] for cybersecurity).

Human vs System as seen from the driving tasks and the liabilities

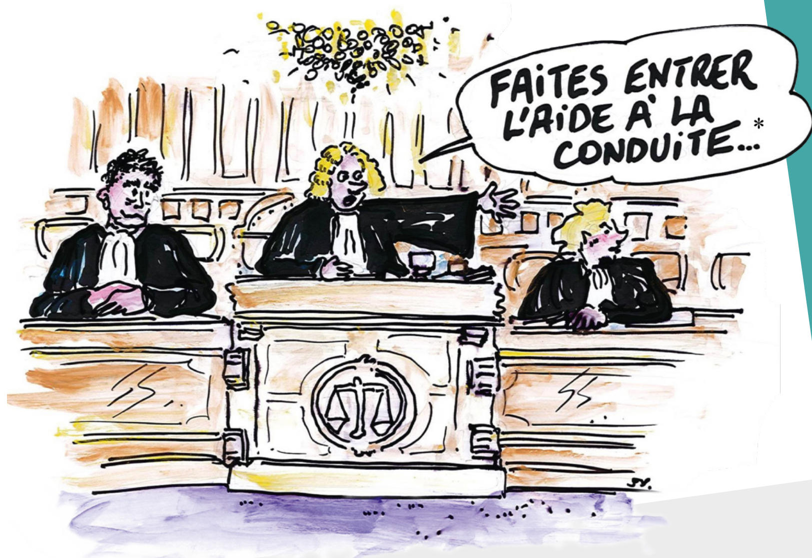
While the legal backdrop to public road experimentations is still under construction in France[16], work is currently undertaken towards the compatibility of international Conventions on road traffic (Vienna, 1968; Geneva, 1949)[17] with automotive technical regulations and in-vehicle technological innovations.
The law will have to envisage a number of major issues: Who shall be regarded as the pilot of the autonomous vehicle? Who will be responsible for traffic violations? How to apportion the steering and control powers over driving tasks between the human driver and the system? What status should the human driver be assigned during phases of total automation?
Answers to these questions will affect the apportionment of accident liability in determining victims' indemnification (third party or administrative liability) or who to sanction for offences, including cases of gross negligence on the part of professional parties (criminal liability). The burden of proof will be key to these cases. The Event

To learn more (FR)

> The executive summary

> Michèle Guilbot's presentation

at the *Entretiens Jacques Cartier EJC2016 (FR)*



*Call driving assistance to the box
Credit: Joël Yerpez
Collection personnelle J. Yerpez - M. Guilbot

1/2>

LEGAL CHALLENGES FOR CONNECTED AND AUTONOMOUS VEHICLES (END)

Data Recorder (EDR) has often been referred to, but itself raises a number of questions: access right, availability, integrity, data interpretation; new debates are emerging between the legitimate interest of economic operators, prevention of road hazards and protection of users' personal data; competition law versus business confidentiality.

Ifsttar contributes to the work on these legal aspects *(Guilbot, Serre et Ledoux, 2016; Guilbot et Pflimlin, 2017; Hautière, Tattegrain et Guilbot, 2017)* as part of a prospective, operational and cross-disciplinary approach. The aim is to take a pragmatic outlook on the evolution of law without unnecessary haste as indeed, the regulations currently in force cover most potential disputes, at least in the transition period. Some of them will need to be adapted gradually to cater for the presence on public roads of driverless vehicles steered by artificial intelligence.

> **“Ifsttar contributes to the work on these legal aspects as part of a prospective, operational and cross-disciplinary approach.”**

1. LMA: Laboratory of Accident Mechanism Analysis
2. TS2: Transport, health, safety Department
3. *Vocabulaire de l'automobile*, JORF, 11 juin 2016, texte n° 111.
4. *Sur l'autonomie d'un robot*, v. Résolution du 16 février 2017 of the European Parliament. Recommendations to the Commission concerning civil law rules on robotics (2015/2103(INL)).
5. Law 2015-992 dated 17 August 2015 pertaining to the energy transition towards green growth (art. 37-IV) and report to the President of the French Republic on Ordinance 2016-1057 dated 3 August 2016 pertaining to the experimentation of delegated driving vehicles on public thoroughfares.
6. SAE International is a worldwide association of over 128,000 engineers and technical experts working together with the aerospace, automotive and commercial vehicles industries. https://www.sae.org/
7. Regulation 2016/679/UE dated 27 April 2016 pertaining to the protection of private persons against the processing of personal data and the free circulation of such data (repeals directive 95/46/CE of 24 October 1995).
8. Directive (EU) 2016/1148 du 6 of July 2016 on security of networks and essential information systems.
9. Directive (EU) 2010/40 of 7 July 2010 pertaining to the framework for deployment of intelligent transport systems in the area of road transport and of interfaces to other transportation modes.
10. International Standardisation Organisation: https://www.iso.org/standards.html
11. ETSI is a private certification body specialising in the area of information security: https://www.lsti-certification.fr/index.php/notre-societe/qui-sommes-nous.html
12. The G29 or “Working Party on data protection and privacy” was established by article 29 of the 1995 directive. It brings together the representatives of every national independent data protection authority (CNIL for France) and one representative of the European Commission. A European data protection committee, having legal personality, will replace it in May 2018 with the enforcement of the European Regulation (art. 68 et seq. of the GDPR).
13. French national data protection commission: *Commission Nationale de l'informatique et des libertés*. https://www.cnil.fr/en/home
14. The European Union Agency for Network and Information Security (ENISA) is a centre of expertise for cyber security in Europe. https://www.enisa.europa.eu/
15. ANSSI is the French national authority for the security and protection of information systems, http://www.ssi.gouv.fr/en/
16. The ratification act of the above-mentioned ordinance has not been voted yet and the statutory instruments are still pending publication. Experimentations are currently authorised subject to a special registration certificate (regulation dated 9 February 2009, art. 8.IV).
17. Discussions taking place between WP1 (Working group on road traffic and safety) and WP29 (World Forum for Harmonisation of Vehicle Regulations) within the UN Economic Commission for Europe.

