Automatiséiert Fueren 2028

the Luxembourg Strategy for Automated Driving

THE GOVERNMENT
OF THE GRAND DUCHY OF LUXEMBOURG

Summary

Foreword

©SIP Claude Piscitelli

©SIP Claude Piscitelli

Automated driving is no longer a distant prospect: it is rapidly becoming a technological, economic, and societal reality. For Luxembourg, this evolution represents far more than a technical advancement. It embodies a strategic opportunity to strengthen our position as an innovation hub, support the competitiveness of our economy, and create new value chains.

Smart mobility is one of this government's priorities, building on decades of expertise in the automotive sector and in information and communication technologies (ICT), now complemented by our digital strategy – a cross-cutting domain in which Luxembourg continues to invest.

With this national strategy, we are laying the foundations for a dynamic ecosystem capable of attracting talent, stimulating research, and fostering the emergence of tangible solutions to serve tomorrow's mobility. Our ambition is clear: to make Luxembourg a European benchmark in technologies related to automated driving, a controlled testing and deployment ground where technology serves humanity.

This strategy is the result of a collective effort, developed in close consultation with public, private, and academic stakeholders. It reflects our commitment to building a resilient economy, forward-looking and true to our values of openness, trust, and responsible innovation.

Lex Delles
Minister of the Economy, SMEs, Energy and Tourism

The strategy developed by the Luxembourg Government for 2028 regarding connected and automated vehicles (CAV) aims to position the country as a major player on the European and global stage. Its geographical size and location, along with its economic stability and influence, provide Luxembourg with excellent assets to assume a leadership role in the mobility of tomorrow.

Thanks to the chosen cross-sectoral and multidimensional approach, and the encouragement of public-private partnerships, we aim to ensure a coherent implementation of the strategy in the coming years. This will support the attraction of new talent while emphasising upskilling and training, to ensure a positive societal impact of the technology. The development of a robust and adaptable legal framework, based on an interdisciplinary approach, will be a central pillar of this strategy, enabling the effective and harmonious deployment of CAV. This will be structured around five use cases, conducive to the emergence of innovative and intelligent mobility services and new employment opportunities.

Integrating CAV into the multimodal transport system is a cornerstone of our approach: high-quality coordination between different modes of transport must be pursued at both national and cross-border levels to achieve optimal interoperability. The ultimate goal is to offer our citizens more refined travel options, leading to improved road safety and a reduced environmental footprint.

Yuriko Backes
Minister for Mobility and Public Works

Executive Summary

Luxembourg has adopted an ambitious national strategy for automated and connected driving, with the **clear ambition of becoming the first European country to enable its deployment across the entire territory by 2028**. This vision is part of a broader transformation agenda focused on innovation, sustainability, and competitiveness.

Through this strategy, Luxembourg aims to position itself as a **leading European competence centre**, leveraging its strengths: an advanced digital ecosystem, an agile governance, a strong capacity for experimentation and a culture of cross-sectoral cooperation. The goal is clear: to position automated driving as a catalyst for economic diversification, the creation of skilled jobs, and an improved quality of life.

The goal is clear: to position automated driving as a catalyst for economic diversification, the creation of skilled jobs, and an improved quality of life.

The strategy is built around **six strategic pillars**, aligned with the *"Accelerating Digital Sovereignty 2030"* initiative: governance and regulation, skills and talent, infrastructure and ecosystems, research and innovation, support services, and international cooperation. Its implementation is overseen by a **dedicated interministerial committee**, ensuring a transversal, coherent, and participatory approach.

Five **priority use cases** have been identified for a gradual and controlled rollout:

1. **Motorway chauffeur**, for safer and potentially smoother driving on major roads.
2. **Robotaxis**, offering on-demand, driverless transport services.
3. **Last-mile automated shuttles**, integrated into public transport networks.
4. **Valet parking and restricted-access sites**, automating manoeuvres in controlled environments.
5. **Automated logistics**, addressing freight transport challenges.

The strategy also places strong emphasis on **skills development**, supporting the training of technical, scientific, and operational profiles, and **fostering synergies between public research, industry, and innovative start-ups**. Dedicated programmes, living labs, and test environments will accelerate innovation and validate technologies from restricted sites to real-world conditions.

Connectivity, data management, cybersecurity, and **artificial intelligence** have been identified as key technological pillars. **Luxembourg is committed to ensuring a clear, adaptive, and secure regulatory framework**, while safeguarding personal data and digital trust.

Finally, the strategy fully integrates **societal and environmental dimensions**. It aims to enhance road safety, promote inclusive and shared mobility, and mitigate rebound effects, including those related to energy consumption. Social acceptance is central to the approach, with awareness campaigns, dialogue, and co-creation initiatives engaging all stakeholders.

This strategy serves as a **comprehensive and structured roadmap**, inviting every reader to explore the thematic chapters to better understand the challenges, opportunities, and concrete actions shaping the future of automated mobility in Luxembourg.

1

Introduction

Part 1

Introduction

Motivation

The development of automated driving is accelerating globally, driven by significant technological progress, particularly the exponential advancement of artificial intelligence. **Considering the rapid emergence of automated driving technologies** and the challenges their market deployment presents, **it is essential to adopt a proactive, structured, and well-managed approach** to fully harness their potential for the collective good.

The implementation of a national strategy for automated driving addresses a dual imperative: **anticipating the arrival and advancement of innovative technologies** and **steering this transformation in a direction aligned with the country's values and objectives.**

Strategic Vision for Automated Driving

Luxembourg aims to position itself at the forefront of technological innovation, with the **ambition of becoming the first European country to offer automated driving across its entire territory.** This bold vision is underpinned by several **strategic orientations and key objectives**, designed to **transform the Grand Duchy into a central hub for automated mobility.** **Five priority use cases have been defined for a commercial deployment** based on their technological maturity, their relevance to key stakeholders, and their contribution to national and European objectives.

Automated and Connected driving harbours significant potential to **support key political priorities** of the European Union, such as the *United Nations Sustainable Development Goals*[1], *Vision Zero*[2], the *Strategy for Smart and Sustainable Mobility*[3], the *European Green Deal*[4], and a *Europe Fit for the Digital Age*[5]. Applied to road traffic, connected and automated driving can positively contribute to road safety.

Built on several innovative technologies, this emerging field also contributes to **strengthen the competitiveness of industry and research**, as highlighted in the second part of the *Report on the Future of EU Competitiveness*[6] (Draghi Report). The development of connected, automated, and AI-based vehicles is also a key pillar of the *Action Plan to Boost Innovation, Sustainability and Competitiveness in the Automotive Sector*[7].

Strategic Directions and Main Objectives

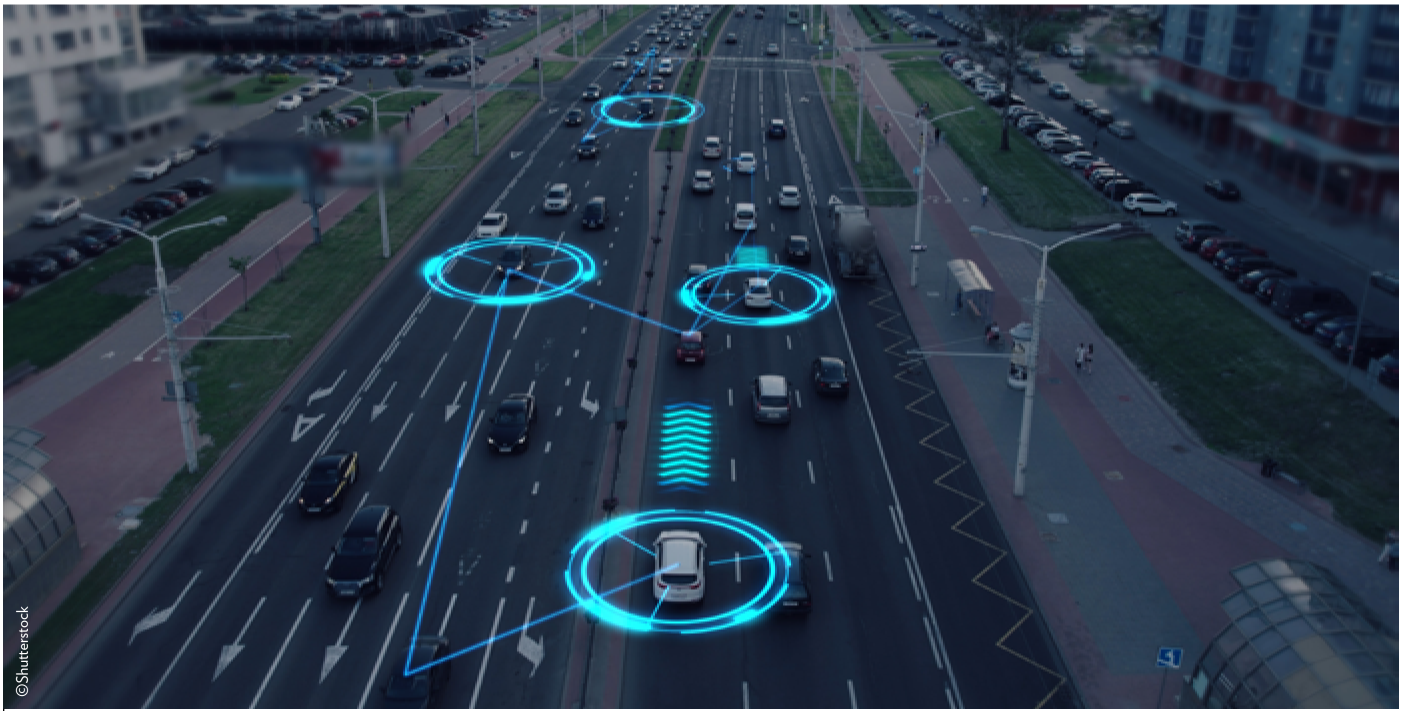
Luxembourg aspires to become a European **competence centre for automated driving** – a place of reference for research, development, and innovation (RDI), leading to the implementation of connected and automated driving technologies. **Supporting RDI, fostering economic development, and the strengthening of scientific expertise and talent are at the heart of this strategy.**

Smart mobility and support for the automotive sector are priorities for diversifying Luxembourg's economy. By focusing on automated driving, Luxembourg seeks to **reinforce its economic position**, develop its ecosystem, attract investments, support the emergence of new mobility services, establish new value chains, and create **new employment opportunities** both within and beyond this sector.

To achieve this, Luxembourg will **promote partnerships between universities, research centres, and industry** to stimulate innovation and accelerate the development of automated driving technologies. To support this transition, Luxembourg will aim to **strengthen scientific and technical skills. Training and talent development programmes** will be implemented to prepare the workforce for the challenges of automated mobility – including through participation in specific initiatives at the European level, such as the *Automotive Skills Alliance*[8].

Luxembourg will **establish living labs and test environments** to simulate and evaluate automated driving technologies under real-world conditions. In parallel, controlled environments will facilitate the experimentation with and optimisation of automated systems prior to large-scale deployment.

Connectivity and the digitalisation of transport are key enablers supporting the implementation of automated



Aerial view of a dual carriageway with automated vehicles

driving and are integral to the strategy. Luxembourg already benefits from an advanced digital infrastructure and will continue to develop its digital ecosystem, including next-generation communication technologies, to ensure the seamless integration of automated vehicles into the existing transport network.

Data management, cybersecurity, and artificial intelligence are among the strategic priorities Luxembourg aims to develop. The *Accelerating Digital Sovereignty 2030*[9] strategic initiative outlines cross-cutting measures through three aligned national strategies. As an example, the flagship project *"AI Move 1.0"* aims to support forecasting by using artificial intelligence to harmonise fragmented mobility data. As part of this strategy, these measures will be complemented by a **dedicated regulatory framework** to ensure data protection and economic security, while leveraging AI to enhance the performance of connected and automated driving systems.

