White Paper on Inclusive Autonomous Vehicles

Capgemini FUNDACIÓN

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INCLUSIVE DOCUMENT

01 Introduction

Following the advent of low-emission cars and new mobility solutions, **autonomous vehicles** represent one of the most disruptive technologies poised to revolutionise 21st-century transportation. It is an emerging technology with an ever-growing ecosystem of companies, car manufacturers and public regulatory bodies that are currently exploring various solutions with endless potential.

However, implementing and integrating autonomous vehicles come with several challenges that go beyond mere technology, as this technological advancement holds the potential for social progress and valuable opportunities for broader segments of the population, including the most vulnerable groups, to benefit from them in daily life.

This White Paper has been prepared in collaboration with a reference group of sector stakeholders to outline the steps for developing this new form of mobility, which must be inclusive of all individuals, not just regular vehicle users or those familiar with new technologies but everyone, regardless of their abilities. Individuals who find driving conventional cars challenging or those who might not even have the opportunity to do so with autonomy are also included. This means considering the needs of all individuals from the outset, focusing on the most vulnerable groups in society, such as those at risk of social exclusion, older people and people with disabilities. And, of course, also all those at risk of suffering the digital divide with the roll-out of this technology, as there is a potential risk that some might not adapt or might reject it due to fear of using it. We stress that accessible design is a more comfortable and functional design for everyone.

Through this White Paper, we aim to explore key issues such as the acceptance of technology, which can be enhanced by design and implementation strategies that prioritise efficiency and user-friendliness with an inclusive design, the interaction between autonomous vehicles and conventional vehicles, as well as the social impact of this technology.

In short, this White Paper **aims to establish the groundwork for strategically fostering an inclusive, sustainable and equitable development of autonomous vehicles,** ensuring this technology benefits society at large, guaranteeing the future of mobility, industry and all the stakeholders involved in the deployment of autonomous vehicles. This approach is the only way to build a future of sustainable, safe and accessible mobility for everyone.

We would like to extend our gratitude to all the professionals, community organisations, companies, associations and public administration bodies for their reflections and contributions, which have made this White Paper possible. Special thanks to the Spanish Red Cross, Fundación MAPFRE and Fundación ONCE, who have accompanied us throughout this exciting journey.

Luis Abad

President of Fundación Capgemini

02 What is an autonomous vehicle?

An autonomous vehicle is a vehicle capable of driving without human intervention.

Therefore, when we speak of an autonomous vehicle, we are referring to one that can **sense its surroundings, process the information it gathers** to understand what is happening around it and **respond by controlling its systems**—such as the steering, accelerator, and brakes—to execute the travel task it has been assigned.

Today, a variety of technologies known by their acronyms[1] — BSD, FCW, EBA and ACC— have been integrated into vehicles as part of advanced driving assistance systems, also known as ADAS. These systems are designed to enhance both the safety and the driving experience of modern vehicles and are no longer exclusive to high-end models. These advanced technologies are already being included across all vehicle ranges. In Europe, the European Union enacted Regulation 2019/2144[2], which mandates that manufacturers equip all vehicles with several driving assistance systems that use these technologies.

ADAS technologies are the cornerstones for the development of autonomous vehicles. The advancement of these active safety systems, equipped with sensors, cameras and software that interpret data and make safe driving decisions, allows a vehicle to operate autonomously without human intervention.

Considering that these advanced systems originate from the need to enhance traffic safety, their optimisation is geared towards autonomous driving. Therefore, the successful development of autonomous driving systems could significantly reduce the risk of accidents by eliminating typically human factors such as inattention or lack of concentration.

1 These terms are explained in the Glossary of Therms.
2 EUR-Lex (europa.eu), Article 6 of REGULATION (EU) 2019/2144.

The level of autonomy in vehicles is gradual. The Society of Automotive Engineers (SAE)[3], an international professional organisation for the automotive industry, has established a classification within the technical standard SAE J3016[4]. This classification outlines six levels of vehicle automation, ranging from no automation at all (Level 0) to full automation (Level 5). This standard has been widely adopted by the industry to categorise the level of autonomy in their vehicles.

Fig. 1

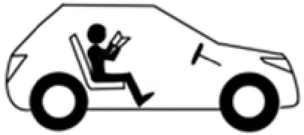
Levels of autonomy[4]

LEVEL 0
100% manually controlled vehicle

LEVEL 1
Vehicle with driving assists

LEVEL 2
Partially automated vehicle. Driving is required for major manoeuvres and attention to traffic signals

LEVEL 3
Semi-automated vehicle. In situations where the vehicle cannot be resolved, personal driving is required



LEVEL 4
Vehicle moving through specific areas without human intervention

LEVEL 5
Fully automated. Vehicle that does not require human intervention and has no controls

3 Society of Automotive Engineers, Official Web Page
4 Society of Automotive Engineers, Levels of driving automation

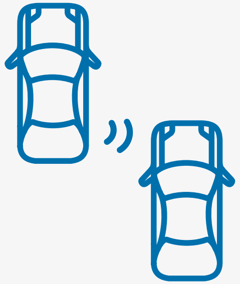
LEVEL 0

100% manually controlled vehicle

A vehicle with no automation whatsoever. The driver is responsible for all driving tasks. This level includes vehicles that may have driving assistance features, such as blind spot detectors in the rear-view mirrors, but these features do not control the vehicle's lateral or longitudinal movement.

Fig. 2

Blind spot detector



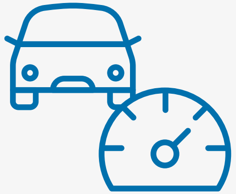
LEVEL 1

Driver assistance

Vehicles at this level are equipped with systems that can take over either the lateral or longitudinal control of the vehicle, but not both simultaneously. Examples include **Adaptive Cruise Control (ACC)**, which maintains a set distance from the vehicle ahead, thus controlling longitudinal movement and a parking assistance system, where the system controls the steering while the driver manages the pedals.

Fig. 3

Adaptive cruise control



LEVEL 2

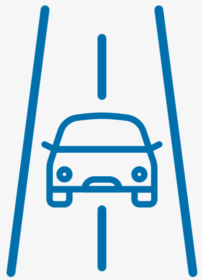
Partial driving automation

Vehicles at this level are equipped with driving assistance systems that can control both lateral and longitudinal movement simultaneously, but they operate under limited conditions and do not have decision-making capabilities in response to unexpected situations, such as detecting unforeseen obstacles. The driver is, therefore, responsible for driving.

An example of Level 2 automation is the combined use of **Adaptive Cruise Control (ACC) and Lane Keeping Assistance (LKA),** which manage the speed and lane position.

Fig. 4

Lane Keeping Assistant



LEVEL 3

Conditional driving automation

From this level onwards, the driver can choose which system controls the driving functions, though within certain limitations. This means that the vehicle does not require constant supervision but does require the driver's attention and intervention when the system is unable to handle a risky situation on its own. The system can be deactivated upon the driver's request or automatically when it reaches the limits of its operational capabilities, at which point it will issue an early warning for the driver to resume control. Level 3 autonomy allows drivers to remove their hands from the steering wheel and feet from the pedals under specific conditions.

An example of this level is **Traffic Jam Assistance (TJA),** which enables autonomous driving in congested traffic situations.

LEVEL 4

High driving automation

At Level 4, the automated driving system operates without the expectation of human intervention, except where it encounters scenarios beyond its operational scope—such as when a traffic jam clears, and normal traffic conditions resume. The system is capable of executing manoeuvres to minimise driving risks in the safest manner possible.

While the driver has the option to activate or deactivate the system, a key distinction from Level 3 is that the system may delay disengagement if it deems it necessary. Compared to Level 3, where the system requests immediate driver intervention, Level 4 provides a longer lead time for such requests. If the driver fails to take control when needed, the vehicle is designed to come to a safe stop autonomously.

LEVEL 5

Complete driving automation

At Level 5, the vehicle achieves full autonomy in all types of geographic locations and under all conditions. There is no need for a driver, which means vehicles can be designed without a steering wheel or pedals.

The state of the art in autonomous vehicles has achieved Level 3 autonomy. At this stage, the vehicle can perform most driving tasks autonomously, but it still requires human intervention in emergencies or under certain specific circumstances.

However, some Level 4 functionalities are already available, such as the ability to stop the vehicle safely if the driver removes their hands from the steering wheel for a short period and fails to re-engage. This capability allows the vehicle to interpret potential emergencies, such as the driver losing consciousness, and bring the vehicle to a safe stop.

The deployment of autonomous driving on public roads also involves adapting national legislation and regulations across different countries to adequately regulate and address critical issues such as safety, liability and privacy.

03 Background

The concept of the autonomous vehicle, as we know it today, originated in 1987 with the *Prometheus* Project[5]. Led by Dr Ernst Dickmanns, a professor at the Bundeswehr University Munich, in collaboration with Mercedes-Benz, this initiative was pioneering and set the groundwork for future research and development in autonomous driving.

