INSTITUT MONTAINGE

What role for cars in tomorrow's world?

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What role for cars in tomorrow's world?

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FOREWORD

The future of mobility:
from the car of "passion" to the car of "reason"

by **Luc Ferry**

As the son of a small racing car manufacturer, who was also one of the best drivers of the pre-war period, it could be said that cars are "in my blood". I grew up in a garage where dozens of Bugatti 35Bs, Cisitalias and Maserati 1500s lined up among the magnificent competition racing cars that my father used to build. I became an amateur racing driver and a tester for Car Life, a prestigious publication on sports cars. I do not mention this to boast, merely to point out that I am far from indifferent to the future of the cars.

When I was young, cars had a whole range of characteristics that are now becoming more or less extinct. Cars were, first and foremost, a question of passion, a symbol of freedom and adventure. Buying a second-hand 2CV as soon as you passed your driving test and setting out alone (certainly not car-pooling!) with your girlfriend, was our dream. In the racing world, risk, and even the risk of death, reigned over the circuits. Until the end of the seventies, car racing was almost certainly one of the most dangerous sports in the world. I remember being with my dad in Montlhéry, in Reims, in Pau, and seeing a number of accidents that put an end to the lives of some of the best racing drivers of the 1960s. But cars were also about beauty: some of them can even be considered as the most beautiful works of art of the 20th century. The prices fetched by certain vintage models today certainly support this claim, since these cars have nothing to do with usefulness, and are all about aesthetic magnificence. Then came the quest for performance. Each year brought more powerful engines, more aerodynamic bodywork, more efficient brakes, and innovation of the competitive world gradually trickled through to the general public's consumption behaviour. Finally, cars were also a means of seduction.

This passion has almost disappeared and the key words used to define today's ideal car express more rational concepts. Reliability, comfort, safety, silence, ecology, and economy have taken priority, accompanying the move from the symbolic to the real, from the emotional to the reasonable. Three major innovations can be added to this mix, directly related to the third industrial revolution: car-pooling (as the French company, Blablacar offers), car-sharing (e.g. Autolib in Paris) and, most importantly, self-driving cars. This last innovation will bring undeniable progress: no need for a driving license, traffic lights, information signs, speed limits, as well as the end of drunk driving (since there is no driver), almost no more road accidents and out-of-town car parks, where cars will go and park themselves. Connected cars will become mobile offices, helping to save vast amounts of time, the most precious of all possessions.

These revolutions come hand in hand with the younger generation's relative disinterest in cars. Many young adults will prefer to spend their money on smartphones, video games and computers rather than the equivalent of the 2CV of my teenage dreams. One of the reasons is obviously that the multiplication of vehicles, combined with urbanisation, has made cars infinitely less mobile than what its less used title of "automobile would" suggests. In fact, it has become more of a burden than anything else in city centres: finding and paying for parking is now a headache in our major cities, wee-kend trips a nightmare of overcrowded motorways and traffic jams in and out of the urban centres. We have experienced what Hegel might have called a "dialectic of mobility", a reversal of mobility into its opposite, with the slowness of heavy traffic eliminating any sense of freedom. For all these reasons, it is obvious that the "office-car" will ultimately replace the original passion for cars - it is merely a question of time. Fluidity will return to the roads, accidents will almost cease to exist and vehicles will be able to transport people and goods without needing a driver, before taking themselves off to park on the outskirts of the cities. Huge progress indeed, but also the extinction of a dream that today's under twenties will never have known.

The present report explores these innovations, which will change our relationship to cars much faster that we might believe. It identifies the major categories of problems that these changes will bring about, notably the societal, economic and ecological challenges. Reaching beyond simple theory, it offers a series of interesting proposals to stimulate the essential public debate on the future of mobility. I am sure that it will be of great interest to many.

What role for tomorrow's cars?

What lies ahead for cars? The need to improve air quality and the quest for more fluid means of mobility, and sometimes dogmatic viewpoints have led some to want to exclude cars from towns.

Despite the undeniable progress that has been made to mitigate its impact, cars remain a source of undesirable externalities. In France, transport represented 26.9% of greenhouse gas emissions in 2013[1] and 28% of particulate emissions in the Île-de-France region.[2] Congestion in city centres leads to increase in both of these emissions and a considerable loss of time (estimated at 38 minutes per day in Paris[3]) and money for those who drive.

The recent, repeated scandals involving automobile manufacturers' efforts to falsify emission testing results have contributed to tarnishing the image of this industry. This lack of transparency increases negative feelings towards a mode of transportation that is already the target of numerous criticisms. Cities' prohibition of certain types of vehicles and pedestrianisation of urban areas illustrate large cities'

[1] Road transport of passengers and goods represents 95% of traffic. Source: European Environment Agency, October 2015. However, it should be noted that greenhouse gas emissions from road transport in the region have decreased 7.3% between 2004 and 2015 (source: The 2015 transport accounts, French Ministry of the Environment, August 2016).

[2] "Inventaire régional des émissions en Île-de-France" *(Regional Emissions Inventory in Île-de-France)*, Airparif, 2012. At the national level, concentrations of particles, in close proximity to road traffic and in urban settings, have been decreasing: PM10 levels have been going down since 2007, and PM2.5 since 2009 (source: "Les particules atmosphériques : la connaissance progresse", Datalab, February 2017, Ministry of the Environment).

[3] Source: TomTom Telematics, 2016 Traffic Index.

"anti-car" dynamic. Today, this orientation appears to be the public authorities' preferred solution for overcoming the challenges faced by the future of mobility.

But are cars really doomed to become a relic of the past, to disappear from our streets and our thoughts? To answer this question, the Montaigne Institute commissioned an in-depth survey[4] carried out not only in France, but also in Germany and in California, thereby providing the Institute with two additional sets of data to which data collected in France can be compared to. This survey concluded that cars remain a crucial social object for a very large part of the French population. It still enjoys a positive image for more than three quarters of the French: it is, above all, a source of independence and freedom (56%) and of pleasure (20%). Only 22% of those surveyed hold an unfavourable view of cars, regarding them as a source of expenditure (17%), a constraint (3%), or harmful to the environment (2%). It is certainly no coincidence that 99.2% of respondents do not consider giving up their car in the medium term, even in the most dense urban areas. Such attachment is identical in the two other geographical areas surveyed: Germany (98.7%) and California (99.5%).

Moreover, cars are essential to a large proportion of the French population. More than 60% of them drive their car to work, 43.7% of whom have no alternative means of transportation. This proportion is greater than in Germany (35%) and in California (41%). Cars are more than just a gadget: they are a daily life necessity. This finding must be taken into consideration when reflecting on the automobiles' future.

[4] Survey conducted by Kantar for Institut Montaigne in December 2016 in France, in Germany, and in California, with approximately 1,000 people surveyed per country.

Beyond cars' social, and even emotional, importance, is its fundamental economic role: in 2015, the French automotive industry employed 440,000 people[5] (full-time equivalents), almost half of whom work in the core business sector (car manufacturers, equipment manufacturers, designers). It indirectly led to 2.1 million additional jobs according to the *Comité des Constructeurs Français* d'Automobiles (CFFA, Committee of French Automobile Manufacturers)[6], including *via* the trades related to using a car (sales, after-sales service, rental, etc.) and trades involved in mobility (road transport of goods, transport of passengers, etc.). The automotive sector generates 16% of the turnover of the French manufacturing industry as a whole, and is one of the leading patent-producing fields in France.

Today, policies prioritise the fight against pollution over mobility issues, which are vital nonetheless. How can these two approaches be reconciled while maintaining ambitious economic and ecological objectives?

Numerous innovations – both recently released and those still under development – show the real efforts being made by the automotive ecosystem both to respond to criticism and to meet citizens' needs. Whether by means of cars' new uses (carpooling, car hire between private individuals, private hire, etc.), the considerable progress made in engine design, or, of course, autonomous vehicles, in the future cars could optimise mobility and make a significant contribution to reducing pollution.

[5] French Ministry of the Economy and Finance, 2016.
[6] CCFA, "Analyses et statistiques 2016".

However, cars have not yet reached this point: they generate both fascination and hostility, they are still indispensable but threatened, and run the risk of being driven out before being able to keep all its promises. And time is not on its side, since updating the fleet of cars on the road is slow work: it takes an estimated 20 years for an innovation to spread to half of the vehicles in circulation.

The future of cars relies on overcoming three challenges:

- A **societal** challenge: the revolution of connected and autonomous cars will make it possible to significantly develop multimodal transport policies and thus respond to communities' various challenges involving mobility (safety, congestion, environment);
- An **environmental** challenge: while the goals are known – improving air quality and fighting climate change – the strategy to achieve them can no longer be limited to imposing ever stricter standards on only new vehicles, it must be comprehensive (European harmonization, actions applicable to the entire fleet of cars, etc.);
- An **economic** challenge: the automotive industry is innovating at a hectic pace, bolstered in part by newcomers (Tesla, Apple, Google), who are a direct threat to the sector's traditional players. For France to produce the car of the future, cooperation between businesses and public authorities is crucial.

In all these areas, close partnerships must be formed between public authorities, industry, and society. The future of the car depends on their collective capacity to respond to this threefold challenge and to ensure a fluid transition towards a new model of mobility.

As such, to respond to these three challenges, the work group formulated ten proposals. They are based on the following guiding principles:

- **Incentive measures,** based on market mechanisms, are preferable to a coercive approach;
- **Experimentation** must be encouraged, starting with tests at the local level before considering a rapid, large-scale deployment;
- Regulations must be guided by a **results-based approach** rather than a means-based approach, and allow actors enough latitude when making technological choices; they must **consider the problems in a comprehensive manner,** to limit possibilities for circumvention;
- **Standards harmonized at the European level** allow the market to reach critical mass, without impeding local variations that take territories' specific characteristics into account;
- All actors – public and private, established and new, large and small – can contribute to innovation, and progress by working **collaboratively.**

PROPOSALS

Responding to the societal challenge by making cars a safer means of transport and improving links with other mobility solutions

Proposal no. 1: Encourage public and private mobility players to develop intelligent and intermodal transport solutions to adapt supply to demand in real time («group private hire», notably in low density areas).

A large proportion of the country has little access to public transport because of profitability reasons. The development of connected vehicles offers a possible way out of this deadlock. Based on the private hire model, passenger transport services can be developed based on low capacity vehicles (minibus, etc.), whose routes would be adapted to real-time user requirements. This would represent a true revolution in the economics of public transport in low density areas.

In addition to buses with fixed timetables and routes, an on-request shuttle system or "micro-transits" could be created, which would only run if enough users were interested. This solution, largely facilitated by current technologies, has already been launched in Canada, via Uber Hop, and could be implemented in France to good effect.

The development of these solutions should associate the various parties involved: local governments, public transport companies, private mobility companies, etc. The role of the public authorities could be both financial – invitation to tender, innovation competition, etc. – and regulatory – introducing some flexibility into the standards governing passenger transport. These services must be financially affordable for users to offer better mobility to as many people as possible.

Proposal no. 2: Adopt common normative principles for the regulation of traffic at a European level, so as to reduce both congestion and pollution.

While it is important to develop new means of transport in less well serviced areas, it is natural to seek to regulate traffic in areas suffering from congestion, usually located in city centres. However, to facilitate the implementation of such schemes without obstructing mobility, it is essential to homogenize norms governing mobility from one city to another and from one country to another.

Traffic regulation will be increasingly reliant on "intelligent" systems: dynamic micro-tolls requiring the installation of a specific device inside cars, connected information signs, etc. Harmonizing regulations would ensure the interoperability and compatibility of these schemes throughout the European Union (e.g.: an automatic toll device recognised in all cities and on all roads applying a toll).

This would also be beneficial to citizens, whose travels around the cities of Europe would be facilitated, as well as to industrial firms, opening up a vast market to which adapted technological solutions could be proposed at reasonable costs. Similarly, a harmonised environmental categorisation of vehicles could be set up as a basis for traffic restriction measures decided locally (e.g. an interoperable European sticker).

The legal and regulatory framework, once harmonised, would serve as a toolbox, enabling local and national authorities to adapt regulations to the particularities of their territories. Simple recommendations (presentation of a range of incentive measures, notably in relation to urban tolls) could be combined with elements that would ultimately become mandatory (e.g. the harmonised environmental certificate, which could be part of a directive).

Proposal no. 3: Develop the collection and collective use of data from on-board computers to maximise joint benefits: at a European level, this will involve defining the concept of mobility data of common interest and the rules of accessing, sharing and exploiting such data to stimulate innovation while guaranteeing security and confidentiality.

The harmonisation of norms must also include the numeric aspects of mobility. The use of driving data represents a hoard of new services and is therefore a leverage of competitiveness for the French industry. However, it also represents a potential risk requiring reassuring and protecting the population.

The definition of data access rules must be combined with the development of dynamic traffic regulation mechanisms (micro-tolls, reserved lanes), whose operation depend upon the collection of data related to cars and their usage (number of occupants, vehicle type, etc.).

The notion of "data of general interest" could also be taken into account: information collected by a vehicle – an accident detected by on-board cameras, for example - could be useful to other vehicles, for example to warn drivers approaching an accident zone.

Proposal no. 4: Accelerate the generalisation of the most effective new safety systems (emergency braking and drowsiness detection systems in particular), as soon as their efficiency has been demonstrated by independent studies, to enable exploitation of the full potential improvement in road safety offered by such systems.

Personal safety could be considerably improved by adopting major innovations that are currently under-exploited. Technologies such as emergency braking or attention systems are successfully used on certain premium vehicles, but are slow to be installed on bottom-range cars: many lives could be saved if the distribution of such technologies was accelerated.

Once their efficiency has been proved by independent studies, a possible approach could be to make these systems mandatory on new vehicles, or even on all vehicles if it is possible to adapt them to existing models. This could be the case of drowsiness detection systems, notably.

It would also be possible to adopt an incentive scheme for users, based on financial benefits for example, such as modulating the price of urban tolls for cars equipped with certain safety features.

Responding to the environmental challenge by setting objectives that are more ambitious and better controlled than at present, while granting more freedom in terms of how to achieve them

Proposal no. 5: Implement incentive schemes (rather than traffic restrictions) to enable effective and fair regulation of traffic and pollution in the densest urban areas.

Traffic regulation in our densest areas represents an essential objective. The solutions proposed must be both adapted to the specific context of their implementation and compatible with the harmonised European normative framework. Rather than a simple blanket ban on all motorised vehicles, it would be possible to limit their use by dissuasive measures, while encouraging more virtuous behaviour.

The first step would consist in setting up self-assessment mechanisms in major urban centres. Using technological progress, data on real time emissions can be collected to inform drivers of their environmental impact and compare it with fellow road users, to encourage them to drive more fluidly and generate less pollution.

This self-assessment phase could then be supported by financial incentive schemes, such as dynamic micro-tolls, or other incentives, such as traffic lanes reserved to car-poolers. The mass of data collected by the self-assessment systems would enable to optimise the design of these incentive schemes, thereby rendering them more acceptable and improving their efficiency. The following principles could be retained:

- micro-tolls and other schemes would first be tested and their impacts assessed independently. They would then be maintained or withdrawn, depending on the results of these assessments, and after public consultation if necessary;

- the price of the dynamic micro-toll would be modulated on the basis of a number of criteria: the *"smart congestion charging"* model, for example using vehicle category (level and type of pollution emitted), use (occupancy rate), traffic conditions and air quality (higher price during rush hours or periods of high pollution), frequency and intensity of use in the target zones, etc. Pricing would take into account the social situation of drivers to avoid weighing excessively on the least wealthy;
- income from the micro-toll would be re-invested in public transport and road infrastructures;
- the micro-toll would apply to private cars and goods transport vehicles, subject to different price conditions, if applicable.
- In the longer term, these intelligent regulation systems could be applied to other areas: adaptive speed limitation on motorways according to weather or traffic conditions, in areas affected by episodes of high pollution, etc.

Proposal no. 6: Revise European regulations regarding manufacturers' calculation method CO_2 emission objectives so as to encourage vehicle weight reduction, an emission limitation measure that is still under-exploited.

European CO_2 regulations aim to make manufacturers internalise the environmental costs of cars by setting a CO_2 emission norm (95g/km by 2021) applicable on average to all new cars sold within the European Union. This general norm is determined for each manufacturer according to a system known as the "emission rights slope". The actual slope (and the ponderation criterion used) is decisive in that it assigns a value to the different ways of "saving" grammes of CO_2.

By favouring vehicle mass over its footprint as the ponderation criterion, European regulations penalise the strategy of reducing vehicle weight as a means of limiting the environmental impact of cars, in spite of the recent progress made in new, lightweight and more resistant materials, which further enhances the potential effects of such strategies.

To resolve this situation, the most consensual option consists in altering the slope of weight reduction neutralisation (for example from 60% to 40%) to encourage further lightening of manufactured cars.

A second, more ambitious option, but less acceptable for manufacturers of heavier, *premium* vehicles, would be to replace the weight ponderation criterion by a vehicle footprint-based system (which is already in use in the USA), making weight reduction all the more advantageous.

In all cases, checks must be stepped up to guarantee the efficiency of regulations and to restore public confidence.

Proposal no. 7: Regulate emissions according to incentive schemes founded on an overall results-based approach, without imposing technological choices.

Emission regulations, whether mandatory or incentive, must be based on a results requirement, without favouring one technological choice over another. In the short term, it would be advisable to accelerate the convergence of emission norms for diesel and petrol powered engines (in the next EURO norms) in collaboration with the industrial stakeholders, notably with respect to the gaps observed between emissions in actual use and in test conditions.

Furthermore, while preserving the current individual vehicle emission limits, more limiting targets could be set for average fine particle and nitrogen oxide (NOx) emissions for cars released each year by individual manufacturers, as is the case for CO_2. This would enable each manufacturer to find the best technological mix to reduce the emissions of its fleet overall, thereby improving air quality in the cities faster.

More particularly in terms of fine particle pollution, emission norms should include all sources of particle emission, and not just from the exhaust pipe, which only represents 5% of the direct and indirect emissions of recent car models (compared with two thirds of emissions due to fine particles being re-suspended[7]).

In the longer term, it would be beneficial to encourage the most promising technologies (petrol-diesel hybrid, hydrogen, electric, etc.) in a balanced manner, by adopting a full cost (including costs related to electricity distribution infrastructures), overall “well-to-wheel” and full product life cycle (notably including the issues of battery recycling) approach.

[7] *Non-exhaust PM emissions from electric vehicles,* Victor R.J.H. Timmers & Peter A.J. Achten, Atmospheric Environment, 2016.

Responding to economic challenges by structuring a highly innovative, forward-looking industrial sector in France

Proposal no. 8: Catch up on experimentations of autonomous vehicles in actual driving conditions. In order to do so, France needs to develop more sites and programmes allowing experimentations in real conditions as well as to to facilitate innovation, by encouraging the various mobility stakeholders (manufacturers, startups, transport operators, public authorities, etc.) to work together in an open innovation approach.

Experimentation is an essential part of innovation and testing technologies in conditions close to reality helps to accelerate the learning curve. Experimentation sites have either already been created or are being set up in Europe, including in France. Some countries are already a step ahead, which is the case for Germany (motorway sections equipped with specific infrastructures, in particular road signs, to allow the use of connected vehicles) and the USA (tests conducted by Uber in Pittsburgh), which have test devices in real conditions, built into the existing infrastructures. It is essential for France to do the same in order for the country to bridge the technological gap from which it suffers

The participation of both local and national authorities in such experiments is important, since it would help to better anticipate future innovations and their consequences, both in terms of regulations and urban planning policies. Such zones must of course be operated under maximal safety conditions (specifically mapped zones, vehicle use restricted to periods of optimal conditions - weather, light etc.).

The development of a truly innovative ecosystem would also stimulate investment, in particular risk capital, i.e. in companies (startups) that have not yet attained their equilibrium. Initiatives that bring the various stakeholders together (incubators, innovation centres, etc.) can play the role of catalysts on this topic.

Proposal no. 9: Anticipate the consequences of the car of the future on the labour market with an ambitious training and redeployment policy.

The stimulation of innovation requires technical investments as well as investments in human resources. The evolution of technology and its uses will have a major impact on employment in certain sectors, such as passenger transit and transport of goods, car dealerships, etc. These transformations are inevitable and carry their own advantages (better mobility, productivity improvements, etc.).

They must be accompanied by a prospective and strategic management of the transformations that will soon occur in the labour market. The automotive industry, with the support of public authorities, must start to analyse the impact of the car of the future on employment as soon as possible, both quantitatively (number of jobs threatened in each sector of activity) and qualitatively (possible redeployment according to skills). This shared diagnosis would enable the adoption of a forward-looking job and skills management strategy, and thus ultimately avoid potential abrupt restructurations.

Proposal no. 10: Gather mobility stakeholders of the future to encourage dialogue, by including the new mobility stakeholders(e.g. by strengthening the role of the PFA, France's car and mobility industry organisation), **in order to optimise our anticipation of the upcoming evolution of industrial needs.**

The contributions of all French stakeholders to design and produce the car of the future should be better coordinated. Instances for dialogue and consultation already exist (e.g. the strategic committee of the automotive industry), but these must be expanded.

It is important to encourage exchanges between traditional big groups and the market's newcomers to promote network innovation. A multitude of experiments could then be carried out rapidly, and the most convincing innovations could be shared on a large scale..

The incentives to such cooperation projects could be amplified *via* private-public partnerships: support for collaborative projects, innovation competitions, etc.

Conclusion: the promises of the autonomous car

Cars face societal, environmental and economic challenges, at the heart of which lies the development of autonomous cars, which is a promising prospect. Indeed, such cars would improve road safety, life quality, access to mobility, and even environmental performance, both in urban centres and in peripheral areas.

It also entails an international competition that extends beyond just companies in the sector. If it tries hard enough, **France can be a leader in the development of accessible autonomous cars.**

From the automotive sector to digital and “smart city” technologies, French companies have tremendous assets. A powerful dynamic is already engaged It must now be strengthened and supported by public authorities.

Public authorities’ role regarding this issue is crucial. A concerted approach must be taken and a favourable regulatory framework must be developed at the European level. Meanwhile in France, this innovative industrial policy must be supported, in particular through the future investment programme and/or by the development of infrastructures that can accommodate autonomous vehicles. Finally locally, experiments under real conditions must be launched to investigate how to manage the integration of autonomous cars in tomorrow’s mobility mix.

Our country’s ability to take the lead in this technological revolution depends on this voluntary, long-term action.

OPINION SURVEY ON CARS AND THEIR USES

The Montaigne Institute has organised an opinion survey on the habits and expectations of citizens regarding mobility and the future of cars in order to inform its discussions on cars and their uses. This survey was carried out in December 2016 by Kantar-TNS, interviewing 3,000 people. The study focussed on three geographic areas: France, Germany and California.

What lessons can be drawn from this survey?

What is the relationship between respondents and cars?

The driving licence is not outdated. In the three geographic areas studied, **more than 9 out of 10 respondents had a driving licence.** Among the 18-24 age group, 83.9% French, 80.1% Germans and 85.1% Californians had their licence.

France mostly has diesel cars, while almost 70% of Germans and 85% of Californians favour the petrol engine.

The survey reveals that the geographic characteristics of the three areas considered have a strong impact on the means of transport that are privileged, in particular in California, where people use cars, planes and trains more frequently, because of the longer distances involved. Seven out of ten Californians use the car to commute from home to work, compared with 64.4% of the French. Those who do not use the car every day in France (47.6%) and in Germany (49.2%) make the most of the shorter distances to travel by foot or bicycle.

They are also more likely to use public transport networks, which are more developed.

However, in all three areas, more than half of those interviewed use their personal car at least once a day, making this the most used means of transport. The real geographic difference lies within each area, as daily use of the car declines with the size of the city. However, even in large cities, this daily use remains significant, concerning an average 35% of those living in the urban centres of the major metropolises,[8] compared with 24% using public transport. In France, the figures are 23% (daily use of the car) and 31% (daily use of public transport). It is interesting to note the differences between those living in urban centres and those in the outskirts of the same cities: daily car use is 15 points higher for the latter, while the use of public transport remains similar to that of the former.

