

# 1

## The Buzz about Autonomous and Connected Vehicles

This book begins with a two-part chapter, directly connected to the technical wizardry that must be implemented in vehicles in general and, by extension, in autonomous and/or connected vehicles.

By way of a general introduction, this first part offers a brief overview of the vocabulary used in the field. This will help to avoid the common confusions arising on the ground, and offer clarity about the various terms used under the umbrella of autonomous vehicles.

The second describes the vast world of vehicles, the surrounding topics, the media buzz, coverage in the ordinary and specialized press, and the concrete reality of defining, designing, manufacturing, fine-tuning and industrially producing a product, and, in particular, successfully selling it at market.

In 2021:

- There are already over a billion automobiles in the world (source: *Comité des constructeurs français d'automobiles* [CCFA – French Automaker Committee]);
- In 2016, in Paris, drivers spent more than 65 hours stuck in traffic jams. The situation in Moscow was worse still (91 hours) and in Los Angeles (104 hours) (source: INRIX research, 2016);
- Each year, worldwide, 1.3 million people die in traffic accidents (source: WHO);
- Every year, globally, 2.6 million deaths are caused by air pollution, which is partly linked to automotive traffic;
- In 2030, it is projected that 2.3 million people will die as a result of a road traffic accident (source: WHO);
- By 2050, according to predictions, 70% of the world population will live in urban areas (source: WHO).

In addition, the world population is continually increasing, leading to:

- Increased traffic;
- Congestion in city centers;
- Soaring CO<sub>2</sub> emissions;
- The upsurge in road accidents.

In the short and medium terms, all these subjects raise the question of *urbi et orbi* (in cities and out of them) transport in the future. In addition, in the early twenty-first century, the automotive industry is experiencing major technological changes, and as mentioned in the Foreword, in time, vehicles will come to be (partially) autonomous, connected, often electric, shared, etc. Their uses will evolve, and new forms of mobility, technologies, and skills will extend the range of possibilities.

As stated previously, this technical book is merely a single stone in the understanding of the vast edifice that is autonomous and connected vehicles. We have therefore restricted our field of study to a specific part of that edifice.

## 1.1 The reasons behind this book and its limitations

Autonomous and/or connected vehicles represent an enormous and highly complex subject, including a great many concepts that must be understood. Thus, we shall begin by briefly presenting the fields we have decided to cover in this book. Note that, while we have chosen to focus on the technical and technological aspects only, each of the subjects has its own accompanying philosophy and technical consequences.

### 1.1.1 Architectures

In a vehicle, there are a wide range of architectures, which clash, overlap, coexist, etc. We shall examine various architectures here. For example:

- **Functional architecture**, which governs the overall organization of all the system functions in a vehicle. Here, functional architecture is discussed only briefly;
- **Network architecture**, which governs the way in which protocols and communications between the functions and ECUs (computers) in the vehicle are chosen and structured. This will be the main focus of the book, as we move progressively from multiplexed network systems to automotive Ethernet architectures;
- **Hardware architecture**, whose purpose is to structure and define the choices of ECUs, the types of electronics, sensors, actuators, etc. We shall also discuss these in some depth, as they are directly involved in the different types of data that need to be transmitted;
- **Software architecture**, which controls the structure and management of the different software modules in a vehicle. At the end of the book, we shall examine the software architectures that are dedicated to networking;
- **Organic architecture**, which is in charge of the implementation of the different functions in the vehicle's electrical and electronic components;
- **Topological architecture**, which manages the physical arrangement of the different systems and components within a vehicle. The topological architecture is of crucial importance in estimating and minimizing network lengths, which are closely connected to the achievable data rates;
- **Cabling architecture**, which governs the way in which the networks and cabling harnesses are physically divided and implemented in the vehicle, their performances, diameters, weight, and so on.

### 1.1.2 Communication networks

As we shall see, for many years, numerous types of communication network have been installed in vehicles. Each network is specifically suited to particular application typologies.

The majority of this book focuses on analyzing their quality and performance, with a view to making suitable, safe applications, carried in vehicles with high levels of autonomy and connectivity. Until recently, such networks were largely based on “multiplexed” modes of operation, and many are in the process of shifting towards modes of operation oriented around the Ethernet philosophy, tailored for use in automobiles. The main goal of this book is to guide readers through that technological transition.

## 1.2 Terminology

It may be unusual to begin a book with a terminology section. However, in order to discuss autonomous vehicles, it is necessary to clearly define and describe the different levels of vehicle autonomy, to overcome the many potential misunderstandings, without the generalization and obfuscation that are typical of mainstream media coverage of this subject.

### 1.2.1 Autonomous and/or connected vehicles

To begin with, readers must appreciate the profound distinction between “autonomous” vehicles and “connected” vehicles. These two terms represent two completely different things, and must, under no circumstances, be confused.

- By definition, a (true) *autonomous* vehicle must be capable of traveling unassisted, alone, anywhere and at any time, etc., with no restrictions, without the help or even the presence of a driver. To be absolutely clear, either a vehicle is autonomous or it is not. It cannot be nearly autonomous or semi-autonomous, etc. – that makes no sense.