A van equipped with cameras was used during the initial phase of the project. The team had to address the challenge of the vehicle interpreting the environment in real time—a challenge that remains pertinent today. They succeeded in developing a model that significantly simplified the tasks of an autonomous vehicle. It was capable of estimating the position and speed of other objects in real time without having to store previous data. After the initial phase, the system was integrated into a Mercedes S-Class saloon. This vehicle is often considered the first autonomous vehicle and was instrumental in laying the groundwork for what we now call Advanced Driver Assistance Systems (ADAS).

The project reached a significant milestone in 1995[6], completing a 1,758 km round trip from Munich, Germany, to Copenhagen, Denmark, with up to 158 km driven with no human intervention. During this journey, the vehicle reached speeds exceeding 175 km/h and performed overtaking manoeuvres in real traffic, all under the supervision of a human driver.

But this was not the only project at that time. Another key project in the history of the development of autonomous driving unfolded in the United States in the 1980s. Named NavLab (Navigation Laboratory)[7], this project involved a series of autonomous vehicles developed by the Robotics Institute at Carnegie Mellon University in Pittsburgh, Pennsylvania, in collaboration with the DARPA agency. Its first prototype, NavLab 1, built in 1986 from a Chevrolet van, was equipped with a computer as large as a refrigerator and a portable 5 kW generator. Initially, the van encountered software limitations that hindered its full operational capabilities. By the late 1980s, these issues were resolved, allowing NavLab 1 to reach a top speed of 32 km/h.

In recent years, autonomous vehicle research has transitioned from academic settings to the commercial realm thanks to current technological advancements. The rapid development of computing and software technologies is accelerating progress in autonomous driving, with numerous companies actively shaping the future of mobility. Prominent examples include *Waymo,* part of the *Alphabet* group in the United States, and *Apollo Go,* from the *Baidu* group in China. Both companies are currently deploying their autonomous taxi fleets in cities.

What once seemed like science fiction is becoming a tangible reality.

5 Wikipedia, Eureka Prometheus Project.
6 ADAS & Autonomous Vehicle International, The Prometheus project: The story behind one of AV's greatest developments.
7 Carnegie Mellon University, Navlab: The Carnegie Mellon University Navigation Laboratory.

Trends

The United Nations estimates that by 2050, the global population will approach 10 billion, with nearly 7 out of every 10 individuals residing in urban areas[8]. Reports from organisations like the International Transport Forum (ITF[9]) also forecast that demand for passenger and freight transport will continue to rise across all regions of the world in the coming decades, regardless of the scenario. For instance, urban transport demand is anticipated to surge by 74% relative to 2019 levels. The combination of these factors will inevitably lead to more vehicles and road transport infrastructure. This growth could also lead to an increase in road accidents, where human factors such as distractions, fatigue and impaired driving due to alcohol or other substances play a significant role. These factors, coupled with increasing concerns about pollution from road transport, create a compelling case for exploring new, safer and more sustainable forms of mobility. And autonomous driving plays a key role in these new plans because of the many benefits it offers, as detailed below:

- Reduction of accidents caused by human error
- More efficient use of roads, reducing traffic congestion
- Environmental improvement by optimising driving and fuel consumption
- Increased user comfort and convenience
- Greater accessibility to transport for people with reduced mobility.

In the coming years, a gradual adoption of autonomous vehicles is anticipated on roads worldwide. Continued advances in artificial intelligence and sensor technology are also expected to enhance the safety and efficiency of these vehicles.

Some key improvements will be seen in automation technology itself, enabling autonomous vehicles to assume more driving functions without any human intervention whatsoever. As a technology that offers the most benefits for autonomous vehicles, artificial intelligence enables these systems to make real-time decisions and adapt dynamically to changes in the environment.

70%

of the world's population by 2050 will live in urban areas, according to the United Nations.

8 United Nations, The Sustainable Development Goals Report 2022.
9 International Transport Forum, ITF Transport Outlook 2023.

The evolution of sensor technology used in autonomous vehicles—including cameras, radar, GPS, ultrasonic sensors and LIDAR—is expected to see significant improvements in accuracy and range, significantly improving the vehicles' ability to detect obstacles and minimising abrupt driving manoeuvres. Vehicle-to-vehicle communication systems are also evolving, which will be key to coordinating movements to avoid collisions and create more efficient traffic flows.

Besides technological developments, efforts are underway to ensure that government regulations and policies are adapted to allow autonomous vehicles to circulate and coexist with the rest of the traffic environment.

Many challenges that society will face in the coming years involve addressing security vulnerabilities associated with cyber-attacks on new hyper-connected technologies. Unauthorised access to autonomous vehicles could allow attackers to take control, potentially leading to serious accidents or even using these vehicles as instruments in terrorist attacks. Furthermore, there is a risk that autonomous vehicles could be remotely paralysed, potentially disrupting their operation and endangering the safety of both occupants and other road users. For autonomous vehicles to gain widespread acceptance, it is crucial to boost public confidence in relinquishing complete control of driving and to enhance the reliability of the systems that operate these vehicles.

The transition from purely manual to fully autonomous driving is expected to be gradual and slow. During this period, autonomous vehicles will need to coexist in mixed traffic, sharing roads with a diverse array of road users and facing a variety of situations, which presents significant deployment challenges.

Current projects

As noted at the start of this chapter, the expansion in computing and artificial intelligence capabilities is propelling numerous entrepreneurial projects, which are beginning to lay the groundwork for the autonomous driving services of the future.

Below are some of the best-known projects:

Waymo[10]

Waymo is developing its fleet of autonomous vehicles across various cities, offering autonomous taxi services and focusing on technological advancements. The company is also collaborating with other passenger transport service providers to lobby for the creation and enforcement of relevant laws.

Tesla[11]

Tesla is advancing the integration of autonomous driving systems into its vehicles, enhancing their capabilities.

Baidu[12]

Baidu is developing its Apollo autonomous driving platform, which is used in various applications, including autonomous taxis and public transport systems.

10 Waymo, Official Web Page.
11 Tesla, Official Web Page.
12 Baidu, Official Web Page.

Cruise[13]

Cruise is focused on developing autonomous vehicles specifically designed for urban environments. The company is currently testing these vehicles in real traffic conditions within cities. They aim to create an affordable autonomous vehicle that is accessible to everyone using a compact car platform.

Aurora[14]

Aurora is focused on developing technologies for autonomous vehicles, including applications in freight transport, and is currently collaborating with several automotive manufacturers.

Nuro[15]

Nuro specialises in autonomous delivery vehicles and is working to provide delivery services using compact vehicles.

13 Cruise, Official Web Page.
14 Aurora, Official Web Page.
15 Nuro, Official Web Page.

In parallel, there are numerous test beds and academic collaborations between various universities and research centres dedicated to advancing autonomous vehicle technology.

Spain is contributing to this development through its companies, universities and technology centres. Notable examples are highlighted below.

A recent example of companies working on R&D in this area is **Capgemini's REMOTIS project[16].** The company designed and built an electric, autonomous vehicle with distributed intelligence both onboard and in the cloud. Edge computing technology alongside 5G networks enhances computational capacity and minimises data transmission latency. Moreover, the vehicle serves as an experimental platform for testing various object detection technologies, including MIMO (Multiple Input Multiple Output) radar, which uses multiple antennas to improve detection accuracy; or trying the SADE (Securing Autonomous Driving Function at the Edge) solution to optimise cloud computing resources. This solution ensures advanced cybersecurity, maintaining the reliability of both the software and hardware embedded in the vehicle.

16 Capgemini, REMOTIS – Remote Intelligence System for Automobiles

Fig. 5
Experimental remote driving platform. REMOTIS project by Capgemini Engineering.

REMOTIS Proyect

A notable example in the academic sector is the AUTOPÍA[17], programme, developed by the Centro de Automática y Robótica at Universidad Politécnica de Madrid and the Consejo Superior de Investigaciones Científicas. This project addresses the potential limitations of autonomous driving by implementing a hybrid approach that combines human-machine control and cooperation with other road agents.

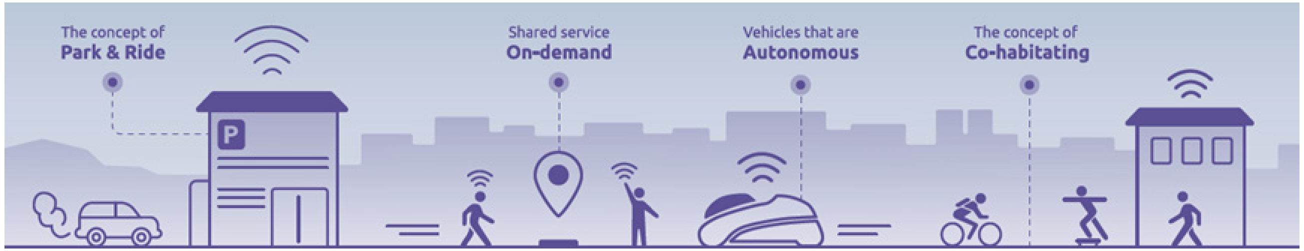
Another significant initiative is from the CTAG Technology Centre[18], which has developed an autonomous shuttle vehicle with Level 4 autonomy capable of operating autonomously in various urban and rural environments. Designed to accommodate up to 12 passengers, it features a motorised ramp to ensure accessibility for individuals with reduced mobility.