The **strategic directions for multimodal mobility** are defined in the *National Mobility Plan (PNM)*[10]. Based on analyses from the "Digital Mobility Observatory", the PNM anticipates future mobility needs and sets modal share targets across a 15-year horizon. Many use cases of automated driving could contribute to these objectives: better road safety and thus increased attractiveness for active modes of transport, more consistent speeds on highways, potentially leading to better traffic flow on these routes, possible expansions of public transport, etc. However, given the primary objective of reducing road congestion, use cases that would lead to an increase in the number of vehicles during peak hours should be analysed with caution.

Finally, Luxembourg will consider the **societal and ethical aspects** of automated driving. Efforts will be made to ensure these technologies benefit the whole of society, respect fundamental ethical values, and lead to a positive social impact. **Public awareness of the socio-economic benefits** is a key factor, and initiatives will be implemented to build trust and acceptance among citizens and future users of automated driving services.

In summary, **Luxembourg's national strategy for automated driving presents an ambitious and comprehensive roadmap aimed at positioning the country as a European leader in the field**, while ensuring sustainable economic growth and improved quality of life for its citizens and users of the transport network.

A **dedicated interministerial committee**[11] has been established by the Government Council to work on the aforementioned topics in an integrated and participatory manner. The implementation of the strategy will be monitored through a cross-sectoral approach involving the entire Government.

2

Context

Part 2

Context

Methodology

In developing this strategy, the Interministerial Committee conducted a **review and evaluation of multiple national strategies** related to automated driving, as well as an **inventory of various orientations and actions at the level of the European Union.**

An external **advisory group**, composed of around thirty leading companies and public research actors - directly involved in ongoing projects or ones in planning - **was consulted to provide insights into the roles, orientations, and expectations of different organisations.** Feedback was gathered on timelines, needs and expectations (e.g. regarding regulatory frameworks, test environments, infrastructure, connectivity, key competencies), perceived obstacles, risks and limitations, as well as potential enablers.

A **complementary consultation targeting institutional representatives** allowed to collect opinions from associations, public administrations, institutions, and municipalities.

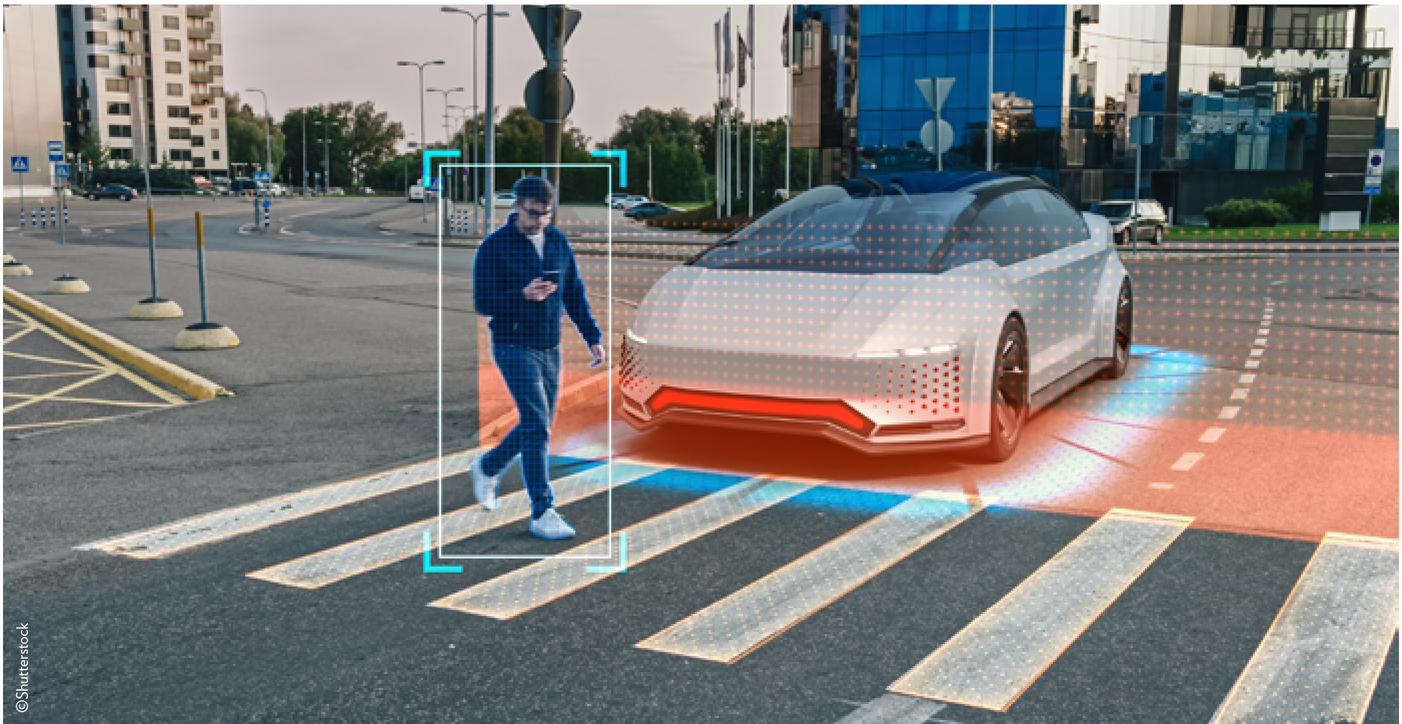
This provided insights into priority use cases, benefits and opportunities, risks and barriers, key elements to be included in a national action plan and regulatory framework, incentive measures, expectations and concerns as well as public acceptance.

Concept Overview

Levels of Automation

The degree of road traffic automation is commonly defined at international level by **six levels of driving automation**, as established by *SAE International*[12]. A simplified definition of the levels of driving automation, along with examples of current usage, is provided below.

This strategy focuses primarily on **Level 3** (conditional automation) and **Level 4** (high automation). It is important to note **that this strategy is limited to road vehicles** and does not cover other transport modes (e.g. rail, maritime, aeronautic).



Automated vehicle detects pedestrian and stops at pedestrian crossing

Level	Description	Examples
Level 0 – *No Automation*	The human driver performs all driving tasks. The vehicle may include alerts or warnings but does not control any functions.	*A standard car with lane departure warning or parking sensors.*
Level 1 – *Driver Assistance*	The system assists with either steering or speed control, but not both. The driver must constantly monitor the system and always remains responsible.	*Adaptive Cruise Control (ACC) or Lane Assist (but not both simultaneously).*
Level 2 – *Partial Automation*	The system controls both steering and speed in specific situations. The driver must continuously monitor the system and intervene as and when needed. It is oftentimes referred to as "Eyes on / hands off".	*Systems known as full self-driving "FSD" or "Super Cruise" (under certain conditions) on highways.*
Level 3 – *Conditional Automation*	The system handles all driving tasks under defined conditions. The driver can disengage but must be ready to take over when prompted, always with sufficient transition time. Should the driver not react, the vehicle needs to adopt a minimal risk manoeuvre. This level of automation is oftentimes referred to as "Hands off, eyes off".	*DRIVE PILOT, Personal Pilot L3, or Traffic Jam Pilot on motorways.*
Level 4 – *High Automation*	The system drives independently in defined areas or scenarios. No driver is needed in these cases. It is oftentimes referred to as "Eyes off, Mind off".	*Urban shuttles or robotaxis in specific zones.*
Level 5 – *Full Automation*	The system can drive autonomously anywhere, anytime (from start to finish), without any human input.	*Concept cars with no steering wheel or pedals (not yet commercially available).*

Overview of Key Technologies

Automated driving is built upon a complex technological architecture that integrates several interdependent subsystems. These components enable the vehicle to perceive its environment, accurately determine its location, make real-time decisions, and interact safely with other road users.

Sensors serve as the "eyes and ears" of the vehicle. **Cameras** detect road markings, signs, pedestrians, and other vehicles, with their effectiveness depending on visual conditions. **LIDAR** systems generate a three-dimensional image of the surroundings, while **RADAR** measures the distance and speed of objects, even in adverse weather such as rain or fog. **Ultrasonic sensors** are used for close-range manoeuvres, such as parking. **Sensor fusion** combines data from these various sources to provide a more reliable perception of the environment.

This data is then processed by the **perception layer**, which uses various algorithms (including those based on artificial intelligence) to interpret sensory information. It identifies objects, estimates their position and movement, and constructs a dynamic representation of the environment. The **planning layer** then develops safe and efficient trajectories, considering driving objectives and traffic regulations. Finally, the **control layer** translates these trajectories into precise commands sent to the vehicle's actuators (longitudinal control = acceleration and braking; lateral control = steering), ensuring smooth and safe execution of the driving task. **Human-machine interfaces (HMI)** inform the driver (or other stakeholders) and facilitate the handover of control when necessary.

In parallel, **positioning systems** ensure the vehicle's precise localisation. **High-precision GPS**, combined with **inertial measurement units (IMU)** and **high-definition maps (HD maps)**, enables the vehicle to locate itself within its environment with centimetre-level accuracy—crucial for automated navigation.

Finally, **connectivity** is a key enabler of safety and allows interaction with other users and the environment. **V2X (Vehicle-to-Everything)** technologies enable the vehicle to communicate with other vehicles, the cloud, service providers, and more. **Over-the-air (OTA)** software updates ensure that systems can evolve regularly without requiring physical intervention.

Analysis of the Current Situation

Political Factors

In line with the commitments made under the 2023–2028 coalition agreement *"Lëtzebuerg fir d'Zukunft stäerken"*[13], Luxembourg's national strategy for automated driving forms part of a broader effort to support smart mobility as a key driver of economic diversification. The strategy aims to **position Luxembourg as a leading European player** by authorising automated and connected driving on its national territory and by developing an environment conducive to technological experimentation, transforming the country into a true living lab.

To this end, the strategy provides for the **development of a legal framework tailored to the use of automated vehicles**, as well as the **implementation of a strategy on mobility data**, including a legal basis for data exchange and reuse. It is also aligned with ongoing structural reforms, notably the **revision of taxi legislation**, to encourage the emergence of **innovative, accessible, and competitive mobility services.**

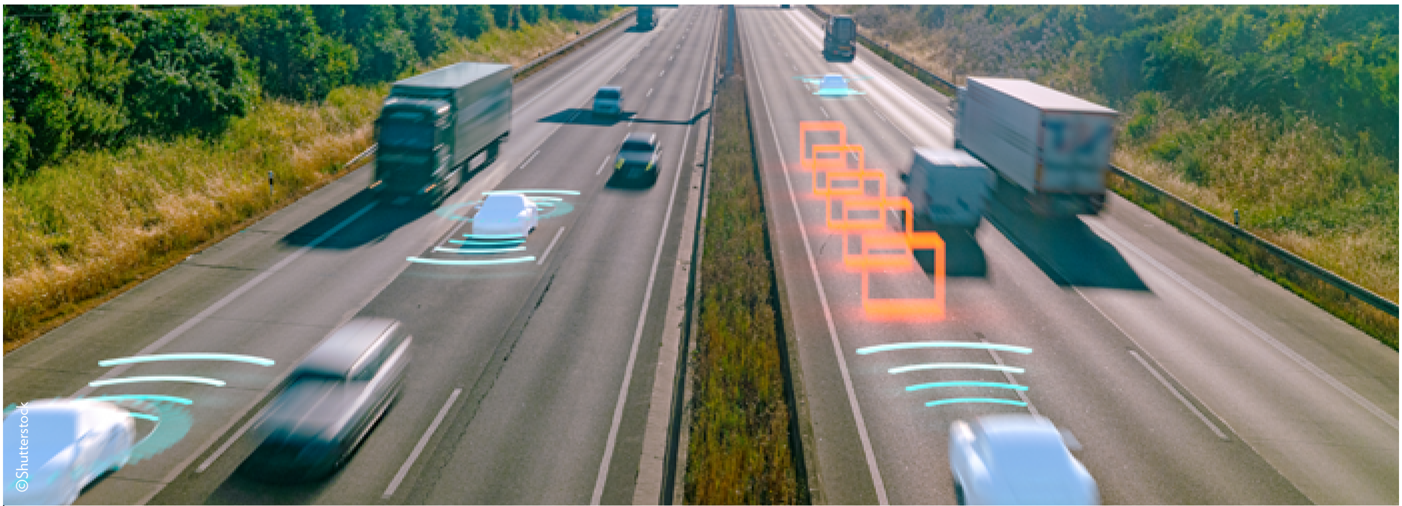
In shaping a framework for the deployment of automated driving, **Luxembourg can build on the momentum of existing national strategies and initiatives** in related fields, including:

- The strategies *"Accelerating Digital Sovereignty 2030"*[9], which aim to **position Luxembourg as a leader in high-value-added applications in highly regulated sectors**, offering real complementarity and added value on the European and global stage. This initiative serves as a natural foundation for the automated driving strategy, as many of the underlying technologies are rooted in these domains.
- The *"Data-Driven Innovation Strategy for the Development of a Trusted and Sustainable Economy in Luxembourg"*[14] of the Ministry of the Economy, which **promotes the development of data-driven smart mobility solutions.**

  A concrete example is a **cross-border project** enabling the testing of automated driving and smart mobility solutions in a zone connecting France, Germany, and Luxembourg. These initiatives demonstrate how the **strategic use of data** can facilitate the integration of advanced technologies, such as automated vehicles, thereby contributing to **safer and more efficient mobility.**
- The *National Cybersecurity Strategy*[15], developed under the coordination of the High Commission for National Protection (HCPN), which aims to **strengthen the country's digital resilience against cyberthreats**, including those affecting the mobility infrastructure.
- The *National Strategy for Research and Innovation*[16], led by the Ministry of Research and Higher Education, which **defines the framework for developing Luxembourg's research and innovation ecosystem.** It supports the mobilisation of public research institutes, the strengthening of public-private partnerships around pilot projects, and the adaptation of the regulatory framework to foster the development, testing, and secure integration of innovative technologies.