Nevertheless, in order to rate a vehicle’s performances, we can speak of the *levels of autonomy* (dictionary: its “capacity to be autonomous”), taking care to clearly indicate the specific domains and references in question;

- A connected vehicle is a vehicle that is linked to other systems by means of telecommunication systems, telephones, etc.;
- An “autonomous” vehicle is not necessarily “connected,” or vice versa.

On the other hand, frequently, an autonomous vehicle often does need to be connected in order to carry out other functions and other tasks (for example: uploading or downloading information about the road on which the vehicle is traveling, etc.) – this is why confusion so often arises.

#### Autonomous vehicles

The terms “autonomous” and “autonomous vehicles” are much too broad and too imprecisely defined. Again, to prevent confusion, in this book describing the habits and customs of the automotive profession, focusing on vehicles from those of the past

to those of the (perhaps distant) future, we shall use precise levels to define these types of autonomy, specified below.

### Connected vehicles

It is all very well to speak of connected vehicles – but connected to what, why, and how? Figure 1.1 illustrates some of the possible links and connections. These will be discussed in greater detail in Chapter 4.

To complete this brief general introduction, Figure 1.2 illustrates a vehicle solution whose functions facilitate a certain degree of autonomy, and which also has a number of connections.

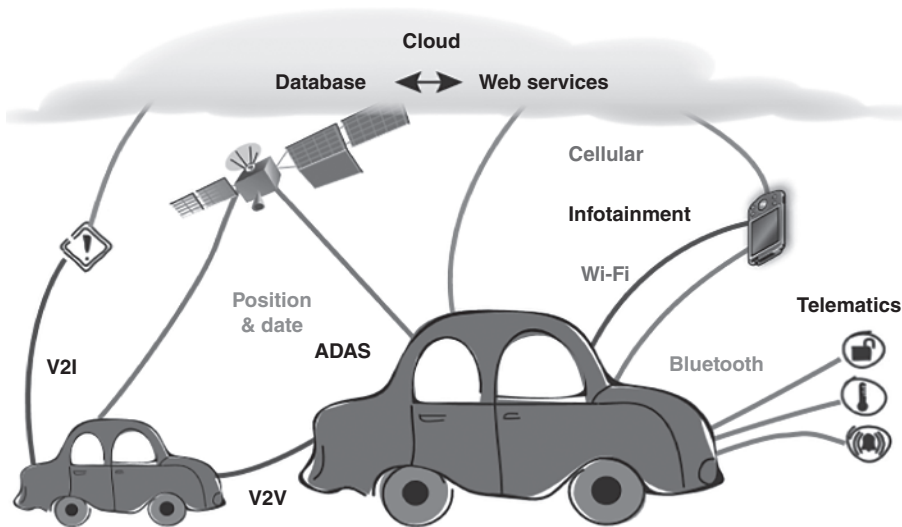
### 1.2.2 Terms and vocabulary relating to autonomous driving

The changes taking place in the automotive sector have made their way into the lexicon – there is a range of terminology dedicated to autonomous vehicles.

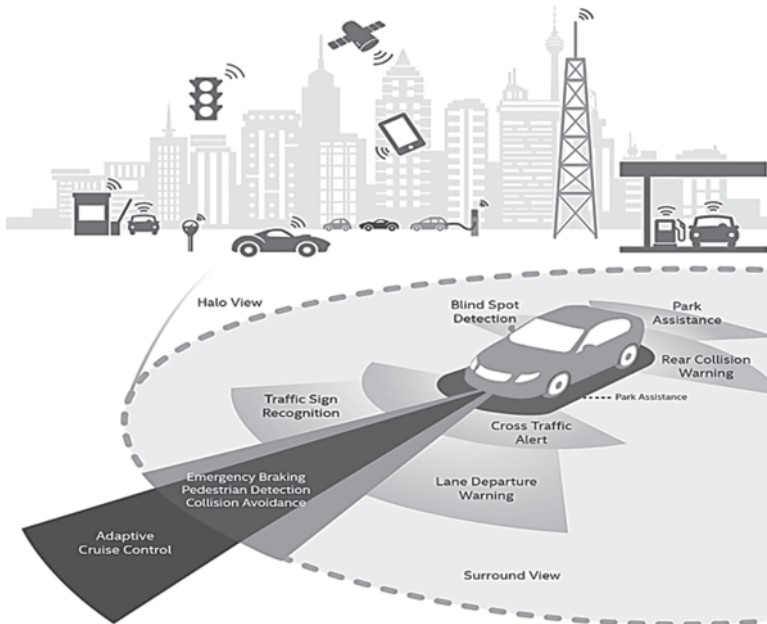
#### Terms and definitions

This vocabulary includes terms such as “ADASs” (advanced driver assistance systems), “driverless taxi,” “participatory geo-navigation,” etc. Consider a few other examples:

- *Pay-how-you-drive (PHYD) insurance*: “a vehicle insurance contract whose premiums are based on the driver’s conduct at the wheel, and the way in which the vehicle is used.” Note that driver behavior and vehicle usage are assessed using data transmitted to the insurance company by onboard sensors;
- *Dashboard camera, dashcam, dash camera, scene recorder*: “an onboard camera that records the scene in front of the vehicle.” Note that often, only the last few minutes of a recording are actually kept in the memory. These recordings may, for example, be used to document the circumstances of an accident;



**Figure 1.1** Example of links and connections in a connected vehicle.



**Figure 1.2** Example of functions that help make a vehicle autonomous.

- Autonomous driving or *automated driving*: “a method of automated driving of a vehicle, which does not require input from its users; and, by extension, a system that facilitates this kind of driving;”
- *Traffic jam assist*, *traffic jam chauffeur*, *traffic jam pilot*: “a system that allows a vehicle to move independently in traffic jams.” The simplest forms of traffic jam autonomous driving systems merely follow the vehicle in front in the same lane (which does represent a certain degree of autonomy); the most complex are also able to change lanes.
- *Driver alert*, *driver alert system*, *driver monitoring*, *driver monitoring system*: “an onboard system that uses sensors and analyzes the driver’s behavior to detect any reduction in their alertness, and warn them about it.” The most advanced form is an alertness monitoring system:
  - The sensors used may be cameras, which analyze the driver’s head and eye movements. There are also systems that analyze the rotation of the steering wheel to assess driver alertness;
  - *Attention assist* is a registered trademark, so the term should not be used in any other context.

For information, Figure 1.3 offers a list of equivalent terms:

Terms
Driverless cab, autonomous taxi, driverless taxi
Mirroring, screen mirroring

**Figure 1.3** Other examples.

Let us now look at the levels of autonomy.

### Autonomy levels

In the automobile industry, the gradual trend towards autonomous driving follows a scaled technological progression, defined by a classification, which itself is established on the basis of multiple autonomy levels. Level 0 corresponds to a 100% manual vehicle, and the highest level (4 or 5, depending on the standards used) corresponds to a fully autonomous vehicle (restricted to specific use cases), which has no need of a driver.

### Use cases

Note
At the time of writing (2021), these different autonomy levels correspond only to applications in specific environments and use cases.

The three defined use cases and their specific features are as follows:

- For private vehicles:
  - In a traffic jam, without changing lane;
  - On the highway, without changing lane;
  - Autonomous parking.
- For industrial vehicles:
  - Speed regulation by infrastructure;
  - Platooning;
  - Garbage trucks;
  - Agricultural sprayers.
- For public transport:
  - Free service on a private site;
  - Shuttle bus services on a sheltered site.

Note
All of these use cases are highly restrictive. Nowhere in these three use cases is “open” circulation of autonomous vehicles mentioned.

We shall now look at the classification of autonomy levels.

### NHTSA classification (United States)

In the United States, the Department of Transportation and the National Highway Traffic Safety Administration (NHTSA) have created a five-level vehicle autonomy scale (Figure 1.4).

Let us briefly recap the definitions of these levels.

NHTSA classification	
Autonomy level	Functionality
Level 4	Fully autonomous driving
Level 3	Limited autonomous driving
Level 2	Automation of combined functions
Level 1	Automation of certain functions
Level 0	No automation

**Figure 1.4** NHTSA vehicle autonomy scale.

***Level 0 – no automation***

“The driver has total control, at all times, of the vehicle’s main functions (engine, accelerator, steering, brakes).”

***Level 1 – automation of certain functions***

“The automation systems, which apply only to certain vehicle functions, merely assist the driver, who retains overall control.”

***Level 2 – automation of combined functions***

“Control of at least two major functions is combined in the automation system, to replace the driver in certain situations.”

***Level 3 – limited autonomous driving***

“The driver can hand over complete control of the vehicle to the automated system, which will then be in charge of the critical safety functions. However, autonomous driving can only take place in certain environmental conditions and traffic conditions (e.g. only on the highway). The driver must be able to re-assume control reasonably quickly when asked to do so by the system – notably when the requisite conditions for autonomous driving are no longer met (exiting the highway, tail-back, etc.).”

***Level 4 – full autonomous driving***

“The vehicle is designed to perform, unassisted, all the critical safety functions for the whole of the journey. The driver enters a destination or directions, but is not required to be available to resume control. Thus, the driver can leave the steering wheel unattended, and the vehicle is capable of traveling without any occupants.”

**OICA-SAE classification**

The International Organization of Automakers (known as OICA, for its French acronym), is founded on the SAE J3016 classification. The classification system set forth by OICA-SAE is very similar to that of the NHTSA, except that it has six levels instead of five – the equivalent to level 3 in the American classification system is split into two sub-levels.

The functional breakdown of the autonomy levels in the OICA framework is presented for information purposes and is not normative (see Figure 1.5).