As was necessary in the past to accommodate increases in traffic with conventional vehicles, infrastructure must also evolve to support autonomous vehicles. This evolution involves developing connectivity within the infrastructure and equipping it with the capability to interact intelligently with autonomous vehicles. Such developments are still under study and will require adaptation following the establishment of a 'substantial' autonomous vehicle fleet.

17 Autopia, Connected and automated driving. Official Web Page.
18 CTAG, Official Web Page.

Fig. 6

Concepts in the city of the future. Shutlink project[19] by Capgemini Engineering



19 Innovaspain, Shutlink: The citizen as a priority in the new mobility.

It is also crucial to acknowledge that there is still significant work to be done on the ethical and regulatory aspects of autonomous vehicle technology.

As this technology progresses, it becomes imperative to conduct thorough research into its social, economic, and legal impacts and focus on developing appropriate regulations that facilitate the adoption of autonomous vehicles in a way that no one is left behind.

04 Technologies and challenges

Autonomous driving represents one of the most complex engineering and technological challenges the world is currently facing.

. Artificial intelligence, computer vision and connectivity technologies are crucial in replicating the tasks performed by a human driver while ensuring the ride is as safe and accurate as possible.

The process of autonomous driving involves the integration of several tasks, which can be divided into **four stages:** perception, interpretation, performance and correction. First, the vehicle collects environmental data using a variety of sensors. This data is fed into algorithms that interpret the environment and make driving decisions based on the input received. The decisions are executed by electromechanical actuators, which control the mechanisms, adjusting trajectory and speed as directed. Throughout the journey, the vehicle constantly adjusts its movement to maintain safety and stability using feedback algorithms that correct the trajectory and speed of the vehicle to adapt to new conditions.

The next section explores the key characteristics of the technologies integral to each stage of the autonomous driving process:

01. Perception

02. Interpretation

03. Action

04. Correction

01. Perception

At this stage, various types of sensors are used to determine the vehicle's location and detect its surrounding environment. Autonomous vehicles use a broad spectrum of technologies, often in concert, to build the most comprehensive and accurate understanding of the environment possible.

Radar

Radar technology uses radio waves to measure the distance and speed of objects. These radio waves bounce off objects, which determine their position and speed by analysing the frequency shift between the emitted and received signals. This makes radar particularly effective for measuring the speed of other vehicles and detecting obstacles over long distances. However, radar often provides low spatial resolution, which can make it challenging to classify objects precisely using this sensor alone. Despite this limitation, radar is largely unaffected by adverse weather conditions such as rain or fog. Although they are often used for outdoor use, there is ongoing research into using microwave-emitting radar technology to monitor respiratory and heart rates, which may also be used to monitor the physical condition of vehicle occupants.

Ultrasonic sensors

These sensors operate by emitting high-frequency sound waves to measure short distances. Ultrasonic sensors calculate the distance to an object by timing how long it takes for the emitted sound waves to return after reflecting off the object. They are particularly useful for detecting obstacles during low-speed manoeuvres, such as parking, and in tight spaces where there are pillars or walls in close proximity. However, the main limitation is their short detection range.

LIDAR (Laser Imaging Detection and Ranging)

LIDAR sensors measure distances using laser pulses. These sensors emit beams of infrared laser light, which reflect off objects and allow the distance to these objects to be calculated by measuring the time it takes for the light to return. This technology enables creating a 3D map of the environment, allowing for the detection of shapes and obstacles with high precision. LIDAR is particularly effective for object recognition, mapping and navigation in complex urban settings. However, LIDAR sensors have limitations in adverse weather conditions such as rain and fog, requiring supplementation from other sensor types. LIDAR technology is also generally expensive, and the units are often too bulky to integrate into vehicles. The most sophisticated systems can produce 360° images of the environment around the vehicle, as their emitters are motorised to perform a complete sweep around the vehicle.

Cameras

Cameras capture images of the environment and enable visual recognition. They provide detailed visual information that is crucial for identifying traffic signs, lane markings, pedestrians and other road elements. Typically, cameras are used for object classification, lane detection and traffic sign recognition tasks. One of the primary challenges is their sensitivity to varying lighting conditions, both direct sunlight and reduced visibility conditions during night-time. Additionally, cameras can be oriented both outward and inward. Inward-facing cameras can monitor the passengers and detect issues such as passenger distress, fainting or any other issue through gesture and facial recognition algorithms.

GPS

Global Positioning Satellite (GPS) systems determine the location of a vehicle with an accuracy level within metres. They use satellite signals to pinpoint the exact coordinates of the vehicle's position. GPS is primarily used to assist in navigation and in finding predefined routes, but they can also experience reduced accuracy in dense urban environments, tunnels and other areas with low satellite signal coverage, such as underground spaces.

IMU

Inertial Measurement Units (IMUs) measure both longitudinal and angular accelerations across various axes. Using accelerometers and gyroscopes, IMUs determine the orientation and movement of the vehicle. They assist in vehicle stabilisation, trajectory calculation and navigation, particularly when GPS signals are unavailable. IMUs face the challenge of cumulative measurement drift over time, which can impact their long-term accuracy.

02. Interpretation

After collecting environmental data through various sensors, an autonomous vehicle progresses to the **interpretation phase.** This stage involves processing and analysing the data gathered to fully understand the driving environment and make safe driving decisions. Environmental interpretation depends on the strategies used for sensor data fusion and the application of artificial intelligence algorithms, which help interpret, predict and plan the journey.

For optimal accuracy in interpreting the environment, artificial intelligence must be trained to classify various elements within the driving environment, such as vehicles, traffic signs, pedestrians, cyclists and street furniture, and predict potential movements. For these AI models to be effective and reliable, a comprehensive interpretation of the situation requires substantial training data. While the quantity of training data is crucial, the quality and variety of the data are equally important, and training AI models with limited or biased datasets could introduce significant risks. Inadequate quality data may result in not having sufficient information to handle unexpected situations or pedestrian behaviours. Therefore, it is essential to provide these systems with a broad range of data that covers as many possibilities and scenarios as possible.

A clear example of a risk is the algorithm's inability to recognise individuals in wheelchairs, those using crutches or individuals with skin colours different from those included in the sample database used to train the model.

Next, we explore some of the most critical tasks performed during the interpretation stage of autonomous driving systems.

Data Fusion

Data fusion involves combining information from multiple sensors (LIDAR, cameras, radar, GPS and IMUs) to produce the most accurate representation of the environment. This task is complex due to the combination of different signal reception latencies and the combination of signals used by the communication protocols. Data fusion employs sophisticated algorithms designed to correct potential inconsistencies between data from different sensors, improve overall accuracy and reduce information noise.

Route and movement planning

After interpreting the environment, the system plans the most suitable route to ensure safety, efficiency and comfort throughout the journey. This planning process involves algorithms that analyse current traffic conditions, the positions of obstacles, signage and pedestrians, allowing for real-time adjustments to the vehicle's course. The primary challenge is the system's ability to adapt swiftly to sudden changes, such as the emergence of new vehicles, pedestrians or roadblocks.

Behavioural prediction

Another useful technique is to predict the movements of other road users (vehicles, pedestrians, cyclists) by analysing their past trajectories and movement patterns. Predictive capability is critical for anticipating and mitigating risky situations, such as braking if it looks like a pedestrian intends to cross the road all of a sudden. However, predicting non-standard behaviours poses a significant challenge and requires highly trained prediction models.

SLAM (Mapeo y Localización Simultánea)

A vehicle can map its environment and determine its location within that map in real time, using a combination of GPS, LIDAR and cameras. This capability is useful when navigating unfamiliar areas or regions without pre-existing maps. The primary challenge for SLAM is maintaining accuracy under difficult conditions, such as in highly congested areas or environments with few reference points.

As can be seen, each technology adds a layer of intelligence that allows the vehicle not only to observe its environment but also to understand it and anticipate possible scenarios to make safe, efficient and autonomous decisions.

03. Action

Once the autonomous vehicle has collected and processed environmental data and determined the optimal trajectory and actions, it enters the action phase. This stage focuses on executing the decisions by directly controlling the vehicle's actuators to ensure that movement is both safe and precise.

Actuators control the steering, acceleration, braking and transmission of the vehicle. Steering actuators adjust the angle or rate of rotation of the wheels to manoeuvre in line with the planned trajectory, while acceleration and braking controllers act on the traction and braking systems to regulate speed as necessary. These systems depend on electric motors, servomotors and electronic control systems, which must be accurate and synchronised to prevent jerky movements and guarantee a safe and comfortable driving experience.

Integrated motion control combines the operation of all actuators to ensure smooth coordination during complex manoeuvres, such as automatic parking or obstacle avoidance. A significant challenge in this respect is adapting the vehicle's response to sudden changes in the environment, such as variable terrain conditions or the appearance of unexpected obstacles while maintaining stability and safety at the same time. Perfect synchronisation among all actuators is critical for the vehicle to execute the decisions of the control system accurately.