Economic Factors

Automated driving represents a **strategic lever for strengthening industrial and scientific competitiveness** in a sector projected to generate between €300–400 billion in revenue by 2035 (McKinsey, 2023)[17]. It engages a **broad value chain**, from vehicle and onboard system development to infrastructure adaptation, digital services, telecommunications, and data. This transition will impact numerous sectors: automotive, electronics, software, logistics, insurance, energy, and maintenance.



Aerial view of a motorway with automated vehicles travelling among lorries and other cars

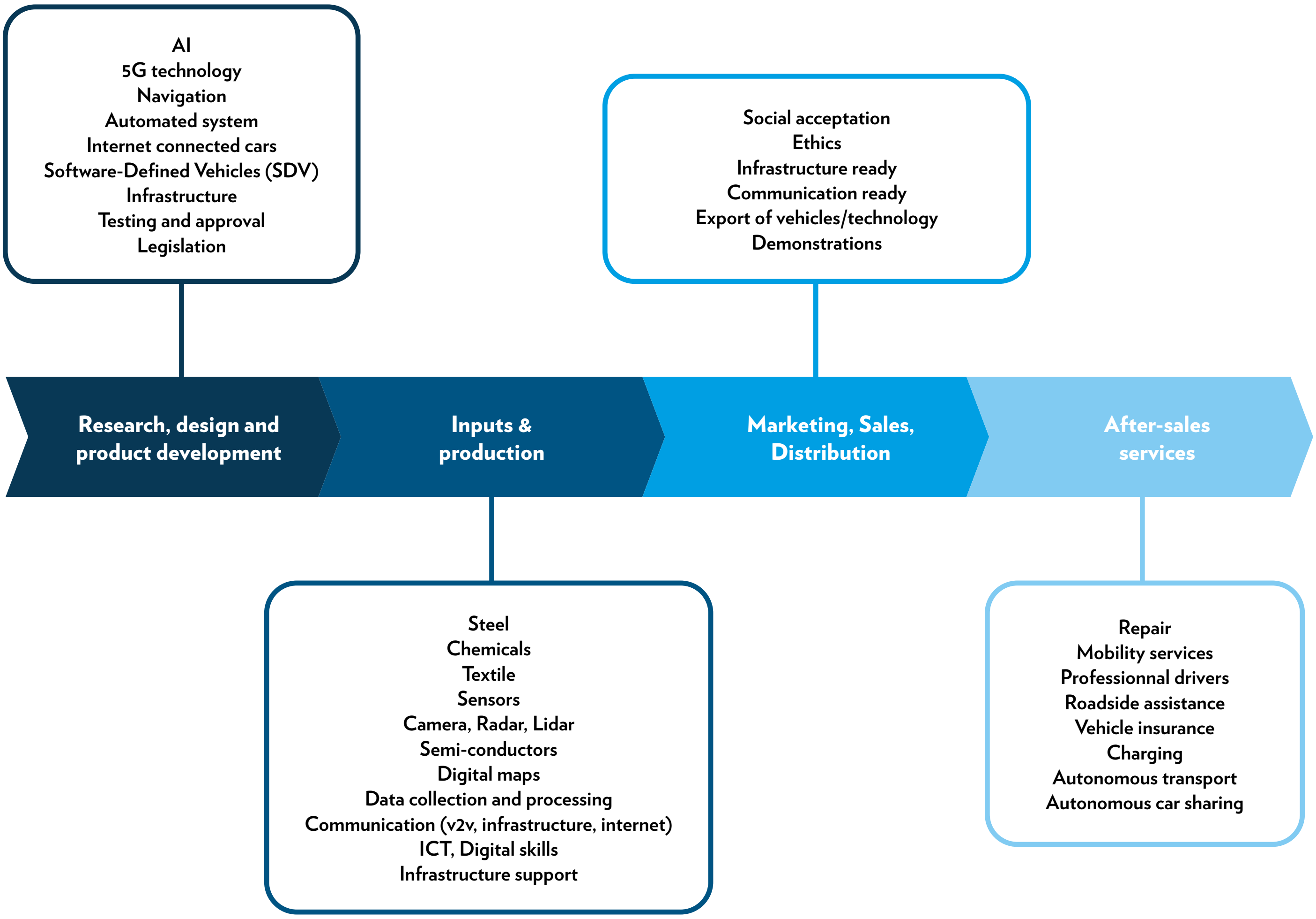


Figure 1. Strategic Forum on Important Projects of Common European Interest – Final Report "Strategic Value Chain Connected, Clean and Autonomous Vehicles" (Sub-value chain automated mobility), 2019

The development of automated driving systems is shifting the **value creation and R&D priorities**, creating **new opportunities** for industry to **enhance competitiveness and maintain its position** by integrating future technologies. Advancing R&D in these areas and **establishing empowering conditions** for a safe transition from testing to commercial operation—starting with selected use cases—will be essential. A proposal of **priority use cases for commercial deployment** in Luxembourg is outlined later in the strategy.

Thanks to its geographic location, digital ecosystem, investment policies, and proximity to key stakeholders, **Luxembourg is well-positioned to serve as a pilot market.** To achieve this, it will be crucial to continue **supporting research and innovation, promoting scientific excellence**, strengthening cross-sectoral cooperation (e.g. public-public, research-industry), and providing adequate testing environments.

Automated driving is expected to **transform the labour market. New jobs requiring new skills** will emerge due to the development of new technologies and services. Through its *European Skills Agenda*[18] and *Union of Skills*[19] strategy, the European Union is prioritising **digital skills across all employment levels.** Luxembourg is committed to anticipating these changes through active policies on training, talent attraction, and professional retraining.

In addition to technical profiles, **new roles related to technology maintenance and user support** will be needed. Examples include control centre operators monitoring driverless vehicle fleets, mobile response teams for incidents, and on-site assistants (e.g. for luggage handling or safety personnel).

While demand for professional drivers may decrease—from 3.2 million to 1 million by 2030 (OECD, 2023)[20], automated systems can **partially take over human driving tasks**, offering a potential solution to the growing shortage of long-distance drivers, which is exacerbated by retirements and a declining workforce.

Finally, automated driving offers **concrete prospects for reducing operating costs and improving efficiency**, particularly in freight transport. Fuel savings of between 2% and 13% are anticipated, thanks to potentially smoother driving patterns[21].

Social Factors

Public acceptance of automated mobility solutions is a critical factor for their successful implementation and widespread adoption. It will therefore be essential to **communicate transparently** about the opportunities and challenges of automation, while ensuring that risks are identified and mitigated in close consultation with relevant stakeholders. This **proactive and inclusive approach** will help foster a collective understanding of the expected benefits and strengthen support for this technological transition.

First-hand experience of automated driving should be encouraged, as it provides valuable insights into real-life use cases. The perceptions and attitudes of different user groups towards automation should be assessed from both an economic and social perspective. In this context, the involvement of the **LISER** (Luxembourg Institute of Socio-Economic Research) is being considered.

From the onset, it will be crucial to **promote realistic expectations** regarding the adoption of automated driving and to **raise public awareness** by addressing societal concerns, fears, and questions.

From the initial phase, it will be essential to manage expectations regarding automated driving and to raise public awareness by addressing potential questions or concern.

Modern driver assistance systems already help reduce the number and severity of road accidents. With increasing market penetration and improving safety technologies, automated driving can make a significant contribution to the Vision Zero initiative and the goals of the *National Road Safety Plan 2024 - 2028*[22]. In 2024, approximately 19,800 people lost their lives in road accidents across the European Union, according to European Commission data – a 3% decrease compared to the previous year, as the EU continues its efforts to improve road safety.

It is therefore essential to highlight **automated driving as a measure to reduce road traffic fatalities and injuries.** A recent study published in *Nature*[23] analysed thousands of accident reports involving both automated and human-driven vehicles. The findings suggest that **automated vehicles are, in most situations, safer than those driven by humans.** It will also be important to consider the impact of automated driving on and its integration with **active mobility modes**, such as walking and cycling.

In conclusion, a **significant reduction in road traffic casualties** can be expected through automation and connectivity in road transport. As automated driving functions are progressively introduced, they will help eliminate accidents due to human error or recklessness. However, this will require **highly reliable vehicles**, even in complex situations, and a **significant penetration of automated driving technologies** in the vehicle fleet.

Technological Factors

From a technological standpoint, several key elements must be considered. Automated vehicles rely on **a variety of sensors**, such as cameras, LIDAR, RADAR, and ultrasonic sensors—to perceive their surroundings, as detailed in the section Overview of Key Technologies. These sensors collect information about objects, pedestrians, other vehicles, and road conditions. **Sensor fusion** enables the combination of data from different sources to create a more precise and comprehensive view of the environment, which is essential for real-time decision-making.

Artificial intelligence (AI) and **machine learning (ML)** – with reinforcement learning (RL) and self-reinforced machine (SRL) learning as an interdisciplinary area of ML and optimal control in particular, play a crucial role in interpreting sensor data. AI-based decision-making algorithms analyse this data to understand the driving situation and make appropriate decisions, such as braking, accelerating, or changing lanes. RL/SRL allows systems to continuously improve by learning from new driving scenarios, thereby increasing efficiency and safety.

Advanced communication infrastructure is also essential for effective coordination and safe driving. It enables vehicles to exchange information—for example, to avoid collisions or improve traffic flow. Several advanced technologies can be used for this purpose. **Terrestrial networks**, such as 5G, and **local wireless networks**, such as ITS-G5 or 5G V2X, are fundamental for providing ultra-fast and reliable connectivity, facilitating the implementation of automated driving. These networks are crucial for real-time data exchange, which is indispensable for automated driving, traffic management, and other advanced functionalities. **Connected vehicles can thus communicate** with each other (V2V – vehicle-to-vehicle), with infrastructure (V2I – vehicle-to-infrastructure), and with other stakeholders (V2X – vehicle-to-everything). Additionally, **non-terrestrial networks** (NTN), such as satellites or space-based broadband cellular networks, can complement terrestrial networks by providing coverage in areas where mobile networks may be limited or unavailable. This ensures that connected vehicles can maintain communication even in rural or remote areas and at border crossings.