What is the relationship between respondents and today's cars?

More than half of the people interviewed use their personal car at least once a day, making it the most used means of transport. This tendency does not seem to slow down: in the three areas studied, **99% of car owners have no intention of getting rid of their vehicle** (they either intend to keep it or replace it). This unanimous response can be explained by the image associated with cars: **for more than one in two people interviewed, cars represent freedom and independence.** The negative aspects related to car ownership (environmental pollution, constraint) are only rarely mentioned by respondents, although one every five people consider the car to be expensive.

[8] Understood here to be agglomerations with more than 1.5 million inhabitants.

Cars therefore remain the privileged means of transport, appreciated by the respondents in all three regions. The car is recognised for its **practicality** (by Europeans) and **comfort** (by Californians). Furthermore, when compared with other means of locomotion, the respondents from all three geographic areas surveyed mentioned **flexibility** one of cars' major assets followed by the practical aspect of cars for the French, comfort for the Germans and speed for the Californians.

Those who do not travel by car have other priorities:
- walking or cycling are privileged because they are healthy;
- public transport is seen as being both practical and inexpensive;
- the train is preferred for its speed and the pleasure associated with its use.

Despite their growth, new forms of mobility (car-sharing, car-pooling, private car rental, etc.) are still only **very partially used.** In France, daily use generally does not exceed 6% of the individuals concerned, regardless of the geographic area concerned.[9] Those who use them, generally do so instead of personal cars, but also to replace train journeys (with long distance car-pooling), public transport or walking (with car-sharing or private hire vehicles).

[9] In agglomerations of between 500,000 and 1.5 million inhabitants, this daily use is highest; for the French population as a whole, the rate is 2%. Occasional use of the new forms of mobility concerns more people, with 36% of the French using them over the twelve months preceding the survey.

What do respondents expect from the car of the future?

When asked about the car of the future that would best suit their needs, the French and Germans mention the **respect of the environment** as their main criterion, while Californians are more sensitive to safety. Finally, only 16.4% of the French, 15% of Germans and 22.3% of Californians consider that among all cars, the autonomous car would best suit their needs, as its potential promises are welcomed with scepticism. When asked "To what extent would such a vehicle meet your mobility needs?", as many people responded positively ("extremely well", "very well") as negatively ("not very well", "not at all").

Paradoxically, **almost two thirds of the people interviewed have an overall positive opinion** of the autonomous car (63.3% for the French, 64.4% for Californians and 54.5 for the Germans). Furthermore, an almost consensual opinion is expressed regarding the capacity of the autonomous car to facilitate travels for people suffering from reduced mobility (more than 4 out of 5 respondents). An autonomous car would also reduce **the time wasted by the search of a parking space,** according to 80.3% of the French. It would allow for longer journeys without being tired for 71.9% of Germans and 79.9% of Californians.

So why such lack of enthusiasm for this new technology?

Firstly, the respondents have doubts regarding the price the autonomous car will have when it reaches the market: **45.8% of the French, 43.1% of Germans and 40.3% of Californians take this to be its main disadvantage.**

Respondents are equally very hesitant regarding the protection of their personal data: the fear of seeing this data misused or hacked is mentioned by 27% of Californians and 33% of Germans. However, even if the price was acceptable, 31.6% of the French, 31.5% of Germans and 33.1% of Californians do not know whether they would buy such a car.

It therefore seems unlikely that these technologies will spread quickly in the short term. To improve this disheartening prospect, public authorities will have to be proactive in **encouraging innovation in the car industry** and paying particular attention to its presentation and promotion to the population.

Method:

The survey was conducted through online interviews, from the 14th to the 27th of December 2016, among 1,006 French, 1,004 Germans and 983 Californians, i.e. at total of 2,993 people representative of the populations in the geographic areas.

INTRODUCTION

From the Magna Carta to the Universal Declaration of Human Rights, freedom of movement is one of our most fundamental rights. In the past, economic growth has accompanied the mobility of goods and populations, both as a cause and a consequence. The availability of fast, reliable transport links facilitates access to employment, consumption, culture and leisure activities.

Throughout the 20th century, technical progress and investments in infrastructures have enabled an incredible reduction of distances and travelling times, even in our everyday lives. Of all modern means of locomotion, cars are surely the one that conjures up the strongest and most contradicting emotions. The French see cars as a symbol of emancipation (most people get their driving license in the early years of adulthood) and freedom, an essential element of everyday life and sometimes even an object of desire. However, it is also perceived as an economic burden, a danger in public areas and a threat to the environment.

The environmental issue has become crucial. Whether with respect to commitments from most developed countries to reduce their greenhouse gas emissions, or the efforts made to improve air quality in all the major cities of the world, the car is centre stage. The feeling of betrayal expressed by the public in the wake of the *"Volkswagen affair"* has fuelled efforts to toughen up regulations. However, certain economic, industrial and social realities cannot be ignored: a place must be found in our societies for the car.

The automotive industry is witnessing major revolutions, with clean cars, car-sharing and, of course, the self-driving car. While some would see our cities car-free, the City is boosted by recent and future innovations, which plead for a balanced approach, structuring the different means of transport according to their respective merits. In the meantime, car manufacture is a cutting-edge industry, representing 440,000 employees in France[10] (full-time equivalents), almost half of whom work in the core business sector (car manufacturers, equipment manufacturers, designers). The automotive sector generates 16% of the turnover of the French manufacturing industry as a whole.[11]

The future of cars and its industrial sector lies at the intersection of three challenges: society, environment and economy.

Addressing the societal challenge (chapter 1) means drawing maximum benefit from the revolution of connected, autonomous cars, reconciling land with cars. In low density areas, the car of the future could be tomorrow's public transport system. In cities, the connected car must fit with the other transport systems and enable the transition to intelligent traffic regulation. Embedded intelligence will reduce the number of deaths on our roads everywhere. However, many risks remain: regulatory fragmentation (with each city defining its own rules), lack of respect for personal privacy, computer hacking, etc. Public authorities must take decisive action to preserve only the best of this gigantic technological potential.

Moving onto the environment challenge (chapter 2), the objectives are well-known: improve air quality and reduce global warming. However, if we are to achieve those goals, we must change our methods. Today's regulations are centred on norms that regulate new vehicles but the stock of cars is huge and it will take several decades for innovation to become widespread.

[10] French Ministry of the Economy and Finance, 2016.

[11] CCFA, "Analyses et statistiques 2016".

It is therefore time to adopt a different approach (European harmonisation, action on the entire vehicle stock, etc.) to start to bring about the behavioural changes that technology makes possible (car-sharing, multi-modal transport, computer-optimised eco-driving). Regulations could also be adapted to make the most of certain technological potentials, such as reducing vehicle weight, or more efficient action against fine particle pollution. The transition to this new model must be conducted with prudence and anticipation to enable the industry to adapt and to limit the economic consequences for households.

The economic stakes (chapter 3) are significant. Every four years, car manufacturers spend the equivalent of the value of their companies on R&D and capital investments, whereas the average in other industries is twenty years. This frenetic renewal of technology opens the door to newcomers (Tesla, Apple, Google, etc.), allowing us to imagine profound changes in the value chain. Downstream, "uberisation"[12] threatens many businesses: dealerships, insurance firms, delivery companies, etc. The industry must therefore organise itself to anticipate these future changes in terms of innovation, employment and economic sovereignty.

In all these areas, close partnerships must be formed between public authorities, the industry and the general public. The future of cars depends on their collective capacity to respond to this threefold challenge and to ensure a fluid move to a new model of mobility.

[12] This term is perhaps somewhat overused. Here, it refers to a profound change in the value chain, related to the disintermediation permitted by new technologies.

Box 1: What about goods transport

E-commerce sales are increasing by 10-15% per year. This corresponds to an explosion in the volumes of goods transported, particularly to residential areas (the "last mile"). In most large cities, this represents yet another challenge in the fight against pollution and congestion. London is a perfect example of how progress in traffic limitation - by means of urban tolls - can be erased by the sudden development of delivery transport.

What impact will this have on future mobility? The keys to analysing this question are not the same as for passenger transport, even though the threefold challenge presented above (societal, environmental and economic) also applies here with equal intensity.

In urban areas, delivery companies generally use fleets of vehicles which can be renewed rapidly and use new engine developments more easily than private cars (electric vehicle charging infrastructures are easier to deploy on the scale of a company fleet than for an entire city). Management of merchandise flows and their division is also central and specific to the transport of goods.

Over long distances, technologies are also different, with trucks that will soon be autonomous, able to group together in convoys to optimise their aerodynamics *(platooning).* They are obvious candidates for the use of energies that are not suitable for private vehicles (notably natural gas).

While most of the principles presented in this report can be applied to the case of goods transport, the modularity of vehicles tends to erase the difference between passenger transport and merchandise transport. It therefore becomes essential to unify regulations at the European level and to develop incentive schemes and *smart regulations* that will affect behaviour, tempting it towards the virtuous. The principle of an overall, technologically neutral approach to environmental regulation must be adopted, constituting industrial logic to develop the technologies of the future in France and to maintain value creation in the country.

THE SOCIETAL CHALLENGE

The role of the various means of transport used in our societies emerges from individual choices (privileging solution over another) and public authority decisions on investment and regulations.

The quality of means of transport can be assessed on the basis of a number of criteria:

- time: limiting journey time by increasing speed and, in the case of public transport, shortening waiting times and ensuring reliable departure and arrival times. Being able to do something else during the journey (reading, having access to internet, etc.) can be seen as an optimisation of travel time;
- cost: travel cost should not be an obstacle to mobility, since it is essential to economic, social and cultural life. However, it may act as an incentive, benefiting a means of transport rather than another (e.g.: subsidising public transport, road toll systems, etc.);
- accessibility: a means of transport is only valuable if it is accessible. This criterion primarily concerns persons with reduced mobility. More broadly speaking, the use of certain means of transport can end up involving other journeys: the advantages of air travel can be substantially reduced if airport access is difficult;
- comfort: we expect transportation to be pleasant. In the case of cars, this includes the "pleasure of driving", which truly differentiates cars from public transports;
- safety: the risks entailed by the trip (accidents, attacks, etc.) must be minimised;
- environment: the environmental impact travels - both locally and globally - must be controlled. In the broad sense, this concern largely supersedes the simple question of pollution: the space occupied by

transport systems (roads, car parks, etc.) or even noise pollution are all consequences of mobility on the environment.

The mobility policy implemented in the future must be as effective as possible regarding these criteria, while guaranteeing a good organisation of the various means of transport in application of a multi-modal logic[13]. It should be designed at both national and European levels, with local application according to the specific challenges of each territory (congested urban areas, deserted regions, etc.).

The car, enhanced with new technologies and strengthened by new uses, appears to be a fundamental element of these mobility policies and must be associated with the other means of transport. The changes in cars, enabled by digital developments, will only be fully accepted if they come with sound guarantees in terms of personal liberties. They could improve road safety considerably but will also alter our attitudes to risk and will raise new psychological and ethical questions.

[13] In terms of infrastructures, this means being able to get from one means of transport to another easily. For example, car parks must be provided around public transport stations to reduce the distances to be covered on foot between different types of transport, or providing real time information on departure and arrival times for public transport to enable overall planning of a journey.

1.1. Bolstered by technological innovations and new uses, cars remain an essential component of our mobility policies

1.1.1. Mobility requirements vary significantly between territories and from one person to another

The territories are not equal in terms of mobility and the predominance of cars varies considerably. The car is the primary means of transport in rural or suburban areas, where public transport networks are less dense[14]. On the other hand, although larger cities have public transport infrastructures, these often tend to be saturated, like the roads, which are generally congested. The transport networks are often organised in a "star" formation: beyond the routes connecting the agglomeration centre with its surrounding areas, the transport offer is not sufficient (notably for travel between suburbs).

In terms of mobility, the question of urban planning is fundamental. Congestion is caused by movements of people in a small area (organisation of cities into residential areas and business districts) within a short period of time (rush hours related to office working hours). Another basic characteristic of cities - of all sizes - is the space devoted to parking, which has, in the past, encouraged the ownership and use of private cars.

A more systematic analysis of the state of mobility according to geographic area enables the identification of several categories, defined by different needs and constraints. Thus, while cars are

[14] Public transport only covers 62.5% of the French population. Regular users (at least once a week) of public transport only represent 17% of the French population, with a high level of concentration in the Paris area (18% of the total population but 46% regular users).

rarely used to travel in Paris (12% of trips), they remain essential in many areas (there are more than 70% of trips in urban areas with less than 100,000 inhabitants).[15]

The relationship to mobility - and particularly to cars - also differs from one person to another (see annex 1). Level of income also appears to be a decisive factor in mobility habits: car use tends to increase with salary - the less well-off tending to prefer walking and public transport - and decreases above a certain level of income.

Similarly, age has a clear influence on mobility habits. The use of public transport decreases over a lifetime – initially in favour of the car, then of walking - before increasing again among the over 60s.

This heterogeneity of use is accompanied by a wide range of emotions regarding cars. This subjective, but essential aspect of the relationship with cars has been analysed by a unique survey.

[15] French commission on sustainable development, "La mobilité des Français" *(mobility among the population of France),* December 2010.

Box 2: Methodology of the survey conducted for the Montaigne Institute

The work group based its observations on an exclusive survey on people's attitudes to mobility and cars. The characteristics of this survey, conducted by Kantar Média, are as follows:

- Geographic perimeter: France, Germany, California.
- 2,993 people questioned (1,006 in France, 1,004 in Germany, 983 in California).
- Representative samples of the population of each of the three geographic areas.
- Survey conducted from 14 to 27 December 2016.

This survey (see annex 2) provides information firstly on the reasons for privileging a means of transport over another. Thus, 61% of respondents praised the practical aspect of the car - more than any other means of transport –, and 37% consider car-pooling to be relatively inexpensive. In France, respondents claim to favour the car over other forms of transport for its rapidity (41.8%), comfort (40.6%) and the pleasure of driving (31.6%).

It is certainly no coincidence that 99.2% of respondents do not envisage ceasing to own a car in the medium term, even in the densest urban areas. This attachment also exists in the other two countries surveyed, in both Germany (98.7%) and California (99.5%). More than one in two people use a car every day in France, compared with only 10% for public transport.

The strong footing of cars in the habits of private individuals is partly explained by emotional factors (see annex 3): cars are synonymous of independence and freedom for 87% of the people surveyed, while it is only seen as a constraint by 13% of them. Relatively significant differences in perception exist between the countries: cars are seen as a means of stating one's personality in 43% of Californians (compared with just 22% of the French).

The relationship with cars appears to evolve significantly with age: it is seen as an object of freedom by 91% of people aged over 65, but only by 78% of people aged under 24. Inversely, those aged 25-34 are those who most consider it as a means of expressing their personality (41%, compared with just 25% of over 65s).

This wide heterogeneity in mobility requirements invites the design and promotion of multiple solutions, adapted to each individual and to different locations. This movement must be guided by the pursuit of overall objectives, notably in terms of improving travel safety (see part 1.3) and limiting environmental impacts (see chapter II).

1.1.2. Mobility solutions must fulfil this wide range of requirements

Cars currently suffer from a number of disadvantages, in particular in dense urban areas: congestion (the French spend an average of 28 hours per year in traffic jams, and even 45 hours for those in the Paris region[16]), parking difficulties (5-10% of vehicles driving in

[16] Assurland; for the purpose of comparison, this figure is 64 hours per year in Stuttgart, and 81 hours per year in Los Angeles.

towns need a parking space and 70 million hours are lost each year finding a place to park[17]), cost for limited use, etc.[18]

Most of these weaknesses could however, be eliminated by car uses, whose development and growing popularity are due to technical innovation (generalisation of smartphones, geolocation systems, on-line payment, etc.). Such solutions include:

- private hire transport services: applications to book car journeys with a professional (Uber, Lyft, etc.) or non-professional driver (UberPop, Heetch, etc.) have opened up markets that were previously limited mostly to taxis;
- car-pooling: this transport habit has developed significantly thanks to applications enabling contact between drivers and passengers (BlaBlaCar, etc.);
- personal car rental: these services (OuiCar, etc.), which enable a private individual to rent his car easily from another private individual, make car rentals much more affordable;
- car-sharing: short-term car rental (Autolib', Mobizen) offers, in some situations, the advantages of a car while avoiding some of its disadvantages.

Such newly visible practices result in some cars being used for longer journeys and with more passengers[19]. This offers an element of response to the many criticisms of cars, and could make this means

[17] A. Lefauconnier, E. Gantelet, "La recherche d'une place de stationnement : stratégie, nuisances associées, enjeux pour la gestion du stationnement en France" *(finding a parking place: strategy, association issues and stakes of parking management in France),* 2005.

[18] The issues of road safety and environmental impacts with respect to cars are covered below in more detail.

[19] These new practices are encouraged by the development of mobility applications, for example to plan an itinerary (Citymapper), to optimise travel in real time (Waze) or to find a parking space (Zenpark).

of transport more attractive. Indeed, a more intense use of vehicles would mean fewer vehicles on the roads (if every car on the road carried more passengers than it does today[20]) and in parking spaces (if the possibility of using a car occasionally, only when needed, means that more people cease to own one).

However, in spite of their strong growth, such uses remain modest compared with the "traditional" use of the car. Car-pooling has developed mainly for long distances and is struggling to exist for shorter trips – short-distance car-pooling only represents between 1 and 2% of this type of transport.[21] The survey indicates that less than 5% of the people consulted use a new means of mobility on a daily basis (car-pooling, personal car hire, etc.).

The market for private hire transport, which costs just slightly less than a taxi, remains limited.[22] By encouraging these forms of mobility (notably with regulations proposing incentives), the public authorities would accelerate their deployment and enable easier travel for everyone (see part 1.1.3).

Ultimately, there is a whole range of transport modes that will enable an optimal solution to be found, according to the criteria given at

[20] Currently in Europe, a car transports 1.4 people on average. Source: European Environment Agency, Term29 Occupancy rates in passenger transport, Europea.eu.

[21] L. Brimont et. al., "Les nouveaux acteurs de la mobilité collaborative : des promesses aux enjeux pour les pouvoirs publics" *(The new players of group mobility: promising solutions for the challenges facing public authorities),* IDDRI, 2016.

[22] Allowing fully autonomous vehicles to use the roads would probably result in a strong decrease in the price of private hire journeys. However, most leading car manufacturers and the firms specialising in artificial intelligence consider that totally autonomous vehicles are unlikely to be released onto the market before 2050.

the beginning of this chapter (cost, time, comfort, etc.), enabling people to use the most suitable form of transport for them.[23]

In areas where the transport modes are highly diverse (mainly in the large urban areas, such as Lyon or Paris in France, Berlin in Germany, San Francisco or Los Angeles in California), the development of multi-modality is relatively strong. In France, 40% of private individuals use several means of transport one after the other for their leisure activities,[24] compared with 26% for work travel.

1.1.3. Public authorities can use incentive schemes to improve the integration of cars into the mobility offer

1.1.3.1. In dense areas: reconciling cars and cities

The disadvantages related to car use may lead the authorities to take measures to restrict the possibilities of travelling by car. Coercive measures – such as preventing cars from accessing certain geographic areas – are inconveniently unilateral, since they limit one form of mobility without encouraging others. In particular, they do not encourage the development of uses such as car-pooling, which are socially valuable. Furthermore, they may also have paradoxical effects, such as increased congestion and pollution around the restricted areas.

Since there is no systematic alternative to the car, it is essential that the public authorities propose balanced policies, aimed at encouraging

[23] The Whim application in Helsinki deserves a mention: it proposes a set price giving access to all modes of transport - including private hire - and compares the travel times combining these different modes.

[24] Elabe PSA, "Les Français et la mobilité" *(the French and mobility),* 2015.

more virtuous uses of vehicles (car-pooling, use of clean cars, etc.). There are two types of incentives:

- financial incentives: offering a monetary benefit (lower toll fares, parking fees, etc.) to the people whose conduct is considered virtuous; this type of toll will be tested in 2017 in Boulogne-Billancourt, where car drivers will be paid €2 for each journey completed outside rush hours;[25]
- incentives in kind: offering better mobility, for example by enabling access to reserved traffic routes which are not as busy.

Urban toll mechanisms are an example of financial incentive schemes, enabling certain forms of mobility to be discouraged (car use with no passengers in the densest areas and during the busiest traffic periods) while favouring others (car-pooling outside rush hours).

In theory,[26] urban tolls are a solution for the problem of optimal personal choices resulting in the over-consumption of limited shared resources, such as urban areas, and therefore an overall sub-optimal situation, in this case traffic congestion caused by too many cars travelling at the same time. By getting users to contribute, urban tolls can influence personal decisions to achieve a more satisfactory overall situation, while leaving each individual free to choose.

Experiments abroad show that such systems can have substantial benefits (see box 3). The main disadvantages of urban tolls can be overcome. They have been criticised for:

- being unfair, obstructing the mobility of the less well-off. On this topic, it should first be noted that an urban toll is less discriminating

[25] Lisa Burek, "Un 'péage positif' anti-bouchons va être testé en Île-de-France", lemonde.fr, mars 2017.

[26] This question has been studied in detailed, notably by William Vickrey, winner of the Nobel prize for economics.

than measures such as banning old diesel-powered vehicles, which affects a vast majority of low income users, or alternating traffic, which penalises those who have no alternative (taxi, second car, etc.). It is also possible to consider modulating the price of the urban toll according to the type of journey (professional or other) or even according to income (see below).

- moving congestion problems to the outskirts. This risk depends on both the dissuasive nature of the toll – therefore the set price – and the geography of the area concerned by the toll. A larger area could limit the congestion induced, since it would encourage the use of other transport modes, while a smaller area would result in evasive movements. These challenges can be dealt with by adapting the prices (possibly dynamically) to the level of congestion in the areas concerned, and by offering real alternatives to use of the private car.

Generally speaking, the switch from a free model – even relatively inefficient – to a payable model is always difficult and requires genuine political commitment. An experimental procedure with gradual deployment, subject to independent assessment and public consultation, could make this measure more consensual.

Box 3: Examples of urban tolls implemented around the world

Urban tolls are in use in a number of cities. One such example is London, where a toll area was defined in 2005; this area currently covers around eight square miles. A fee of £11.50 per day must be paid to enter this zone in a car, within which car registration plates are identified by a network of cameras. The obligation only applies on weekdays, from 7am to 6pm and certain types of vehicles are exempt (taxis, motorbikes, buses, ambulances, etc.). A recent report[27] indicates that between 2005 and 2014, car use in London – number of trips, distance covered, time spent driving – fell by approximately 25%. At the same time, the modal share of the private car fell from 41% to 32%, in favour of public transport. This report recommends replacing the single toll price with a range of modulated prices depending on the time of day, time spent inside the toll area, etc.

The world's first urban toll was created in 1975 in Singapore. Vehicles have to be equipped with an electronic device enabling their identification by gates at the boundaries of the toll area. The price is adjusted dynamically, according to the level of congestion. Parking inside the toll area is also payable. The toll has had a major impact, reducing the number of vehicles entering the toll area by 76%.[28]

An urban toll was also tested in Stockholm, and its revenue used to fund new bus routes. A referendum on whether to keep the toll – and the new bus lines – was then organised, resulting in the scheme being maintained. The toll resulted in an estimated 30-50% reduction in the time wasted due to congestion.

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27 London Assembly, London stalling Reducing traffic congestion in London.

28 Centre d'analyse stratégique, "Pour une ville plus durable : les principes d'une loi sur le péage urbain" *(For a more sustainable city: the principles of an urban toll law),* September 2008.

The price of the urban toll could also be adjusted according to vehicle category (level and type of pollution emitted), use (fill rate), geographic area (higher price for denser areas) and time of use (price modulation according to traffic). Similarly, prices could be modulated according to the overall level of pollution, with a price increase during peak pollution periods. This kind of approach would be more adapted than the current system of alternating traffic, which is highly arbitrary since the travel authorization or ban is not truly correlated to the actual environmental impact of the vehicles, nor to the driver's need to use the vehicle.

It could also take into account characteristics specific to each individual: exemptions for reduced mobility people, incentives for ecological cars, modulation according to income to avoid the effects of urban segregation, etc. Vehicle connectivity technologies could be used to implement such price differentiation strategies.