04. Correction

The correction phase in an autonomous vehicle focuses on constantly adjusting the decisions to ensure it adheres to the intended trajectory and speed in real time. Feedback control systems compare the planned route with the vehicle's actual position and movement by adjusting its steering, acceleration and braking to correct any deviations. These systems operate on algorithms, including PID controllers and predictive mechanisms, which enable rapid and smooth responses to unexpected changes, such as skidding or deviations caused by external factors.

The correction phase includes a dynamic re-evaluation of the environment and predictive behavioural modelling that monitors road conditions and the movements of other vehicles continuously to anticipate potential risky situations and adjust its decisions accordingly. This phase is reinforced by redundancy and safety systems that oversee the status of critical components and activate emergency modes if they detect an anomaly. Correction is, therefore, essential for maintaining vehicle safety and stability in dynamic and complex environments, enhancing the vehicle's ability to respond effectively to unforeseen events.

Autonomous and connected vehicles: challenges and opportunities

Integrating autonomous driving with connected vehicle technologies presents a wide range of opportunities to reshape mobility in the coming years. Among them are remote driving, which allows vehicles to be controlled from a distance, and fleet management services, where companies can oversee the operation of multiple vehicles via connected platforms both in terms of passenger and freight transport. Connectivity will enable more collaborative driving, allow vehicles to communicate with one another to enhance safety, optimise traffic flow and reduce congestion. It also promises significant advancements in user experience (UX) services, which should improve passenger interaction with vehicle systems. Software updates in autonomous vehicles will enable continuous improvements in functionality and the addition of new features without visits to a workshop or upgrades.

Connected vehicles depend on V2X (Vehicle-to-Everything) technology to facilitate communication between vehicles and with other elements in the environment, including other vehicles, traffic lights and pedestrians. This communication is crucial for enhancing road safety and improving energy efficiency. 5G and NB-IoT (Narrowband Internet of Things) will provide the infrastructure needed to support this level of connectivity. The challenge lies in optimising key factors such as bandwidth, transfer speed and latency, which are critical elements for the rapid exchange of data, besides minimising the energy consumption of these networks and enhancing their resilience against cyber-attacks.

Achieving level 5 autonomy demands a substantial increase in computing capacity. Current technologies in levels 1 and 2 vehicles are capable of executing a considerable number of operations per second, but in level 5, it is estimated that systems will need to handle approximately 100 trillion operations per second[20]. To meet these demands, vehicles must be equipped with powerful electronic data processing units that include powerful CPUs and GPUs.

20 EV Design & Manufactoring. Four Megatrends in the Automotive Industry.
MDPI, Data and Energy Impacts of Intelligent Transportation—A Review, by Kaushik Rajashekara and Sharon Koppera.
Samsung, Navigating into the Driverless – from a First-Hand Autonomous Driving Experience to the Technology Behind It.

Over
100BI

floating-point operations per second to reach level 5.

Planning for autonomous vehicles must extend beyond technological capabilities and include decision-making in emergencies. One of the most significant challenges is how vehicle algorithms should respond in situations where every possible decision involves a potential risk to human safety. For instance, when an autonomous vehicle has to choose between avoiding an obstacle, potentially jeopardising the safety of the passenger, or continuing on its path, risking harm to pedestrians. These are complex ethical issues that autonomous systems must be able to resolve within fractions of a second.

In response to these dilemmas presented by autonomous driving, MIT's *Moral Machine*[21] project has emerged as a significant research platform to explore how individuals from various cultural and social backgrounds perceive these moral dilemmas associated with autonomous vehicles. The platform presents situations where the vehicle must decide between two ethically challenging outcomes, such as choosing between saving the life of a pedestrian or that of a passenger. The results from the Moral Machine project reveal that public opinion is markedly divided and influenced by factors such as region, gender and socio-economic background. These cultural differences should be considered when designing decision-making systems in autonomous vehicles to ensure that solutions are globally accepted.

21 Moral Machine Project, Official Web Page.

A paramount challenge –and the reason behind this project– is ensuring these systems adequately understand and address societal diversity, particularly in their interactions with vulnerable groups such as older people, disabled people or those at risk of social exclusion.

The forthcoming chapters will delve deeper into the aspects critical for achieving universal inclusion. Reaching level 5 autonomy does not only depend on technological advancements, such as interpretation accuracy, processing power or real-time decision-making capabilities, it also requires a deep understanding of ethical dilemmas and societal needs, where factors such as accessibility, equity and cultural diversity are essential for the acceptance, integration and long-term success of autonomous vehicles.

05 Autonomous vehicles: inclusive means of transport

For autonomous vehicles to be successfully implemented in the coming years, it is crucial to address a range of needs that would greatly contribute in a transversal, comprehensive and equitable manner.

. If autonomous driving is to be embraced as a universal mobility option, it must ensure accessibility for all individuals, regardless of their physical, cognitive or economic conditions. This means that autonomous mobility solutions must be designed to meet a diverse set of requirements that cater to different populations.

This section examines **how autonomous driving can cater to the needs of specific population groups,** such as older people and people with disabilities. It also explores the development from the perspective of social equity, considering factors such as gender, cultural diversity and affordability. Currently, the provision of transport accessibility for people with disabilities is not extensively developed by private vehicle manufacturers and is often outsourced to third parties, such as coachbuilders. This forces many people to rely on public transport services, which can also be limited, or face high costs to adapt a vehicle to their specific needs.

That is why it is essential to consider the needs and challenges of as many people as possible to ensure that autonomous vehicles are useful and beneficial for all members of society. Technology will play a crucial role in achieving this ambitious goal. While the current pace of development and technological capabilities may not fully reach this objective in the short term, it is imperative that we collectively work to lay the foundations and set a course toward universal accessibility.

The design of autonomous vehicles for people with disabilities, older people and various minorities should be approached as a fundamental quality assurance requirement. By adhering to the principles of 'Design for All', we ensure that interaction, access and use of these vehicles are feasible and comfortable for the entire population.

An autonomous and accessible vehicle guarantees a sustainable service over time that adapts to the evolving needs of individuals throughout their lives. Our needs change from childhood to adulthood and into periods of temporary or permanent disability. These vehicles are designed to cater to scenarios requiring the transport of wheeled items like suitcases, prams or shopping trolleys. An accessible and versatile vehicle ensures sufficient flexibility, making it usable in all situations, regardless of an individual's specific conditions.

To achieve consensus on the critical aspects of integrating autonomous vehicles for all individuals, we have implemented a social innovation working model with a network of stakeholders in three main axes:

» **A survey aimed at professionals from various sectors** to gather first-hand insights into their views and opinions on autonomous driving systems, particularly regarding their impact on people at risk of social exclusion. The survey was completed by 25 specialists, providing essential information and data that helped shape the content of this book and identify themes to create seven workshops for the next phase.

» **7 social innovation workshops** involving over 50 participants from different professional and personal backgrounds, including officials from responsible public administrations, automotive experts, representatives from elderly and disabled communities, and leaders of influential social entities. The workshops aimed to explore and pinpoint the specific needs and challenges of vulnerable groups, placing these insights at the forefront of autonomous vehicle design. Each workshop included two main activities: The first was a brainstorming session, where participants identified the barriers typically preventing them from using vehicle mobility in its various forms. The second activity involved a hypothetical scenario where level 5 autonomous vehicles were available. Participants were asked to imagine how such vehicles could make each stage of a journey easier, including planning for contingencies, to understand how individuals might react to different situations. Each of the seven workshops was organised to address key insights through the lenses of older people, people with disabilities, gender perspectives, technological solutions, individuals suffering the digital divide, cultural diversity and social inequality.

» **Personalised interviews** with key individuals to delve deeper into significant findings from the surveys and workshops to gain further insight into areas such as disability, gender perspective, and social inequality.

Next are the main conclusions from the collective work generated around these 3 lines of work:

Older people

According to the *'World Population Prospects 2022'*[22] study by the United Nations, the population over 65 years of age is growing faster than the population under 65 years of age. It is estimated that by 2050, the percentage of the world's population over 65 will increase from 10% to 16%.

Biologically, ageing results from the accumulation of molecular and cellular damage over time, which leads to a gradual decline in physical and cognitive abilities. A study conducted by Fundación MAPFRE[23] in collaboration with the Hospital de la Santa Creu y Sant Pau in Barcelona highlights that the prevalence of cognitive impairment doubles every five years after the age of 75. This data underscores the importance of paying special attention to the mobility needs of the increasing population over 65 and adapting mobility solutions to their specific conditions to ensure the best possible quality of life.