In parallel, with the **Internet of Things** (IoT), modern vehicles are equipped with multiple intelligent sensors and can connect with each other and with other sensors in the road environment. These IoT devices collect **real-time data**, such as traffic, weather, and more. The data collected by IoT and exchanged via terrestrial or satellite networks must be processed quickly. Two solutions are possible: **cloud computing**, where vehicles connect to the cloud to store and analyse driving data, or **edge computing**, which ensures proximity and very low latency, thereby improving the responsiveness and efficiency of connected systems. Intelligent algorithms adapt the connection between these two methods to optimise the driving outcome.

Cybersecurity is another critical aspect. Automated vehicles must be protected against cyberattacks that could compromise their operation.

Cybersecurity is another critical aspect. Automated vehicles must be protected against cyberattacks that could compromise their operation. This includes securing onboard systems, communication networks, and digital infrastructure (backend), as well as perception systems throughout the product lifecycle. **Protecting users' personal data and ensuring confidentiality** are also of paramount importance to prevent the misuse of sensitive information.

Rigorous testing protocols and certification processes have been published by the United Nations Economic Commission for Europe (UNECE). To obtain type approval under EU Regulation *2018/858*[24], manufacturers must demonstrate that their components and systems comply with regulatory requirements. Regular audits may be conducted to ensure ongoing compliance. This regulation is essential to ensure that vehicles remain safe and reliable.

Furthermore, the UNECE's **WP.29 working group** is working on the **harmonisation of international regulations** for automated vehicles. Notable developments include ***UN Regulation No. 157*** (Automated Lane Keeping Systems – ALKS, the first binding international regulation for Level 3 automated driving) and ***UN Regulation No. 171*** (Driver Control Assistance Systems – DCAS). Additional measures concerning **emergency manoeuvres and the transition of control between the automated system and the driver** are also under development. These efforts aim to create a robust regulatory framework for the integration of automated vehicles while ensuring road user safety.

Environmental Factors

The integration of automated and connected driving brings with it **a variety of environmental impacts**, particularly in terms of energy consumption. While automated driving promises gains in efficiency and reduced emissions, **negative externalities must also be considered**, as highlighted by the NGO Earth.org[25]. The energy used during driving—and any associated emissions—depends largely on the driver's style. In the case of automated vehicles, onboard sensors and intelligent systems generally enable a **more efficient and eco-friendly driving style.** However, these intelligent systems **themselves require significant electrical power.**

According to a recent study by the European Commission's Joint Research Centre (JRC, 2025)[26], automated vehicles generate **additional energy demands** due to sensors, onboard computing systems, connectivity, and supporting digital infrastructure (e.g. data centres, HD mapping). These demands can account for up to **18% of the total energy consumption** of an automated vehicle in current configurations.

Nonetheless, the study notes that **significant savings are possible through technological optimisation.** Advanced Technology Optimisation (ATO) configurations can reduce the energy consumption of automation systems by more than **80% compared to current prototypes.** These gains rely on progress in sensor miniaturisation, more efficient onboard electronics, and distributed data processing.

From a behavioural perspective, the study warns of **rebound effects**: the attractiveness of automated services—particularly private-use robotaxis—could lead to an **increase in vehicle kilometres travelled (VKT)**, a **modal shift away from active (walking, cycling) or public transport**, and a rise in overall energy consumption. Conversely, **shared automated shuttles and high-frequency buses** appear to be more energy-efficient solutions, capable of reducing energy demand by up to **15% compared to conventional electric fleets**, provided they are integrated into a sustainable mobility policy.

Regarding **external environmental factors** that influence automated driving, it is essential to consider the relationship between various elements (e.g. weather conditions) and their **overall impact on the automated mobility system.** In both urban and rural settings, it will be important to understand the specific requirements of each deployment environment and the potential implications for spatial planning and infrastructure design.

These considerations highlight the importance of a **strategic framework for the deployment of automated vehicles**, combining technological innovation, incentives for shared mobility, and demand management measures. Such an approach will help **maximise the environmental benefits** of automated driving while **minimising its negative impact.**

Legal Factors

The **current legal framework** in Luxembourg does not yet provide a general regime for the circulation of automated vehicles. However, it already includes **specific provisions**

allowing for targeted testing. Under existing regulations, vehicles designed using new technologies or based on unregulated principles may be authorised for road use for technical or scientific testing purposes, provided they display a distinctive sign marked "essai scientifique". The use of this sign is subject to an individual authorisation issued by the Minister responsible for transport. This regime currently allows for the **authorisation of automated driving tests under strict conditions**, including temporary exemptions from certain provisions of the Highway Code—such as the rule prohibiting the driver from simultaneously releasing both hands from the steering wheel. These tests are governed by a specific authorisation granted for a limited duration and conducted under the close supervision of the competent ministry.

Significant developments are also taking place at the international level. For example, the United Nations Economic Commission for Europe (UNECE) has published regulations on automated driving systems and associated cybersecurity. The European Commission has also adopted an implementing regulation[27] establishing procedures and technical specifications for the type rating of **Automated Driving Systems (ADS)** for fully automated vehicles. At the national level, some countries have already introduced dedicated legislation around automated driving.

However, as technologies evolve, **many fundamental legal questions arise**, including:

- How should Luxembourg's national legislation define the **allocation of responsibilities** between the various actors involved in automated driving—such as manufacturers (OEMs), remote operators, safety drivers, and users—in terms of criminal, civil, and administrative liability, as well as applicable insurance regimes?
- What will be the **practical implications for traffic control**, particularly regarding the identification of automated vehicles in daily traffic, the issuance and renewal of circulation authorisations, and the compatibility of national procedures with European regulations? What stance should Luxembourg adopt regarding **additional conditions imposed by other Member States** on the use of these driver assistance systems?

These questions highlight the urgency and necessity of a coordinated reflection, at national and European levels—and beyond—on how the law should evolve in response to the automation of driving.

These questions highlight the **urgency and necessity of a coordinated reflection**, at national and European levels—and beyond—on how the law should evolve in response to the automation of driving.

The goal of this process is to **establish a robust and coherent legal framework** capable of supporting the rise of automated vehicles while ensuring public safety. This framework must meet several essential conditions: it must ensure that automated vehicles comply with strict standards, and it must clearly define the **distribution of responsibilities in the event of an accident**, whether it involves the manufacturer, the owner, or the software developer.

To ensure that the **legal framework for automated driving is adaptive, integrated, and coherent**, it is essential that it be based on an **interdisciplinary approach** and that it includes provisions involving various ministries, administrations, and organisations.

Priority Use Cases for Commercial Deployment

1. Motorway Chauffeur

The first use case for automated driving is the **motorway chauffeur.** This mode promises improved traffic flow and enhanced safety, as human error remains the leading cause of road accidents. **The system takes over driving on motorways**, including lane keeping, lane changes, and speed management. The driver may temporarily disengage (commonly referred to in the industry as "eyes-off / hands-off") but must be able to retake control as and when necessary.

As of January 2023, **UN Regulation No. 157** allows contracting parties that choose to apply it to authorise the use of SAE Level 3 automated driving systems in passenger cars and light commercial vehicles at speeds up to 130 km/h on motorways – under certain conditions. National type-approval authorities are responsible for granting system approval based on this regulation, paving the way for commercial deployment in Europe.

Some car manufacturers have already integrated motorway chauffeur functions into their production vehicles.

Network coverage is a key factor for automated driving. The availability of V2X communication technologies is crucial, as they **complement onboard systems** with external data, enhancing perception and planning functions (see text box). Regarding 5G availability as a widely used communication channel, it is important to assess whether data on coverage and service quality is available or can be obtained for the targeted Operational Design Domain (ODD). More details are provided in the chapter Connectivity and 5G Strategy.

2. Robotaxis

The second use case concerns the **robotaxi concept.** This term refers to **highly automated vehicles capable of providing shared, connected, and on-demand passenger transport services.** Ultimately, these vehicles will be able to operate without an onboard driver, in line with SAE Levels 4 and 5. They operate autonomously within predefined **Operational Design Domains (ODDs)**, such as urban areas, specific motorway sections, or restricted-access zones.

The integrated technology and sensors enable these vehicles to handle complex situations such as navigating busy intersections, overtaking, parking, or reacting to pedestrian intrusions. In the event of difficulties, **remote supervision allows a human operator to issue general instructions** (e.g. “change route” or “wait for the obstacle to clear”). Once the technical capabilities required to qualify as an automated vehicle are met, the second objective is to ensure that these vehicles **fully comply with the legal and regulatory requirements applicable to passenger transport services.**

Naturally, integrating robotaxis into a **mixed traffic environment** (private cars, public transport, cyclists, pedestrians, motorbikes, micromobility) presents several challenges: social acceptance, ethical concerns, legal certainty, and socio-economic impacts—particularly for existing professions. One of the major challenges for passenger transport services is **user communication** and the **current incompatibility with sector-specific legislation.**

This issue is also evident in pilot projects already underway outside the European Union, where some of these services are being offered commercially within limited areas. As a result, **manufacturers and technology providers now wish to test their systems in the specific context of European traffic.**

Experimental Framework in Luxembourg

In this context, Luxembourg is preparing to **regulate the testing of robotaxis under real-world operating conditions.** Notably, a **draft law on taxis and chauffeur-driven rental vehicles (VLC)** proposes that **operating licences may be granted to companies as part of scientific trials**, including robotaxi services.

This **trial authorisation** will allow operators to deploy robotaxis—clearly marked as such—without delaying the adoption of a baseline legal framework or infringing on the rights of traditional drivers. The dual objective is to **foster innovation** while **monitoring safety, real-world usage, and socio-economic impacts** in a controlled setting.

Licensing and oversight will fall under the Ministry of Mobility and Public Works. Operators will be required to submit detailed data on journeys, incidents, ridership, and employment impacts to support a continuous dialogue and enable regulatory adjustments.

Data Availability as a Facilitator for Automated Driving

Consider the following scenario: a driver who appreciates the benefits of automated driving would like to use this function for as much of their journey as possible. Before choosing a route, the driver wants to know which sections are suitable for automated driving, so they can minimise manual driving.

However, automated driving may not be possible under certain conditions—such as roadworks, poor road conditions, adverse weather, or limited network coverage. These factors can be considered when determining potential routes.

The driver enters their destination into a navigation app, which calculates possible routes. The app then retrieves data on roadworks, road conditions, weather, network coverage, etc., for each route. It indicates the number and length of road segments where automated driving is not possible. The driver selects a route and begins navigation—and, where applicable, automated driving.

Most of the required data is already available in Luxembourg. For example, tunnel data sets exist. Roadwork information is available in XML and DATEX II formats and includes key details such as end dates and follow-up measures. Traffic measurement and congestion data are also available, providing a good overview of current or potential traffic bottlenecks. Weather data is also accessible and includes road condition information in addition to standard meteorological values.

Pony.ai's automated experimental vehicle, operated in partnership with Emile Weber, displaying the words 'essai scientifique' (scientific trial)

3. Last-Mile Automated Shuttles

The third use case involves **last-mile automated shuttles integrated into on-demand mobility services.** This model offers a wide range of possibilities and can take various forms. The fundamental characteristic of mobility services using last-mile shuttles is that they are **only provided when needed.**

In most cases, these are **low-speed vehicles operating on fixed routes in urban or semi-urban environments.** They are designed to transport multiple passengers without a driver on board, within clearly defined conditions.

As automated shuttles become part of a new mobility reality, they can be used to **connect different transport options within a multimodal system**, potentially offering a level of convenience, speed, cost-efficiency, reliability, and predictability that competes with various forms of individual mobility.

The routing of these automated ride-sharing services is **automatically planned based on demand**—whether scheduled, real-time, or predictive—within the operational area and transmitted to the journey planning system.

A **transition between the last-mile environment and the road network** must be possible for the shuttle to reach public transport stops. These transition points should be clearly defined and included in both the automated service's route network and the road network.

However, several challenges must be addressed to operate an automated shuttle as an on-demand mobility service. **Clear criteria must be defined in advance** for determining stop locations, including virtual stops.

4. Valet Parking and Restricted-Access Sites

The fourth use case involves **automated vehicles operating in controlled-access environments**, such as underground car parks, bus depots and terminals, logistics hubs, industrial sites, or airports. These vehicles operate within private areas with restricted access or park autonomously in designated spaces. This use case typically relies on precise mapping, intelligent infrastructure, and controlled conditions.