Further redings

Guilbot, Serre and Ledoux, 2016: http://www.revuetec.com/revue/protection-donnees-personnelles-conducteurs/

Guilbot and Pflimlin, 2017: http://www.congres-atecitsfrance.fr/wp-content/uploads/2017/02/03-V%C3%A9hicule-connect%C3%A9-facteurs-humains.zip

Hautière, Tattegrain and Guilbot, 2017: http://www.hst.fr/dms/hst/data/articles/HST/TI-VP-17/vp17.pdf

Credit: Epictura

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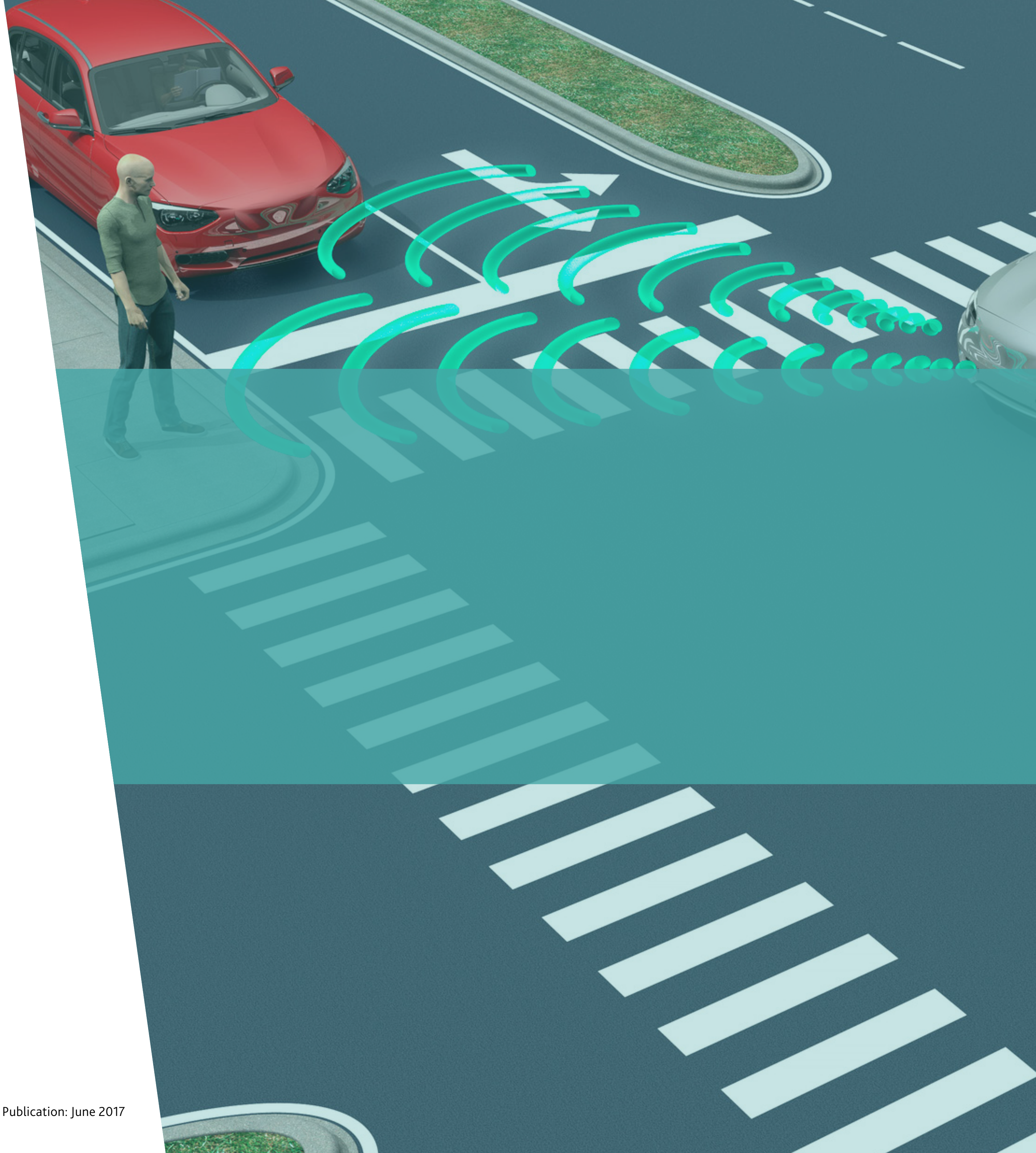

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