A scheme of this type would generate income for the community, paid by car drivers. A fair return would be the use of such income to invest in public transport: this would enable a real alternative to cars to be proposed, while allowing each individual free to choose how he/she wants to travel.

The same type of mechanism could be designed to regulate parking, adjusting the price according to geographic area and time period. A number of American cities, including Washington, San Francisco, Boston, etc., have started experimenting in this area: in some districts, parking prices vary and adapt to the actual demand for parking.[29]

[29] The price of parking in San Francisco can therefore change from 25 cents to 18 dollars.

Along with the implementation of financial incentives, schemes that offer more virtuous drivers more fluid mobility should, ideally, be tested. For example, it would be possible to reserve one lane of certain roads – affected by serious congestion and with enough lanes – to cars with a certain proportion of passengers in relation to their maximum capacity.

This type of measure already exists in the USA and Canada, for example *(High Occupancy Vehicles Lanes)*. These lanes, reserved for cars with more than the average number of people aboard (at least two in addition to the driver in Ontario), enable eligible drivers, and particularly car-poolers, to benefit from shorter travel times. A proposal to implement this type of incentive scheme in France is presented in chapter II.

1.1.3.2. In areas with less public transport: making cars the public transport of the future

The aforementioned incentive schemes that affect driver choices will enable traffic regulation and a move towards better mobility in the areas where traffic is densest. However, they offer little improvement in peripheral areas, where the lack of mobility is not due to excessive traffic but to a meagre transport offer. This itself is due to the low level of demand, which does not, a priori, make major investments cost-effective.

However, lighter, more flexible mobility solutions can now be envisaged, and could develop with a little help from public authorities. The Chariot company or the Uber Hop experiment in Toronto based on the traditional private hire model but with pre-defined routes and several passengers, are examples that deserve a mention. These services are similar to «conventional» public transport services (bus, etc.), except for the essential difference that they adapt to demand in real time. The number and capacity of vehicles on the roads are therefore adapted to actual needs, which enables a transport offer to be maintained even when demand is low (unlike public bus services, for example, which hardly ever run at night).

The advantage of these new means of transport is not even limited to remote areas with little public transport. In denser areas, extending the transport offer and improving the match between supply and demand would be equally beneficial to the community.

Proposal no. 1: Encouraging the development through public and private mobility stakeholders of intelligent and intermodal transport solutions to adapt supply to demand in real time («group private hire», notably in low density areas).

A large proportion of the country has little access to public transport because of profitability reasons. The development of connected vehicles offers a possible way out of this deadlock. Based on the private hire model, passenger transport services can be developed based on low capacity vehicles (minibus, etc.), whose routes would be adapted to user requirements in real time.

In addition to buses with fixed timetables and routes, an on-request shuttle system could be created, which would only run if enough users were interested. This type of approach, made possible by current technologies and already being tested abroad (Uber Hop in Canada), deserves promotion.

The development of these solutions should associate the various parties involved: local governments, public transport companies, private mobility companies, etc. The role of the public authorities could be both financial – invitation to tender, innovation competition, etc. – and regulatory – introducing some flexibility into the standards governing passenger transport. These services must be financially affordable for users to offer better mobility to as many people as possible.

These new services could be directly proposed by the public authorities or left to private initiatives with public support, if necessary (simplification of approval procedures, toll exemptions, etc.). In exchange, operators could be required to provide the authorities with their transport information.[30]

At the same time, measures must be taken to encourage access to cars in these remote areas. This could involve making it easier to get a driving licence, for example (increasing the number of examiners, reducing the price of learning to drive by eliminating certain regulatory barriers, etc.).

[30] This is what Uber has done in the USA, with "Movement".

1.1.4. The harmonisation of regulations at a European level would entail a better visibility for the economic stakeholders, while preserving the possibility of local adaptations

1.1.4.1. Why harmonise mobility rules at a European level?

Better mobility could be achieved by adapting the transport offer in more detail to local needs, including the various uses of the car. This tailored approach does not obstruct the adoption of a harmonised European normative framework, which alone could reduce inequalities in the field of mobility.

A common legal framework would also enable the creation of a vast market, inside of which the rules would be coherent, making it easier for the most efficient mobility solutions (car-pooling services, etc.) to flourish. These could be deployed rapidly on the scale of the continent, offering an economic advantage to their designers. Similarly, common norms would prevent local decisions made unilaterally from weakening the industrial strategies adopted previously.

Finally, improving the coherency of legal systems related to mobility would be consistent with the European commitments in terms of efforts to reduce global warming. The Member States of the European Union have adopted a restrictive objective to reduce greenhouse gas emissions within the Union by at least 40% compared with 1990 levels by 2030.[31] Transport represents around one quarter of greenhouse gas emissions in Europe, so it would be beneficial if the Member

[31] European Council, 24 October 2014.

States coordinated their actions regarding the control of road pollution.[32]

1.1.4.2. The harmonisation of rules, which has already begun, must be continued

The European Union legislator adopted a directive to support the deployment and the coordinated and coherent use of intelligent transport systems within the Union on 7 July 2010.[33] In this context, the Member States are required to deploy the infrastructure necessary to implement the emergency call system "eCall" within their territories by 1 October 2017.[34] This system consists in equipping all new vehicles with an emergency call device to send an automatic alert to the emergency services in the event of an accident, no matter where the vehicle is within the European Union.[35]

Following on directly from the above, the deployment of intelligent transport system could be further facilitated and accelerated by adopting norms, at a European level, to ensure interoperability and

[32] The Communication from the European Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, "A European strategy for low-emission mobility", COM(2016) 501 final/2, 20 July 2016.

[33] Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of intelligent transport systems in the field of road transport and for interfaces with other modes of transport. The transport code, which transposes the directive into French law, defines intelligent transport systems as systems that implement computer and electronic communication technologies in the transport sector, notably to improve traffic management, enhance road transport safety and reduce its impact on the environment (article L. 1513-1 of the French transport code).

[34] Decision no. 585/2014/EU of the European Parliament and of the Council of 15 May 2014 on the deployment of the interoperable EU-wide eCall service.

[35] EU regulation no. 2015/758 of the European Parliament and of the Council of 29 April 2015 concerning type-approval requirements for the deployment of the eCall in-vehicle system based on the 112 service and amending directive no. 2007/46/EC. Certain types of vehicles must be equipped with this system as of 31 March 2018.

compatibility of the systems used within domestic markets.[36] The continuity of information services regarding traffic conditions, for example, would thus be guaranteed from one Member State to another, ignoring national borders.

Furthermore, several Member states condition the access to certain road and motorway segments to fee payment. Toll systems rely increasingly on electronic pass and pay systems, notably for heavy vehicles. Although a European framework has been created for a "European electronic toll service",[37] the interoperability of electronic toll systems is not yet guaranteed. However, the implementation of operational electronic payment systems throughout the Union would facilitate vehicle mobility, particularly for those travelling frequently in the different Member States.

In addition to the harmonised regulations applicable to vehicle type-approval in the domestic market, a directive could be adopted to instigate a European environmental certificate. This could enable the identification and classification of the vehicles on the road, regardless of their engine systems, according to the pollution they emit. The States who have already opted for a certificate sticker system, or who are at least considering it, would therefore be acting within the framework defined by the directive.[38] The cities adopting

[36] These norms could be adopted on the basis of article 8 of the directive of 7 July 2010.

[37] Directive 2004/52/EC of the European Parliament and of the Council of 29 April 2004 on the interoperability of electronic road toll systems in the Community.

[38] Such a directive could be derived from the treaty on the functioning of the European Union. Insofar as low-emission areas are tending to spread without any real coherency throughout the Union, the threat of such barriers to the free circulation of vehicles and drivers is increasing. Article 114 of the aforementioned treaty, which enables the Union's institutions to take measures for the establishment and functioning of the European market, could serve as an initial basis. Furthermore, since the directive also aims to improve the protection of the environment and personal health, another basis for its adoption could be article 192 of the treaty, which gives the Union's institutions the power to adopt measures in this area.

traffic restriction measures could be incited to do so in application of the framework defined by the directive and transposed into national law.

Local authorities would, however, retain their authority in other matters according to the organisation of each Member State. Thus, the cities deciding to restrict traffic in certain parts of their territories could use the classification defined by the European certificate. Cities implementing an urban toll system could differentiate the prices according to the certificate categories.

To encourage the adoption of best practices at a local level, the various traffic regulation systems could be assessed in a systematic manner. This assessment mission would be entrusted to an independent body of the Union, whose composition and organisation would guarantee its impartiality. Based on the assessments made, the Commission would adopt guidelines to define a range of instruments based on the European certificate and inspired by the best practices observed. Cities would thus be encouraged to use this "toolbox" of best practices when adopting traffic restriction measures.

Proposal no. 2: Adopting an interoperable normative framework at a European level for traffic regulation, with the aim to reduce both congestion and toxic emissions.

While it is important to develop new means of transport in the less well serviced areas, it is natural to seek to regulate the traffic in those areas suffering from congestion – notably in city centres. However, to facilitate the implementation of such schemes without obstructing mobility, it is essential that the norms governing mobility are homogeneous from one city to another and from one country to another.

Traffic regulation will be increasingly reliant on "intelligent" systems: micro-tolls requiring the installation of a specific device in the vehicle, connected information signs, etc. The harmonisation of regulations would ensure the interoperability and compatibility of these schemes throughout the European Union (e.g.: an automatic toll device recognised in all cities and on all roads applying a toll).

This would also be beneficial to citizens, whose travels around the cities of Europe would be facilitated, as well as to industrial firms, opening up a vast market to which adapted technological solutions could be proposed at a reasonable cost. Similarly, a harmonised environmental categorisation of vehicles could be set up as a basis for traffic restriction measures decided locally (e.g. an interoperable European sticker).

The legal and regulatory framework, once harmonised, would serve as a toolbox, leaving local and national authorities room to manoeuvre, in order to adapt regulations to the specificities of their territories. Simple recommendations (presentation of a range of incentive measures, notably in relation to urban tolls) could be combined with elements that would ultimately become mandatory (e.g. the harmonised environmental certificate, which could be part of a directive).

1.1.4.3. Better visibility over European regulations

In the European Union, the technical rules to be applied to the coming vehicles within the domestic market are harmonised by a framework directive.[39] This directive details the technical requirements with which vehicles must comply according to their category (e.g. category M for motorised vehicles designed and built to transport people, and with at least four wheels).

Furthermore, European Union law harmonises the toxic emission norms to be respected by vehicle manufacturers (Euro 1 to 6). These norms are defined according to vehicle category, weight and the type of fuel they use. They set limits according to the different pollutants (carbon monoxide, nitrogen oxide, fine particles, etc.). For example, the emission norms for private vehicles are set by regulation no. 715/2007 of 20 June 2007.[40]

The European norms in this area are contained in a large number of different texts.[41] Furthermore, these texts are revised regularly. The aforementioned regulation of 20 June 2007, for example, was amended in 2008, 2009, 2011 and 2012. The legibility, intelligibility and predictability of the European framework could be improved, both for consumers and for equipment and vehicle manufacturers. The adoption of an action plan indicating the update of binding

[39] Directive no. 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles. The directive is transposed notably in article R. 311-1 of the French Highway Code.

[40] Regulation no. 715/2007 of the European Parliament and of the Council of June 20, 2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information.

[41] Other regulations include no. 443/2009 and no. 510/2011.

norms on emission for the next few decades would offer security and allow to plan the investments required today for the vehicles of the future.

While the European Commission recently announced its intention to adopt binding norms on emissions for heavy vehicles,[42] a schedule for the evolution of these future norms could be defined.

1.2. Digital technology is revolutionising our behaviour towards cars, but raises questions on the respect of privacy and computer security

1.2.1. Driving data produced by vehicles represent a major source of innovation

We have come a long way in a very short time from the milometer information of the cars of the 20th century to the dozens of gigabytes of data produced hourly by today's connected vehicles. While car manufacturers and internet giants claim to control these data, users do not yet seem totally convinced by the direction taken by the connected car.

The enthusiasm for connected objects encourages users to share large quantities of personal data in order to benefit from attractive new functions. In the realm of the connected car, this sharing promises

[42] Communication from the Commission to the Council and the European Parliament, *Strategy for reducing heavy-duty vehicles' fuel consumption and CO_2 emissions*, 21 May 2014, COM(2014) 285 final; aforementioned Communication from the European Commission, COM(2016) 501 final/2, 20 July 2016.

wonders – and some promises are already coming true. For example, it could enable:

- improved safety, thanks to real time knowledge of vehicle wear, automatic detection of signs of driver fatigue, or the possibility of alerting emergency services in the event of an accident;[43]
- better control over costs, notably by adjusting insurance premiums more precisely to the actual quality of driving[44] or by helping drivers to limit their fuel consumption;[45]
- improving the driver and passenger experience with audio and visual media.[46] These technologies could gain ground with the development of semi or totally autonomous cars, which would free time for the driver;
- time saving, thanks to real time traffic management (which is already starting to become available with on-line GPS systems, such as Waze). This type of tool could be generalised, paving the way for the introduction of more global traffic management.

This last example is of particular importance: the aggregation and sharing of driving information benefits society as a whole - and not just one driver– since it enables better knowledge of traffic and mobility habits. This will lead private individuals to adjust their usage, and public authorities to refine their transport investments.

There are various ways of accessing the data supplying the new on-line services, and a number of players are likely to do so. Car and equipment manufacturers who design or install the sensors can

[43] Geolocated emergency call systems, like "e-call", will be mandatory in 2018.

[44] Several companies already propose "behavioural" insurance contracts, based on the "pay how you drive (PHYD)" model.

[45] The startup Drust proposes an application which uses a device connected to the car to tell the driver how to improve his acceleration actions or when to change gear.

[46] Some vehicles have integrated access to Deezer or Spotify.

of course equip the vehicle with functions related to data exploitation. However, third parties can also access certain information *via* OBD II connectors,[47] enabling the design of new services.

It would also be wrong to assume that only data directly from the vehicle count: external systems (smartphones or *ad hoc* objects) can also provide precious information. Even before the arrival of the smartphone, the “Coyote” system enabled drivers to be informed of imminent dangers.

1.2.2. The use of digital technologies will also lead to more interaction between cars and their environment

Connected cars are not just vehicles equipped with a number of sensors and connected to internet: they interact with their environment, which is also connected:

- connection between vehicles (“car2car”) could ultimately enable the development of “platooning” systems, i.e. moving vehicles one behind the other close together, to improve the aerodynamics of the series, reducing the space used, with limited intervention by the drivers;
- connection between vehicles and traffic infrastructures (“car2infrastructure”) – roads, signs, etc. – could be a first step towards the development of autonomous vehicles, enabling analysis of the driving environment to be transferred from man to machine.

Vehicle connection to infrastructures goes beyond the simple question of vehicle autonomisation. It is part of a more global “smart cities”

[47] On-Board Diagnostics: standard interface to access vehicle data.

approach, enabling optimised modulation of traffic: adjustment of traffic lights to the traffic and the presence of pedestrians waiting to the cross the road, acceleration of the change to a "green light" if an emergency services vehicle is approaching, etc.

Box 4: The German "digital motorway test bed" experiment

In 2015, the German transport Ministry, the Bayern region and the car and computer sectors launched a joint initiative called the "digital motorway test bed". The project consists in equipping certain portions of the motorway between Nuremberg and Munich with devices (detectors, transmitters, etc.) to connect cars with one another and with their environment, to allow for various stakeholders to conduct experiments. For example, new infrastructures have been designed (road markings, safety barriers, etc.) to enable cars to have an easier detection system - which constitutes a first step towards vehicle autonomisation. Communication systems to send digital alerts to vehicles regarding speed limits or traffic jams have also been tested.

A similar initiative has recently been announced for a stretch of the cross-border motorway between France and Germany (between Sarrebruck and Metz).[48]

This type of experiment, both within urban areas and beyond, could be carried out to good effect in France, to provide companies and public authorities with places in which to develop new solutions based on vehicle and infrastructure connectivity (see chapter III).

[48] Luc André, "Voiture autonome : l'Allemagne et la France lancent une zone test transfrontalière", L'Opinion, 8 February 2017.

1.2.3. The risks of hacking and invasion of privacy require the definition of rules regarding access to driving data

The use of vehicle data involving disclosure to third parties is not necessarily a threat in itself. However, it must be confronted to the right to personal freedom and the pressing need to preserve confidentiality and privacy, regardless of the enthusiasm for the car of the future. For example, drivers may not hesitate to share their locations, but this is far from being inconsequential since it reveals information on their private lives, preferences and habits.

Awareness of these issues must be increased, even though users are perfectly conscious that they have a fundamental right to control and protect their personal data.[49] This is of utmost importance in a context of "cyberattacks" of all kinds, where the threat no longer exclusively comes from the company exploiting the data with whom the user shared voluntarily. Using the networks connected to the car, hackers are now able to access the vehicle remotely and to enter the on-board system, which could be a cause of considerable damage (material damage, personal injury, data hijacking, etc.).

To make data exploitation acceptable, specific precautions must be taken. The type of data available or that could be accessed, and the conditions in which the data can be used, must be defined.

In France, the data privacy law of 6 January 1978, amended on 6 August 2004, applies to all cases of personal data processing.

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[49] A survey conducted by the CNIL (France's data protection agency) reveals that 95% of respondents wanted strong legislation to protect their data and to be able to decide when they are connected and the use made of their data.

The notion of personal data is broadly defined by the CNIL as referring to any data from the vehicle that, alone or combined with other such data, may be associated with a private individual (driver, car owner, person named on the ownership papers, passenger, etc.) in particular *via* the serial number of the vehicle.

The law defines a number of obligations for the processing manager: people must be informed of any processing carried out, given the right to access their data, certain CNIL formalities must be completed beforehand, etc. If there is no specific agreement concerning the use of personal data, said data must remain anonymous.[50]

The CNIL is currently preparing a “conformity pack” on the subject of connected vehicles, in collaboration with the stakeholders of the car ecosystem community (manufacturers, equipment manufacturers, telecommunications partners, insurance firms, etc.). It aims to define clear norms to enable each party to develop data exploitation tools in compliance with confidentiality rules,[51] with the aim of protecting personal data from the early design stages of goods and services[52] (“privacy by design”).

Discussion on these topics is also under way at the European Commission in relation to the “free flow of data” initiative and ideally, a normative text should be adopted quickly.

[50] The Article 29 working party of the European Commission made specific recommendations on this topic, see G29 opinion of 05/2014 on anonymisation techniques.

[51] G. Dorne (2016), “En route vers un pack de conformité consacré aux véhicules connectés”, *(towards a conformity pack for connected vehicles),* CNIL.fr.

[52] French and European processing companies must ensure compliance with the principles proposed by the European Regulation on the protection of personal data (EU regulation 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data) by 25 May 2018.

Proposal no. 3: Provide a European level definition of the data from on-board computers that are of general interest and define the rules regarding the access, sharing and exploitation of such data so as to allow innovation stimulation while guaranteeing safety and confidentiality.

The harmonisation of norms must integrate the numeric aspects of mobility. The use of driving data represents a hoard of new services and therefore leverage of competitiveness for the French industry, but it also represents a potential risk which means the population must be protected and reassured.

The definition of data access rules must be combined with the development of dynamic traffic regulation mechanisms (micro-tolls, reserved lanes), whose operation depends upon the collection of data related to the vehicle and its usage (number of occupants, vehicle type, etc.).

The notion of "data of general interest"[53] could also be taken into account: information collected by a vehicle – an accident detected by on-board cameras, for example - could be useful to other vehicles, for example to warn drivers approaching an accident zone.

[53] The notion of data of general interest was introduced in the draft law for a digital republic in September 2016 and applies to "data which are private by nature but whose publication may be justified due to their contribution to improving public policies".

1.3. Connected vehicles may improve road safety, but they also raise ethical issues

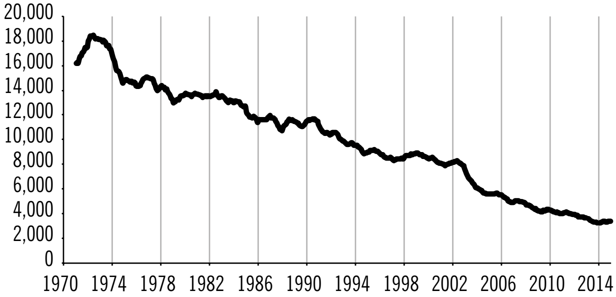
1.3.1. Major progress would be possible in the field of road safety, which justifies the rapid deployment of these new technologies

Although much lower than in the 1970s, road accidents continue to blight our societies: in 2015, they caused 3,616 deaths and 73,384 injuries in France, including 27,717 requiring hospital treatment.[54] The perspective outlined herein of fully autonomous vehicles, controlled by computer systems based on a range of sensors (cameras, radars, lasers, etc.), suggests that one day, road accidents will be a thing of the past. The calculation capacity of on-board computers, the detection speed of sensors and the high level of action constancy of electronic devices (which do not suffer fatigue or stress, etc.) should enable autonomous cars to surpass human driving skills.[55]

[54] ONISR (France's inter-ministerial observatory on road safety), *Les accidents corporels de la circulation* (traffic accidents involving physical injury), 2015.

[55] The recent successes of artificial intelligence in extremely complex exercises (such as a computer programme winning a game of Go, etc.) suggest that driving could ultimately be controlled by a machine, in spite of the huge variety of situations that may arise.

Figure 1: Number of deaths on the roads of France since 1970



Source : ONISR.

However, it is likely to take many years before autonomous vehicles are authorised for use in an open environment. The urgent need to reduce road fatalities, particularly since figures have remained stable in recent years, incites us to find new solutions, however incomplete, as quickly as possible.

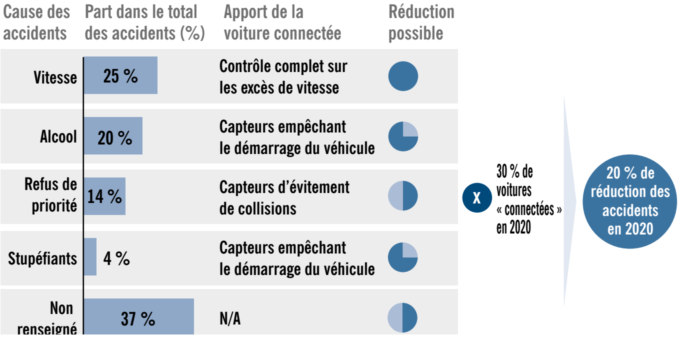
So far, the first driving assistance functions have been introduced as options and only on certain models: emergency brakes, automatic trajectory correction, etc. These innovations pave the way to the release of semi-autonomous vehicles, able to drive without human intervention in favourable driving conditions, in the short or medium term (notably on motorways, in good weather). Order no. 2016-1057 was introduced on 3 August 2016 to allow the testing of self-driving cars on public roads. A Decree is expected to define the terms of issue of the necessary authorizations.

The potential effects of this type of technology on road accidents can be estimated. Fatal accidents generally occur during simple driving situations: in 2015, in 80% of cases, the weather was clear;[56] 38% of fatal accidents involved no other vehicles or pedestrians. It is therefore estimated that emergency braking systems are likely to reduce the number of collisions by around 80%.

Furthermore, 70% of fatal accidents involve additional risk factors (alcohol, fatigue, lack of experience, etc.). Again, even limited autonomy functions could, in certain cases, compensate for the driver's lapse of attention or lack of judgement. Additional *ad hoc* systems, such as ignition interlock devices (866 deaths in 2015 due to alcohol) or drowsiness detectors (327 deaths due to fatigue or faintness resulting in an accident) could have a very significant impact on the number of road victims in France.

[56] Conversely, more difficult weather conditions (rain, snow, etc.) can affect the proper operation of the sensors used by semi-autonomous vehicles (such as the cameras used for emergency braking, etc.).