Confined areas are generally controlled environments equipped with perimeter protection and barriers to prevent unauthorised access by vehicles or individuals. Within these zones, traffic may be **mixed**, with both manually driven and automated vehicles. Vehicles typically operate at **lower speeds, and specific traffic rules may apply.** As these areas are usually monitored, the risk of unauthorised vehicles or vulnerable road users (VRUs) being present is significantly reduced.

Key enablers for this use case include infrastructure-related elements, such as: Perimeter security control (e.g. using barriers, fencing, or geo-fencing), The ability to provide high-bandwidth, low-latency connectivity across the site, real-time traffic monitoring and management, and mechanisms to ensure acceptable performance even under imperfect conditions (e.g. redundant systems).

5. Logistics

The fifth use case concerns the **use of automated vehicles for goods delivery** (e.g. hub-to-hub transport, last-mile delivery, yard operations). These vehicles can operate nonstop without breaks, thereby extending driving hours and improving logistical efficiency. This use case aims to optimise logistics services, reduce transport costs, and enhance operator safety. Supervision centres will allow remote operators to monitor operations continuously.

Recent figures show that **a growing number of truck driver positions remain unfilled** across Europe. The International Road Transport Union (IRU) forecasts that by 2028, Europe could face a shortage of 745,000 truck drivers—equivalent to 17% of the total workforce required.

The introduction of automated logistics transport **requires a complete overhaul of the system**, from the digitalisation of logistics processes to the revision of delivery schedules. Initially, automated vehicles may operate at lower speeds than human-driven ones, but they will be able to run **24/7 without interruption**, enabling **new routing possibilities** and potentially optimising infrastructure use.

Although national and European frameworks are still under development, logistics companies can already begin to prepare by **exploring practical pilot projects** and actively participating in technical platforms and forums to share ideas. Early engagement will help ensure that companies are ready when automated logistics becomes viable.

Facilitator: Remote Supervision

Even in cases where no driver is present on board, **remote human supervision remains essential.** Also referred to as **Remote Management**, this function enables operators to:

- **Monitor vehicle status in real time,**
- **Intervene in unforeseen situations** (e.g. a blocked vehicle, complex incident, or system failure),
- **Authorise or validate critical decisions.**

This role is central to ensuring safety, regulatory compliance, and user trust in automated driving systems. The **modalities for integrating this function** will be examined as part of the development of the national regulatory framework for the deployment of automated driving.

Limitations and Risks

The **large-scale deployment of automated driving** involves several risks that must be anticipated and managed within a **responsible and secure framework.**

- **TECHNICAL:** Failures in automated systems can lead to **unexpected behaviours**, potentially causing accidents. The **loss of human control in critical situations**, especially under extreme or unusual conditions that push systems to their limits, raises important safety concerns. Additionally, **algorithmic decisions** made by these systems may lead to **complex ethical questions**, requiring strict oversight. Increased vehicle connectivity also exposes the system to **cyberthreats**. Vulnerabilities to cyberattacks could compromise both **user safety and the reliability of the transport network.**

- **SOCIAL:** The widespread adoption of automated driving could lead to e**xcessive dependence on technology**, accompanied by a **gradual loss of driving skills.** It may also **exacerbate social inequalities** if access to these technologies is not distributed equitably, potentially excluding certain segments of the population.

- **ENVIRONMENTAL and URBAN:** Excessive attractiveness of automated driving could **divert users from sustainable transport modes**, such as public transport, walking, or cycling. This could result in **increased road congestion**, longer distances travelled by motor vehicles, and potentially **higher energy consumption and emissions**, if modal shift effects are not properly managed. Furthermore,

Automated shuttle developed by Ohmio and operated by CFL, used in Belval the **accelerated turnover of technological components** could generate a **non-negligible environmental impact.**

The **national strategy takes all these risks into account** and includes **specific measures to mitigate them**, following a logic of **progressive, safe, inclusive, and sustainable deployment.**

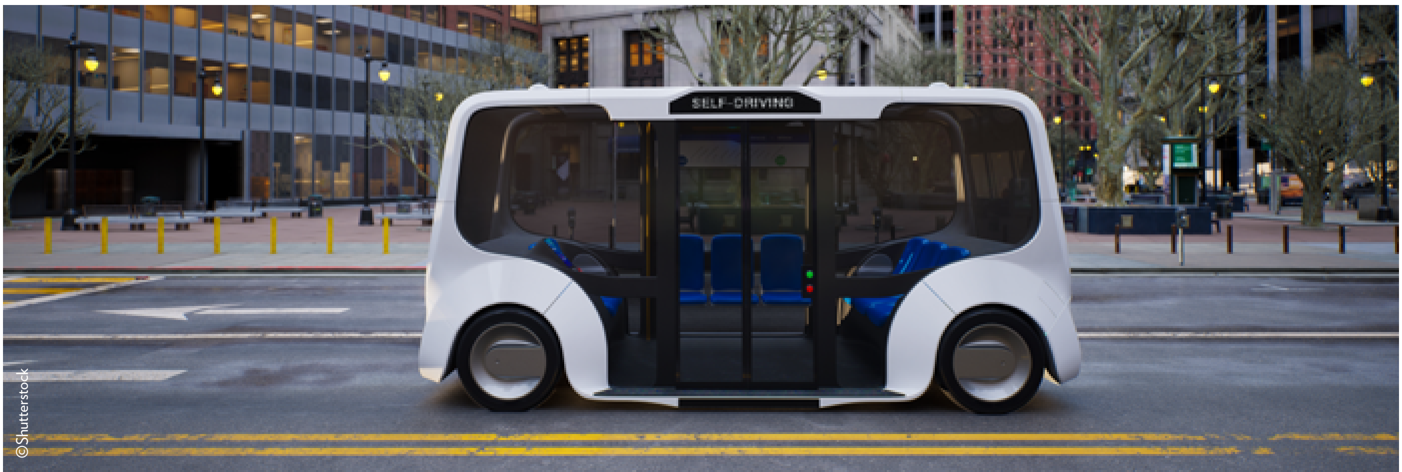
Integration of Automated Driving into a Multimodal Mobility Offering

Multimodal mobility is effective only when different modes of transport, vehicle types, and technologies **operate in an integrated manner.** No single mode of transport, vehicle type, or technology can, on its own, improve the overall mobility offering. It is therefore essential to prioritise these three categories in a targeted way, so that each can contribute its strengths to the overall system without its weaknesses hindering performance. The same applies to automated driving. The primary opportunity lies, of course, in improved road safety through the reduction of human error. One can also expect that the automated driving style may prove smoother, more comfortable, and more predictable for passengers and other road users. In certain cases, automated driving may help to strengthen existing transport services. Regardless of how quickly automated driving becomes integrated into public transport, there will still be a need for personnel on board or nearby the vehicle—at least for certain types of journeys (e.g. specific passenger profiles, feelings of insecurity, passengers in difficulty, etc.).

In terms of **public transport use cases**, the general rule followed by organising authorities is as follows: when a particular type of public transport currently operates effectively with non-automated vehicles in a specific context, it would likely retain its usefulness with automated vehicles. Conversely, a service that does not currently fill a gap in the multimodal system using conventional vehicles is unlikely to do so with automated ones. It is also important to consider the **specific characteristics of public transport in the Grand Duchy**, which differ significantly from those abroad. Firstly, it is free of charge. Secondly, rural services differ in terms of density, network coverage*, and scheduling**, and are far more developed than in other parts of Europe. The **growing number of public transport users**, along with their feedback via surveys and comments, indicates a desire to strengthen the current system rather than radically change it. This means that certain automated public transport services that may seem relevant in rural areas abroad are likely to be less so in Luxembourg.

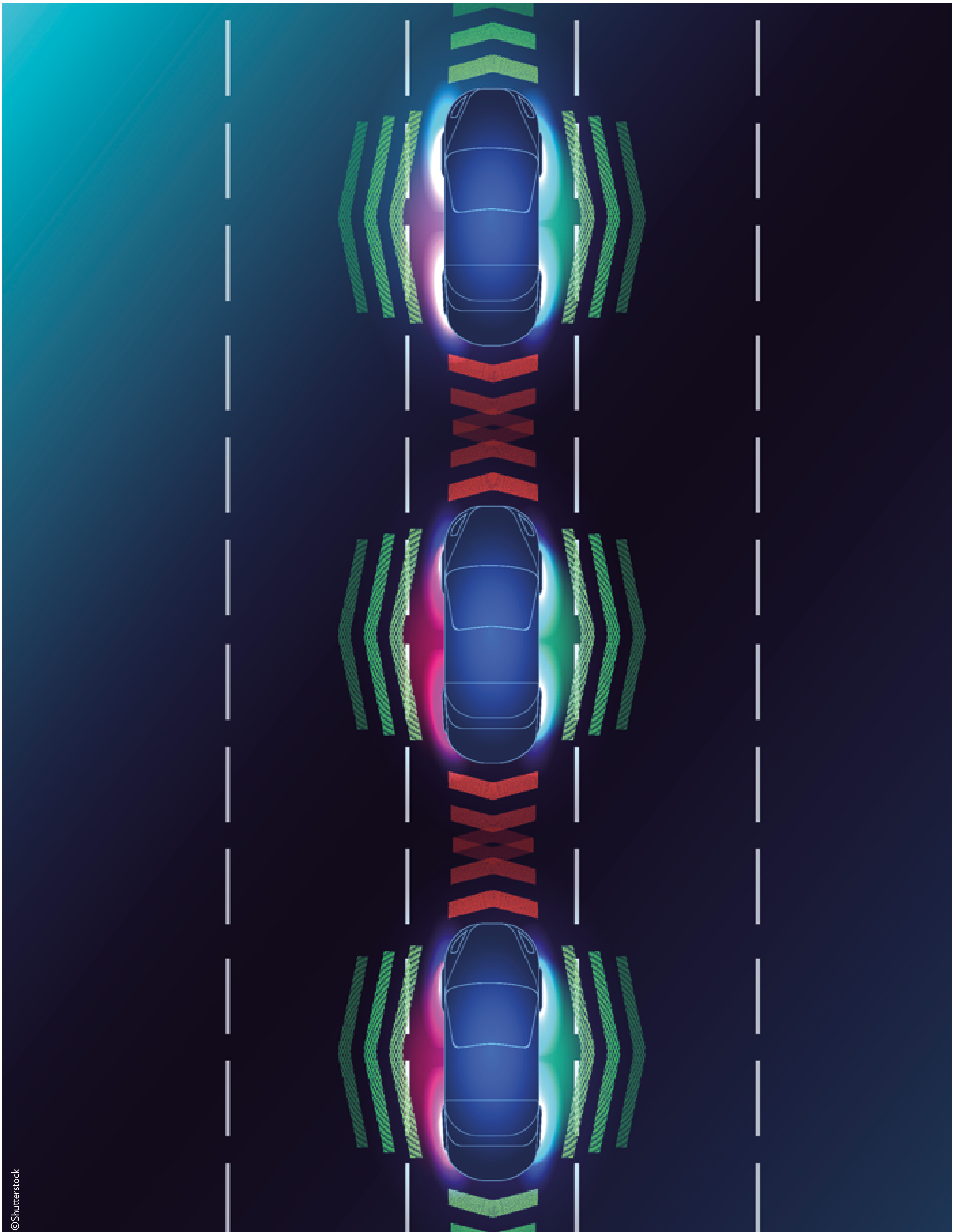
The main mobility challenge in the Greater Region is to provide the largest possible number of residents and cross-border workers with **alternatives to single-occupancy car use**, which contributes more than any other mode to road congestion. While single-occupancy car use will always remain an option and the road network will continue to be adapted, it is both financially and spatially **impossible to increase its overall capacity in line with demographic and economic growth**. The imperative of a *modal shift* towards greater use of public transport and active modes is based on the **more efficient use of public space.** The goal is to transport a maximum number of people comfortably using a minimum amount of space, by **prioritising space-efficient transport modes** and **increasing average occupancy rates** of vehicles in circulation.