One of the primary challenges for older adults is their integration into an increasingly digital world. This demographic is at a high risk of vulnerability and must not be excluded from digital advancements. Typically, screen and interface designs do not account for varied ages or cognitive abilities, potentially marginalising those who struggle with complex digital interfaces packed with numerous functions. Integrating technologies that facilitate omnichannel human-machine interactions—such as voice and gesture recognition—can significantly contribute towards more seamless communication and lesser reliance on intricate physical or cognitive interactions. It is also crucial to develop graphical screen designs that are intuitive and straightforward, which are easy to understand and view for everyone.

Autonomous vehicle management applications must be equally accessible and user-friendly. Ideally, these applications should also feature real-time voice assistance capabilities to address queries or resolve incidents.

The preferred communication channel for older adults often involves personalised attention and human interaction. Various sectors have already adjusted their services to maintain personalised benefits, specifically to prevent social exclusion among this demographic. According to the guidelines from the *'Decalogue for the Good Treatment of the Elderly'*[24] developed by the Spanish

22 United Nations, World Population Prospects 2022: Summary of Results.
23 Fundación MAPFRE, The process of driving cessation in older adults.

24 Spanish Society of Geriatrics and Gerontology, Decalogue for the Good Treatment of the Elderly

Se estima que para el año 2050, el porcentaje de la población mundial mayor de 65 años aumentará del

10 al 16%

Society of Geriatrics and Gerontology, real and face-to-face support during the use of new mobility forms could be beneficial to alleviate fears associated with the unknown and build greater confidence to introduce older individuals to autonomous driving technologies.

Another significant challenge to address is the speed at which new technologies are adopted and assimilated. We live in a world of continuous transformation, where technological progress can be overwhelming for many. Older people often have trouble in using the technological resources that are so commonplace today.

The incorporation of new technologies into vehicles marks a significant shift from predominantly mechanical or analogue systems to more automated or digital solutions. Not long ago, vehicles were outfitted with innovations such as automatic air-conditioning, music playback systems, automatic transmissions, steering wheel controls and electric windows, to name a couple of examples. The gradual transition to digital or automatic mechanisms has increased user comfort over time and has provided the opportunity for a learning curve, allowing these technologies to become viewed as ‘everyday’ or ‘normal’. The challenge lies not in accepting new technologies but in learning to use them effectively. Training and a gradual introduction are crucial for helping users overcome the ‘fear of the unknown’ associated with autonomous vehicles, as happened with previous advancements. Moreover, the design of digital interfaces should not focus solely on functionality at the expense of usability. Emphasising user experience (UX) in technology design is essential, and when combined with user training, it becomes a critical success factor in bridging the digital divide.

In addition to the above, there is a need for vehicle design to advance while remaining familiar to users, avoiding drastic changes in usage habits. A primary concern for this segment of the population—and indeed for a broad spectrum of the population—is the assurance of their security. To build and maintain their trust, it is essential to focus on demonstrating the reliability of these vehicles and incorporating sufficient advanced security systems.

Ensuring easy access to and from the vehicle is a fundamental aspect of facilitating universal use, particularly for individuals with mobility limitations.

People with disabilities

According to the World Health Organization[25], 16% of the global population, or approximately 1.3 billion people, live with some form of disability. This prevalence is even higher in highly developed countries, with the US Department of Health reporting that 28.7% of US adults have some form of disability—translating to more than one in four individuals. In Europe, Eurostat indicates that 25-30% of people over 16 live with a disability[26]. Additionally, over 60% of this population is at risk of poverty. The spectrum of disability causes and possibilities is broad, and the limitations experienced by individuals are influenced not only by their physical, sensory, cognitive or mental characteristics but also by the social, physical and cultural environments in which they live. Therefore, the design of autonomous vehicles must prioritise flexibility to adapt to various situations and specific needs and the ability to adjust their functions and services to accommodate the diverse profiles of users who require them. The greater the accessibility of autonomous vehicles from the outset, the broader the benefits for everyone.

25 World Health Organization, 10 facts about disability.
26 European Council, Council of the European Union, Disability in the EU: facts and figures

It is, therefore, **crucial that the perspectives and needs of people with disabilities are heard and integrated from the very beginning of the design and development process for autonomous vehicles.** Employing universal design principles can minimise the number of special adaptations and reduce barriers to usage, which is not solely a challenge for vehicle manufacturers but a call to action for society at large to foster inclusivity in every aspect of daily life.

If autonomous vehicles are regarded as a mobility service, this service must ensure the well-being of its users, prioritising their welfare over monetisation. This approach is especially beneficial for individuals with physical disabilities, many of whom are unable to drive. Autonomous mobility services can offer door-to-door transportation solutions that address the specific needs of these individuals—needs that are often unmet by conventional public transport systems.

When considering autonomous vehicles as a service for individuals with cognitive impairments, there are specific challenges that must be addressed to ensure their safety, accessibility and autonomy. While autonomous vehicles offer the potential for increased independence for these individuals, there is also a concern that they may encounter confusing situations that could jeopardise their safety. These individuals should be able to use autonomous vehicles in a supervised or tutored manner or with additional support to ensure that the technology provides tangible benefits without compromising their well-being. For instance, a person with Autism Spectrum Disorder (ASD) might perceive various visual or auditory stimuli emitted by the vehicle differently, and these reactions must be understood.

As with older people, the manner in which they interact with autonomous vehicles is critical to preventing cognitive overload and enhancing accessibility. The interfaces must be designed to be predictable, simple and enable users to perform tasks without feeling overwhelmed. Incorporating user-friendly tools such as predictive text software, straightforward voice commands, and simple button operations can significantly improve their experience. Employing clear and approachable interaction language is also essential.

The design of the interface and how it interacts with visually impaired travellers is crucial for the success of autonomous vehicles, and therefore, ensuring compliance with and implementing regulations on accessibility for the visually impaired is a priority.

Moreover, the way autonomous vehicles interact with their environment and pedestrians is equally important. Therefore, special consideration must be given to the challenges faced by people with disabilities in urban pedestrian mobility and not create new barriers or exacerbate existing difficulties.

Social equity

The **right to mobility** should be the primary goal of future transportation systems. People value having options in how and when they use transport, which can contribute to enhanced social equity by providing more accessible and affordable alternatives. Efforts should be made to ensure that vehicles are available to everyone, not just those who can afford individual ownership. The rise of shared mobility services has already begun to make transportation more accessible and has the potential to reduce social and economic inequalities. However, the convenience and status associated with individual vehicle ownership continue to hold significant value for many. Therefore, an integrated approach will be crucial for the equitable development of the autonomous vehicle sector.

To address the varied preferences and needs of users, it is crucial to develop business models that incorporate both shared and individual ownership. Flexible and shared services, which allow vehicles to be adapted for uses

16%

of the world's population lives with some form of disability, according to the World Health Organization

60%

of people with disabilities are at risk of poverty, according to Eurostat

like work, leisure and family activities are well valued for the economic benefits they provide. However, private ownership is still appealing because of its perceived status, vehicle availability and personal comfort. For instance, many older individuals place a high value on the safety and familiarity of travelling with family members in their own vehicles.

Shared autonomous driving significantly influences urban mobility by reducing traffic, increasing vehicle availability and eliminating the need for parking. The widespread adoption of autonomous car-sharing services can decrease the necessity for individual vehicle ownership, thereby reducing the total number of vehicles both parked and in circulation. This reduction not only alleviates traffic congestion but also fees up valuable urban space that can be repurposed for pedestrian areas and public activities. Besides, the availability of shared autonomous vehicles, which can be summoned on-demand, eliminates waiting times and enhances the overall efficiency of transportation.

Gender Perspective

The BMW Group's Closinggap[27] study highlights that women's mobility behaviour is catalysing a shift towards more shared, sustainable, and connected transportation options. Women are more inclined towards car sharing and demonstrate a greater environmental awareness and complexity of travel patterns that often result in using mobility apps more often. With the advent of autonomous driving, these trends are expected to intensify, as autonomous solutions are anticipated to further enhance journey planning, efficiency and safety—qualities that align closely with women's expressed mobility needs.

In her book 'Invisible Women'[28], Caroline Criado Perez discusses, among other topics, the significant (both new and old) gender gaps in vehicle safety testing, which has used male anthropometric and biomechanical dummies.

Similarly, Violeta Alcocer, in her book 'Authentic Impostors', provides an overview of the significant efforts and the price women have historically had to pay in the quest for mobility. She recounts the story of Jeanne Baret, who resorted to disguise to join Louis-Antonine de

27 Closingap, Gender gap in transport
28 Caroline Criado Pérez, Invisible Women.

Bougainville's expedition and became the first woman to circumnavigate the globe in 1766, the redesign of horse saddles that allowed women to ride in the same manner as men, the significant role that bicycles played in advancing women's mobility and even the legal restriction in Spain that lasted until 1975, which required women to obtain permission before they could acquire their driver's licences.

In addition to the gaps described by the author, she added findings from the 2022 Valencia Biomechanics Institute Study[29] conducted by Begoña Mateo. Thus, Violeta focuses on some very specific data, such as:

- 64 per cent of pregnant women beyond six months of gestation do not have safe restraints.
- Women are 47% more likely to sustain serious injuries in an accident compared to men under the same circumstances.