Graphique 2 : Réduction des accidents de la route grâce aux voitures connectées



Source : Institut Montaigne, A.T. Kearney, , Big data et objets connectés : une opportunité pour la France *(Big data and connected objects: an opportunity for France).*

New functionalities, however, are particularly slow to reach cars: it takes an average 19 years for fifty percent of cars to be equipped, and 37 years for the equipment rate to reach 80% (see annex 4). Furthermore, car renewal is even slower among the underprivileged.[57] Yet this population suffers from a higher than average level of road fatality,[58] and would therefore benefit all the more from new safety systems. If road safety improvements enabled by these new systems, especially emergency braking which appears to be particularly effective for a moderate price, are confirmed by independent studies, it would be advisable to accelerate their distribution.

[57] The average age of vehicles of the poorest decile is 11.2 years, compared with 6.6 years for the wealthiest decile.

[58] Matthieu Grossetête, "L'enracinement social de la mortalité routière" *(the social roots of road fatality),* Actes de la recherche en sciences sociales, 4/2010 (n° 184), p. 38-57.

The subsequent equipment of vehicles with autonomous technologies, such as emergency braking, appears problematic due to the detectors and braking system control systems involved. However, public authorities could impose that all new cars be equipped. In terms of external devices[59] (drowsiness detectors, etc.), rapid distribution is possible, provided the purchase cost is acceptable to households, of course.

The principle of making road safety devices mandatory on the scale of Europe is not new: it has already been done for Anti-lock Braking Systems (ABS - since 2003 on new cars) and Electronic Stability Programs (ESP - since 2011). It would probably be the best way to continue to reduce road deaths beyond the current level. Alternatively, incentive measures could be implemented (explicit consideration in the Euro NCAP classification of the presence or absence of these safety features, for example).

Proposal no. 4: Accelerate the generalisation of the most effective new safety systems (emergency braking and drowsiness detection systems in particular), as soon as their efficiency has been demonstrated by independent studies.

Personal safety could be considerably improved by adopting major innovations. Systems such as emergency braking or attention systems are successfully used on certain vehicles: many lives could be saved if the distribution of such technologies was accelerated.

59 The example of Nauto is a good indicator of the technological progress in external safety devices. Using a double camera system connected to artificial intelligence, this company claims to be able to anticipate both internal risks (fatigue, lapse of concentration) and external risks (collision anticipation).

Once their efficiency has been proved by independent studies, a possible approach could be to make these systems mandatory on new vehicles, or even on all vehicles if adaptation to existing models is a possibility. This notably could be the case for drowsiness detection systems.

It would also be possible to adopt an incentive scheme for users, based on financial benefits for example, such as modulating the price of urban tolls for vehicles equipped with certain safety features.

Note that shrewd use of these new technologies requires knowledge of their limits: although they may be able to compensate for drivers' weaknesses in some situations, they are not yet able to replace drivers' vigilance completely. Consequently, to assist the rapid distribution of such systems, car drivers must be made aware of their use. The simplest solution would be to include a section on new driving assistance systems in driving license training programs.

The perspective of partially or fully autonomous cars in urban areas also requires the awareness of all other road users (pedestrians, cyclists, etc.), which could be incorporated in the road safety training dispensed in French high schools.

1.3.2. New technologies will transform the nature of road hazards, which will mean changing our attitude to risk

The road risk as we know it today is marked by high frequency (70,442 injuries in 2015[60]), and a relatively limited number of victims generally speaking, for any given accident, excluding pile-ups or accidents involving group transportation. Most road accidents (around 90%) are also due to human error. This situation may change significantly with the introduction of new technologies and new uses.

In terms of new uses, the main change in accident rates is expected to come from the development of car-pooling. This new habit will help limit the number of vehicles on the roads, and therefore the number of accidents, but each accident will involve more passengers. Yet accidents that involve a large number of people are the most visible ones and those which have the greatest impact on public opinion. If the growth of car-pooling were to lead to an increase in the number of accidents causing a large number of victims, society's view of the dangers of road travel could intensify.

In terms of new technologies, the connected, autonomous car should help reducing overall risk, but also introduces a new risk: machine failure. This could take the form of an occasional fault in a given driving situation[61], but it could also occur far more systemically, affecting a large number of cars at the same time. There is no guarantee that a computer error, or hack attack, would not have large-scale consequences. In this case, we would be faced with a peak risk, which is highly unlikely but which could have major consequences.

[60] ONISR (France's inter-ministerial observatory on road safety), January 2016.

[61] One such example is the fatal accident in 2016 caused by a Tesla vehicle which failed to detect an obstacle.

This new role for technology changes our attitude to risk. Human error, by definition, corresponds to a failure in behaviour, driving in this case. We can all imagine ourselves to be immune to this type of mistake, being confident in our own abilities. Accidents are more acceptable, or at least more easily explained, if they are due to dangerous behaviour. However, machine failure does not follow this moral perception of risk, which thus appears all the more unfair and shocking. This represents a major challenge for autonomous cars, whose approval for use depends upon the technologies reaching an extremely high level of maturity and safety.

1.3.3. The movement towards increasingly autonomous vehicles requires redefinition of the legal concept of driver liability

French road regulations are founded on a series of texts,[62] which are based on the principle that the driver is responsible for his vehicle and therefore for any damage caused to third parties. The perspective of partial autonomy does not modify the current state of law, since there is merely a difference of degree between driving assistance systems and partial autonomy systems: in both cases, the driver must remain in control of his vehicle. This is not the case for artificial intelligence systems taking over full control of the vehicle.

Autonomous vehicles, i.e. with no human driver, would demand a complete review of the implementation of our liability laws (see annex 5 for a detailed analysis of this issue and its legal consequences):

- in the case of partial automation (where the vehicle remains ultimately under the control of its driver), the changes with respect to

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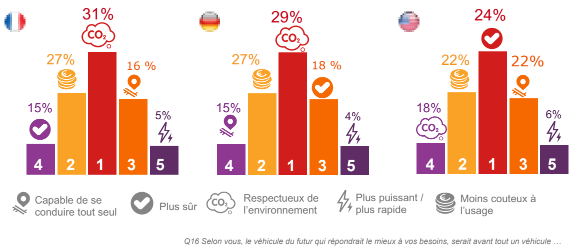
current laws appear to be relatively modest; the greater presence of electronic systems is, however, likely to impose the installation of "black boxes" in vehicles to ensure the attribution of responsibilities in the event of an accident, accompanied by the vigilance required to protect personal data (see 1.2.3);

- the case of total automation is more complex:
  - it would imply modifying the Vienna Convention to include the possibility of an artificial intelligence system replacing the human driver;
  - there would be no immediate impact on the legal insurance system, but a substantial modification of how this market operates (see chapter 3.1.2.1);
  - it would imply redefining the criminal liability aspect of accidents (since the French criminal code states that *one can only be held criminally responsible for one's own actions*); it would mean either the disappearance of criminal liability from road accident situations or the transfer of this criminal liability to the legal entity that designed or sold the autonomous driving system.

2.1. Citizens have high expectations concerning air quality and climate protection, which must be treated differently

When questioned on the characteristics that the car of the future should have according to them, German and French respondents cited the respect of the environment as their priority. Paradoxically, in California, where vehicles produce far more CO_2 (see figure 3 and discussion below), this is a lesser concern. This can probably be explained by the lower presence of diesel cars in this geographic area, as well as by more pressing road safety problems (in 2015, after population adjustments, two and a half times more people were killed on the roads in the USA than in France).

Figure 3: Expectations regarding the car of the future



Source: Kantar TNS survey for the Montaigne Institute; 2,993 people questioned (1,006 in France, 1,004 in Germany, 983 in California).

There are three main types of undesirable compounds emitted by road traffic:
- greenhouse gases, the most important of which is carbon dioxide (CO_2);
- fine particles;
- nitrogen oxides (NOx).

Fine particles and nitrogen oxides are local atmospheric pollutants which are harmful to human health. Greenhouse gases, on the other hand, have no direct negative impact on health, but an overall effect on the climate.

The approach to these types of pollution must be differentiated locally and globally: CO_2 emissions demand regulations that are as global as possible, while a combination of local and more global measures must be applied to NOx and fine particle emissions.

2.1.1. The approach to greenhouse gases must be as global as possible

CO2 is the main greenhouse gas, and thus the main source of global warming due to human action. Article 2 of the Paris agreement on climate change, adopted by the parties at the United Nations Climate Convention on 12 December 2015, defines the measures that need to be implemented in order to keep global warming *"to well below 2°C above pre-industrial levels"* and, if possible, to continue efforts *"limiting global average temperature rise below 1.5°C"*.[63]

[63] Paris agreement, Article 2.

Road transport represents:[64]

- globally: 10.4% of greenhouse gas emissions in 2010;
- in Europe: 18.6% in 2012;
- in France: 25.5% of greenhouse gas emissions in 2012 (the difference with the European level is due to the lower emissions related to electricity production, 95% of which uses nuclear or renewable sources in France).

The reduction of CO_2 emissions coming from road transport therefore represents a major lever to reduce greenhouse gas emissions, used and monitored in all geographic areas (see annex 10).

In Europe, these CO_2 emission levels are measured thanks to standardised test cycles carried out in laboratories. Over time, a growing divergence between the values measured during tests and the values measured in real conditions is observed, reaching 30 to 60% according to studies: car manufacturers adopt a rational attitude and have, over the years, optimised their vehicles to meet the tests standards imposed by flawed regulations rather than to reduce the amounts of CO_2 emitted in real conditions of use (see annex 11). The difference between the values measured by the tests and actual emissions is also due to:

- the number and variety of equipment options between the various versions of a model, which have increased significantly since the definition of the current measurement cycle in the early 1980s. The cycle only imposes measurements on the basic versions, whereas certain equipment options have an impact on consumption in actual conditions;

[64] IPCC, working group III, 2014 and French Ministry of Ecology, Sustainable development and Energy, key climate figures for France and the world, 2015.

- the current driving test cycle ("NEDC") is not sufficiently dynamic and offers a poor representation of average driving in terms of speed and acceleration.

The implementation of a new test procedure ("WLTP") in Europe in September 2017 will correct these two problems to a large extent.

Finally, it is important to note that diesel plays an important role in reducing CO_2 emissions: a diesel vehicle emits between 10 and 20% less CO_2 than its petrol equivalent (see 2.4.2.1).

2.1.2. Fine particles and nitrogen oxides are local pollutants, for which a combination of local and global regulations is necessary

- **Fine particles** *(see annex 8 for a more detailed analysis)*

Fine particles or particulate matter (PM) include a set of pollutants suspended in the air. Their negative impact on human health has been established, and their effect increases as particle size decreases. It is estimated that these particles cause several thousands, even tens of thousands of deaths per year.

In developed countries, fine particle pollution is generally concentrated in relatively limited zones, where activity is more intense than elsewhere. When the acceptable thresholds for human health are exceeded, it is generally due to specific atmospheric conditions around large agglomerations. In France, on average, the portion of particle emissions due to road transport is low[65] (around 5%), but this figure reaches 28% in Île-de-France[66] (compared with 26% due

[65] CITEPA, Dust in suspension, October 2016.
[66] Airparif, Regional inventory of emissions in Île de France, 2012.

to individual heating systems, in particular fireplaces). This local pollution mainly affects urban centres and major roads, but also the Parisian underground railway network (where particles are generated by worksites and trains: wear of brakes and rails, effects of air flows due to train movements, etc.).

The sources vary significantly depending on the season and economic activity. Thus, during the period of high pollution at the end of December 2016, on the coldest days, more than half of the fine particles measured in Paris came from domestic fires.[67]

Exhaust fumes from diesel vehicles are, on the whole, responsible for 17% of the 28% of emissions due to road transport. Exhaust fumes from petrol vehicles contain negligible amounts of fine particles. These exhaust emissions are mainly due to the age of the fleet of vehicles on the roads: the exhaust fumes of diesel vehicles conforming to the strictest emissions norms (Euro 5 and Euro 6) contain almost no fine particles.

At the end of 2013, more than a third of the private diesel cars in use were equipped with particle filters, i.e. approximately 7 million vehicles. The level of equipment of particle filters among heavy-duty vehicles, which have longer lifespans, remains low, as this feature was only introduced with the Euro 4 norm, applicable from 2005.

- **Nitrogen oxides** *(see annex 10 for a more detailed analysis)*

Nitrogen oxides, also known as NOx, are the gases formed by the combustion of fuel at high temperature and high pressure. They

[67] L'Obs', "Pollution : trafic routier, chauffage, industrie... Qui est coupable ?" *(Pollution: road traffic, heating, industry ... Who is guilty ?)*, december 2016, based on AIRPARIF figures.

have an indirect influence on greenhouse effect, but are mainly irritants for the bronchial tubes. Prolonged exposure to high doses causes breathing disorders, particularly for young children and people suffering from asthma.

In 2012 in Île-de-France, 54% of NOx came from road transport. Diesel vehicles – even the most recent ones – produce much higher levels of NOx emissions. 89% of road transport emissions come from diesel vehicles (41% from heavy vehicles, 33% from private cars and 15% from light utility vehicles).

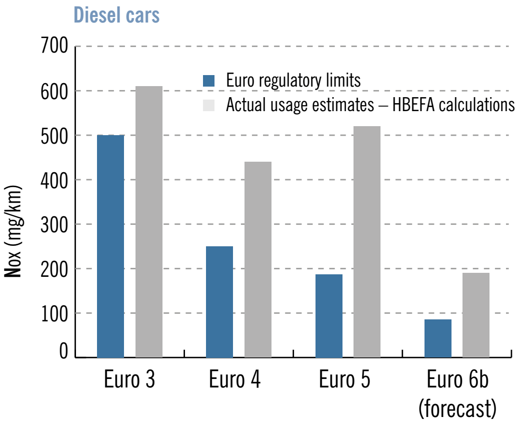
Modern petrol engines, whose combustion temperatures and pressures increase to improve their efficiency *(downsizing)*, are also generating more and more NOx. To counter these effects, car manufacturers are developing additional systems to capture and destroy the NOx: NOx traps and catalytic reduction by urea injection. Diesel-powered heavy vehicles, which are equipped with more costly anti-NOx systems than light vehicles, emit around half as much NOx per km as the latter.[68]

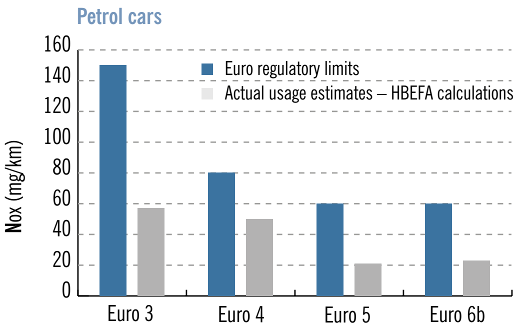
The so-called *"dieselgate"* scandal (Volkswagen), involving the rigged tests on diesel engines, mainly concerned NOx emissions. The production of these substances is highly dependent on the engine's combustion parameters. These parameters are managed by the engine's electronic computer system and the activation or not of additional systems to trap / catalyse the NOx, which, in the case of the Volkswagen models concerned, were deactivated or under-used outside of standard tests.

[68] See ICCT note, December 2016, on the most recent vehicles (EURO 6 norms): http://www.theicct.org/sites/default/files/publications/Euro-VI-versus-6_ICCT_briefing_06012017.pdf.

In actual conditions, i.e. not during the standard test cycles, the diesel vehicles on the market exceeded the permitted emission norms in 2014 (see figure 4).

Figure 4: NOx emissions by road vehicles according to their Euro certification





Source : ADEME, "Émissions de particules et de NOx par les véhicules routiers", *(NOx and particles emissions by road vehicles), June 2014.*

2.2. Public authorities' response remains uncoordinated

The Volkswagen scandal revealed the weaknesses of current regulations, which still fail to measure pollutant emissions in actual use. Regulations allow car manufacturers to optimise their technical choices and adjustments based on other parameters (cost, consumption, performance, etc.). The emissions measured in laboratories have thus become too far removed from actual emission levels. Volkswagen went beyond these legal methods by installing a software which recognises certification tests and enables the vehicle to run in a specific manner if it is identified as being tested. The differences concerned both CO_2 emissions (the differences go from 30 to 60%, see 2.1.1) and NOx emissions (values tripled, see 2.1.2).

This scandal inflamed public opinion, casting doubt upon both the practices of car manufacturers and the real inclination of public authorities to tackle the issues of air quality and global warming. The European institutions reacted by adopting regulations to measure vehicle emissions in actual conditions. These regulations, adopted at the start of 2016[69], gradually introduce tests in real driving conditions (as opposed to laboratory tests) and a *"conformity factor",* corresponding to a multiple of laboratory emissions that the vehicles must not exceed. This factor is initially at 2.1 (instead of 80mg NOx/km, vehicles can therefore emit 168), and will be lowered to 1.5 in 2021.

The introduction of these *"conformity factor"* is evidence of the need to develop regulations that are as transparent and as effective as possible, and to revise them regularly. Considering the technological

[69] EU regulations 2016/427 and 2016/646 of 10 March and 20 April 2016, modifying EC regulation 682/2008 on emissions from private cars and light utility vehicles (Euro 6).

and economic challenges related to the industry and vehicles, it is obvious that the design of these regulations must be coordinated in the largest possible geographic area, and at least within Europe, including possibilities for local adaptation.

An even more global point of view/perspective must be adopted on measures against global warming (see 2.2.1) and in favour of air quality (see 2.2.2).

2.2.1. The battle against global warming

Globally, road transport emits 10.1% of greenhouse gases and up to one quarter of the emissions of the most developed countries (see 2.1.1). Within the framework of the United Nations' negotiation cycles on climate change (including the last milestone event, COP21), all the geographic areas must set themselves reduction goals for CO_2 emission due to road transport. This necessarily requires regulations to force manufacturers to ensure that the new vehicles sold do not emit, on average and for a given year, more than a certain amount of CO_2 per kilometre driven.

These goals, which are binding for manufacturers, are generally combined with local incentive measures. The three geographic areas concerned by our survey thus set themselves reduction goals for the greenhouse gas emissions of road transport (at the federal level for California, at European Union level for France and Germany, see table 1). These objectives are completed by a cap and trade mechanism to encourage the production of very low emission vehicles in California. In France, a "bonus/malus" system applicable to all vehicles has been created. In Germany, a bonus system exists for electric or rechargeable hybrid vehicles (up to €4,000 for all-electric vehicles).

Note that, adjusted to the number of inhabitants, road transport in California emits twice as much CO_2 as in France or Germany.

Table 1: CO_2 emission reduction targets for private car

Country	CO_2 emissions related to road transport (qty CO2, in 2012)	Emissions per inhabitant due to road transport (t CO_2/person)	Emission reduction goal
France	125	1.89	By 2021 (with gradual introduction from 2020), the average emissions of vehicles sold per manufacturer may not exceed 95gCO_2/km (i.e. average consumption of 4.1l/100km petrol or 3.6l/100km diesel).
Germany	146	1.81	The next wave of regulations, currently under discussion, considers a threshold between 68 and 78gCO_2/km, for introduction between 2025 and 2030. The 2015 and 2021 targets correspond to 18% and 40% reductions respectively compared to the 2007 average, which was 158.7gCO_2/km.
California	154	3.97	At the federal level, the target is an average of 163gCO_2/mile in 2025 (i.e. 101gCO_2/km). In the state of California, the goal is to achieve a 50% reduction in fuel consumption between 2015 and 2030 (which, in terms of emissions per inhabitant, would bring California to the current level in France or Germany). To encourage innovation, the state has set up a mechanism to force manufacturers to sell a minimal proportion of zero or very low emission vehicles (with the creation of a "cap and trade" exchangeable credit system).[70]

Source: Eurostat and European Commission; California Greenhouse Gas Emission Inventory: 2000-2012, California environmental protection agency, 2014; US Federal environment protection agency (EPA).

[70] During the third quarter of 2016, Tesla sold $139 million of these credits, representing 6% of its total turnover.

The reduction in CO2 emissions due to road transport mainly implies reducing the consumption of fossil fuels, by reducing the number of kilometres driven, increasing the use of more efficient vehicles, and replacing them by other forms of energy (electricity, hydrogen). The technologies of the connected, shared and more autonomous vehicle can help to reduce these emissions (see 2.3 and 2.4).

In the meantime, the battle against global warming is primarily a matter of globally coordinating all stakeholders, and goes far beyond the simple question of road transport, which only represents 10.1% of emissions worldwide. Thus, initiatives such as implementing a high price for carbon appear inevitable.[71]

2.2.2. Regarding local pollutants

The battle against climate change must be coordinated globally. This should less be the case for local pollutants. It is certainly natural to impose technical standards common to new vehicles, as the European Union does, to provide manufacturers with a single market.[72]

Overall, the joint action of public authorities has led to quite tangible results, with the amount of atmospheric pollutants in a city such as

[71] On this topic, consult the report by Canfin, Grandjean and Mestrallet, "Propositions pour des prix du carbone alignés avec l'accord de Paris" *(proposals for carbon pricing in line with the Paris agreement)*, July 2016, or the Montaigne Institute publication, "Climat et entreprises : de la mobilisation à l'action Sept propositions pour préparer l'après-COP21" *(climate and companies: from mobilisation to action. Seven proposals to prepare for post-COP21),* November 2015.

[72] Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 defines total harmonisation of the technical requirements to be respected by new vehicles within its scope at the time of type-approval for the domestic market. Regulation 715/2007/EC of the European Parliament and of the Council of 20 June 2007 sets the limit values for emissions (the Euro norms) applicable to certain categories of vehicles for their approval for the domestic market.

Paris halved over the past twenty years. Some local authorities, however, seem today to consider that new measures are required to regulate traffic or to ban certain polluting vehicles in order to improve air quality.

This is certainly the philosophy behind the "low emissions zones" (LEZ). A recent publication from ADEME[73] investigates the implementation of such zones throughout Europe. This is done in a highly variable manner:

- in some cases, a national framework defines the options open to local authorities with respect to the creation of such zones (this is the case in Germany, Denmark, the Netherlands, the Czech Republic and Sweden);
- in other cases, each local authority defines its own protocol (e.g Austria, Spain, Greece, Italy, Portugal, UK).

In March 2015, there were 211 low emission zones in ten European countries. In France, the first LEZ was created in Paris in 2017 (see box 5). More than twenty other French authorities are expected to create such zones in the next five years.[74]

According to ADEME, these zones are particularly efficient in some cases, justifying their implementation by the following arguments:

- NO_2 and PM10[75] concentration reductions of up to 12% can be observed and PM2.5 reductions up to 15%;

[73] ADEME. M.Pouponneau, B.Forestier, F.Cape, G.Le Clercq, D.Fayolle. 2016. "Les zones à faibles émissions (Low Emission Zones) à travers l'Europe : déploiement, retours d'expériences, évaluation d'impacts et efficacité du système" *(Low Emission Zones around Europe: deployment, experience feedback, impact assessment and effectiveness of the system).*

[74] Ministry of the Environment, Energy and the Sea, Winners of the call for projects - "Respirable cities in 5 years", September 2015.

[75] Fine particles with a diameter of less than 10 micrometres.

- the number of days during which the limit of the daily value for PM10 is exceeded can also be reduced (17% drop in Cologne during the first year of LEZ operation).

Box 5: The limited traffic zone in Paris

The city hall and police headquarters in Paris first implemented traffic restrictions for certain vehicle categories in June 2016 (see order no. 2016 P0114 of 24 June 2016).

A new scheme was then introduced, in application of the national LEZ system, called the "zone à circulation restreinte" (limited traffic zone), and established by the August 17th 2015 law concerning the energy transition for green growth, and defined by a decree from the 28th of June 2016 on limited traffic zones[76].

Such schemes are based on a vehicle classification system, which assigns a "Crit'air" certificate, dividing vehicles into seven categories (see table below).[77]

[76] This system is governed by articles L. 2213-4-1 and R. 2213-1-0-1 of the general code of territorial authorities.

[77] The Crit'air (or *"air quality certificate"*) is defined by article R. 318-2 of the French highway code. Vehicle classification according to this certificate is defined by the order of 21 June 2016.