This leads to the main challenge for automated driving from a multimodal mobility perspective. While **making the most of the many benefits of automated driving**, national and local authorities will need to **anticipate and, where necessary, regulate use cases whose effects may run counter to the goals of reducing road congestion and calming urban areas.** Examples include children increasingly travelling to school in individual cars rather than by school bus; empty vehicles adding to the traffic alongside those carrying passengers; or significant numbers of public transport users shifting across to urban taxi services. In the case of the latter risk, **Luxembourg's free public transport system is a clear advantage.**



Automated electric minibus, operating in an urban setting

* 99.97% of households reside in a locality served by at least one RGTR line.
** At least one bus every two hours, seven days a week, between 6 a.m. and 10 p.m., with several routes per location in general.



Figurative illustration of a group of three connected and automated vehicles following each other in a single lane

3

Ambitions and Actions

Part 3

Ambitions and Actions

Aiming to create a **dynamic and interconnected ecosystem for automated driving**, the strategic orientations and key objectives outlined in **Part 1 – Introduction** will be achieved through the **same six action levers** defined in the three national strategies grouped under the initiative *Accelerating Digital Sovereignty 2030*. Each lever in this strategy involves **specific actions and targets** related to automated driving, which will work together to achieve the overall goals.

1. Governance and Regulation

Luxembourg's strategy for automated driving is guided by a **clear ambition**: to make the Grand Duchy a **trusted territory for experimentation and controlled deployment of innovative automated mobility solutions**, while safeguarding the public interest, social acceptance, and environmental balance. The goal is to demonstrate, at the national level, that **automated driving can enhance accessibility, safety, and sustainability**, provided it is properly regulated and integrated into a comprehensive vision. Achieving this will require **close collaboration between industry, public research institutes, public organisations, and government entities.**

Governance and Interministerial Cooperation

Luxembourg's competitiveness in the field of automated driving depends on the **expertise and effective collaboration of multiple stakeholders**, working together to achieve the ambitious objectives set for the current legislative period.

To ensure an efficient collaboration and strengthened coordination across sectors, the government has established an **Interministerial Committee for Automated Driving.** Set up under the Ministry of the Economy, the Committee includes representatives from the Ministry of Mobility and Public Works, the Department of Media, Connectivity and Digital Policy of the Ministry of State, the Ministry for Digitalisation, the Ministry for Research and Higher Education, the Ministry of Justice.

The Committee is responsible for **developing strategic orientations and defining the national action plan** for automated driving. It must also **monitor the implementation** of the strategy. This includes translating measures into action by involving the entire government, including various ministries and administrations whose responsibilities and activities impact the national mobility and transport ecosystem (e.g. *Directorate-General for Mobility, Roads and Transport Infrastructure, National Roads Administration, Emergency Services, Police, Public Transport Administration,* etc.), through a **cross-sectoral and comprehensive approach.** To this end, the Committee will establish and lead **thematic platforms, multidisciplinary working groups**, and ensure the **overall strategic coordination** involving all ecosystem stakeholders.

Finally, the Committee will be tasked with **developing a clear and adaptive regulatory framework**, rooted in a policy that aligns with Luxembourg's fundamental principles. The **creation of test environments and living labs** will complement this framework.

Development of the Legal Framework for Commercial Deployment

The implementation of a national strategy for automated driving **requires the creation of a new legal framework**, one that is **tailored to the specificities of these technologies** and **flexible enough to evolve alongside them.** This framework must simultaneously ensure **safe operating conditions** for automated vehicles on public roads, a **clear allocation of legal responsibilities** of the various stakeholder, the protection of data generated by onboard systems, and the **alignment with European and international regulations.**

In the initial phase, Luxembourg plans to build upon its existing framework for **scientific testing**, expanding its potential. The country already allows vehicles developed using new technologies to operate for experimental purposes, subject to individual authorisation by the Minister responsible for transport. While this framework provides a useful foundation, it remains partial. A **dedicated regulatory framework for scientific testing of automated driving** will be formalised, offering clear guarantees to operators while enabling the State to maintain a close oversight of these trials. A key challenge will be to **permit tests without a driver on board**, in line with the technological evolution of Level 4 systems and beyond. Such authorisations must remain **limited in time and scope**, and include **strict requirements for safety, traceability, and supervision.**

In a second phase, the strategy foresees the development of a legal framework to support the **progressive commercial deployment** of automated driving, targeting five priority use cases.

Initially, the legislation will be adapted to allow **motorway chauffeur functionalities**, requiring a redefinition of the responsibilities between a human driver and the automated system. This includes specifying the conditions under which the feature may be used and the legal consequences of failing to retake control when prompted. New concepts and definitions will need to be integrated into national law and made understandable to both the users and the authorities.

Subsequently, a specific framework will be created to regulate **robotaxis and last-mile automated shuttles.** These large-scale projects require a thorough review of existing legislation—not only the Highway Code but also the laws governing **remote vehicle supervision** and **taxi services.** Additional use cases, such as **automated valet parking** and **restricted-access zones** on private or semi-public sites, will also require tailored legal provisions..

The establishment of this framework raises **complex practical and legal questions**, including:

- **Communication protocols between operators and authorities** (e.g. generic contact points for emergency services),
- **Pre-test requirements** (e.g. test tracks in Luxembourg or the Greater Region),
- **Recognition of technical documents and reports** from other Member States,
- **Obligations for signage, reporting, documentation, and event recording** (e.g. Event Data Recorder, DSSAD),
- **Insurance conditions** (scope, coverage, liability),
- **Roles and training for police and emergency services**,
- **Compliance with data protection and information security regulations** (e.g. GDPR),
- **Conditions for paid passenger transport**,
- **Import procedures for automated vehicles**,
- **Remote supervision or driving modalities**, and
- **Data sharing and operational information exchange**, including potential **exemptions** for private domain use (e.g. depots, industrial sites, logistics centres, car parks).

All these elements must be **progressively structured into a coherent, adaptive framework, built upon dialogue** between public authorities, industry stakeholders and citizens.

Single Point of Contact for Automated Driving

The establishment of a **single point of contact** will be explored, as it could serve as a key strategic lever to ensure the effective and coherent coordination of initiatives related to automated driving in Luxembourg.

Among its responsibilities, this centralised body would **facilitate the management of authorisation procedures** by streamlining processes for stakeholders wishing to test, validate, or deploy automated solutions. It would also act as a cross-cutting advisory body, providing expertise on legislative, technological, ethical, and operational aspects.

With an **extensive international network**, the point of contact could **support cross-border and European cooperation**,

An automated vehicle developed by Waymo is approaching an urban intersection while ensuring **structured monitoring of relevant national and international projects**. It would play a key role in **supporting R&D projects**, **implementing joint roadmaps**, and **disseminating results** to stakeholders.

By centralising information, promoting the exchange of best practices, and ensuring a comprehensive overview, this single point of contact would **enhance the clarity, efficiency, and ambition of Luxembourg's national strategy** for automated mobility.

Acceptability

Social acceptability is a key lever for the successful integration of automated driving into Luxembourg's mobility landscape. To build a lasting relationship of trust with citizens and relevant professionals, the strategy **includes an inclusive, transparent, and participatory communication approach.** Identified measures include dialogue workshops, information campaigns, the publication of various material (explanatory videos, brochures, web portals), as well as the participation in demonstrators, pilot projects, or open days hosted by ecosystem stakeholders.

By combining information, dialogue, and active participation, Luxembourg aims to demystify embedded technologies and **foster a climate of trust around automated driving**—encouraging acceptance, ownership, and informed use of automated driving technologies.

Impact Monitoring

The introduction of automated driving in Luxembourg requires the **establishment of a monitoring and qualitative evaluation** framework to assess its effects over time. The results will serve to guide public policy, adjust accompanying measures, and ensure that the transition brought about by the deployment of automated driving technologies benefits society as a whole—while remaining aligned with the strategic directions and main objectives outlined above, particularly those related to safety, sustainability, and innovation.

This framework could be structured around **several complementary areas**, such as: user feedback and social acceptance; monitoring of economic impact, including cross-sectoral innovation; evaluation of talent attraction as well as effects on employment, skills, and training; and measurement of the impact on mobility, road safety, and travel behaviour.

In a second phase, the introduction of key performance indicators (KPIs) to measure some of the above elements could be considered. This evaluation framework must be adaptable, co-developed with stakeholders, and **embedded in a logic of transparency and continuous improvement.**

2. Skills and Talent

Luxembourg's ambition to **strengthen talent and skills** in the field of connected and automated driving will require a **multidimensional approach.**

Luxembourg's ambition to strengthen talent and skills in the field of connected and automated driving will require a multidimensional approach.

The *Interministerial Committee for the Attraction, Retention and Development of Talent* already **defines strategic priorities and ensures coordinated monitoring of government action.** Various initiatives aimed at **enhancing the attractiveness of Luxembourg** as a destination of choice for international talent are being implemented across sectors, particularly in education, training, talent attraction, and retention.

In terms of **developing expertise in digital technologies**, *Luxembourg's AI Strategy*[28] has identified three key skill profiles and tailored approaches to harness the potential of AI. Similarly, *Luxembourg's Data Strategy*[29] outlines three complementary profiles to strengthen data-related talent.

In the same vein, the deployment of automated driving in Luxembourg relies on the coordinated development of **three complementary skill profiles**, all essential for the design, operation, and governance of these technologies:

To accelerate the deployment of automated driving systems, it is essential to develop technical, legal, and practical skills alike.

Technology EXPERTS form the scientific and strategic foundation of this transformation. They design AI systems, embedded software architectures, V2X communication protocols, and ensure the cybersecurity of intelligent transport systems. Their role is also central in defining safety standards, assessing socio-economic impacts and ensuring the interoperability of solutions. To support these profiles, the strategy foresees to strengthen interdisciplinary research, encouraging efforts to fund doctoral and postdoctoral scholarships, and promoting public-private partnerships (PPP) that foster technology transfer and experimentation.

Field OPERATIVES include operators, technicians, planners, and managers responsible for the practical implementation of automated services and the adaptation of infrastructure. Their roles may involve traffic management, maintenance of connected equipment, supervision of automated fleets, or the integration of new services in urban environments. To support these professionals, continuous education modules will be developed, a certified skills label will be introduced, and simulation platforms will be used to enable training on real-world use cases in collaboration with local authorities.

FACILITATORS bring the cross-disciplinary expertise required for a responsible and secure deployment. These include legal specialists, risk analysts, insurance experts, ergonomists, and human factors professionals, amongst others. They play a key role in setting and adapting regulatory frameworks, in data protection, in liability management, and in ensuring user-centred interface design. The strategy provides for the integration of specialised modules into university curricula and continuing education, the development of interdisciplinary programmes, and strengthened cooperation with professional bodies and service sector stakeholders.

To accelerate the deployment and adoption of automated driving systems, it will be essential to **cultivate not only the technical skills needed to design and develop the associated technologies, but also the legal, analytical, and practical skills** required to fully realise the potential of ADS.

Luxembourg will continue to invest in **talent recruitment and training programmes to strengthen skills** and will work with ADEM and the vocational training centres to **co-develop reskilling and upskilling pathways**, to enable the existing workforce impacted by all areas related to automated driving to retrain. Building on the priorities of the *High Committee for the Attraction, Retention and Development of Talent*[30], the goal is to enhance national competitiveness, foster innovation, and lead in future-oriented technologies.

Luxembourg will adopt an **agile, cross-sectoral, and inclusive approach**, aiming to strike the right balance between developing elite talent and ensuring broad citizen inclusion. Close collaboration between industry, academia, and public services will be encouraged through various measures, promoting the country as an attractive destination for both national and international talent. To ensure that skills development aligns with the needs of the Single Market, **Luxembourg will engage with European-level initiatives** such as the *Pact for Skills*[31] and the *Automotive Skills Alliance*[8].