	OICA-SAE J3016 Classification					
	0	1	2	3	4	5
	No automation	Driver assistance	Partial automation	Conditional automation	High automation	Full automation
						
<b>VDA</b>	Driver only	Assisted	Partially automated	High automated	Fully automated	Driverless
<b>NHTSA</b>	0	1	2	3	3/4	

Figure 1.5 Levels of vehicle autonomy according to OICA-SAE.

Level	Functions		
		Driver	Vehicle
Level 5	Full autonomous driving	No longer needed at all.	Capable of performing all dynamic driving functions, whatever the circumstances.
Level 4	High automation	Should no longer be needed, either for driving or for backup.	Can handle almost all driving tasks in various scenarios.
Level 3	Limited autonomous driving	No longer needed to drive the vehicle, but must be prepared to take over the controls within a specific length of time if asked to by the system.	Steers, accelerates, and brakes automatically, but only in certain situations. The system recognizes its own limitations and alerts the driver to resume control.
Level 2	Automation of combined functions	Must remain alert, even when the vehicle is performing basic driving tasks, and must be able to take over immediately.	Steers, accelerates, and brakes automatically, but only in certain situations.
Level 1	Automation of certain functions	Must drive constantly, but with some basic support in certain situations. Must be able to take over the controls immediately.	Provides basic assistance, such as automatic emergency braking and lane-keeping.
Level 0	No automation	Must always be in charge of driving.	Merely responds to the driver's instructions, but can provide alerts about the vehicle's surroundings.

Figure 1.6 Details of the vehicle autonomy levels according to OICA-SAE.

The OICA-SAE classification offers the distinct advantage of more precisely defining the respective roles of the driver and of the vehicle (see Figure 1.6).

Let us now look at these six levels, starting with the lowest, and offer a little more detail and background explanation, as well as some examples.

**Level 0 – no automation**

**Driver** At all times, the driver has total control over the vehicle and its main functions (engine, accelerator, steering, and brakes).

**Vehicle** The vehicle merely responds to the driver’s commands and does not raise any alerts about the environment.

Of course, this is the most conventional level, and the easiest to understand – everything is manual. At all times, the driver has total and exclusive control of the vehicle’s primary functions (brakes, steering, acceleration, and driving force), and, logically, there are no automated functions. However, even when the driver does everything themselves, and none of the main functions is automated, the vehicle may still have alert mechanisms. Thus, all old cars can be described as being *level 0* autonomous!

Consider the example of a 4×4 convertible, with hands-free entry, keyless ignition – in short, a 1942 Army Jeep – is a level-0 autonomous car (see Figure 1.7).

Example of level-0 assistance: the audio alert of a reversing sonar sensor, lane departure warning, etc.

This level includes a great many vehicles on the road today.

Let us now examine levels 1 and 2, which hinge on advanced driver assistance systems (ADASs).

**Level 1 – Driver assistance**

**Driver** The driver retains overall control, with certain basic supports in place in certain situations.

**Vehicle** The vehicle can provide some basic assistance, such as emergency braking and lane-keeping support.



**Figure 1.7** A level-0 “autonomous” car.

In level-1 autonomy:

- The automation systems, which are in place for certain functions of the vehicle, merely assist the driver;
- The driver can temporarily hand over a driving task to the vehicle, on condition that it only handles one of the two dimensions of steering (longitudinal or transverse);
- The human operator always remains responsible for maneuvers, delegating a portion of the tasks to the systems. The driver must always be able to take over full control of the driving, if the situation requires.

Example of level-1 assistance:

- Adaptive cruise control: the vehicle takes control of the longitudinal dimension (the acceleration), but the driver is responsible for keeping the most appropriate lane position (transverse dimension);
- The anti-lock braking system (ABS) and the electronic stability program (ESP) automatically act on the brakes to help the driver maintain control of the vehicle.

### ***Level 2 – partial automation of combined functions***

**Driver** The driver must remain fully alert while the vehicle performs certain basic driving tasks.

**Vehicle** The vehicle controls at least two main functions, which are combined in the automated system, to replace the driver in certain situations. It can automatically turn, accelerate, or brake in certain situations.

At level 2, the driver ought only to need to play a supervisory role as the vehicle drives itself. In the event of an accident, the driver is still entirely liable for the failure of the system, because they have not been sufficiently attentive to their environment and neglected their supervisory duty. In all cases, it is important to remember that “the safety of the system as a whole is independent of the autonomy level.” At this stage, any action by the driver, however small, will supersede the car’s own behavior, in all circumstances. The human remains responsible for maneuvers at all times, and must be ready to take over fully if the situation requires. Note that certain automated functions have been in place in consumer vehicles for a number of years – such as automatic braking, electronic stability control and cruise control – but the human driver is still in charge. In addition to the electronic stability control system, level-1 and level-2 systems, such as AEB and LKA (see below), have begun to be rolled out. In summary:

- Level 1 means that only one automated system can be active at any given time in the vehicle;
- Level 2 means that multiple automated functions can work in tandem.