These inequalities are too great to be overlooked. We must collaborate to include all stakeholders in the design process of autonomous vehicles. Autonomous vehicles have the potential to equalise users in terms of space usage and driving style, thereby diminishing disparities that currently arise from traditional gender biases. Autonomous vehicles offer all users enhanced autonomy and confidence, fostering a sense of respect. From the perspective of autonomous vehicle technology, there is no distinction based on gender. However, there remains a pressing need for societal education and awareness to promote an equitable approach.

29 Valencia Biomechanics Institute, Official Web Page.

Cultural diversity

Opinions and attitudes toward autonomous vehicles are influenced by various factors, including age, education level and cultural background. Studies have shown that younger individuals and those with higher education levels tend to be more willing to embrace these technologies. However, the effects of cultural diversity and geographic origin on perceptions of autonomous vehicles are not as well understood.

Preferences for autonomous vehicles, whether shared or private, vary significantly across different cultural and geographical contexts. Sociologists and anthropologists often study the relationship with power, levels of individualism and discomfort in the face of uncertainty, which play crucial roles in shaping these perceptions.

64%

of pregnant women who are more than six months pregnant do not have safe restraint devices, according to the Valencia Biomechanics Institute Study

For example, in societies where hierarchy and collectivism are highly valued and respected, such as in some Asian countries, the shared use of autonomous vehicles may be more popular. Conversely, in more individualistic cultures, people are more likely to prefer owning their own autonomous vehicle, as they value independence and stability.

Autonomous vehicles should provide open access to meet essential mobility needs, such as medium-distance travel for accessing medical services or educational facilities. The adoption of autonomous vehicles must be gradual and tailored to the specific circumstances of each region, and priority should be given to addressing more critical needs, such as ensuring access to food, education, health services, public safety and conflict resolution. The introduction of autonomous vehicles should remain optional, considering cultural, religious and economic factors to avoid potential issues stemming from forced adoption.

The following is a compilation of key aspects of the universal integration of autonomous driving:

Languages and signage

Autonomous vehicle systems must accurately interpret traffic signs and offer multilingual support to accommodate the diverse linguistic backgrounds of users worldwide.

Human-machine interaction

The user interface should be intuitive and accessible to people with varying levels of technological proficiency and cultural preferences.

Integration with existing infrastructures

The implementation of autonomous vehicles should consider existing transportation infrastructures and how these new systems can integrate seamlessly, respecting the specific needs of different regions.

Ethical considerations

The decision-making algorithms, especially in critical situations, must be transparent and reflect the ethical norms and values of different cultural groups.

Environmental impact

The introduction of autonomous vehicles should be assessed for its environmental implications, ensuring alignment with the sustainability practices of different cultures.

Education and awareness-raising

Educating the public about the capabilities and limitations of autonomous vehicles and promoting a culturally sensitive understanding of this technology is essential.

Privacy and data security

Privacy and data security concerns can differ significantly across cultures. Therefore, autonomous vehicles must be deployed in adherence to local privacy expectations and regulatory requirements.

By addressing these critical elements, we can facilitate a smoother transition towards the adoption of autonomous vehicles, ensuring that the process respects cultural diversity, inclusion and equity.

Affordability

For autonomous vehicles to be well and truly accessible to everyone, they must not remain a luxury available only to those with substantial financial resources. Manufacturers are challenged with the task of reducing production costs without compromising on quality, ensuring decent working conditions and adhering to environmental standards while maintaining profitability as businesses.

Manufacturers should be encouraged to embrace business models that prioritise accessibility and inclusion, which could involve developing more affordable versions of autonomous vehicles, implementing car-sharing options or creating cost-effective service packages that combine transport and maintenance.

Society's perception of transportation and car ownership is shifting significantly with the rise of car sharing. If 10 people share a vehicle, the costs associated with its use will consequently be reduced to one-tenth, and its carbon footprint from operations will also be drastically decreased. Manufacturers will have to shift their business models away from selling vehicles to individual consumers and offer their fleets to cities and organisations as a service to society as a new form of public transport, potentially through concessions or public tenders.

From a business perspective, autonomous driving represents a significant opportunity to tap into a large and underserved market segment. A notable example is the visually impaired population, both partial and complete, which totals approximately 30 million individuals in Europe. These individuals are currently unable to drive due to their limited vision, highlighting a clear opportunity for their inclusion in the development of autonomous vehicles. Some aspects of this path will develop naturally as the demand for autonomous vehicles rises, alongside the growing confidence of society in them and their ability to be mass-produced.

Converting a car with wide accessibility is a complex task. The investment required to accommodate a percentage of the population with specific disabilities is not always cost-effective. On one hand, it would be necessary to advance policies that mandate the incorporation of certain functionalities or features in vehicles. This approach is similar to past developments like the ISOFIX system, the universal child seat anchorage system. The UNECE[30] is playing a significant role in developing norms and standards for greater inclusiveness.

The automotive industry needs to take the initiative in incorporating functionalities or features that

30 United Nations Economic Commission for Europe (UNECE), Official Web Page.

support vulnerable individuals, rather than leaving the responsibility solely to coachbuilders, who are tasked with modifying vehicles for specific needs. To streamline this process, establishing a set of standard accessories that could be universally fitted to all vehicles would be beneficial. Manufacturers could then offer these accessories optionally, tailored to the diverse needs of their customers.

Despite the challenges that digitalisation presents for certain sectors of the population, it can greatly assist in providing personalised services to those in need at a competitive cost.

At the same time, there should be public-private partnerships between public administrations and companies. As an incentive, governments could consider offering subsidy programmes to support manufacturers working to integrate technological solutions in autonomous vehicles specifically designed for vulnerable populations.

There is a direct correlation between having a disability and experiencing limited financial resources. Many cities offer financial assistance programmes to facilitate access to public transport for older people and people with disabilities, but they should be maintained and expanded to include autonomous driving services.

06 Integration of autonomous vehicles into the environment

Today, increasingly more urban spaces are being reclaimed for people rather than cars. Urban planning is shifting from car-centric models to those that place the citizen at the centre. As a result, private cars are progressively being excluded from city centres. In this new urban landscape, autonomous vehicles could play a crucial role as they have the potential to navigate these areas in ways that are both environmentally friendly and safe for the environment.

However, the environment extends beyond the physical space around us. As discussed in previous sections, it is crucial to analyse not only the physical and psychological aspects of potential users but also their mobility habits, relevant legislation, types of infrastructure and the management practices of both public and private entities in urban areas and rural and isolated regions, alongside the ongoing evolution of technology. Such a broad analysis will require a change in vehicle design and a significant shift in people’s mindsets.

Interaction with other users, vehicles and infrastructure

One of the primary concerns in the deployment of autonomous vehicles is road safety. The interaction of these vehicles with other elements and individuals in their environment is crucial and can be highly complex, depending on the scenario. Technology must be capable of responding to and adapting to the real-world conditions these vehicles will encounter. Perception systems and AI algorithms are essential for helping the vehicle understand its surroundings, including recognising infrastructure, signs and other vehicles in the same space. While this may seem obvious, it is equally important, though less emphasised, that these systems recognise the diversity of the population for safe and inclusive integration. Significant advancements are still needed in this area. People recognition algorithms must draw from databases that represent a diverse cross-section of the population, encompassing variations in skin colour, age and mobility. Autonomous vehicles should be able to identify whether a person is using a wheelchair, accompanied by a guide dog or using other mobility aids like canes. They must also account for other physical characteristics, such as height or the absence of a limb. Based on these recognitions, the vehicle's interactions should be tailored to ensure it provides user-friendly and accessible experiences.

Willingness to relinquish complete control to autonomous vehicles varies among different user groups. Older individuals are often more sceptical towards these technologies, and a limited understanding and familiarity with new technologies can significantly increase mistrust among users.

This fear is particularly heightened during emergencies where the appropriate response may not be clear to all individuals. While there is no consensus on how these situations should be handled, autonomous vehicles must provide maximum safety autonomously, particularly for users with impaired driving abilities. However, it would

be beneficial to allow for the option of manual control by the individual or remote intervention by a human operator in certain scenarios. Providing such options could significantly enhance user confidence.

Preventive measures, early warnings of potential breakdowns, standardisation and automation of emergency protocols in the event of an issue and emergency pushbuttons are essential for ensuring the safety of autonomous vehicles.

Moreover, the interaction between autonomous vehicles, infrastructure and other vehicles largely depends on specific situations and scenarios. Specifically focusing on Level 5 autonomous vehicles, which operate with no human intervention, there is a strong belief that optimal interaction is only achievable when all vehicles on the road are 100% autonomous. Therefore, mixed scenarios are not considered viable.

Until Level 5 autonomy is achieved, and in order to gradually build user confidence, the steering wheel should remain in the vehicle as a symbol of control and safety. This approach allows users to adapt to 100% autonomous driving while maintaining the option to take control if necessary. Additionally, voice commands and interactions with AI will be crucial in fostering the growing confidence required to reach the last level of autonomy. At this stage, the speech recognition system must be designed to adapt and learn from the human (user), including their tone of voice, sentence construction, colloquialisms and specific expressions.