Development of Scientific Competencies

Scientific competencies in the field of automated driving exist at the University of Luxembourg, notably within its *Interdisciplinary Centre for Security, Reliability and Trust* (SnT) and the Engineering Department of the *Faculty of Science, Technology, and Medicine* (FSTM), at the *Luxembourg Institute of Science and Technology* (LIST), as well as at the *Luxembourg Institute of Socio-Economic Research* (LISER).

The *Ubiquitous and Intelligent Systems* (UBIX) research group at **SnT** conducts research activities on distributed systems, communicative systems, applied machine learning, robotics, and computer vision, with connected and automated mobility as one of the areas of application. It operates the **"360Lab"**, an interdisciplinary platform for research on smart mobility, including connected and automated driving, as well as cooperative and teleoperated driving. It has also developed the automated driving software **"Robocar"**, which is made available as an open-source platform to other researchers. Robocar has been tested under real-world conditions on the public roads of the city of Luxembourg. Current research focuses particularly on remote-operated driving.

The **Engineering Department at the University of Luxembourg** is interested in automated driving, particularly from the perspective of integrating automated vehicles into traffic and transport planning and management.

The research activities of **LIST** related to automated driving focus on four aspects:

1. Connectivity: Development of reliable, low-latency, and adaptive connectivity solutions (e.g., 5G/6G, V2X, SATCOM) aimed at enabling cooperative, connected, and automated mobility, as well as new digital infrastructures for automated driving;
2. Modelling and Simulation through digital twins, traffic simulation tools, and predictive models that help design, evaluate, and optimize mobility scenarios before physical deployment;
3. Testing, Deployment, and Validation in Real Conditions: Provision of infrastructure and services enabling simulations, field testing, and laboratory testing, as well as participation in several European projects and consortia (CitCom.Ai, IN2CCAM);
4. Trust, Security, and Acceptance: Development of tools and techniques to assess occupant/driver experience, improve driver behaviour, and facilitate acceptance of connected, cooperative, and automated transportation methods.

Finally, **LISER** focuses on various factors (attitudes, personality, levels of trust) that can influence people's mobility choices – including the public's acceptance of connected and automated transport methods – as well as the anticipation of mobility habits and the potential influence of automated driving on these habits. It also examines potential risks of modal shifts that automated

Image generated by artificial intelligence depicting a person wearing a virtual reality headset developing a system

vehicles could bring, such as replacing soft mobility or public transport. Another area of interest is **inclusive mobility**, particularly the benefits that automated driving can bring to young or elderly individuals, or those without a driving license.

It is important to continue supporting research activities in these areas, focusing on **existing competencies, particularly in terms of automated systems, connectivity, and simulations**, while fostering synergies with other potential application domains for the technologies thus developed.

3. Ecosystem and infrastructure

The **automated driving ecosystem** relies on a complex and interconnected architecture. It is comprised of **several key components** which, when well-coordinated and aligned, enable the environment to be prepared for the successful deployment of automated driving.

Good **Governance** ensures strategic coordination at multiple levels. **Services** aim to deliver sustainable, inclusive, and accessible mobility solutions. **Standards** help establish a framework that ensures interoperability, security, and the ability to certify key elements. **Regulation** provides the legal framework for responsibility, safety, and data governance. **Data** is essential for delivering real-time, accessible, reusable and secure information. The **Business** pillar supports innovation through new business models and partnerships, while **Financing** mobilizes public and private financial resources. **Infrastructure** encompasses intelligent roads, connectivity, and charging stations. **Hubs** serve as nerve centres for planning, logistics, vehicle maintenance and charging. **Society** focuses on social acceptance, education, and accessibility. Finally, the ecosystem relies on **Solution providers** (manufacturers, suppliers and subcontractors, developers, and partners for engineering and R&D) to develop automated driving systems and on **Institutions** (ministries, authorities, regulators, standardization bodies) to ensure its proper functioning.

A more detailed description of the various actors is provided in the chapter Stakeholders and decision-makers, while further information on the Development and Use of Digital Infrastructure in Luxembourg is given below.

Stakeholders and decision-makers

The national ecosystem of automated driving includes several key stakeholders, each playing a distinct role:

Industry Actors: This group includes car manufacturers, subcontractors and technology suppliers, software developers, and service providers. They develop and integrate the necessary technologies for automated vehicles. More specifically:

- Vehicle manufacturers design, build and market vehicles and strive to design them in the most user-friendly manner, while also catering to operators. They are responsible for integrating technologies and functions from suppliers, and therefore determine the overall capabilities of vehicles in terms of automated driving.
- Automated driving system suppliers design and integrate technologies that enable vehicles to perceive their environment, make decisions, and control their trajectory without human intervention. They develop software,

sensors, and algorithms to ensure safety, autonomy, and performance.
- Fleet operators handle the procurement, insurance, maintenance, and cleaning of vehicles and are responsible for fleet availability within a given service.
- Operation control centres are responsible for monitoring vehicles in circulation and, where necessary, intervene remotely to manage errors.
- Mobility providers serve as the interface with end customers. They offer services that allow to book, manage, and bill trips, typically based on applications. Their algorithms also optimise ride-pooling by grouping trip requests efficiently while maintaining user comfort.
- Service providers integrate services into their customer-centric offering that go beyond mobility itself, and vice versa. This could include offering their own services within the vehicle or linking them to route information, as well as integrating mobility services into their own platforms.
- Cloud operators are responsible for ensuring the robust and reliable availability of data and computing operations for processing digital services, monitoring of trips, and, as the case may be, fleet manoeuvring and cooperative driving.
- Communication technology companies ensure stable communication between vehicles and cloud services.
- Insurance and reinsurance providers are preparing to adapt risk models and products to an environment where liability might shift from the human driver to the vehicle manufacturer or system/software provider. New offerings specific to automated vehicles, incorporating guarantees related to technical failures or cyberattacks, need to be developed. Reinsurers help pool risks on a larger scale, especially for automated vehicle fleets. This sector is also involved in regulatory discussions to redefine civil liability frameworks.

Public Authorities: The government and relevant municipalities develop policies and strategies to guide and regulate the development and adoption of automated vehicles. They also support the funding of pilot projects and necessary infrastructures.

Road Operators: These entities manage and maintain road infrastructures. They are responsible for adapting roads to accommodate automated vehicles, for example by providing information or by installing sensors and communication systems.

Representative Bodies: These groups include professional associations, trade unions, and specific interest groups. They represent the interests of their members and participate in policy and regulatory discussions.

Regulators: Regulatory bodies establish safety standards and legal frameworks for the use of automated vehicles. They ensure that technologies meet safety and performance requirements.

Research Actors: Universities, research institutes, and laboratories play a crucial role by conducting advanced studies on algorithms, sensors, and automated driving systems. In Luxembourg, institutions such as the University, LIST, and LISER are notable examples.

Each of these stakeholders plays a vital role in ensuring the harmonious and secure development of automated driving. **Close collaboration is necessary to overcome technical, ethical, and regulatory challenges.** Managing the ecosystem will require not only diverse technical expertise but also the ability to integrate the visions and contributions of these varied actors through a **cross-sectoral approach.**

Development and Use of Digital Infrastructure

Digitalisation of the road infrastructure

To support the deployment of automated driving in Luxembourg, it will be useful to **assess the need for a gradual and coordinated adaptation of the transport infrastructure.** This includes conducting **periodic checks on the compatibility of the road network** with the requirements and limitations of automated vehicles, particularly within the main Operational Design Domains (ODDs) identified in the priority use cases for commercial deployment.

The **visibility, legibility, and condition of road markings and traffic signs, historically of high quality in Luxembourg**, must continue to be taken into consideration to ensure reliable detection by onboard systems, for example in the context of Intelligent *Speed Assistance (ISA)****. **Consideration should also be given to the interoperability of dynamic signage elements** (e.g. traffic lights, variable message signs, etc.) to enable **real-time control and communication** with automated driving systems. Guidance and positioning devices, such as dedicated signs, sensors, or beacons, can further help to improve navigation accuracy.

To enable more robust planning for automated driving systems, it will be crucial to **maintain the availability and further develop the quality of data** from systems deployed and operated by public actors (notably those of the Ponts-et-Chaussées / CITA*****, cities, municipalities), as well as traffic information services (Info Trafic). As outlined in the *Luxembourg AI Strategy*, the flagship project "AI Move 1.0" aims to leverage AI to improve the quality and availability of data in the mobility sector.

Furthermore, the integration of cooperative V2X communication, standardisation of requirements related to intelligent transport systems (ITS), and **the creation of flexible infrastructure elements such as virtual stops** for vehicles are key levers to further support safe automated mobility.

The **Trans-European Transport Network** (TEN-T) – and particularly motorways – forms the backbone of road traffic in

*** It should be noted that, as part of the introduction of the GSR regulation, the Commission has set up a catalogue in which each Member State must list its traffic signs. However, as this is still a manual process, it is not guaranteed that the information will necessarily be up to date at European level.
**** Existing data (e.g., construction sites of the P&Ch.) is made available as open data on data.public.lu for use by third parties.

Europe. In Luxembourg, the A3 and A6 motorways are part of the central TEN-T Core Network *"North Sea – Rhine – Mediterranean"*, while to the south of its border, the A31 (at the level of Maizières-lès-Metz) intersects with the TEN-T *"Atlantic"* network. With its strategic geographical location at the heart of Europe, **Luxembourg offers exceptional road connectivity.** Its 165 km toll-free motorway network is among the densest in Europe.

Thanks to its strategic location in the heart of Europe, Luxembourg benefits from exceptional road connectivity, with one of the densest free motorway networks in Europe.

As part of the measures to support the growth of automated driving at European level, **Luxembourg aims to be part of the candidate corridors for large-scale testing and deployment**, leveraging its road infrastructure and communication system capabilities to support the deployment of automated and connected vehicles. As a member of **the first cross-border corridor for connected and automated driving** (see Chapter on the "Cross-Border Digital Testbed France-Germany-Luxembourg"), Luxembourg regularly participates in European projects, including those on 5G corridors, and is involved in various technical platforms and European initiatives related to these themes, as detailed in the chapter "International Cooperation / Participation in International Initiatives".

The specific domain of the **digitalisation of assisted corridors and motorways** is likely to further enable typical applications for driving automation, such as the use of automated trucks for *"Hub 2 Hub"* logistics operations, as well as infrastructure-assisted cooperative driving (*"V2I assisted automated driving"*). In this context, vehicles equipped with CCAM functionality can be deployed with the help of digitised road infrastructure that complies with the latest standards. The impact of certain factors that may restrict the ODD of some automated systems can indeed be mitigated, or even avoided, through adaptations of the infrastructure. Since the perception capabilities of automated vehicles can be restricted by the range and capacity of onboard sensors, this limitation could be alleviated by complementary information provided by the road infrastructure.

According to the **ISAD levels for the categorisation of road infrastructure** proposed by the European project INFRAMIX[32], connectivity between road infrastructure and vehicles will develop gradually. In this regard, Ponts-et-Chaussées, the national road operator is also focused on the continuous expansion of the communication capacity (V2I, I2V) of their road infrastructure, in line with the ISAD philosophy, without necessarily restricting this capacity to the pre-established levels. The requirements of automated vehicles in terms of ODD will likely evolve in parallel with the development of onboard sensors, software, and AI technologies.

Connectivity and 5G Strategy

As automation levels increase, an **automated vehicle must be able to determine whether it is operating within its Operational Design Domain** and adjust its driving delegation modes accordingly.

In this context, its **ability to communicate with its environment** (e.g., vehicles, infrastructure, other road users, the cloud), the availability of data from infrastructure-level sensors, as well as real-time high-definition mapping (HD Map), provide valuable information that can be combined to **complement the vision from onboard sensors and enhance the reliability** of automation systems. The instant transmission of data from sensors and mapping systems facilitates the real-time adaptation of decisions made by vehicles in response to changes in their surroundings. These technical elements serve as an acceleration factor for the development of cooperative, connected, and automated driving.

Luxembourg's legislation on electronic communications does not hinder automated driving. This framework allows operators and various stakeholders to innovate and improve infrastructure, thus facilitating the deployment of connectivity solutions and services for automated driving.