Examples of level 2:

- Adaptive cruise control combined with lane centering would qualify a vehicle as level 2;
- Automatic emergency braking (AEB) – the vehicle can apply the emergency brake automatically, of its own accord if a collision is imminent – plus *lane keeping assist*

(LKA), which alerts the driver if the vehicle begins to stray – and/or change direction if the vehicle deviates from its lane;

- *Park assist* is a good example of a level-2 function, which is able to park the car without input from the driver on the steering wheel or pedals. The car itself handles all steering and motion parameters, under the driver’s supervision. The driver is able to reassume control and correct trajectory at any time.

Today, safety managers all over the world are beginning to include level-1 and level-2 technologies as an essential precondition for a vehicle to aspire to levels 4 or 5. For example, in Europe, all vehicle models launched after 2018 must have automatic emergency braking, *road edge detection* and *lane keeping assist* in order to eventually attain a level-4 or level-5 rating. Given that around 85% of vehicles are intended to eventually reach level 4 – that is, basic cars that are equipped with more advanced ADASs, where the driver must remain fully alert at all times, level-1 and level-2 technology is likely to gain a greatly increased presence over the next three to five years. In good conditions, such a vehicle can take care of a great many normal aspects of driving.

At present, this represents the legal limit, as it is not possible to transfer liability to a machine, even if that machine’s decision-making is said to be better than that of a human being.

At levels 3 to 5, we enter into the realm of autonomous driving – to a certain degree.

### ***Level 3 – autonomous driving under certain circumstances***

**Driver** The driver can cede complete control of the vehicle to the automated system, which will then be in charge of the critical safety functions. However, upon request from the autonomous driving system, when it finds itself unable to continue, the driver must always be ready and able to resume control within an acceptable, specified window of time (especially when the conditions for autonomous driving are no longer met – e.g. exiting the highway, approaching a tailback, etc.).

In 2019, Tesla and Google Car were at this stage of automation (see Figure 1.8).

**Vehicle** The vehicle can take complete control of the steering, acceleration, and brakes in certain conditions. However, autonomous driving is only allowable in certain, specified environmental and traffic conditions (for example, only on an open highway).

In this case, the human driver can delegate a portion of the two-dimensional task of driving, and let their attention slip to carry out other tasks “briefly.” However, in certain circumstances, the vehicle will have to ask the driver to take over once more. The driver must be capable of resuming control if conditions require.

Because the driver presumably cannot *instantly* assume control of the vehicle, the system must ensure continued safety for a period of time when the driver has still not re-engaged (for example: in this case, pull over and stop the vehicle if the driver does not respond to repeated requests to take over control). This redundancy must be covered by additional sensors, such as radar, lidar (to detect shapes and objects), and map location, to identify safe drivable roads, and be aware of intersections and other signaling or instructions.



**Figure 1.8** *Google Car.*

At this level, the driver can disengage completely until the vehicle requests otherwise. During that time, the vehicle demonstrates a true “capacity for autonomy,” and the technology begins to display a number of substantial advantages in addition to safety, such as increased protection.

The transition from level 2 to level 3 requires a substantial improvement of the levels of functional security and redundancy in the system. At this stage, the technical level is the same as level 2, but liability is temporarily transferred to the system during periods of autonomous driving.

This immediately raises the question: what would the legal position be if the driver were to fail to take over the controls? The answer to this question is rather too tricky, but will be discussed in Chapter 2. In brief, the legal problem that embroils drivers, insurers, and automakers is so complex that only the law can decide on the appropriate behavior if the driver does not respond, when they were supposed to resume control of the vehicle within a given period of time.

This level means that, in certain circumstances, the vehicle can take charge of all driving functions:

- Example 1: the least complex driving environment is the highway (all vehicles are traveling in the same direction, with no pedestrians and no complex intersections). All the major functions are automated, including braking, steering, and acceleration;
- Example 2: slow-speed driving in traffic jams, in which the vehicle’s autonomous system takes charge of positioning and keeping the vehicle in its lane, whilst maintaining a speed that is appropriate for the traffic conditions and the speed of other vehicles. In such cases, a driver could, for example, read a newspaper without paying too much attention to the traffic jam. However, when the jam clears, the car will ask the driver to take over control once more.

Whilst it is true that the levels of vehicle autonomy are based primarily on the sharing of responsibility, it is important to remember that the first three levels of autonomy



**Figure 1.9** Examples of level-3 vehicles: the Renault Espace (left) and Peugeot 508 First Edition (right).

imply no responsibility (or liability) on the part of the vehicle. The systems are intended to be no more or less than driver supports (see Figure 1.9).

Level-4 and level-5 vehicles are autonomous in all situations and driving environments – no longer just “in certain circumstances,” as is the case at level 3.

#### **Level 4 – high automation**

**Driver** The driver can be a passenger who, on request, can take over the controls and driver when the automated driving system is unable to continue.

**Vehicle** The vehicle can perform all driving tasks in almost all specified conditions, without requiring attention from the driver.