This level of automation and connectivity provides an opportunity for vehicles to collaborate, enabling them to alert each other about incidents on the road or to coordinate with emergency response vehicles. Therefore, despite the increased automation of the car fleet, there is a possibility of creating safer and more collaborative environments.

Ensuring the safety of vehicle occupants is another essential matter. It is essential for individuals using these vehicles to feel secure within the passenger compartment. Ideally, if an issue arises that threatens the safety of any occupants, the vehicle should have the capability to take control and initiate communication with emergency services autonomously.

For these reasons, it is crucial to ensure that no external parties can interfere with the vehicle's operation without prior authorisation. In this respect, implementing robust location tracking systems would significantly enhance the safety and peace of mind of both travellers and those monitoring their journeys. Additionally, there would be an added feeling of safety if autonomous vehicles adopted protocols that ensure passengers have safely reached their destinations before departing, mirroring the current practices observed in taxi services.

The importance of equipping these vehicles with vital signs monitoring systems to detect any anomalies, particularly in vulnerable passengers, is also highlighted. Additionally, maintaining direct contact with emergency services and ensuring the availability of a first aid kit are essential measures.

The increasing digitalisation that enables mobile applications to interact with autonomous vehicles introduces significant safety concerns, particularly regarding cybersecurity. Given the widespread worry about cyber-attacks, it is essential to ensure that user data is well-protected and that the communication systems of autonomous vehicles are secure.

Focusing on the interior of the vehicle, access should be barrier-free to ensure safety and prevent slipping, enable good visibility and feature easy-to-use doors. Support features to assist with entering and exiting the vehicle would also create a safe experience from start to finish.

The advantage of vehicles designed for autonomous driving is that they are not constrained by traditional seating arrangements, allowing for adaptability to suit all users and be arranged in any direction. This flexibility means seats can be customised according to different user needs, and these seating configurations can be specified at the time of vehicle purchase or adjusted through retrofitting as required.

A versatile interior configuration in autonomous vehicles enhances their utility by allowing users to customise the number of seats and the amount of cargo space according to their specific needs.

Fig. 7

The concept of the interior of an autonomous vehicle. ORGANICS project y Capgemini Engineering

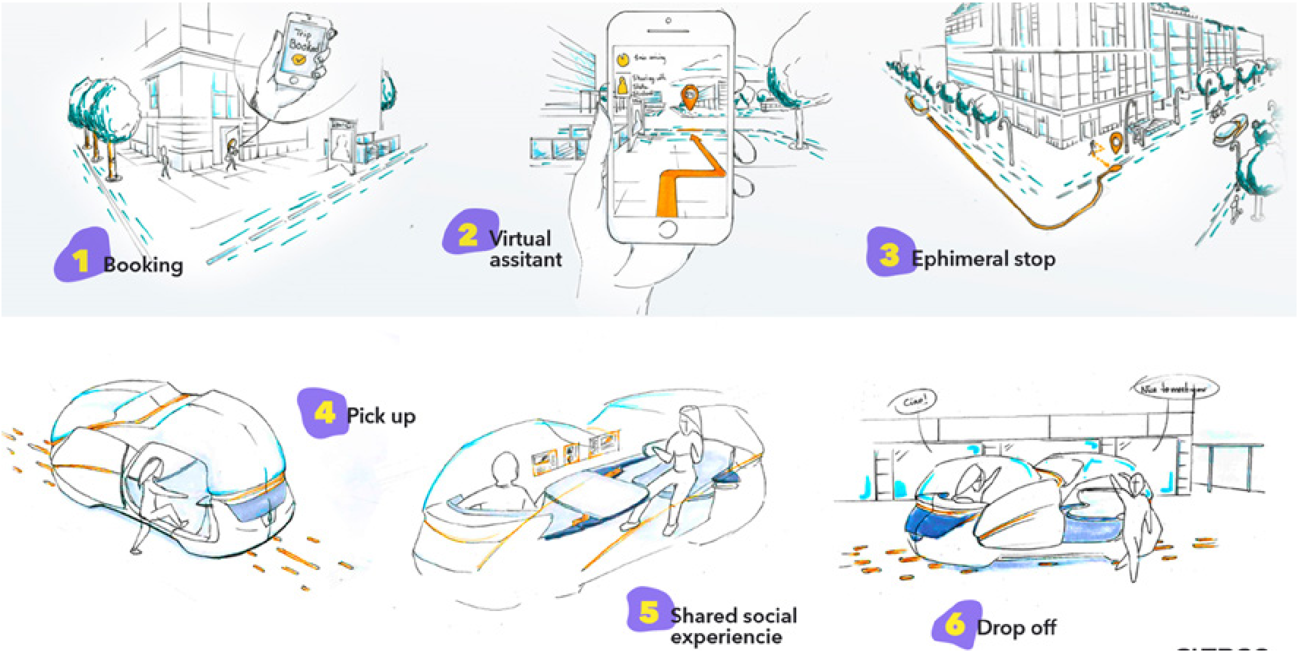
Perception of autonomous vehicle ownership and usage

The traditional paradigm of vehicle ownership and usage is undergoing significant changes. Modalities such as leasing and car-sharing services are increasingly persuading users to opt out of owning vehicles.

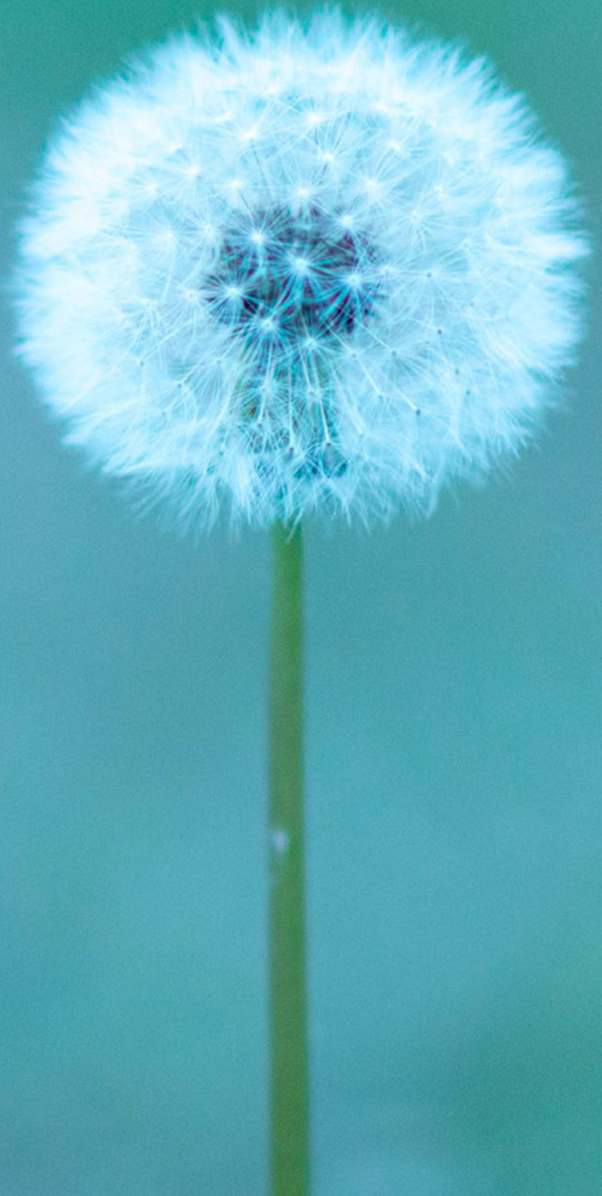
Autonomous vehicles are poised to adapt to diverse realities and uses. It could function as an on-demand service or be owned collectively by a community, such as a family or company. The shared ownership model not only reduces access and maintenance costs but also optimises the utility of the vehicle. This flexibility ensures that various groups can have vehicles tailored to their specific needs. Just as today's vehicles come in different sizes and specifications, autonomous vehicles can be offered for individuals with reduced mobility, older adults, and other groups, ensuring no one is left behind.

Fig. 8

Concept of autonomous driving service. Shutlink Project by Capgemini Engineering



07 Conclusions



Engineering and technology are advancing rapidly towards the development of autonomous vehicles. As a society, we are presented with a significant opportunity to include all individuals and groups, particularly those who face mobility challenges with current vehicle models, right from the start of this journey.

Addressing the diversity of needs is undoubtedly a complex task. The research, co-creation, analysis and synthesis efforts documented in this White Paper aim to outline a path that facilitates this transition, making it more accessible for everyone.

01

We must **put people at the centre** to ensure that autonomous vehicles are an opportunity for inclusive, sustainable and equitable mobility beyond the economic interests that each company may have.

02

To **define the mobility of the future,** it is essential to listen to the needs and concerns of all groups. Along the way, solutions to the complexity of the challenge will be found. Breaking down these barriers is what must enable universal accessibility to autonomous driving.