		
All "zero engine emission" vehicles: 100 % electric and hydrogen	Petrol and others **EURO 5 and 6** From 1 January 2011	Petrol and others **EURO 4** Between 1 January 2006 and 31 December 2010 inc. Diesel **EURO 5 and 6 from** 1 January 2011
6 % of private cars		**23 %** of private cars
		
Petrol and others **EURO 2** and **3** Between 1 January 1997 and 31 December 2005 inc. Diesel **EURO 4** Between 1 January 2006 and 31 December 2010 inc.	Diesel **EURO 3** Between 1 January 2001 and 31 December 2005 inc.	Diesel **EURO 2** Between 1 January 1997 and 31 December 2000 inc.
43 % of private cars	**14 %** of private cars	**6 %** of private cars
		Unclassified: **9 %** of private cars

In application of these texts, the city of Paris introduced the following regulations for private cars:

- vehicles with no certificate (registered before 1 January 1997) may not use the roads of Paris during week days between 8am and 8pm;

- from the 1st of July 2017, Crit'air 5 category vehicles will also be banned (diesel vehicles registered before January 1st 2001).

The regulation is stricter for utility and heavy vehicles. Paris city hall also announced that the traffic ban would be gradually extended to all diesel vehicles, on a timescale between 2020[78] and 2025[79], according to its various declarations.

Source: Montaigne Institute, based on information from the Paris city hall and environment ministry websites.

In practice, the characteristics of these zones are highly diverse, although they generally use the EURO norms to classify the vehicles. Several schemes (with the notable exception of Germany and the Czech Republic) use certificate systems different from those in use in other Union countries. Note that, in certain cases, vehicle classification is also used for incentive schemes (reserved traffic lanes, parking benefits, etc.).

There are a certain number of disadvantages associated with this growing heterogeneity:

- limitation of the free movement of drivers around Europe, due to both the actual restriction and the difficulties for travellers to understand highly diverse local regulations (although in some cases, vehicles registered abroad may be exempt);

[78] Interview with Anne Hidalgo on BFMTV, 10 June 2016: "we are gradually phasing out very old vehicles and the vehicles that generate the most pollution, moving towards a total ban on diesel vehicles by 2020".

[79] Press release from C40 cities, 2 December 2016.

- unpredictability of future regulatory changes, which limits the capacity of car manufacturers to anticipate their technological strategies;
- constraints that can be unreasonable for private car owners concerned by restrictive measures, which can have a significant economic impact (see 2.3.1).

On this last point, it should be noted that the people suffering from such constraints are often not the ones residing in the zone concerned (in the case of Paris, those who use the oldest cars are generally the least well-off families, often living outside the city centre).

All these points underline the increasingly pressing need for greater harmonisation at a European level of traffic regulation schemes in urban areas.

2.3. Aside from regulations concerning new vehicles, action must be taken with respect to driver behaviour, in particular *via* new technologies

Today, with the notable exception of occasional traffic restrictions and low emission zones, anti-pollution measures mainly concern the technical characteristics of new vehicles and not the actual use that is made of them (see 2.2).

However, it takes decades for an innovation to spread through the entire fleet of vehicles and it is unrealistic to speed up the rate of vehicle renewal significantly, since this would imply considerably reducing vehicle lifespan, resulting in a major economic loss for society (see 2.3.1). Important progress can be made by altering travel and driving habits (eco-driving, car-pooling, smart use of the different modes of transport, etc.). This could be achieved *via* a range of incentive and coercive measures, based on the possibilities offered by new technologies:

- development of the connected car (2.3.2);
- generalisation of driving assistance systems (2.3.3);
- development of new mobility uses (2.3.4).

2.3.1. The question of fleet age is crucial

The major changes in environmental norms (see 2.1) mean that recent vehicles generate much less pollution than older models. The public authorities are therefore tempted to bring in coercive measures to limit the use of old vehicles (see 2.2.2, notably in the form of limited traffic zones in France). However, there are limits to this type of approach: the economic impact of banning some vehicle categories from the roads is actually huge, and directly penalises the population.

The value of the vehicle fleet can be modelled according to the vehicle Crit'air category (see table 2). Extendingthe Paris measures to the rest of France (banning the vehicles classified as Crit'air 5 or below from July 2017) would imply imposing a €21.2 million tax on the households and businesses which own these older vehicles.[80]

Going one step further, and banning diesel vehicles in the medium term (e.g. 2025), as proposed by certain political leaders, seems

[80] This figure is probably under-estimated, since it does not include the value loss of vehicles that are not yet affected by the age limit, but soon will be.

unrealistic given the financial weight of this vehicle category (current value: around €298 billion). Even assuming that only the vehicles used in the Paris region are affected, this measure implies a cost of several billion euros, mostly borne by modest households and small businesses.

Table 2: Vehicle values according to the Crit'air system

Crit'air certificate category	Corresponding fleet value (private cars and light utility vehicles, in € billion)
No certificate	9.5
Crit'air 5 and below	21.2
Crit'air 4 and below	64.6
Crit'air 3 and below	184.0
The entire diesel fleet	297.9
The entire fleet	422.9

Source: Montaigne Institute calculations based on data from UTAC-OTC, CCFA and Argus.
Methodology: Only vehicles registered after 1990 are considered, i.e. a fleet of 49 million vehicles (private cars and light utility vehicles); data for vehicles registered between 1990 and 2011 come from the log of vehicles presented for the mandatory roadworthiness and safety inspection; data for vehicles registered between 2012 and 2016 come from CCFA sales; for each vehicle, an average residual value is calculated using Argus data and applied in the same manner to the entire fleet registered in a given year.

We must therefore find other ways to act on the existing fleet. Governments sometimes introduce *"car scrappage bonuses",* to accelerate the removal of old vehicles from the fleet. However, these measures are costly for public authorities and their environmental effects are relatively slight.[81] Similarly, *retrofit* measures (some countries, such as Germany, offer subsidies for the installation of

[81] See Transport Ministry "Évaluation environnementale des dispositifs de prime à la casse" *(environmental assessment of the scrapping incentive schemes),* June 2007.

particle filters on old vehicles) seem relatively ineffective[82] and/or very difficult to implement (modified vehicles lose their engine certifications). Unless car manufacturers decide to invest themselves, other types of modification (making an old car an electric hybrid, or installing a NOx trap system) also appear unrealistic on a large scale.

2.3.2. Connected vehicles, the possibilities of smart regulation and virtuous incentives

Most of the vehicles sold since the 2000s are equipped with an on board diagnosis system (OBD). In Europe, this system is mandatory since the EURO 3 norm (applicable since October 1st 2001). It was first developed in the USA and in particular in California (where it has been imposed on all vehicles sold since 1996).

Initially designed to enable vehicle maintenance and fault detection, OBD ports, which now equip most of the vehicles on the road, enable the development of new applications, such as connected insurance *(pay how you drive)*, and provide users with detailed information on how they drive, the level of pollution generated by the vehicle, and even links with a maintenance service.[83] These remote diagnosis functions are also proposed by the car manufacturers in certain models, *via* applications functioning thanks to their own operating system.

There are also other technologies, which do not use the OBD port, that enable real time monitoring of vehicle pollution emission (e.g.

[82] The retrofitting of particle filters is relatively ineffective: see the article by Challenges on this topic and the June 2014 publication by ADEME.

[83] Mobivia, for example, markets a compact device – dongle – that can be connected to an OBD socket to provide detailed vehicle data via smartphone and to connect to a maintenance service.

the GECO air app for smartphones, developed by IFPEN, which informs users of the level of emissions of their journeys).

We can therefore imagine the development of relatively inexpensive technologies (well below €100 per car), to enable each driver to know how much pollution is generated by his journeys, according to actual use of the vehicle. This flow of information, available via smartphone for drivers, could also provide input for a global database, while guaranteeing, in compliance with privacy laws, anonymity of the connected cars. This would have a number of advantages:

- providing public authorities with detailed information on our actual journeys, to be used in urban planning and improve regulations;
- enabling users to compare their behaviours with those of others: do they pollute more, or less, and why? Such comparisons, which lie at the heart of "soft" regulation systems based on peer comparison *(nudge*[84]*),* could have an effective, non-coercive impact on behaviour.

This is all the more interesting now that knowledge of the air quality is better and is becoming intelligible to the general public. For example, within a geographic area, applications like the one proposed by PlumeLabs provide an air quality report, with a predictive dimension.

84 Nudge - Improving decisions about health, wealth and Happiness is a book by Richard Thaler, economist at University of Chicago, and Cass R. Sunstein, Harvard Law School professor. The book draws on research in psychology and behavioural economics to defend techniques to enable private individuals to make the choices that are considered to be more virtuous, notably using peer comparison and *"soft"* social constraints, while limiting coercive approaches.

In Europe, cities like London have already introduced urban tolls, and are considering making them the main lever of their environmental transport regulation.[85] Re-distribution mechanisms, widely reported in the literature,[86] offer a suitable method to deal with the potential unfairness of urban tolls for the most modest households. In France, law 2010-788 of July 12th 2010 on the national commitment in favour of the environment authorises the introduction of experimental urban tolls, but only for periods limited to three years. The investment required for such tolls (several tens of millions of euros) makes this time limitation a prohibitive obstacle, as illustrated by the fact that no such schemes have been introduced.

Proposal no. 5: Implement incentive schemes (rather than traffic restrictions) to enable effective and fair regulation of traffic and pollution in the densest urban areas.

Traffic regulation in France's densest areas is an essential goal. The solutions proposed must be both adapted to the specific context of their implementation and compatible with the harmonised European normative framework. Rather than a simple blanket ban on all motorised vehicles, people can be dissuaded from using them by encouraging more virtuous behaviour.

The first step would consist in setting up self-assessment mechanisms in the major urban centres. Using technological progress, data on real time emissions can be collected to inform drivers of their environmental impact and compare it with fellow road users, to encourage them to drive more fluidly and generate less pollution.

85 Press release from London's Mayor, 5 July 2016.

86 Stéphanie Souche, LAET, "Péage urbain, une revue de la littérature" *(urban tolls, a literature review),* 2007.

This self-assessment phase could then be supported by financial incentive schemes, such as dynamic, urban micro-tolls, or other incentives, like traffic lanes reserved for car-poolers. The mass of data collected by the self-assessment systems would enable the design of these incentive schemes to be optimised, making them more acceptable and improving their efficiency. The following principles could be retained:

- micro-tolls and other schemes would first be tested and their impacts assessed independently. They would then be maintained or withdrawn, depending on the results of these assessments, and after public consultation if necessary;
- the price of the micro-toll would be modulated on the basis of a number of criteria: the «smart congestion charging» model, for example using vehicle category (level and type of pollution emitted), use (occupancy rate), traffic conditions and air quality (higher price during rush hours or periods of high pollution), frequency and intensity of use in the target zones, etc.;
- income from the micro-toll would be re-invested in public transport and road infrastructures. The pricing would take into account the social situation of car users to avoid over-burdening the least wealthy;
- the micro-toll would apply to private vehicles and goods transport vehicles, subject to different price conditions, if applicable.

In the longer term, these intelligent regulation systems could be applied in other areas: adaptive speed limitation on motorways according to weather or traffic conditions, in areas affected by episodes of high pollution, etc.

2.3.3. Driving assistance systems, in particular autonomous cars, will enable the environmental impact of vehicles to be reduced even further

The overall impact of autonomous technologies, in the sense of driverless cars, on the environmental performance of vehicles is ambiguous but likely to be positive overall.[87] It is reasonable to believe that the automation of driving will have certain beneficial effects, such as total greenhouse gas emission reductions of up to 40% in certain conditions:

- generalisation of eco-driving while the vehicle is in the autonomous mode;
- less accent on performance and sensation, limiting the need to optimise engines for sudden accelerations, which use up a lot of fuel;
- in the medium term, the development of platooning, i.e. a series of vehicles forming a convoy to benefit from the suction effect of the vehicle in front (thus reducing aerodynamic friction);
- in the longer term, if a global vehicle supervision becomes possible: reduced traffic jams.

However, certain rebound effects must be anticipated:

- increased road traffic due to a reduction in average transport costs;
- or the acceptance of higher speeds on motorways (due to the improved level of safety offered by driving assistance systems).

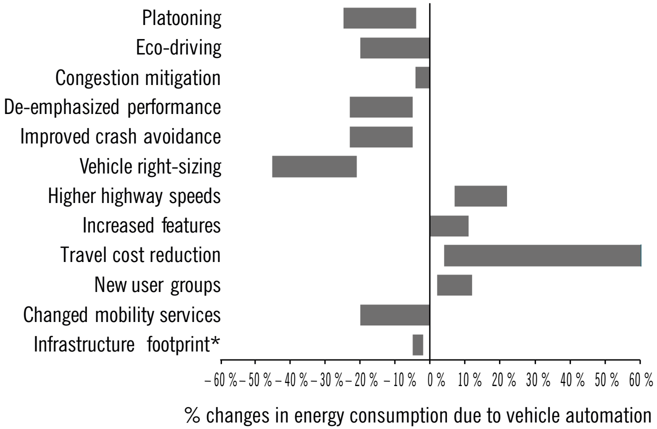
[87] The data and elements presented herein come from a literature review published in April 2016 ("Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles", Zia Waduda, Don MacKenzieb, Paul Leibyc, Transportation Research Part A: Policy and Practice, Volume 86).

Furthermore, certain beneficial effects can only be achieved with a high level of technology penetration:

- with a "robotaxi" system, it is possible that the occupancy rate of vehicles will rise significantly; however, this implies a very high level of penetration to obtain a marked effect on emissions;
- if the level of safety increases, the passive safety systems in vehicles can be limited, thus reducing their weight considerably; however, this would imply that all vehicles have active safety features, making such improvements very unlikely, even in the medium term.

Based on a literature review, figure 5 summarises the possible effects. In all, the various effects constitute a challenge in terms of regulation: how to encourage the adoption of technologies with a positive impact without triggering a rebound in use?

Figure 5: Impact of autonomous vehicle technologies on CO_2 emissions



Source: "Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles", Zia Waduda, Don MacKenzie, Paul Leibyc, Transportation Research Part A: Policy and Practice, Volume 86, April 2016, Pages 1–18.

2.3.4. New uses to maximise vehicle use rate must be encouraged

EIn Ile-de-France, the cars on the roads have on average 1.1 passenger on board.[88] Increasing this figure to 1.4 would enable a 20% decrease of the number of cars on the roads. This requires incentive measures to encourage carpooling and a good use of multi-modal transport options, which would probably involve the development

[88] Study by DRIEA, the regional and inter-departmental division for equipment and planning, the Île-de-France transport union (Stif) and the Île-de-France urban planning institute.

of new infrastructures to encourage these new forms of mobility, as well as financial or non-financial incentives (lanes reserved for car-poolers, discounted toll rates, etc. – see 1.1.3 and 2.3.2).

2.4. The emissions reduction of the new vehicles will benefit from the technological progress made by car manufacturers (and not only in terms of engine design)

In addition to the innovative measures presented in 2.3, the technological developments of new cars must be pursued. Adequate technological choices must be encouraged by public authorities. These changes will certainly concern both thermal and electric engines (2.4.2), but there is also still progress to be made in the field of vehicle weight reduction (see 2.4.1).

2.4.1. Vehicle weight reduction is an area that is not sufficiently exploited and European regulations in this field could be improved

CO_2 emissions are directly correlated to vehicle weight. This is also true of fine particle pollution. Their presence in the atmosphere is due to the fact that particulate matter on the ground are re-suspended in the air by air movements generated by moving cars.

A review of the scientific literature published on this topic[89] indicates that for modern vehicles, exhaust gases represent less than 5% of total emissions, while re-suspension represents around two thirds

[89] Victor R.J.H. Timmers & Peter A.J. Achten, Atmospheric Environment, *Non-exhaust PM emissions from electric vehicles,* 2016.

of emissions (see annex 8 for details). This same study also claims that most fine particle emissions are linearly correlated with vehicle weight (wear particles from brakes, tyres and the road that become suspended in the air): a 1% weight increase results in a 1% increase in particle emissions from these sources, all else being equal.

The increased use of plastics and composite materials in vehicle design would therefore enable a greenhouse gas emissions reduction of approximately 40%.[90] This is a virtuous circle: reducing body weight by 250kg saves an additional 100kg, by resizing the engine and safety elements, with financial savings (which could then be re-invested in more costly materials to further reduce weight).

However, European regulations neutralise 60% of the weight reduction gains in the calculations used for CO_2 emission regulations for new vehicles.

European regulations (see 2.2.1) state that cars sold by an individual manufacturer must emit less than an average of 130g CO_2/km. This average is balanced by the weight of the vehicles sold, and the influence of vehicle weight is partly neutralised. In practice, if car weight is reduced by 100kg, it will emit 6g CO_2 less per km, on average. However, because of the regulations of EU calculations, only 2.4g CO_2/km of the reduction is included in the weighted average mentioned above. This means that 60 % of the gains are neutralised, as shown by the "60 %" slope currently used in the EU[91] in the left section of figure 6.

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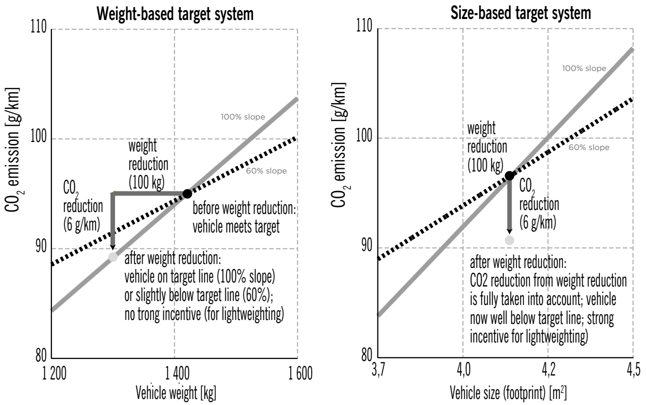
[90] A.T. Kearney – Plastics. *The future for automakers and chemical companies*, 2012.

[91] The slope will remain at 60% at least until 2020.

Figure 6: Various systems weighting vehicle emissions according to vehicles' size (weight, on the left, or footprint, on the right)



Source : : http://www.theicct.org/sites/default/files/publications/ICCT_EUemissionstargets_jun2011.pdf (p.45)

Considering the environmental advantages of reducing vehicle weight (with an impact on all types of toxic emissions: CO_2, NOx and fine particles), it would be logical to support this approach. However, weight reduction encouragement schemes must not penalise large vehicles excessively, since they remain essential for some uses.

A first option would be to replace the weight-based equilibrium criteria with a vehicle footprint-based system (see right part of figure 6), which would restore the advantages of weight reduction. A second option would be to modify the slope of reduction neutralisation (which would go from 60% to 40% for example) to encourage weight reduction. In both cases, the changes in European regulations would penalise the manufacturers mainly selling heavy vehicles, such as Daimler and BMW, which could make negotiations complicated.

Proposal no. 6: Revise the calculation method of CO_2 emissions by manufacturers in European regulations in order to encourage vehicle weight reduction, an emission limitation measure that is still under-exploited.

LEuropean CO_2 regulations aim to sensitize manufacturers on the environmental costs of cars, by setting a CO_2 emission norm (95g/km by 2021) applicable on average to all new cars sold within the European Union. This general norm is determined for each manufacturer according to a system known as the "emission rights slope". The actual slope (and the ponderation criterion used) is decisive in that it assigns a value to the different ways of «saving» grams of CO_2.

By privileging the use of vehicles' mass rather than their footprint as the weighting criterion, European regulations penalise the weight reduction strategy to limit the environmental impact of cars, despite the recent progress made in new, lightweight and more resistant materials enhancing the potential of such a strategy.

To resolve this situation, the most consensual option would be to modify the slope of the neutralisation of weight reduction (which would for instance go from 60% to 40%) to encourage further lightering of manufactured cars.

A second, more ambitious option, although less acceptable for some manufacturers of heavier, *premium* vehicles, would be to replace the weight weighting criterion by a vehicle footprint-based system (which is already in use in the USA), making weight reduction all the more advantageous.

In all cases, controls must be reinforced to guarantee the efficiency of regulations and to restore public confidence.

2.4.2. The engine design issue

The issue regarding the design of the engine of the future has not yet been settled, particularly since the transition towards this type of engine will be long (see 1.3.1). Petrol or diesel, rechargeable or non-rechargeable, hybrid, electric with batteries or using hydrogen... there are many options (see annex 14 for a glossary of engine types), and the forecasts are uncertain. In any case, the continued reduction of CO_2 emissions appears to first require the development of hybrid engines, since it seems that all-electric vehicles would only esent a very small portion of the fleet by 2030 (according to various predictions,[92] all-electric vehicles will only represent around 5% of French vehicles in 2030; the proportion of hybrid and rechargeable hybrids will be around 20% – these forecasts can be considered as optimistic). Globally, the proportion of alternative engine types will therefore represent less than 2% of the vehicles manufactured in 2022.

[92] For a more detailed review of predictions and the future proportion of engine types, see the CGE report of July 2016: "Quelle place et quelles perspectives pour l'industrie française dans les véhicules à nouvelles motorisations ?" *(what are the place and perspectives for French industry in vehicles with new engine designs?).*

Public authorities will have an important role to play, particularly because of the mandatory reductions of greenhouse gas emissions by vehicles. Government choices in this area will have to adopt a global, "well-to-wheel" approach as much as possible. (see 2.4.2.1).

Consumer expectations focus on the cost of the vehicle, its autonomy and the availability of recharging facilities (charging stations for electric vehicles, fuel stations for hydrogen-powered cars). The technological choices able to offer a solution are uncertain, and depend on a number of factors that are difficult to control (innovation capacity and technological progress, industrial strategies, changes in the energy markets, etc.).

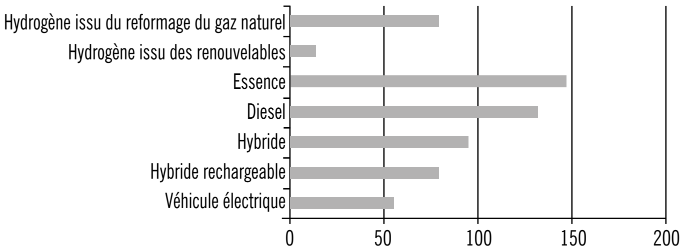
Therefore, governments will need to adopt a cautious approach. This means providing adequate support in terms of the public infrastructures required for the various types of electric vehicles (battery or hydrogen – see 2.4.2.2), and creating a context that encourages such progress, without necessarily favouring one technology over another (see 2.4.2.3).

2.4.2.1. Well-to-wheel CO_2 emissions

CO2 emissions vary significantly depending on the engine type. Whether the engine is powered by diesel or petrol or whether it is a hybrid engine using one of the two, emissions do not depend on where the engine is used: a litre of petrol or diesel has (almost) the same carbon content all over the world (see figure 7). A diesel vehicle actually emits 10 to 20 % less CO2 per kilometre driven than an equivalent petrol-driven car.

The case is different for hydrogen vehicles: emissions depend on how the gas is produced: 78gCO2/km for hydrogen from natural gas reforming, and just 14gCO2/km for hydrogen from water electrolysis, using solar or wind electricity.

Figure 7: CO_2 emissions per engine type, in Japan

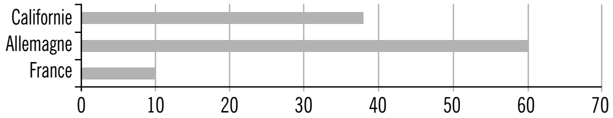


Source: Japanese ministry of economy, trade and industry (METI).

Above all, CO_2 emissions depend on how the electricity used to supply them is generated, for rechargeable hybrids as well as for electric or hydrogen vehicles (if the hydrogen comes from electrolysis). For example, this carbon content varies by a factor of one to six between France and Germany (see figure 8).

It should also be noted that this well-to-wheel approach is valid, although to a lesser extent, for other types of pollution emissions, especially if the electricity used is produced by old coal-fired power plants (pollution is, in this case, exported from city centres to less dense, more industrial areas).

Figure 8: Well-to-wheel emissions of a "standard" electric vehicle, according to the energy mix (in gCO_2/km, based on 13kWh consumed per 100km)



Source: International energy agency (2013) for France and Germany, California Air Resource Bureau (2014) for California.