Level 4, which is almost full autonomy of a vehicle, is characterized by the vehicle’s ability to override the human agent in relation to specific functions, and in a number of specific cases. At level 4, the human is no longer supposed to be a driver, because the vehicle is prepared for all situations: thus, the human goes from being a driver to being a mere passenger. In these cases, the system takes care of all functions, autonomously, and is responsible for maneuvers, not even requiring the driver to be present. However, it is always the driver who decides to activate or deactivate autonomous driving mode.

Example: *valet parking*, where the vehicle finds a space and parks on its own, and then comes back to collect the driver.

This level of autonomy is only to be found in the European system (though it has no normative framework). It consists of a system with the capacity for full autonomous driving, all of the time, where the human does not intervene at any time, except to set the destination and allow themselves to be transported, and indicate their preferences. Thus, the vehicle acts as a smart robot.

#### **Level 5 – full autonomous driving**

The vehicle is designed to perform, unaided, all critical safety functions, over the entire journey (subject to the usage restrictions mentioned at the start of this chapter). The driver inputs a destination or navigation instructions, but is not required to be available to take over control of the vehicle. Thus, the driver may leave their post, and the vehicle is capable of traveling even without occupants.

**Driver** There is no longer a need for a driver to take the wheel (if indeed there is a wheel in the vehicle), and anyone can be a passenger.

Level-5 systems never have need of a driver. The vehicle genuinely drives itself, in all conditions, and is capable of reacting in the same way as a human driver would (or better). Therefore, the control components such as the steering wheel and pedals are no longer needed.

**Vehicle** The vehicle is in charge of driving and can operate in all environments (defined use cases), without human help.

Autonomy level 5 is distinguished from level 4 by the idea of “machine certainty”, whereby the system is permitted not to obey a human order if the instruction is deemed abnormal, rash, or dangerous, in which case the machine will need to take an initiative based on the measurements of its sensors. In a number of cases, the vehicle systems can carry out a maneuver that the driver did not request, and can even refuse to perform an operation that would endanger either the vehicle or its passengers (for example: opening the door whilst driving on the highway).

For example, the vehicle drives itself, even without a steering wheel, pedals or other controls used by humans (e.g. indicators). The rollout of this level of autonomy begins with fleets of “carpooling” vehicles, in restricted sectors. Driverless vehicles make the carpooling model more financially viable and more attractive, because they eliminate the most significant cost in carpooling fleets: the driver. In addition, the initial rollout of carpooling fleets will offer two further important benefits:

- When first used, they will include a qualified operator in the driving seat, allowing consumers to gain initial experience with the technology, with the assurance that a qualified operator is monitoring the situation;
- The ability to safely generate real-world performance data. Once a sufficient quantity of data has been generated, then the legislature should approve the wider use of the vehicles.

The transition between autonomy “somewhere” and autonomy “everywhere” should ultimately be achievable at the flick of a switch or the touch of a button, because the underlying maps will be constantly updated, everywhere, rather than only in confined areas that are geolocated and geofenced (see Figure 1.10).

We have now seen the lists of “official” titles for the levels of “autonomy” to which we refer in this book. Unfortunately, the press, the audiovisual media, and marketing services often use language that is somewhat different and imprecise, opening the door to significant confusion.

### **The problem with these classifications**

There is, undeniably, a major problem in these classifications. Often, in the above paragraphs, we see the use of little phrases such as “use cases” or “in certain conditions...” that, unfortunately, are incompletely (if at all) defined explicitly, leaving room for a great deal of fuzzy interpretation, on a technical, legal, and commercial level. When the day comes that there is a “truly totally autonomous vehicle, which can drive anywhere, in all countries, all road conditions, free roads, open roads,



**Figure 1.10** A typical example of a level-5 vehicle (the NAVYA shuttle).

roads with heavy traffic... so with absolutely no restrictions,” it will be a true level-5 vehicle, but that day is still a very long way off, though certain people would imply that it is near.

### **Other terminology**

Commercially, there are almost as many names for these technologies as there are different models (“genuinely” autonomous vehicles, semi-autonomous vehicles, automated vehicles, robot taxis, etc.). Often, the marketing departments of automakers and other technological giants deliberately maintain a degree of fuzz as to the true capabilities of vehicles they call “autonomous”. The official classification into six categories by the OICA-SAE International can be used to roughly define what human drivers and/or autonomous systems can (and cannot) do. On the basis of these categories and their limitations, certain automakers introduce wordplay into their communications. Indeed, there are other names that lend themselves well to marketing/commercial activities, and it is highly likely that these terms will enjoy a certain success in the media. For example:

- Eyes on/eyes off;
- Hands on/hands off;
- Hands off/eyes off;
- Mind on/mind off;
- Autopilot; etc.

“Hands off/eyes off” technology corresponds, approximately, to autonomous driving without human supervision. During periods when control is delegated to the automated system, drivers no longer need to keep their eyes on the road or their hands upon the wheel: the driving is given over entirely to the vehicle. This function is envisaged for the most “boring” or “monotonous” types of driving (for example, in traffic jams), and only on authorized roads. In the press, the expression “hands off/eyes off” recurs frequently, and often with the addition of “mind off.” No longer is it a case solely of “muscular disengagement, but mental disengagement too.” However, the use cases are not defined.