03

The responsibility lies with everyone. As a society, we must work hand in hand with all stakeholders: manufacturers, automotive component suppliers, public administrations and the general society. They all have an important role to play in working together in the same direction to achieve the objective.

04

Technology stands out as a determining factor in helping, from the outset, those with the most difficulties, considering all their needs and unique characteristics.

05

Autonomous vehicles are an opportunity to **redefine the sustainability of cities** from an inclusive, sustainable and equitable perspective. Current urban travel is not sustainable. Congestion, pollution and the lack of useful space for citizens in the streets have become one of the main problems of large cities.

06

Autonomous driving is the key to providing everyone with reliable and safe access to mobility. The diversity of the population requires models and solutions that respond to those who, due to different circumstances, cannot currently afford to travel by car.

07

Urban environments must be redefined, adapting to new concepts of mobility. This transformation must also include the more isolated, rural areas, where autonomous vehicles can provide the opportunity for greater connection between the people who live in these areas and the big cities.

08

Innovative, flexible, scalable, networked solutions that facilitate physical access, providing real-time connectivity between vehicles and infrastructure, will be required for **cities to be more inclusive.**

09

Autonomous mobility will **create new opportunities** for mobility, social integration, and collaboration between all sectors, which will make it possible and generate new models that will help its economic, social, and digital sustainability.

10

Autonomous vehicles should be conceived as a **service for the whole of society,** offering people an improved quality of life and making a substantial improvement in accessible and safe travel a reality.


This is only a first step.
Dialogue and reflection
must continue.

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09 Glossary of terms

ACC (Adaptive Cruise Control)

A speed control system that automatically adjusts vehicle speed to maintain a safe distance from the vehicle in front.

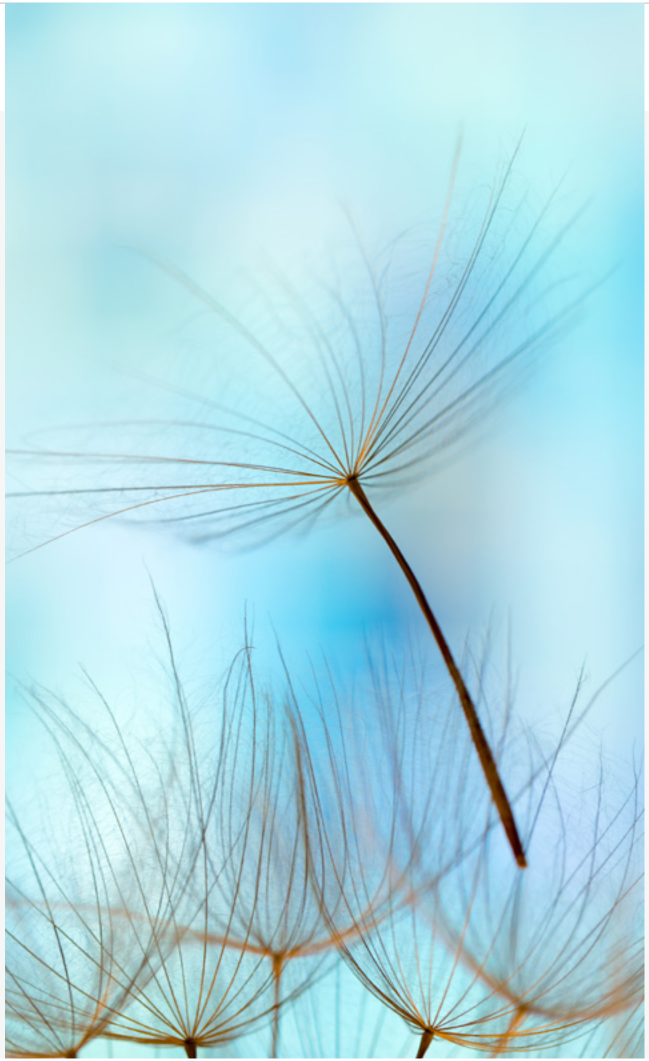
ADAS (Advanced Driver Assistance Systems)

A set of electronic systems designed to assist the driver in driving, improving safety and efficiency.

BSD (Blind Spot Detection)

A system that detects vehicles in the driver's blind spots and issues alerts to avoid collisions.

CTAG (Centro Tecnológico de Automoción de Galicia - *Galician Automotive Technology Centre*):



A research and development centre specialising in advanced automotive technologies.

DARPA (Defense Advanced Research Projects Agency)

An agency of the United States Department of Defense responsible for developing emerging technologies for military use, including advances in autonomous driving.

EBA (Emergency Brake Assist)

A system that enhances the vehicle's braking force during emergencies to help avoid or minimise collisions.

FCW (Forward Collision Warning)

A system that alerts the driver to a possible front-end collision, allowing for preventive action.

ITF (International Transport Forum)

An intergovernmental organisation that brings together transport ministers and experts to promote sustainable transport policies at the global level.

LIDAR (Light Detection and Ranging)

A laser-based technology used to create three-dimensional maps of the environment for autonomous driving.

LKA (Lane Keeping Assist)

A system that helps the driver stay in lane by issuing alerts or making automatic steering corrections.

MIMO (Multiple Input Multiple Output)

A wireless communication technique that uses multiple antennas to enhance transmission quality and capacity.

PID (Proportional Integral Derivative)

A control mechanism used in various systems to adjust process variables, enhancing accuracy through error correction.

SADE (Securing Autonomous Driving Function at the Edge)

A strategy that enhances the security of autonomous driving functions by processing data at the edge of the network, improving efficiency and safety.

SAE (Society of Automotive Engineers)

An organisation that defines technical standards for the automotive industry, including vehicle autonomy levels.

TJA (Traffic Jam Assist)

A system that assists the driver in heavy traffic by maintaining a constant speed and assisting with steering.

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Óscar is a passionate leader with the purpose of making society more equitable through innovation and technology. General Manager of the Capgemini Foundation since its inception, driving and transforming the first and only non-profit entity of the Capgemini group. From the Capgemini Foundation, Óscar leads the non-profit's social programs aimed at improving the quality of life and education, especially for the most vulnerable sectors of society.

Trained as an architect at the Escuela Técnica Superior de Arquitectura de Madrid (ETSAM), he is an expert in Management and Administration of Foundations from the UNED. His career is a constant commitment to innovation and the improvement of living conditions through technology and education. Since 2023, Óscar is a member of the Board of Directors of the Spanish Association of Foundations, coordinating its Digital Transformation.

Óscar is recognised for his ability to lead multidisciplinary teams, manage large projects and develop strategic initiatives that have a positive impact on society. His work has won him numerous awards, reflecting his dedication and success in the field of social innovation and digital transformation.

Yoann Groleau

VP Market Unit Head Capgemini Manufacturing, Automotive, Aerospace, Life Sciences & Public Sector Capgemini. Trustee Fundación Capgemini.

Yoann Groleau is an industrial engineer graduated from ESEO in Angers, France, with more than 25 years of experience in various industrial sectors. He started his career at the Commissariat à l'Energie Atomique (CEA) and subsequently developed his work in industrial environments such as postal systems, agri-food, railways and automotive.

Since 2002, he has been based in Barcelona, where he started working for Altran in engineering activities. Between 2014 and 2020, he was responsible for the automotive sector. Currently, he is responsible for the automotive, aerospace, railway, pharmaceutical, industrial and public sectors at Capgemini Spain.

Edgar Aneas

Electric Vehicle Specialist Capgemini Engineering Spain

Edgar Aneas is an industrial engineer, specialist in sustainable mobility and battery energy storage systems. Throughout his career, with more than 15 years of experience in the electromobility sector, he has participated in multiple automotive R&D projects, contributing to the development of technology integration solutions in vehicles. Committed to creating a more accessible and sustainable future, he combines his technical expertise with his work on various Capgemini Foundation projects, reflecting his passion and work to make technology a tool at the service of all.

Jorge Vega

Senior Compliance Quality Regulatory Engineering, Capgemini Engineering Spain

Jorge Vega Hernández is an Automotive Technician and Mechanical Engineer from the Carlos III University of Madrid. Driven by a passion for the automotive sector, with more than 10 years of experience in the sector, he has worked in R&D&I in automotive design and manufacturing processes, as well as project management and quality management both in Spain and Germany, and has experience in the machine tool, aeronautics and renewable energy sectors. He is part of Capgemini Engineering since 2022 as a senior quality engineer in the pursuit of continuous improvement and excellence following the commitment to sustainable industrial development in all the projects he is part of. An active partner of the Capgemini Foundation, he brings his passion and experience to the environment of equality and innovation that it represents.

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We would also like to thank the following entities and individuals for their participation and collaboration in the 'White Paper for an inclusive autonomous vehicle'[2].

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1 on an individual basis
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FUNDACIÓN

About Fundación Capgemini

The purpose of the Capgemini Foundation is to promote the development of technological innovation, science, the improvement of living conditions and education in the general interest, as well as the most disadvantaged sectors of society.

It is the first non-profit entity of the Capgemini Group, developing its activity in Spain, with an impact on society and benefiting the most vulnerable groups.