Despite these large variations, the general hierarchy of greenhouse gas emissions remains stable:
- petrol vehicles emit the most;
- followed by diesel vehicles;
- then hybrids;
- then battery or hydrogen electric vehicles (for hydrogen produced using electricity; if the hydrogen is produced by steam-methane reforming, emissions are closer to those of a hybrid vehicle.)

2.4.2.2. The issue of infrastructure

- **Recharging facilities / fuel stations**

The massive deployment of electric cars, using either batteries or hydrogen, seems illusory in the short term without public support.

This must begin with supporting the drafting of international norms. For electric charging stations, the unification of standards appears to be almost complete in Europe, except for very fast charging (above

150kW). In terms of infrastructures for hydrogen powered vehicles, the project is less advanced.

Support from public authorities for the deployment of charging facilities must also be financial, since these technologies and markets are relatively immature. In France, the delays experienced by Bolloré[93] in the deployment of charging stations, in spite of the contract signed with the state, are a perfect example of the difficulties of developing profitable business models. The deployment of stations throughout the national territory is, however, making progress thanks to support from the state (which funds 30 to 50% of the installation of charging stations, depending on their type, via the future investment programme) and local authorities. In the meantime, and according to the sector's stakeholders consulted by the working group, the availability of charging stations remains structurally deficient (even at the operating stage, excluding investment costs). Public support is therefore essential to develop a national network of electric charging facilities or hydrogen gas distribution.

French legislation includes the objective of installing at least seven million charging stations throughout the country by 2030, *"to offer access to charging stations for all types of electric and rechargeable hybrid vehicles to as many people as possible".*[94]

[93] According to Les Echos (article on 16 December 2016), Bolloré promised to install 8,000 stations before the end of 2016, and actually installed none.

[94] Article 41 of law 2015-992 of 17 August 2015 on energy transition for green growth.

With respect to hydrogen distribution, several regions in the world are developing infrastructure programmes:

- California has launched a programme to install 60 to 80 stations; in January 2016, around thirty were in operation and another 20 under construction; other states along the east coast of the USA are also developing similar projects;
- in Germany,[95] the target is 400 stations by 2023, representing an investment of €350 million; of these 400 stations, 100 will be financed by the H2MOBILITY, comprising Air Liquide, Daimler, Linde, OMV, Shell and Total, with public support (50 stations funded by the state and a further 50 by European schemes); by the end of 2016, 20 stations were in operation;
- in Japan, in 2016, around 80 stations were operational, with a target of 160 stations and 40,000 vehicles by 2020.[96]
- in France, 40 stations are funded and planned for 2018. Mid-2015, eight stations were operational. France, and its car manufacturers, therefore seem less committed to this type of engine design. A report dated September 2015[97] recommends the development of adapted public support.

The state will soon be publishing a "strategy for the development of clean mobility", notably with the objective of defining a framework for national action to develop the market for alternative fuels and the deployment of the corresponding infrastructures.[98] France's strategy fits with the broader framework defined by the European Union to coordinate the deployment of the infrastructures required

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95 H2ME, Germany, *H2 MOBILITY targets 400 hydrogen fueling stations by 2023,* may 2016.

96 Japan Times, Japan eyes 40,000 fuel-cell cars, 160 hydrogen stations by 2020, march 2016.

97 CGEDD/CGEIET, Hydrogen-energy industry, September 2015.

98 Article 40 of law 2015-992 of 17 August 2015.

for the use of alternatives to fossil fuels between Member States.[99] Member States are thus required to define a national strategy for the deployment of infrastructures for alternative fuels and report back to the European Commission by November 18th 2019. This strategy must find a balance between the various technological options available.

- **Impact on the production and distribution of electricity**

Another argument weighing against the coexistence of battery and hydrogen electric vehicles in the medium to long term is that of the full cost of charging infrastructures. The charging stations installed today use a constant distribution system, therefore cost is marginal. According to the industrial partners consulted, the consideration of full cost alters the economic equilibrium, notably increasing the installation cost of a station.

Furthermore, electric vehicles are charged according to a random schedule and may alter electricity peaks (typical case of a vehicle that starts charging in the morning, when work starts in companies, and at 7pm, when workers return home). Although *smart grid* systems can smooth this intra-daily peak to some extent, the production of hydrogen, which is easily stored, could enable absorption of these peaks of renewable energy production and make a significant contribution to the stabilisation of the electric grid.

[99] Directive 2014/94/EU of the European Parliament and of the Council on the deployment of alternative fuels infrastructure.

2.4.2.3. Necessity for regulations on emissions and an incentive policy based on results rather than means, adopting as global an approach as possible

Today, the EURO technical emission norms are differentiated according to each engine type (petrol or diesel): the boundary values for emissions are generally higher for diesel engines, notably since the introduction of *"conformity factors"* (see 1.2). While this type of differentiation may be justifiable during a transition period to enable manufacturers to adapt their production processes and develop suitable technologies, it would ultimately be logical to adopt a purely results-based obligation, without differentiating between the technological means used. This is enabled by the strong convergence observed between petrol and diesel since EURO 6. This regulatory convergence is part of the discussions currently under way at a European level for the EURO 7 norm.

More generally, it also appears that this overall results-based logic should be applied to fine particle emissions. Today's emission norms only concern exhaust gases, while scientific literature claims that exhaust fumes only actually represent around 5% of total fine particle emissions for modern vehicles (see 2.4.1). Norms should therefore be drawn up to take into account all emissions.

Similarly, for electric or hydrogen cars, the environmental equation is made more complex by the heterogeneity of energy mixes for electricity production, depending on the country (see 2.4.2.1). The environmental challenges of producing and recycling lithium-ion batteries must also be taken into account.[100]

[100] For example, see the USA's Environmental Protection Agency (EPA) report: *Application of Life-Cycle Assessment to Nanoscale Technology: Lithium-ion Batteries for Electric Vehicles,* April 2013.

Battery-powered electric cars are already being mass produced, which is not yet the case for hydrogen vehicles (despite a few counter-examples, like the Toyota Mirai). Economies of scale can therefore be expected from hydrogen vehicles: the US transport department thus anticipates a 4-5-fold decrease in the cost of fuel cells by 2020.[101] Considering the uncertainties weighing upon the adoption of electric or hydrogen vehicles, it would seem logical to adopt a cautious, balanced approach, especially in the choice of infrastructures (see 2.4.2.2).

Proposal no. 7: Regulate emissions according to incentive schemes founded on an overall results-based approach, without imposing technological choices.

Emission regulations, whether mandatory or incentive-based, must be grounded in a results requirement, without favouring a technological choice over another. In the short term, it would be advisable to accelerate the convergence of emission norms for diesel and petrol powered engines (in the next EURO norms) in collaboration with the industrial stakeholders, notably with respect to the gaps observed between emissions in actual use and in test conditions.

Furthermore, while preserving the current individual vehicle emission limits, more limiting targets could be set for average fine particle and NOx emissions for the vehicles released each year by individual manufacturers, as is the case for CO_2. This would enable each manufacturer to find the best technological mix to

[101] McKinsey 2016: *Assessing hydrogen's future role in powering passenger cars.*

reduce the emissions of its fleet overall, thereby improving air quality in the cities more quickly.

More particularly in terms of fine particle pollution, emission norms should include all sources of particle emission, not just the exhaust, which only represents 5% of the direct and indirect emissions of recent car models.

On the longer term, it would be beneficial to encourage the most promising technologies (hydrogen, electric, petrol-diesel hybrid, etc.) more and in a balanced way, by adopting a full cost approach (including costs related to electricity distribution infrastructures), an overall "well-to-wheel" approach, and for the full product life cycle (notably including the issues of battery recycling).

THE ECONOMIC CHALLENGE

The car sector occupies a central place in France in terms of industry, employment and research. In 2015, the French automotive industry represented 440,000 jobs in France[102] (full-time equivalents), almost half of which are in the core business sector (i.e. car manufacturer, equipment manufacturer, design). It has an indirect impact on an additional 2.1 million jobs, according to CCFA,[103] especially *via* the jobs related to vehicle use (sale, after-sales, rental, etc.) or mobility (road freight, passenger transport, etc.). The automotive sector generates 16% of the turnover of the French manufacturing industry as a whole.

Car manufacturers spend the equivalent of the value of their companies on R&D and capital investment, every 4.1 years, on average. Other industries do this for over 20 years. Such investments continue to grow: investment and R&D spending by the leading manufacturers increased from €76 billion in 2010 to €137 billion in 2015, i.e. almost double in just 5 years.

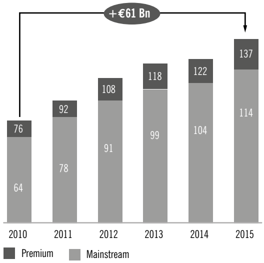
[102] French Ministry of the Economy and Finance, 2016.
[103] CCFA, "Analyses et statistiques, 2016" *(analyses and statistics, 2016).*

Figure 9: Investment and R&D spending by the main car manufacturers

Main regulations

CO_2	**The most difficult is yet to come** • Changes from –200 to –100g between 2000 and 2020 demanding optimisation of traditional engines • Reduction to below 100g in Europe and 120g in China or in the USA would involve mass deployment of electric engines and different vehicle concepts • Transition to the WLTP cycle will add to investment efforts that are already strong
Local pollution	**What is the return on investment for diesel depollution modules?** • The norms will become stricter with RDE regulations liable to impose costly combined solutions, such as SCR/NOx traps • The high costs of developing these technologies may not be covered by sales due to the decline in this type of engine, whose reputation has suffered

CAPEX and R&D spending of leading manufacturers[1]
€billion[2]



1. **Mainstream :** FCA, Ford, GM, Honda, Hyundai, Kia, Nissan, PSA, Renault, **Premium :** BMW, Daimler Cars.
2. Converted from 2010 exchange rate (average January - December 2010)

Source : A.T. Kearney.

New mobility companies (Blablacar, Zenpark, etc.) are creating jobs, although often on the basis of low labour intensive models, and, more broadly speaking, economic activity, by encouraging people to travel. The new technologies of the car industry (advanced electronics, mass data processing, etc.) are also creating new, often highly qualified, employment opportunities.

This innovation dynamic can benefit everyone, provided French companies can anticipate the transformations in the chain value and public authorities create the conditions for developing the car of the future in France.

3.1. The development of the car of the future will transform the value chain and help new stakeholders emerge

3.1.1. New technologies

3.1.1.1. Historic value chain: changes in engine design

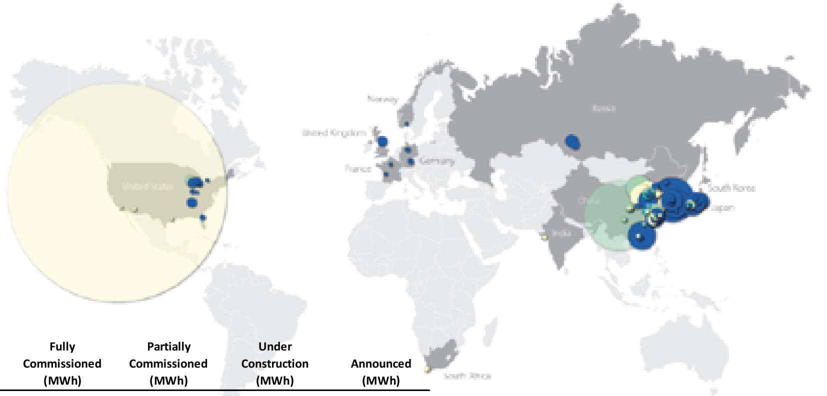
The car engine industry changes rapidly, especially under the influence of environmental concerns, not to mention norms, which are pushing designers towards a *"zero emission"* engine. In practice, this entails both improving existing technologies (petrol and diesel thermal engines, hybrids) and developing new engine designs (electric, hydrogen, etc.).

Perfecting thermal engines tends to strengthen our economy since French manufacturers are naturally positioned on this market. However, the boom in new engine types, particularly electric ones, also benefits other industrial sectors, often less developed in France. The production of electric batteries (and the use of lithium, which is now the main raw material) is mainly located in Asia, and in particular in Japan[104]. The giant battery factory project announced by Tesla could restore some balance in this market[105], but not in favour of Europe or France.

104 Panasonic is the leader in this market, notably thanks to its partnerships with Tesla and Volkswagen, see EV Obsession (2016), "TOP 10 EV Battery Manufacturers (Q1 2015)", evobsession.com.

105 "Gigafactory" project in Nevada.

Figure 10: Global lithium ion car battery production capacities in 2015



	Fully Commissioned (MWh)	Partially Commissioned (MWh)	Under Construction (MWh)	Announced (MWh)
China	16,704	3,576	18,730	12,847
Japan	10,778	0	1,200	0
Korea	16,059	0	0	0
U.S.	3,770	0	1,200	35,000
EU	1,798	0	0	0
Rest of World	2,440	0	0	564
TOTAL	**51,549**	**3,576**	**21,130**	**48,412**

Note: This map includes factories that are fully and partially commissioned, under construction, and announced. Capacity is not disclosed for all factories.
Source: Corporate reporting. Bloomberg New Energy Finance BNEF (2015).

Source: D. Chung, E. Elgqvist, S. Santhanagopalan (2015), "Automotive lithium-ion battery supply chain and US competitiveness considerations", *CEMAC.*

This represents a major industrial and economic challenge, since the battery unit of an electric car accounts for almost one third of its purchase price.[106] For French manufacturers, the risk is to see a growing proportion of the added value of their vehicles disappearing.

Furthermore, electric engines, which has a design simpler than that of the thermal engine, represent a lower entry barrier for newcomers to the car manufacturing market. Tesla is the perfect example, although having previously been contained within a niche market, it is currently experiencing the difficulties of mass production.[107]

The hydrogen car is still mostly at the experimental stage but massive investments by major stakeholders and the commitments of certain States suggest that significant progress will be made in the next few years. The main obstacles to its deployment today are financial. These vehicles suffer from a dissuasive price, which is itself due to the low production volumes which do not cover overheads. Furthermore, hydrogen distribution facilities must be more widely deployed (see 2.4.2.2). The situation will change once *early adopters* have triggered the large scale production dynamic.

[106] Y. Rousseau, "Voiture électrique : la bataille des batteries est lancée" *(electric cars: the battery battle has begun)* lesechos.fr, 2016

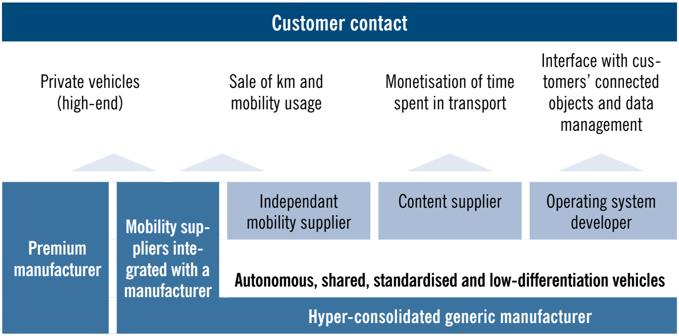
[107] The Californian company, which plans to produce more than 500,000 cars in 2018, i.e. more than ten times its 2015 production, has been in the news a number of times over the past three years with extended production lead times and delivery delays on some of its models (see "Tesla, les promesses non tenues d'Elon Musk" *(Tesla: the promises Elon Musk has failed to keep)*, Les Echos, 17/08/16; "Tesla brings its output targets forward by two years", Financial Times, 5 May 2016).

3.1.1.2. Digital technology as a new value segment

The value chain of connected car surpasses the strict confines of the car industry, opening up to stakeholders from the electronics, digital services and telecommunication sectors. At the moment, it is difficult to know the role that each party will play in this new version of the value chain, and is likely to result in a lively struggle among industrial stakeholders. There is a clear risk that car manufacturers of high added value segments might be captured by other types of companies.

More specifically, the consumption action may, in the future, consist in purchasing a service *via* a single platform for all vehicle brands (e.g.: on-demand TV or video games for passengers), the vehicle itself being relegated to the status of a simple *"container".*

Figure 11: The stakes of customer contact in the transformed car of the future



Source : A.T. Kearney.

Table 3: Examples of newcomers to the car value chain

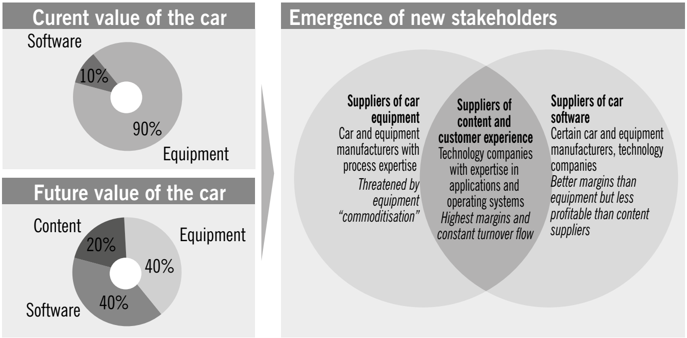
Position in the value chain	Newcomer sector	Players	Activity description	Maturity
Car equipment	Semi-conductors	• Intel	• Availability of telematics solutions • Development of vehicle autonomy technologies	• November 2016 announcement of 250M investment over 2 years in autonomous driving technologies • Investment in Here, digital mapping specialist
		• Nvidia	• Development of systems for the autonomous and assisted car, particularly involving artificial intelligence	• Multiple partnerships with car and equipment manufacturers (Valeo, Audi)
	Digital / Electronic	• Apple (partnership with Telogis • Google	• Apple, Google: development of mobility systems and applications; Carplay, Navigation, Android Auto	• November 2015 announcement of a partnership between Apple and Telogis, fleet management solutions expert
		• Panasonic	• Development of detection, artificial intelligence, navigation and passenger compartment systems	• May 2016 announcement of a growth target of $3.6 billion in 2 years on new car technologies
		• Samsung	• Development of hardware solutions for connected vehicles	• Acquisition of Harman (high-tech car equipment specialist) in 2016
	Petrol / fuel	• Shell • Aral (BP)	• Development of applications to reduce fuel consumption	• First launch in 2013
	On-demand transport platforms	• Uber *via* Otto	• Development of autonomous heavy vehicles on the motorways	• Successful motorway test in the USA in September 2016
Car manufacture	Logistics	• DHL *via* Street Scooter GmbH	• Production of commercial electric cars	• Market launch in 2016

Source : A.T. Kearney.

It is therefore possible to imagine a two-tier market, where only high-end manufacturers succeed in generating value with the vehicle alone, other manufacturers proposing inexpensive vehicles with a low level of differentiation. In the latter case, the value would mainly lie in either on-board services, making the most of the passenger attention time available, or in *"mobility providers",* whose vehicle fleets are made available to people needing to travel.

90% of the value of today's vehicles lies in the infrastructure *("hardware")* and 10% in the software. In the future, infrastructure may only represent 40% of its value, software 40% and content 20%.

Figure 12: Possible evolution of vehicle value and impact on the value chain



Source: A.T. Kearney.

Today, the value created by this new vehicle complexity is mostly captured by car and equipment manufacturers. They develop almost all of the electronic and electric systems used in the vehicles, telematics and active safety equipment, etc.

Box 6: The development of on-board services

It is thus estimated that connected services (mapping and guidance, applications using vehicle data, *infotainment* like Netflix or Spotify, etc.) may reach $100 billion by 2030. By comparison, all recurrent income related to vehicle use (connected services and new mobility solutions) currently represent approximately €30 billion.[108] It is therefore essential for companies to get into the car.

The vehicle's operating system remains, for the moment, under the control of the car manufacturer. Electronics and numeric technology stakeholders, such as Google, Apple, etc. are mainly positioned on systems related to *infotainment* and solutions used in addition to those developed by car manufacturers, under brands such as Apple Carplay or Android Auto. With this type of service, they are both partners with and competing against traditional car and equipment manufacturers:

- they are in competition because they supersede the original vehicle systems, for certain uses, without actually replacing them, since only proprietary systems have access to the internal vehicle operating data and driving functions;
- they are partners because only car manufacturers can integrate these new solutions into their vehicles and because the latter

[108] McKinsey, *Automotive revolution – perspective towards 2030,* 2016.

are signing agreements with digital technology stakeholders; e.g. Renault has been working in close collaboration with Microsoft for its connected vehicles since September 2016.[109]

The challenge for manufacturers is therefore to maintain a privileged relationship with passengers. New platforms certainly have a prescriptive role and can orient user choices towards a given service or provider, which is not necessarily the one privileged by the manufacturer. In particular, control of the vehicle auto-diagnosis system and service centre recommendations will have a major impact on business in garage networks. Companies like Mobivia (with its brands Norauto and Midas in particular) understood what this opportunity represented and developed connected gadgets, to be used in addition to the basic vehicle system, which is able to guide users' consumer choices.

These monetisation models for passengers are likely to represent a decisive turning point when the autonomous car is released. The driver will become a passenger of his own vehicle, freed of the need to focus on the actual driving, and able to enjoy other activities (watching films, browsing the web, etc.).

The strong growth in added value related to electronic systems arouses the interests of new stakeholders, often firmly embedded in other sectors. Some of them are accelerating their development via the acquisition of historic companies of the automotive industry. Panasonic thus acquired 49% of Ficosa, an equipment manufac-

[109] Microsoft, Renault-Nissan and Microsoft are collaborating to prepare the future of connected driving, Microsoft.com, 2016.

turer specialised in electronic devices for approximately $275 million in 2014, and Samsung paid $8 billion to control the equipment manufacturer Harman, specialised in connected vehicle systems (telematics, cyber-security, audio systems) in November 2016.[110]

This probably foreshadows a massive entry of leading digital technology and electronics firms into the car equipment market. The financial strength of such companies is a threat for the traditional stakeholders. Apple has liquid assets of around $200 billion, i.e. five times the market capitalization of Renault and Peugeot combined.

The challenge for traditional players will be to preserve their place. One of their main assets will probably be their experience in terms of safety and reliability. The car industry draws its credibility from its ability to produce safe vehicles, since the slightest malfunction can have consequences that are far more serious than in other sectors.

From an economic perspective, the challenge for France is to keep high added value companies in the country. While France has dynamic car and equipment manufacturers who are competitive on the international market, it has no giants in the electronics or digital sectors capable of competing with the world leaders of North America (Google, Apple, etc.) or Asia (Samsung, etc.).

[110] Samsung, Press release, November 14th 2016, *Samsung.com*

The development of connected cars will also affect other economic sectors, notably insurance, with a number of combined effects:

- the range of connected services includes driving assistance functions (emergency braking, lane keeping assistance, etc.) which can significantly reduce the loss ratio and therefore costs for insurance firms in the car sector. However, in a context of strong competition, loss ratio reductions are partly absorbed by the *premiums* paid by users to preserve competitiveness, thus reducing the business volume of insurance companies;
- this reduction in business volume will be partly compensated by an increase in offers related to cyber-risks, which are starting to develop and are expected to grow in the coming years;
- this movement will also induce a strong homogenisation of the loss ratio, since technology will help to close the gap between good and bad drivers. This could also limit the usefulness of behaviour-related pricing ("pay how you drive"), an area in which insurance companies have invested heavily in recent years.

Another sector affected by the digitisation of mobility is that of car maintenance. The networks will have to adapt to vehicles able to generate an automatic diagnosis of their condition, component wear and even repair requirements. These changes mean that skills must be adapted. Employees specialised in mechanics will no longer suffice to service computerised cars, implying major efforts in the fields of training and recruitment.

New engine designs, hybrids, electric and possibly fuel cells, will also require new skills and further training: as well as being able to understand and repair these engines, the safety issue must be considered, since the risks are different from one design to another.

3.1.2. New uses

3.1.2.1. A buoyant market for services

New mobility solutions fulfil specific needs and do not yet represent complete replacements for the private car. For example, car-pooling applications, led by Blablacar, are more suited to long distance trips than daily shuttle services, and generally replace train or coach trips rather than private car use. Taxi and private hire services, which remain costly, cannot replace private cars entirely either. It would therefore be risky to predict a short term reduction in car purchases due to changing practices and the move from possession to pure usage. The survey conducted for the Montaigne Institute confirms that only a tiny proportion of those interviewed are considering giving up car ownership in the coming years (see part 1.1.1).