OICA SAE (J3016)	0	1	2	3	4	5
	No automation	Driver assistance	Partial automation	Conditional automation	High automation	Full automation
VDA	Driver only	Assisted	Partially automated	Highly automated	Fully automated	Driverless
Eyes						
Hands						
Mind						

Figure 1.11 Concordance between OICA-SAE levels and eyes/hands/mind on and off.

Thus, when autonomous driving is activated, numerous devices/sensors are responsible for watching the road and monitoring 360° around the vehicle. Certain vehicles include the following:

- Three lidars, or long-range laser scanners (two in the front, one in the rear);
- One long-range forward-facing radar;
- Four medium-range angular radars;
- Three digital cameras with different focal lengths (short/medium/long range) at the top of the windshield;
- Four short-range digital cameras with 180° vision, beneath the rear-view mirrors and in the license plates;
- A strip of 20 short-range ultrasound (sonar) sensors.

The dataset collected by these sensors is analyzed by multiple onboard software “brains,” which decide how the vehicle should behave. The driver has no need to look at the road or keep hold of the steering wheel: the vehicle is in “hands off/eyes off” mode. The devices controlling the vehicle’s path (steering and brakes), and the associated electronic architecture, are duplicated, in order to obtain the level of safety required for hands off/eyes off autonomous driving. Thus, if there is a fault, the vehicle remains in control of its trajectory, and is capable of achieving safety automatically, in the event that the driver does not take over the controls once more. Figure 1.11 summarizes and illustrates these situations.

Finally, in years to come, in the use of vehicles, we shall see the rise of auto-companies in the areas of “ridesharing” and “shared ownership,” where people and organizations share ownership of a vehicle that will take them wherever they want to go. This latter concept is even more transformative than carpooling, because it opens up completely new business models for transport.

**In summary**

Figure 1.12 offers an overview of this chapter.

Having set out the official backdrop, we are finally ready to launch an in-depth discussion.

## 1.3 A brief history of the autonomous vehicle

Before diving in to look at the major issues, here is a brief history of the discipline.

The history of autonomous vehicles goes back a long way, before the time of Jules Verne. However, it was in the 1990s that designers began to think seriously about how to achieve such automation, notably devising industrial ADASs that would, gradually, lead to the design of autonomous vehicles.

### 1.3.1 Autonomous vehicles

The rollout of autonomous vehicles has produced two main models:

- That of a new type of transport, with totally autonomous driving that is easier, more fluid, effortless, auto-adaptive, and so on;
- That of a new type of management of total safety and security (physical, cyber-X, etc.) in our normal, daily environment, in all circumstances.

In addition, it will no longer be necessary to own your own vehicle, or even be able to drive. These two points will have an influence on the vehicles as a whole, and also on public transport and freight.

On the technical aspect, an autonomous vehicle is an extremely complex system. Broadly speaking, it comprises:

- Huge numbers of onboard sensors;
- A great deal of very fast communication technology;
- Onboard, complex “artificial intelligence” systems that are highly sophisticated, notably capable of supporting and deciding on the path the vehicle should take, steering and monitoring the vehicle’s different control systems (steering, brakes, accelerator, suspension, etc.) with verifications and redundancy.

In addition, the vehicle must be able to conform to a great many use cases and demonstrate reliability in the face of an infinite number of critical events that it may encounter:

- In ideal conditions, in sunshine, on a clear road with a good surface, this challenge should, in theory, be reasonably easy to meet;
- On the other hand, in rain, snow or on a bad road, road markings are unclear, and the likelihood of encountering an obstacle is high. In this situation, the only way forward is to limit speed or revert to manual driving.

Level	
0	The driver has total control over the vehicle's main functions (steering, acceleration, and braking).
1	<p>The system is able to take charge of either the longitudinal dimension (speed and distance from the vehicle in front) or the lateral dimension of the vehicle's motion (following the white lines), but not both at the same time. It assists the driver, but the human driver is still in charge of driving.</p> <p><b>Example:</b> cruise control, lane departure warning (radar), automatic emergency braking, and collision warning system.</p>
2	<p>In certain situations, the driver can delegate both longitudinal <i>and</i> lateral control of the vehicle to the system, but is still required to supervise: they must keep an eye on the system at all times, monitor the vehicle's environment, and take back total control if necessary.</p> <p><b>Example:</b> traffic jam assistance (adaptive cruise control) or parking assist.</p>
3	<p>The vehicle system, rather than the human driver, is responsible for monitoring the surroundings. However, the driver must remain alert to road conditions, and must be able to immediately resume control if necessary (which implies that the machine must allow them enough time to respond). In this context, driving can be given over entirely to the machine, but only in predefined conditions: on the highway, for example. The system must be capable of recognizing its own limitations – i.e. recognizing when the traffic conditions are no longer compatible with its operation. In this situation, the vehicle asks the driver to take over control by means of a visual and auditory alert, raised several seconds in advance.</p> <p><b>Example:</b> highway driving, automatic parking, platooning.</p>
4	<p>No assistance is needed on the part of the driver. They may turn to whatever occupies them, without worrying about the road. However, total autonomy is limited to a specific geographic zone, such as a highway or a parking lot with which the vehicle is compatible. It is also limited to specific weather conditions and visibility (with no fog or snow, or only during the daytime, for example, which is also the case with the above levels of autonomy).</p> <p>When these criteria are fulfilled, the driver is no longer responsible for driving: that responsibility is turned over entirely to the system. However, the human driver is still obliged to take over driving when the vehicle leaves the automated driving zone. Unlike with level 3, if the driver does not respond, the vehicle must be able to react for itself – e.g. by pulling over into a safe position.</p> <p><b>Example:</b> An end to the boredom of long journeys or sitting in traffic jams on the highway.</p>
5	<p>A fully autonomous, driverless vehicle. Restricted to known and limited journeys (e.g. shuttle buses, etc.).</p> <p><b>Example:</b> In 2016, Mobileye announced a collaboration with BMW and Intel to produce a fully autonomous, level-5 vehicle by 2021. As things stand in mid-2021, we shall still have to wait and see!</p>

**Figure 1.12** Overview of levels of vehicle autonomy.

Such demonstrable reliability is all the more important when we consider that, should an accident occur, it is/becomes highly complex to define where the responsibility lies. Though it is widely accepted that autonomous vehicles will be equipped with black boxes (acting as spies, which certain players vociferously decry), it may not be possible to define the reasons for an incorrect trajectory simply by analyzing the data. To demonstrate the performances of these vehicles, it is necessary to conduct numerous tests in environments that are as closely representative of the various use cases as possible. Also, there is no doubt that we shall become accustomed to sharing the road with these vehicles which, it is said, will or should be safer than conventional vehicles.

Beyond the pure technical detail and technology discussed above, the development of these highly complex systems is hampered by a number of technical and non-technical barriers, which we shall discuss at length in Chapter 2, entitled “Aspects relating to autonomous and connected vehicles,” and examine:

- The definition of a legal framework and liability in the event of an accident;
- The adaptation of the driving regulations;
- The development of appropriate standards;
- The adaptation of infrastructures to support these new types of vehicles;
- The availability of onboard intelligence technologies, their performance and cost;
- Operational safety, cybersecurity, and guarding against cyberattacks;
- The acceptability of new uses, etc.

### 1.3.2 Types of propulsion and autonomous vehicles

In principle, there is no direct relation between the terms “propulsion type” and “autonomy.” The vehicle may have an internal combustion engine (running on gasoline, diesel, LPG, or similar fuels), be purely electric or hybrid (thermal–electric hybrid, electric fuel cell), etc. It should be of no importance – beyond a few minor adjustments. Vehicle autonomy and connectivity are new functions that are added to the existing vehicle architecture. Inevitably, they consume energy (a few tens or a few hundred watts). Thus, sooner or later, they will impact the vehicle’s range – that is, the distance it is able to travel on a specific amount of fuel or energy (see Section 2.14). This is a parameter that needs to be taken into account, because it is clear that we are on the cusp of a total transformation in the auto industry. The French Government has announced its intention, by 2050, to transition from combustion engines to electric vehicles, which echoes the transition to electric trams around 1900. In short, the world has seen this type of transition before. All the technical and economic factors that we see today in the early twenty-first century are similar to those that existed in the early twentieth century: there are numerous small automakers, numerous types of propulsion, distribution networks for new fuels, and types of energy are – quite literally – in the pipeline! and so on.

## 1.4 Impact of the COVID-19 pandemic

In early 2020, the planet was hit full force by a pandemic, caused by the coronavirus known as COVID-19, and its variants. We could not, in good faith, fail to include a note about the effects the pandemic has had on the autonomous vehicle industry. The financial repercussions of the pandemic will be grave, and sometimes extremely painful for certain automakers, OEMs, and partners (it is likely that the effects will be felt over an extended period of time).

For mainly economic and budgetary reasons, the pandemic had the effect of, for example, greatly accelerating the transitions from combustion engines to hybrid and/or electric engines, to cope with technical demands, leading to immediate (short-term) financial gains.

With respect to the advent of autonomous vehicles, the crisis:

- Lent momentum to projects to develop “robot” vehicles (autonomous mini-trucks to make deliveries, robot taxis, etc.)
- Delayed/postponed certain long-term projects to develop higher-level or top-of-the-range vehicles, which were deemed to be less immediately and less desperately needed. Nonetheless, only part of the work on these projects has been put back until 2022.

These general comments should have no bearing whatsoever on this book, because, as stated in the preface, its content reaches a long way into the future, spanning from 2020 to 2035. Certainly, early on, we should expect a slight delay early on, in the phase of work projected for 2021–2025. However, in our view, there should be little, if any, impact on the subsequent stages in the project. Broadly speaking, the estimated time of arrival of autonomous vehicles that are truly capable of driving on completely open roads, worldwide, ought to be unaffected.