This does not prevent certain economic players from being directly impacted by the boom in these new uses. This is obviously the case of taxi drivers, who now face much more intense competition.

Car rental companies are another category affected by new mobility offers. The stunning growth in private car-sharing solutions, by which private individuals rent their cars to other individuals for a price much lower than that proposed by rental companies, affects professionals in this sector. For example, when questioned on the means of transport affected by car-sharing between private individuals, 35% of users estimate that their use of traditional rental services has declined since signing up for such services.[111] However, a certain complementarity between the two offers exists, and thus, a potential equilibrium: professional services, more expensive, but more pre-

[111] Ademe, "Enquête nationale sur l'autopartage entre particuliers" *(national survey on car-sharing between private individuals),* 2015.

dictable (in terms of both availability and level of service), are, for example, best suited to last minute requirements and to business rentals. This complementarity is highlighted by the partnerships that have developed: Avis purchased Zipcar in 2013 – and conversely, some car-sharing players, such as Drivy, are trying to integrate professional rental vehicles into their offer.

These new solutions to mobility, whether car-pooling or car-sharing, also have an impact on insurance. Such solutions increase the use rate of the vehicle. Shared vehicles (e.g. *via* car-sharing schemes between private individuals), more widely used, are therefore more exposed to risk. This invites insurance firms to adjust their offers to take into account the transformed risk. Vehicles proposed by Drivy are automatically insured by a contract with Allianz, which substitutes the vehicle's regular insurance contract for the rental period. The development of car-pooling will have an ambivalent effect on risk: it may ultimately result in a reduction in the overall number of cars on the road (and therefore the number of accidents), but could increase the severity of accidents (causing more victims). Eventually, insurance companies may have to modulate premiums according to the number of passengers in the car.

3.1.2.2. Economic models to be consolidated

Private hire service providers find it difficult to make a profit. For example, Uber is currently recording losses of around $2 billion per year.[112] This unstable situation encourages these players to accelerate the development of autonomous cars, which they believe will generate profit. According to a Citi Group analysis, this technological wager could be successful: with autonomous cars, private hire services

[112] J. Marin, "Les pertes d'Uber se creusent : un milliard de dollars en six mois" *(Uber's continued losses: a billion dollars in six months),* lemonde.fr, 2016.

would make a profit from the price of $0.52 per mile, i.e. approximately three times less than the current rate.[113]

These perspectives could lead many players to position themselves as vehicle fleet operators, but it remains impossible to predict who will win this "gold rush":

- major digital companies (notably Google, Apple, Facebook and Amazon). With their expertise in the exploitation of gigantic volumes of data, artificial intelligence skills and the capacity to invest massively in technology development, these firms are in good position. They also have direct access to a very large number of users and already operate within a network;
- on-demand transport service providers (Uber, Lyft, Chauffeur privé, etc.). These firms have the best experience in managing trips in urban areas, with algorithms for trip planning and supply/demand adjustment. The accumulated data will further enhance this advantage, as will the possibility of testing autonomous vehicles in actual driving conditions on a large scale (which will also enable the deployment of autonomous vehicles alongside traditional cars to ensure a fluid transition from one model to another);
- car manufacturers. This fits with the strategy to invest in mobility services, which is already in place (PSA and Renault have recently launched a brand devoted to these activities). Their main assets in this race are knowledge of the vehicle as well as of drivers and their habits (*via* the data collected). Most manufacturers have already announced plans for the mass production of autonomous vehicles;
- urban transport companies (Keolis, RATP). The autonomous car would reduce operating costs, allowing transport lines to be proposed in less dense areas.

[113] Citi, *"Car of the Future v3.0"*, 2016.

Box 7: Towards an autonomous vehicle?

The design of an autonomous vehicle requires expertise in a number of key fields: detector development, data analysis, decision making (artificial intelligence) and vehicle control (robotics).

One of the current obstacles to the development of autonomous vehicles is unreliability of the detectors used (cameras, radars, lasers, etc.), which do not enable the precise, and therefore safe, reconstitution of the environment.

Another is due to the current limits of artificial intelligence and *deep learning* systems. Ultimately, these are expected to be able to cope with highly diverse situations and multiple unpredictable events (notably in less developed countries, where road infrastructures may be less advanced and less standardised).

3.1.3. Essential public investments

The emergence of new technologies and new uses must be accompanied by authorities. The latter can encourage the development of the car of the future directly (purchase of low emission buses) and indirectly (implementing charging stations for electric cars).

In terms of investments in infrastructure, public authorities can also form partnerships with private sector firms, even if they continue to play an essential role – if only by authorising the deployment of such facilities. For example, Tesla installs its own charging stations for electric cars, and Air Liquide installed a hydrogen station in Paris.

3.2. France has all the assets to invent the mobility of tomorrow

3.2.1. Encouraging innovation by enabling real life experimentation

The car and mobility sectors are currently characterised by their flourishing innovation. However, they face intense international competition, with certain giants (Uber, Google, etc.) threatening to establish hegemonic positions, which would be difficult to challenge.

The key is therefore to stimulate innovation, then to transform it into a commercial product for large-scale distribution. The best way of doing this is to encourage experimentation and to enable companies to test their ideas in actual conditions. The research and development phases are thus conducted in parallel, enabling the rapid transformation of an innovation into an operational system.

In this area, a number of States have authorised the testing of new technologies (connected vehicles, autonomous vehicles) in actual conditions, in traffic areas that are also open to the public. France would benefit from the adoption of this kind of approach, aimed at accelerating innovation.

Opening experimentation areas to all players (digital startups, major car manufacturers, public transport companies) also helps them to learn to work together, thereby encouraging the development of coherent solutions. This guarantees that the new solutions will be better understood by the public authorities, which could then do their job better, notably by adapting regulations and investing public funds wisely.

Proposal no. 8: Catch up on experimentations of autonomous vehicles in actual driving conditions. In order to do so, France needs to develop more sites and programs allowing experimentations in real conditions as well as to facilitate innovation, by encouraging the various mobility stakeholders (manufacturers, startups, transport operators, public authorities, etc.) to work together in an open innovation approach.

Experimentation is an essential part of innovation and testing technologies in conditions close to reality helps to accelerate the learning curve. Experimentation sites have already been created or are being set up in Europe, including in France. Some countries are already a step ahead, such as Germany (motorway sections equipped with specific infrastructures, notably road signs, to allow the use of connected vehicles) and the USA (tests carried out by Uber in Pittsburgh), since they allow test systems in actual conditions, built into the existing infrastructures. It is essential that France does the same, to catch up any technological lag.

The participation of both local and national authorities in such experiments is important, since it would enable better anticipation of future innovations and their consequences, both in terms of regulations, and urban planning policies. Such zones must, of course, be operated under maximal safety conditions (specifically mapped zones, vehicle use restricted to periods of optimal conditions - weather, light etc.).

The development of a truly innovative eco-system would also stimulate investment, notably risk capital, i.e. in companies (startups) that have not yet attained their break-even point. Initiatives that bring the various players together (incubators, innovation centres, etc.) can serve as catalysts in this matter.

3.2.2. Preparing for employment market transformation to avoid "uberisation"

The rapid development of Uber throughout the world has overturned the taxi sector. At the same time, it has offered a glimpse of the profound, and sudden, changes in employment that the car of the future may bring. This phenomenon is both quantitative and qualitative.

In terms of quantity, new technologies and new uses will destroy some jobs and create others. In the case of Uber, between 2012 and 2015, the number of taxis in France increased from just over 16,500 to approximately 18,000,[114] while the number of Uber drivers increased from zero to around 15,000.[115] Much more radical changes may occur in the future, notably when fully autonomous vehicles reach the market: the transport trades may then disappear altogether.

[114] Facta, "Taxis et VTC dans les grandes métropoles, le cas parisien" *(taxis and private hire services in large agglomerations: the case of Paris),* 2016.

[115] A. Landier, D. Szomoru, D. Thesmar for Indef/Uber, "Travailler sur une plateforme internet ; une analyse des chauffeurs utilisant Uber en France" *(working on a web platform: analysis of the drivers using Uber in France),* 2016.

The survey conducted by Kantar for the Montaigne Institute reveals that 65% of French respondents believe that the autonomous car will have a positive impact on employment. This perception also prevails in Germany (63.2%) and California (57.5%), albeit to a lesser extent. The changes are also qualitative: the types of jobs and associated working conditions could also be affected. The example of a Uber driver is a poor illustration of the change, since the job remains very similar to that of taxi driver, but it does reflect a certain number of major changes: complex relations with the platform, which can impose fee increases unilaterally on its drivers or exclude them from service without fearing any inspections whatsoever; fiscal and social conditions that remain ill-defined, etc. Other professions will also see profound changes, notably in industry, where the skills required will differ from those previously needed: the manufacture of an electric engine largely differs from that of a thermal engine.

These changes will come about faster and will be more widespread than first imagined. For example:

- Tesla sells its car directly, without going through a dealership; this is possible because electric cars need much less maintenance over the first five years than thermal engine cars; in France, around 13% of jobs (i.e. more than 3 million people)[116] are in the sectors of car sales and repair and are therefore directly concerned by this change;
- before becoming autonomous in all situations, vehicles will be able to drive themselves on motorways; in the short term, this represents a threat to all long distance transport jobs (coaches and goods transport), i.e. approximately 170,000 jobs concerned by inter-urban road freight,[117] and several thousand for passenger transport; the

[116] INSEE 2014.

[117] CGDD, "Bilan social annuel du transport routier de marchandises" *(Annual social review of road freight),* 2010 figures.

startup Otto, a subsidiary of Uber, is currently making its first autonomous trips in the USA;
- ultimately, all jobs in the passenger and goods transport sectors will be affected, which represents more than a million people.

Such transformations are not negative in themselves, since they bring with them the promise of a more fluid, less costly and more environmentally-friendly mobility, as well as productivity gains that will create new business opportunities and new jobs. It thus seems futile to attempt to prevent them.

However, it is important to anticipate these changes in the employment market to arm the employees concerned. With an objective and realistic analysis of the jobs that will be transformed, and by means of a better focussed, more dynamic policy for both initial and professional training, people could be trained today for the jobs of tomorrow.

Proposal no. 9: Anticipate the consequences of the car of the future on the labour market with an ambitious training and redeployment policy.

Stimulating innovation requires technical investments as well as investment in human resources. Changes in technologies and uses will have a major impact on employment in certain sectors, such as passenger and goods transport, or even car dealerships. These transformations are inevitable and bring other kinds of advantages (better mobility, higher productivity, etc.).

They must be accompanied by prospective and strategic management of the transformation of the employment market: the automotive industry, with support from public authorities, must start now to analyse the impact of the car of the future on employment, both quantitatively (number of jobs threatened in each sector of activity) and qualitatively (possible redeployment according to skills). This shared diagnosis would enable the adoption of a forward-looking profession and skills management strategy and thus avoid the difficulties of sudden restructuring operations in the future.

3.2.3. Sharing an industrial strategy within the mobility sector

The time of major industrial projects implemented with varying degrees of success by the State (e.g. nuclear industry, TGV, etc.) has passed. Support for new car technologies will not be completely planned, but will focus on widespread, decentralised innovation, enabling a variety of technologies to mature: new engine designs, autonomy functions, digital services, new uses, etc.

However, it is fundamental that the French stakeholders in the mobility and car industries consult one another, coordinate their efforts, and form partnerships. The multiple initiatives must be coordinated to develop a clear, strategic logic for the mobility sector.

The players must share more than just a strategy, but a vision and business models, constructing an innovative approach together. One good example is the interaction between car manufacturers and the road sector: how to manage the cohabitation of traditional and autonomous vehicles, and how to coordinate the transition? Cars can no longer be considered mere objects, and must be given their place in the centre of a broader eco-system, which surrounds them.

Proposal no. 10: Gather mobility stakeholders of tomorrow to encourage dialogue, by including the new mobility stakeholders (e.g. by strengthening the role of the PFA, France's car and mobility industry organisation), **in order to optimise our anticipation of the upcoming evolution of industrial needs.**

The contributions of all French stakeholders to design and produce the car of the future would benefit from better coordination. Instances for dialogue and consultation already exist (e.g. the strategic committee of the automotive industry), but these must be broadened.

Dialogue must be developed between the historic major groups and the new players proposing connected, autonomous mobility solutions; this would favour network innovation, resulting in a multitude of experiments being conducted rapidly, while distributing the most convincing innovations on as wide a scale as possible.

The incentives to such cooperation projects could be amplified *via* private-public partnerships: support for collaborative projects, innovation competitions, etc.

The autonomous vehicle has the potential to face up to the three challenges – social, environmental and economic – that cars will face tomorrow. Indeed, progress is not yet sufficient in the eyes of the general public to generate real enthusiasm: only a fourth of the French believe that the autonomous (driver-less) car would fulfil their needs[118]. However, in a single object, if it keeps all of its promises, the car of the future could indeed improve road safety, quality of life, the environment and offer mobility to all[119], while transforming our urban centres. Thus, competition over the car of the future is not only limited to private economic players. States have a particular interest in implementing measures to make their national industries the leaders of tomorrow's industrial sectors.

France must establish itself as a pioneer in the development of autonomous cars accessible to all. On its national territory, France is already endowed with the technological capacities to enable the development and expansion of autonomous cars. The country has a world-ranking car industry, in both car and equipment manufacture, leading skill centres in artificial intelligence and robotics (which have given rise to the first experiments, currently in progress, on autonomous buses), and an entire eco-system of global companies offering connectivity or cyber-security solutions.

[118] Kantar TNS survey for the Montaigne Institute; 2,993 people questioned (1,006 in France, 1,004 in Germany, 983 in California).

[119] According to the French respondents of the Kantar TNS – Montaigne Institute survey, 40% cite assistance to reduced mobility people as the main advantage of the autonomous car.

The autonomous car offers France a new opportunity to demonstrate its ability to plan major strategic projects at the heart of an industrial policy resting on its strongest endowments.

But how? Firstly, by implementing and funding a national experimentation programme with transport authorities and local communities. This type of approach is already deployed in the USA, and could be so in France through the "Avenir" investment programme. Encouraging the development of on-board intelligence technologies will also be key, along with the structuring of the associated ecosystem, a sine qua non condition of the development of the autonomous car. Ultimately, the autonomous car will only be permitted to enter our cities in the future if regulations and legislation evolve.

I. Young People and Cars

Have young people fallen out of love with cars?

The idea that the younger generations could bring about a revolution of automotive mobility involves two overlapping concepts, which should be distinguished:

1. The younger generations' disaffection toward cars is proven by the decline in the rate at which driving licences are being obtained, a lower rate of vehicle ownership, and lower car usage compared to their elders at the same age;

2. This disillusionment could persist and become pervasive, i.e., the younger generations would bring about a new relationship with the automobile, which would then spread gradually to the rest of society. This proposal is in line with the hypothesis emitted by some transport experts that we will reach an irreversible decline in automotive mobility ("peak car theory").

Proposal (1) does not necessarily imply proposal (2), unless one considers that a number of conditions have been met: the observed trends must both continue (from one cohort to another) and their effects must persist over time (for a given cohort); the source of their determinants must be specific to the generations studied rather than extrinsic factors, related to the period analysed. What is actually happening?

In support of the first proposal, in a number of developed countries since the 1980s and 90s we have indeed observed a decline in the rate at which those in the younger generations are obtaining driving licences. It should however be noted that this decline has not been uniform: the decline is more apparent in urban youth and males. It is also more pronounced in some countries than in others.

In the United States, in 1983, 58.8% of those aged 20 years or younger and 91.8% of those aged 20-24 years held a driving licence; by 2015, these rates had fallen to 40.4% and 77.5%, respectively.[120]

[120] In France, the most complete data available on the subject are issued in the National Survey on Transport and Travel (ENTD, Enquête Nationale sur les Transports et les Déplacements). The last two editions were for the years 1994 and 2008. During this period, the rate at which young men aged 18-24 years obtained driving licenses dropped by three percentage points, whereas it increased 3.5 points among young women in the same age group. There is more recent data available on Île-de-France, where a similar survey is conducted at the regional level: in 2010, less than one in two (46%) young people (18-24 years) in the region held a driving licence, versus 55% in 2001 and 61% in 1983 and 1991. However, it is possible that the more pronounced decline in this region could attributed to the majority of individuals living in a dense urban area. As the ENTD revealed, geography indeed creates large disparities in the rates at which driving licences are obtained: "The rates at which driving licences are obtained are highest in the peripheral municipalities of large cities, followed by rural areas, and lowest in the Parisian agglomeration. The differences in young people's behaviour are quite marked: more than 80% of young adults under 30 years of age in peri-urban communities hold the 'Permis B' licence, 10 points more than young people in provincial urban centres, 20 points more than those in the Parisian agglomeration" (Thomas Le Jeannic and Tiaray Razafindranovona, "Près d'une heure quotidienne de transport : les disparités se réduisent mais demeurent" *(Nearly an hour commute daily: the disparities are being reduced but remain),* Insee, France Portrait Social, 2009 edition).

Possession of Driving Licences in the United States

	1983	2008	2015	Change 1983/2008	Change 2008/2015
Together					
Aged 16-19	58.8	46.3	40.7	–12.5	–5.6
Aged 20-24	91.8	82.0	77.5	–9.8	–4.5
Aged 25-29	95.6	86.3	85.8	–9.3	–0.6
Men					
Aged 16-19	62.0	46.1	40.4	–15.9	–5.7
Aged 20-24	95.4	80.3	76.4	–15.1	–3.9
Aged 25-29	99.2	84.0	84.1	–15.2	0.2
Women					
Aged 16-19	55.5	46.4	41.0	–9.1	–5.4
Aged 20-24	88.1	83.8	78.7	–4.3	–5.1
Aged 25-29	92.1	88.8	87.5	–3.3	–1.4

Source : Highway Statistics.

In parallel, travel surveys show a decline in young Americans' automotive mobility: today, young Americans' probability of owning a vehicle is lower than their elders' at the same age.

However, explanations for the origins of this phenomenon differ, although it is likely that several of them are at play simultaneously, even mutually influencing each other:

- Some analysts cite the changes that have taken place in the younger generations' sociodemographic composition: today, young adults are more likely to live in cities, to be single and/or childless, or to pursue higher levels of education than their elders at the same age; however, geographical location, employment status, and family status strongly influence the rate at which people obtain driving licences, regardless of age;
- Others put forth the economic factors affecting young people, whether they are cyclical (impact of the economic recession on employment

and/or income), or structural (lengthening of the time before integration into the workforce; accessibility of housing, which affects one's access to other costly items), pointing out in particular that the younger generations' financial situation has deteriorated in comparison to the generations that preceded them;

- Other observers make note of the values and attitudes that will define the younger generations, who are both "post-materialist" and "connected". "Digital natives", the members of "Generation Y" ("Millennials") tend to view digital tools, not cars, as their means of emancipation.[121]
- Lastly, some analysts highlight the postponement of a certain number of steps traditionally associated with entry into adulthood, such as marriage or having a child. The lengthening of the period between moving out of the family home and forming a new family unit would thus imply the emergence of a "new age of life",[122] that of the post-adolescent or young adult, whose behaviours should, over time, normalise compared to those of their elders.

Five recent studies shed light on these explanations:

- Among the multiple causes that could explain the change in the rate at which driving licences are being obtained, A. Delbosc & G. Currie (2013) point to sociodemographic factors as being both the most likely to have a significant impact, and whose impacts are most empirically substantiated. Their analysis is based on a review of literature from around 15 developed countries.

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[121] As expressed by a marketing specialist interviewed by *Le Monde:* "They no longer achieve emancipation with a car, but with a smartphone. They no longer leave their parents at the age of 18, but at 13, in their room", "Cette jeunesse qui ne veut plus rouler en voiture" *(The young generation that no longer wants to drive cars), Le Monde,* 18/09/2015).

[122] Olivier Galland, "Un nouvel âge de la vie" *(A new age of life)*, Revue française de sociologie, Volume 31 Number 4 (Oct. - Dec., 1990) pp. 529-551.

- Based on the latest travel surveys from the United States, N. McDonald (2015) describes a decline of automotive mobility between 1995 and 2009 that affected all Americans, but had a particular impact on those aged 19-36 (that is, "Millennials" and the younger members of "Generation X"). According to her, 10% to 25% of the phenomenon can be explained by "lifestyle-related demographic shifts"; 35% to 50% by characteristics specific to the younger generation ("millennial-specific factors"); the remaining 40% can be attributed to a lower demand for transportation across all age groups. The author also emphasizes uncertainties about the future of this trend.
- Based on longitudinal surveys on the income of U.S. households, N. Klein and M. Smart (2017) show that the decline in the rate at which young adults are purchasing automobiles compared to their elders at the same age is better explained by economic factors (income, wealth, and financial independence) than by cultural factors. As such, young adults who have gained their financial independence are just as likely, or even more likely, to possess a vehicle than their elders at the same age, once the precariousness of their economic situation is taken into account. The opposite relationship exists for young people who are financially dependent on their parents. The two authors are also very sceptic regarding the hypothesis that new technologies could supplant the need for travel: on the contrary, some studies have found a correlation between the increased use of the Internet and the demand for transportation.
- C. Kurtz, G. Li, and D. Vine (2016) show that in the United States, the average age of new vehicle buyers went up by 7 years between 2000 and 2015. According to them, this change reflects both the overall ageing of the population and also a change in purchasing behaviours within each age group. The drop in the vehicle purcha-

sing rate of the 35-54 age group and the rise in this rate among those aged 55 years and older would have had more of an impact on the period than the purchasing behaviours of the 16-34 age group. The study also shows that for all of the age ranges considered, the change in purchasing behaviours is explained more by economic factors (income, employment) than by a structural change of individual preferences and the relationship to automotive property.

- V. Garikapati, R. Pendyala, E. Morris, P. Mokhtarian, and N. McDonald call into question the hypothesis of a structural decline of individual mobility by car ("peak car theory") on the basis of the most recent time-use surveys rather than mobility surveys. Stressing the impact of the cyclical effects related to the financial crisis, they also show that even if young adults display mobility behaviours specific to their age group when compared with their elders at the same age, they will nonetheless end up adopting the same behaviours as their elders, although a bit later than them.

Overall, the idea that the younger generations will move away from the automobile and, more generally, will bring about change in our societies' new relationship with automotive mobility, remains a hypothesis that requires further support, even if undeniable changes are indeed underway in parts of the younger age groups.

The results of our survey support our conclusion: focusing on how the automobile is viewed, the majority of the young people surveyed continue to see the car as a symbol of independence and freedom (78% of those aged 18-24 years) and as a source of pleasure (65%), even if these proportions are lower than the overall population (87%

and 72%, respectively).[123] The younger generations, however, are the most sensitive to the ecological aspect (the car is seen as harmful to the environment for 33% of those aged 18-24 years vs. 23% for the overall population) – even if this gap is diminishing for the preceding generation (aged 25-34 years).

It is therefore important to prevent the “magnifying glass effect”, by avoiding the emphasis on the preferences and usages of a minority population – the (hyper)metropolitan, well-off, and educated youth– and by fully appreciating the importance and the permanence of the changes underway. Thus, while it is a significant change, the decline in the rate at which the younger generations are obtaining driving licences must not overshadow the fact that in all developed countries, the majority of young adults continues to get driving licences and use cars, even if, in certain cases, some prefer to postpone.

[123] However, these results cannot be attributed specifically to age, generation, or time period.

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II. II- Figures and useful data

The societal challenge

Annex 1 - Relationships between income and mobility

Revenue per household CU	Car (in%)	Two-wheeled, motorized (in %)	Public transport (in %)	Bicycle (in %)	Other mechanized mode (in %)	Walk (in %)	Together
Less than €500	36	2	18	3	0	41	100
€500 to €999	52	2	10	3	1	32	100
€1,000 to €1,499	68	2	8	2	0	20	100
€1,500 to €1,999	70	1	7	3	0	18	100
€2,000 to €2 999	73	2	7	2	0	16	100
More than €3,000	67	2	9	2	1	20	100
Together	65	2	8	3	1	22	100

Source: "La mobilité des Français" (mobility among the population of France), *French commission on sustainable development, December 2010.*

Annex 2 - Criteria cited to explain choices of different modes of transport

%							Covoiturage entre amis		Location	Auto partage	BlaBlaCar		Location entre Particuliers	Vélo en auto partage
L'aspect pratique	61	33	42	37	35	37	46	42	44	36	30	26	29	26
Le confort	50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14
La fiabilité (sûr d'être à l'heure)	47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12
La rapidité	46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10
Plaisir	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14
La proximité	27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10
Le coût	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19
L'aspect bénéfique pour ma santé	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21
La protection de l'environnement	2	20	21	19	24	3	21	4	5	15	17	7	12	18
Je n'ai pas le choix	7	6	13	12	6	16	8	22	18	15	13	17	18	18

pourriez vous me fournir la version en anglais au même format que celle que j'ai reçu pour la version française

Enquête Véhicule du futur

Q12 Pour quelles raisons utilisez-vous chacun des modes de transport suivants ?

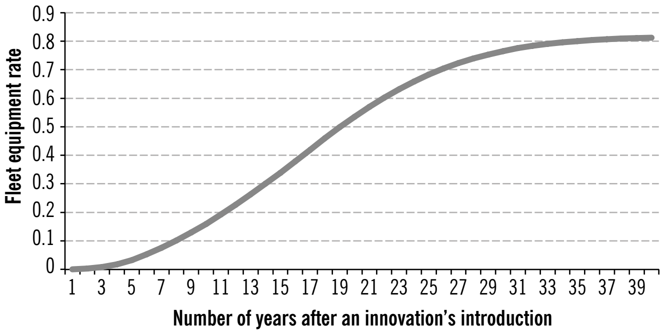
Source: Kantar survey for the Montaigne Insitute.

Annex 3 - Interviewees' perceptions of the car

Overall	Total	France	Germany	California
Gross basis	2,559	866	819	874
A symbol of independence, freedom	87%	88%	86%	87%
A pleasure	72%	68%	70%	78%
A source of expenditure	70%	77%	68%	64%
A way to express one's personality	34%	22%	35%	43%
Harmful to the environment	23%	28%	23%	17%
A constraint	13%	15%	16%	9%

Source: Kantar survey for the Montaigne Institute

Annex 4 - Dynamics of an innovation's introduction to the fleet of automobiles



Source : : Montaigne Institute.

Annex 5 – Scenarios of how the concept of a driver's legal liability may change in the context of the emergence of autonomous vehicles

Partially automated driving scenario

In this scenario, the vehicle remains under the human driver's control in one way or another: this may include cars with simple driver assistance features[124] as well as vehicles that can operate without the driver's constant attention, but the driver must nevertheless retake control at any time if needed.

In March 2014, the Vienna Convention of 1968 was amended to authorise embedded systems that have an impact on the conduct of the vehicle, under the condition that the implemented technologies can be controlled and disabled by the driver. Changes to applicable strictly internal legal provisions are predicted, although the current framework is already capable of handling a certain a number of questions.

Although "driver" is not defined by the Highway Code *(Code de la route),* the legal system considers it to be the vehicle's "guardian", that is to say, the one who has the ability to use, control, and direct the vehicle in the event of an accident.[125] In a partially automated driving scenario, when the driver ultimately retains control on the vehicle, he/she remains, in principle, the vehicle's "guardian". The current legal regime does not need to be amended.

[124] Such as those available now, e.g., cruise control, emergency braking, parking assistance, etc.

[125] The notion of "guardianship" draws on the general regime of liability provided for in Article 1384 s. 1 of the Civil Code, which became Article 1242 s. 1.

Likewise, the current regime of compulsory insurance does not exclude, in principle, accidents involving a partially automated autonomous vehicle. Motorized land vehicles, which are covered by compulsory insurance,[126] are defined broadly enough to apply to cars that offer partial driving automation.

The current liability regime stipulates that the driver (or guardian) of the vehicle at fault for the accident must pay compensation to the victim, and the costs incurred by traffic accidents are ultimately borne by the insurers. In the event that a driver assistance system were to fail, the insurers would appeal to the manufacturers (designer, programmer, etc.). However, this brings up the question of the burden of proof for the technical failure: is it up to the driver to demonstrate that the partially autonomous vehicle involved in an accident had a defect? Or is the designer responsible for providing evidence to the contrary? Manufacturers will likely develop ways of reconstructing accidents, similar to the use of «black boxes» in aircraft, which will help in determining liability. The connected vehicle's embedded systems will no doubt make it possible to gather information that will prove useful in the event of a judicial inquiry, or even automatically if provided for in the insurance contract. Of course, this will bring up the issue of protecting personal data.

With regard to criminal responsibility, Article R. 412-6 of the French Highway Code currently states that: *"Any driver must*

[126] So that the damage caused to third parties by the insured perpetrator of the accident is covered. This obligation is found in articles L 211-1 et seq. of the French Insurance Code and article 110-1 of the Highway Code.

constantly remain in a state and in a position to effectively and expediently carry out any manoeuvres that are incumbent upon him/her". This obligation does not seem to be incompatible with partially (even largely) automated driving, as long as the driver can resume control of the vehicle at any time.

Fully automated driving scenario

In a fully automated driving scenario, the notion of the "driver" would be replaced with the "user". A "user" does not have the ability to resume control of driving of the vehicle.

It will be necessary to amend the aforementioned Vienna Convention, as Articles 1 and 8 provide that:

- *"Any vehicle in motion must have a driver;*
- *The driver is the person who directs the vehicle;*
- *Any driver must:*
  - *Possess the necessary physical and psychological qualities and be in a suitable physical and mental state to drive;*
  - *Have the knowledge and skill necessary to drive the vehicle;*
  - *Constantly maintain control of his/her vehicle;*
  - *Avoid any activity other than driving".*

The text of the Vienna Convention will need to include the possibility of an artificial intelligence system replacing the human driver.

With regard to applicable strictly internal legal provisions, changes of the same nature are also expected since this law transposes the international rules and those of the European Union. With regard to civil liability, since the current compensation regime is based on the notion of a driver – in the "guardian" sense – of the vehicle, a change will be necessary. Indeed, since the user does not have the ability to resume control of the vehicle, the user cannot be regarded as the vehicle's "guardian". The party liable for the accident will therefore need to be determined between the designer, the manufacturer, the programmer of the software embedded in the autonomous vehicle, and the designer of the artificial intelligence.

With regard to insurance, current policy covers *"any person deemed guardian or driver"* of the motorised land vehicle. This could, in theory, make it possible to cover people who are not physically positioned behind the steering wheel of the vehicle involved,[127] so that no significant change to this regime appears to be required. In practice, autonomous vehicles would, however, have an important impact on the functionality and characteristics of insurance.

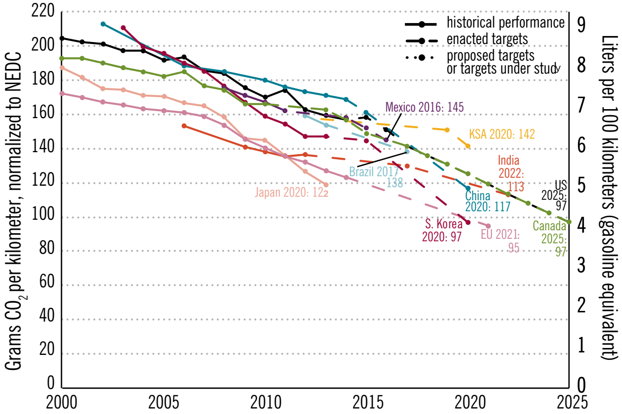
With regard to criminal responsibility, since the user physically positioned in the vehicle has no control over the vehicle's conduct, he or she is not, in theory, able to commit an offence likely to incur criminal responsibility. *Article 121-1 of the French Penal Code stipulates that "no one is criminally responsible for anything other than his or her own actions". Road traffic's progression toward autonomous vehicles could thus eliminate criminal*

[127] "Quel avenir juridique pour le 'conducteur' d'une voiture intelligente ?" *(What is the legal future for smart car "drivers"?)* Iolande Vinginao; *Petites affiches* 01/12/2014 - no. 239 - p.6.

responsibility for traffic accidents (excluding intentional accidents). In this case, technological progress would be accompanied by true societal progress. Another way could be to maintain the existence of criminal responsibility for legal persons representing either the designer, the manufacturer, the programmer of the incriminated software programme(s), or the designer of the faulty artificial intelligence, etc. This option would evidently not be the most favourable to innovation in serene conditions.

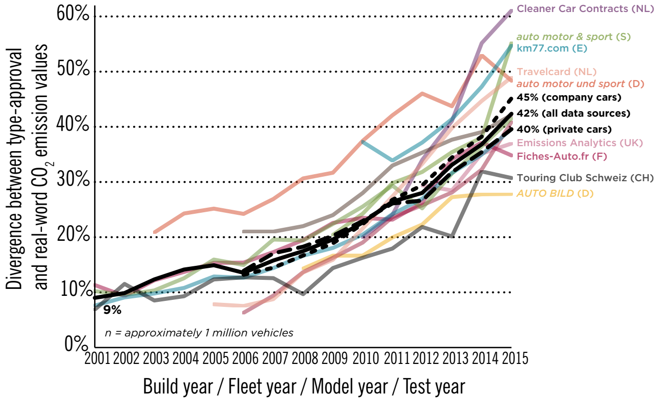
The environmental challenge

Annex 6 – Comparison of CO_2 emissions regulations for new passenger cars, worldwide



Source: CO_2 emissions from new passenger cars in the EU: Car manufacturers' performance in 2014, ICCT, July 2015.

Annex 7 – Gradual divergence between type-approval and real-world CO_2 emission values, in Europe, over time (2001-2015)



Source: From Laboratory To Road A 2016 Update Of Official And "Real-World" Fuel Consumption And CO_2 Values For Passenger Cars In Europe, ICCT, 2016.

Annex 8 – Particulate Matter: Origins and Issues

Particulate matter (PM) is a term used for a variety of pollutants present in suspension in the air. They are traditionally distinguished by their size: particles with diameters between 2.5 and 10 microns are known as "PM10" or inhalable coarse particles, which can get into the lungs, and those with diameters of less than 2.5 microns ("$PM_{2.5}$") can penetrate the alveoli in the lungs.

$PM_{2.5}$ particles, created mainly by automobiles, present a greater health risk and are more difficult to measure and to filter.

A quantitative health impact evaluation conducted by Santé publique France (Public Health France) established a national estimate for mainland France of the health impact that pollution from PM2.5 particles has on human activity. The toll on health was **estimated at 48,000 deaths per year,** which represents 9% of the mortality in France and a loss of life expectancy at age 30 sometimes greater than 2 years.[128] According to this same agency, the bulk of these mortalities is linked to the chronic effects of this pollution, and not specifically to pollution peaks.[129] **This quantification has not earned full scientific consensus:** the margins of error are significant (the 95% confidence interval varies between 17,500 and 74,400 deaths) and are based on high assumed risk ratios (correlations between levels of particles and mortality).[130]

In developed countries, fine particle pollution stems largely from local sources. Exceedances of the acceptable thresholds for human health are generally related to the specific atmospheric conditions

[128] "Impacts de l'exposition chronique aux particules fines sur la mortalité en France continentale et analyse des gains en santé de plusieurs scénarios de réduction de la pollution atmosphérique", *(Impacts of chronic exposure to fine particles on mortality in mainland France, and analysis of several atmospheric reduction scenarios to improve public health),* "Santé publique France", *(French national public health agency),* June 2016.

[129] "Quelle est la part des pics de pollution dans les effets à court terme de la pollution de l'air sur la santé dans les villes de France", *(What affect do pollution peaks have on short-term air pollution and heath in French cities?) Santé* publique France (French national public health agency), June 2016.

[130] Choice of risk ratio: 1.15 (risk increases by 15% when particulate concentration increases by 10 micrograms per m^3 of air), whereas the WHO recommends 1.06.

around major cities. In these countries, economic activity is subject to strict enough standards that this type of pollution is not generalized, in contrast to, for example, the "Asian brown cloud" that often covers certain regions in Asia (in China and India in particular).

In France, on average, the portion of particle emissions caused by road transport is small (approximately 5%).[131] It is generally **local pollution,** mainly noticeable on the outskirts of urban centres and near major roads.

This pollution, of course, is found near major roads, but it also affects the confined spaces of the Paris subway system, certain sections of which are much more polluted by fine particles than the roadsides on the surface. On the subway platforms, PM_{10} concentrations can range between 70 and 120 micrograms per m^3, with 1,000-microgram peaks (when work is being done on the tracks at night[132]). By comparison, in 2015, the averages measured by Airparif on the surface were around 38 micrograms. These particulate emissions are evidently not generated by the subway's motors (which are electric), but by the air kicked up by subway carriages' movement, their braking, and the construction works that raise dust in the tunnels.

131 According to the CITEPA (the Interprofessional Technical Centre for Studies on Air Pollution): https://www.citepa.org/en/air-and-climate/pollutants-and-ghg/particulate-matter.

132 In the Châtelet train station, according to the RATP's SQUALES network.

In Île-de-France in 2012, particulate emissions broke down as follows:[133]

- 28% of the emissions in Île-de-France were related to road transport, without counting the resuspension of particles present on the ground caused by vehicles' movement;
- 26% is due to the residential and tertiary sectors (the bulk due to burning wood for heat);
- 18% linked to agriculture;
- 18% linked to construction sites and quarries;
- The remainder is split between rail and river traffic (4%), industry, energy generation and distribution (4%), and airports (2%).

These distributions vary greatly between seasons and economic activities. For example, during the pollution peak that took place in the Parisian agglomeration at the end of December 2016, on the coldest days of the year, more than half of the particulates measured in the area came from residential fires.[134]

At the national level, improvement is being made: according to the Ministry of the Environment, particulate concentrations near road traffic and in urban areas have been declining since 2007 for PM_{10} levels, and since 2009 for $PM_{2.5}$.[135]

[133] "Inventaire régional des émissions en Île-de-France" (Regional Emissions Inventory for Île-de-France), Airparif, 2012.

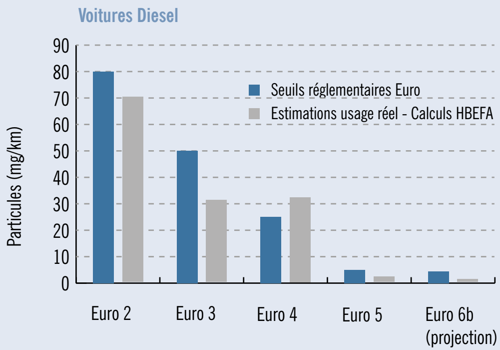
[134] According to *l'Obs'*, based on figures from AIRPARIF: http://tempsreel.nouvelobs.com/planete/20161206.OBS2261/pollution-trafic-routier-chauffage-industrie-qui-est-coupable.html

[135] Source: "Les particules atmosphériques : la connaissance progresse" *(Atmospheric particles: understanding advances),* Datalab, February 2017, French Ministry of the Environment). Nitric oxide (NO), nitrogen dioxide (NO_2)

Of the 28% of the emissions in Île-de-France region related to road transport, 17% was due to the exhaust from diesel vehicles. Exhaust from petrol-burning vehicles contains practically no fine particles. It should be noted that these exhaust emissions are largely linked to the age of the fleet of vehicles in circulation: exhaust from diesel vehicles that comply with the most stringent emissions standards (Euro 5 and Euro 6) emit nearly no particulates (*cf.* annex 9).

At the end of 2013, more than a third of the fleet of diesel passenger vehicles in circulation was equipped with particle filters, amounting to around 7 million vehicles. Heavy-duty vehicles, which have comparatively longer lifespans, remain very seldomly equipped with particle filters, as this equipment did not emerge until the Euro 4 standard, which has been in force since 2005.

Annexe 9 - Particulate emissions in exhaust from diesel vehicles, by generation of vehicle



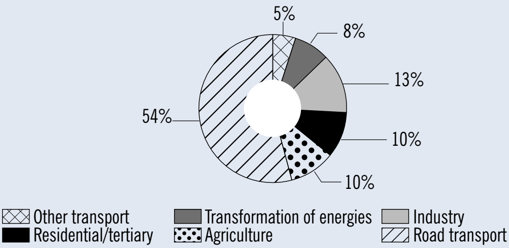
Source: ADEME, "Émissions de particules et de NOx par les véhicules routiers" (Emissions of particles and NOx by road vehicles), *June 2014.*

Annexe 10 - Les oxydes d'azote : origines et enjeux

Nitrogen oxides, also expressed as NOx,[136] are gases formed by fuel combustion at high temperatures and high pressures, in the presence of air (which is itself essentially composed of oxygen and nitrogen).

They are local air pollutants, some of which are visible (nitric oxide is a colourless gas, nitrogen dioxide is reddish brown; nitric oxide combines with oxygen in the air to form nitrogen dioxide). They have an indirect influence on the greenhouse effect, participating in the formation of ozone by interacting with other pollutants. Nitrogen dioxide is a gas that is irritant to the bronchi. Prolonged exposure to high levels of nitrogen dioxide causes of respiratory disorders. Asthmatic individuals and young children are more sensitive to this pollutant.

Annex 11: Sources of NOx emissions in France (2012)



Source: Ministry of the Environment.

[136] Nitric oxide (NO), nitrogen dioxide (NO_2)

According to the French Ministry of the Environment, in France, between 1990 and 2015, "NOx emissions have decreased by 62% thanks to fleet renewal and the gradual introduction of catalytic converters. Nevertheless, these advances have been stymied by the increase in traffic (+36% between 1990 and 2014) and the increased proportion of diesel vehicles (21% in 1990 to 63% in 2014)".[137]

Diesel vehicles, including recent models, are responsible for much more of NOx emissions (*cf.* annex 12). Diesel vehicles account for 89% of emissions from road transport (heavy-duty diesel: 41%; personal-use, catalysed diesel vehicles: 33%; light-duty, catalysed diesel vehicles: 15%). This problem is exacerbated by the tendency to downsize engine blocks, which entails increasing temperature and compression levels during fuel combustion, thus generating NOx in petrol engines, which were spared until now. In response, manufacturers are developing additional systems to capture and destroy NOx (*cf.* Box 5.). Heavy-duty diesel vehicles, which are equipped with costlier anti-NOx devices than light vehicles, emit approximately half as much NOx per kilometre than light vehicles.[138]

137 Source: The 2015 transport accounts, French Ministry of the Environment, August 2016.

138 *Cf.* ICCT's note from December 2016 on the latest vehicles (EURO 6 standards): http://www.theicct.org/sites/default/files/publications/Euro-VI-versus-6_ICCT_briefing_06012017.pdf Internal combustion engine electric vehicle

Annex 12 : Anti-NOx devices: catalytic reduction or NOx trapping

Two technologies can be used to reduce emissions of nitrogen oxides (NOx) from diesel engines, which emit more than petrol engines: NOx traps and SCR (Selective Catalytic Reduction).

The first option (the NOx trap), theoretically less expensive and primarily used in small- and medium-sized vehicles, essentially works like a particle filter. Composed of precious metals (platinum, barium, rhodium), it chemically traps (adsorbs) oxides of nitrogen and steadily converts them into neutral gases, mainly nitrogen (N_2) and oxygen (O_2). But this system necessitates that the engine regularly enriches its fuel mixture to trigger the chemical process that purges the filter. This increases consumption and CO_2 emissions. This device is being seen less and less on new models of vehicles because its effectiveness is limited and not fully compliant with new emissions standards.

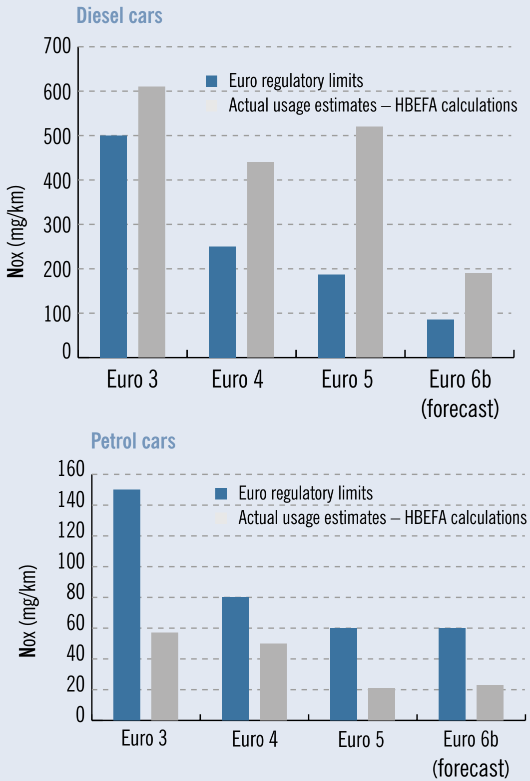
SCR employs an additional catalyst that continuously converts NOx into H_{20} and harmless diatomic nitrogen (N_2). To prompt this reaction, a liquid called AdBlue, a solution of deionised water and urea, is continuously sprayed into the exhaust stream before the SCR catalytic converter. Upon contact with the heat of the exhaust gas, it is transformed into ammonia (NH3). In the SCR, the ammonia reacts with the nitrogen oxides and the diesel engine's excess oxygen to safely convert the dangerous NOx into nitrogen (N_2) and water vapour (H_{20}). This technology is more complex: it requires an additional tank for the AdBlue (urea-based additive), an additional injector for this additive located in the exhaust line, and a specific management system with sensors to monitor pressure, temperature, and NOx. Paired with an upstream diesel particulate filter (DPF), another advantage is its additive-enhanced particulate filter capable of burning starting at 500°C (650°C for non-additive-enhanced systems). As this DPF functions at a lower temperature, the SCR can be placed upstream, where it benefits from more heat to trigger the conversion of the NOx. The SCR system therefore also has the advantages of being effective sooner during cold starts and of staying fully operational during city driving, when diesels' exhaust generates little heat.

Source : Automobile magazine - http://www.automobile-magazine.fr/lexique/44-piege-a-nox-scr.

The so-called "dieselgate" scandal, the Volkswagen emissions scandal where programming was used to rig testing of diesel engines, involved emissions of NOx. NOx production depends heavily on the engine's combustion settings. These settings are managed by the engine's electronic controller and also depend on whether or not additional NOx trapping/catalysis systems have been activated (*cf.* Box 5 *supra*). In the case of the Volkswagen models concerned, these systems were disabled or under-used outside of standardized laboratory emissions testing.

In real-world driving (outside of laboratory testing), the diesel vehicles on the market exceeded permitted emissions standards (in 2014, *cf.* annex 13).

Annex 13 : Emissions of NOx by road vehicles by level of Euro certification



Source: ADEME, "Émissions de particules et de NOx par les véhicules routiers" (Emissions of particles and NOx by road vehicles), *June 2014.*

Annex 14 – The different types of motorisations

Electric vehicle with an internal combustion engine (diesel or petrol) - ICEV:[139] consumes diesel or petrol. Fast refuelling (2 to 3 minutes). Battery life of up to 1,000 km.

Hybrid electric vehicle (diesel or petrol) - HEV:[140] consumes diesel or petrol. Fast refuelling (2 to 3 minutes). A battery is used to recover braking energy and reuse it later to accelerate, which reduces the vehicle's fuel consumption. Battery life of up to 1,000 km.

Rechargeable Hybrid Vehicle - PHEV:[141] essentially identical to the HEV, except that its battery is slightly larger and can be recharged using the public electrical network. Battery life of up to 1,000 km.

Battery-powered electric vehicle - EV:[142] vehicle that has only an electric motor and an often sizeable battery. Battery life generally between 100 and 300 km.

Fuel cell electric vehicle - FCEV:[143] consumes hydrogen, stored in gaseous form in a pressurized reservoir aboard the vehicle. Fast refuelling (2 to 3 minutes). FCEVs are propelled by an electric motor that derives its energy from a fuel cell which consumes hydrogen and air and produces just electricity and water vapour. Battery life of up to 700 km.

Source: Montaigne Institute.

139 Internal combustion engine electric vehicle.
140 Hybrid electric vehicle.
141 Plug-in hybrid electric vehicle.
142 Electric vehicle.
143 Fuel cell electric vehicle.

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