The Government encourages the development of digital infrastructure, as well as the connectivity of major road networks and urban areas, particularly those with high population density or those serving as research hubs. Specifically, the Government will encourage stakeholders (network operators, road managers, local communities, etc.) to invest in enhancing coverage across various road network segments using different connectivity technologies, and to closely monitor the evolution of this field with respect to the needs arising from CCAM use cases.

5G, with its low latency and ability to handle numerous simultaneous connections, enables real-time communication between vehicles and their environment. It **plays a key role in the safety and efficiency of connected mobility.** In Luxembourg, as in the rest of the European Union, **the deployment of 5G connectivity for automated mobility is based on a harmonised legal framework.** This framework relies on standards set by European and international bodies such as ETSI, 3GPP, and UNECE, ensuring a coherent and interoperable approach across Europe.

An **extensive and reliable network coverage** is essential for the deployment of connected mobility solutions.

Luxembourg benefits from a well-developed mobile telecommunications infrastructure, with a coverage rate of 99.6% according to the *'Digital Decade 2025'* report[33]. However, challenges persist regarding **signal continuity in rural or underground areas** (e.g., tunnels) and **near borders zones.**

Nevertheless, today's automated vehicles are designed to operate even in the absence of continuous connectivity, thanks to a combination of HD maps and onboard sensors such as LIDAR, cameras, and radar. These technologies allow them to analyse their environment in real time and make instant decisions autonomously. This enables efficient operation, even in areas with limited network coverage.

Luxembourg adopts a technology-neutral approach, favouring hybrid and interoperable solutions.

Luxembourg adopts a technology-neutral approach, favouring hybrid and interoperable solutions. This flexibility allows the integration of different communication technologies based on specific needs, while ensuring seamless connectivity, particularly in cross-border areas. By exploring the complementarity of different terrestrial and satellite technologies, Luxembourg aims to establish a robust and scalable infrastructure for future smart mobility applications.

Ensuring Cross-Border Continuity of Connectivity

Automated driving, particularly in a cross-border context, presents technical and regulatory challenges, notably regarding the **continuity of connectivity between international mobile networks.** While uninterrupted connectivity is not strictly essential for the operation of automated vehicles, maintaining a stable connection remains crucial for many advanced use cases, such as real-time data updates, vehicle-to-vehicle cooperation, and remote supervision.

In this regard, the *CEF Digital* programme of the European Commission actively supports the **deployment of cross-border digital infrastructure through the 5G corridors initiative**, aiming to ensure seamless transitions between different 5G networks ("cross-border handover"). Luxembourg is notably involved through the pilot project **"5G DeLux"**, conducted in partnership with Germany. This project seeks to guarantee continuous connectivity along the corridor between Frisange and Saarbrücken. It brings together POST Luxembourg, Deutsche Telekom and the BMW Group, along with equipment providers and specialists in connected mobility to enable testing and securing of network transitions without perceptible interruption for the user.

Other European projects complement this initiative, such as **"5GCroCo"**, funded under the Horizon 2020 programme as part of the 5G-PPP (Public-Private Partnership). This project plays a key role in testing automated and connected driving at a cross-border scale. Implemented along the corridor linking Luxembourg, Metz (France), and Merzig (Germany), 5GCroCo aims to test connected mobility scenarios where transitions between different network operators must occur with low latency and guaranteed service continuity. The project has notably enabled experimentation with use cases such as cooperative driving, real-time map updates, and dynamic incident management. Coordinated by CTTC, it brings together major vehicle manufacturers, mobile network operators, as well as academic and institutional partners.

Aerial night view of a motorway in a metropolitan area, showing connected vehicles

Radio Frequency Allocation

In Luxembourg, **the management of radio frequencies** is handled by the Institut Luxembourgeois de Régulation (ILR), which develops the *National Frequency Plan* in accordance with European and international legal frameworks. The ILR relies notably on the decisions and recommendations of the European Conference of Postal and Telecommunications Administrations (CEPT), and in particular the work of the Electronic Communications Committee (ECC), which is responsible for harmonizing the radio spectrum across Europe. Luxembourg's frequency plan officially incorporates these instruments.

In the field of Intelligent Transport Systems (ITS), **specific frequency bands have been allocated in Luxembourg to enable the development of services related to road safety and connected mobility.** Notably, the frequency bands referenced in the decision **ECC/DEC/(08)01**, the recommendation ***ECC/REC/(08)01***, and the decision **ECC/DEC/(09)01** concerning ITS are included in the National Frequency Plan of the Grand Duchy of Luxembourg (version dated May 26, 2025[34]) and are therefore designated as portions of the radio spectrum intended for this purpose at the national level.

Thus, **Luxembourg ensures the availability of the necessary spectrum resources for the deployment of modern and interoperable ITS solutions at European scale.**

Future PPDR Network – Towards Better Emergency Vehicle Management with Automated Driving

With the development of automated driving in Luxembourg, communication between automated vehicles and emergency services could enhance road coordination and facilitate interventions. The future **PPDR (Public Protection and Disaster Relief) network**, the successor to the RENITA network in Luxembourg, could therefore play an important role in this domain.

This ongoing project will allow users of the service to **retain full control of their data** and decide whether they wish to share it, how frequently, and with which stakeholders. Furthermore, thanks to **extended coverage, more frequent and precise datapoints**, and an **adapted communication interface**, this future PPDR network could notably **enable the following functions**:

- **Alert automated vehicles** to the presence of an emergency vehicle,
- **Indicate the trajectory and direction** of the emergency vehicle,
- **Facilitate priority passage**, in coordination with smart traffic lights and other vehicles.

The network could also **enable direct device-to-device (D2D) or machine-to-machine (M2M) communication**, if the user wishes and if the vehicles are equipped with the necessary hardware.

Data Governance, Valorisation, and Protection

The exchange of data generated by intelligent mobility systems, and in particular by cooperative, connected, and automated driving, represents a **strategic lever for creating economic value** through the development and delivery of innovative products and services. Its exploitation relies on emerging technologies such as High-Performance Computing / Big Data (HPC-BD), cloud computing, High-Performance Data Analytics (HPDA), Artificial Intelligence (AI), and quantum computing – domains in which Luxembourg is already actively positioning itself. The corresponding objectives and key measures have been outlined within the aforementioned strategic initiative *Accelerating Digital Sovereignty 2030*.

The **advancement of automated driving is fundamentally dependent on data collection, which is essential for the proper functioning and continuous improvement of embedded systems.** Data processed by automated vehicles includes information **from the vehicle itself** (e.g., location data, sensor and camera data, recording data) as well as **from its environment** (e.g., traffic conditions, congestion detection, road surface status). In addition to data collection and use, automated driving may also involve **transmitting data to third parties**, for example, for the improvement of road safety, cooperative traffic management, or communication with other road users and stakeholders.

The Government is committed to establishing a **national framework** to facilitate data exchange and promote data valorisation, while ensuring compliance with **personal data protection regulations, cybersecurity requirements**, and the evolving **European regulatory landscape.**

This framework will **define the conditions for accessing data** originating from vehicles, infrastructure, and other road users (e.g. pedestrians, cyclists), for use in:

a. Economic activities that depend on specific datasets produced by the intelligent and sustainable mobility ecosystem *(e.g., mobility services, fleet management, usage-based insurance, predictive maintenance, smart EV charging networks, fraud mitigation, optimisation of key processes, etc.);*
   and
b. Activities related to the provision of public services of quality *(e.g., road safety, infrastructure operation and management, accident investigations and analysis, etc.)*.

Valorisation of Mobility Data

To foster the valorisation of mobility data within a trusted environment, **Luxembourg encourages the adoption of FAIR data principles** (Findable, Accessible, Interoperable, and Reusable) that meet the quality standards commonly practised by the sector.

To promote the responsible use of mobility data within a trusted framework, Luxembourg encourages the adoption of FAIR data (Findable, Accessible, Interoperable, and Reusable), in line with industry quality standards.

Automated mobility is a strategic driver of transformation, particularly when **fully embedded within a digital ecosystem built on data quality and interoperability.** Intelligent exploitation of mobility data can enhance the reliability of automated systems and maximise their societal impact. This approach supports the optimisation of public services, evidence-based policymaking, technological innovation, national competitiveness, and the development and attraction of talent essential to a rapidly evolving sector.

It is also important to note that the *European Data Strategy*[35], adopted and presented by the European Commission in 2020, has led to the adoption of several European regulations aimed at establishing a coherent framework consisting of rules, mechanisms, and procedures to facilitate data exploitation and organise data sharing.

This includes regulations such as **EU Regulation 2022/868** on Data Governance ("Data Governance Act") and **EU Regulation 2023/2854** on harmonised rules for fair access and use of data ("Data Act"), as well as sector-specific regulations where data plays a significant role, such as **EU Regulation 2024/1689** on Artificial Intelligence ("Artificial Intelligence Act").

At the national level, *Luxembourg's Data Strategy* provides for a centralised, unified, and effective data governance model to manage access to public sector data and European common data spaces.

The implementation of European regulations, alongside national decisions on data governance, aims to **enable data valorisation** while ensuring **legal certainty for all stakeholders** concerning the use of this data and **safeguarding individual rights and freedoms.**

In this context, the **legislative proposal No. 8395**[36] **foresees the controlled access to certain public sector data** protected by trade secrets, professional confidentiality or data protection requirements. Appropriate safeguards are applied to regulate disclosure. The bill also introduces **rigorous oversight mechanisms** via the Government Commission for Data Protection (CGPD) and **establishes secure processing environments for the use of protected data within closed and controlled settings.**

While such data can enhance safety, optimise navigation, and support the evolution of automated vehicles, **access to and use of certain mobility data can raise significant privacy concerns.** For instance, data related to travel habits, schedules, and frequented locations may pose profiling risks. In terms of **protection of personal data**, the data exchange framework must comply with the General Data Protection Regulation ("GDPR")[37]. The National Commission for Data Protection ("CNPD"), as the supervisory authority under the GDPR, ensures compliance with this regulation.

It is indeed essential to reconcile technological innovation with respect for fundamental rights. This entails implementing appropriate safeguards to ensure the confidentiality and protection of data, such as anonymisation, pseudonymisation and adherence to the principles of *"privacy by design"* and *"privacy by default"*. The development of automated driving in accordance with fundamental privacy rights and personal data protection helps **build public trust** without hindering innovation, economic development, or research.

Conscious of its central position in Europe, Luxembourg will make sure that **it remains consistent with prevailing organisational and technical standards** for data exchange to **ensure interoperability at the European level.**

Data Spaces

The proliferation of data sharing spaces in the transport sector, such as *GAIA-X*, the *European Mobility Data Space* (EMDS), and the Mobility Data Space (MDS) in Germany, **reflects an increasing desire to leverage data to improve mobility in Europe** and encourage innovation in the sector, in line with the *Strategy for Smart and Sustainable Mobility*, as well as legal obligations such as Directive 2010/40/EU ("ITS Directive")[38] and the corresponding delegated acts[39].

However, the emergence of multiple data spaces has led to **fragmentation, which complicates interoperability and reduces the efficiency of data exchange.** It is therefore essential to **promote a single standard for the collection and exchange of transport and mobility data.** Whether this harmonisation is achieved through the *Interoperable Europe Board*[40], a *European Digital Infrastructure Consortium* (EDIC), other public sector initiatives, or by supporting the most appropriate market-ready solution, the **establishment and adoption of a common standard** (e.g. *mobilityDCAT-AP* and *DATEX*, already mandated under the ITS Directive) is a critical action point for the future of mobility in Europe.

Luxembourg will promote the adoption of a pragmatic framework to support access to and reuse of mobility data within a trusted environment.

At a national level, Luxembourg will also need to consider how to best support the establishment and coordination of a **national data space specific to the mobility and transport sector.** Luxembourg will encourage the **adoption of a pragmatic framework** to enable access to and reuse of mobility data within a trusted environment. For data held by public sector entities, Luxembourg will ensure that designations and procedures are aligned with Chapter II of Regulation (EU) 2022/868 as referenced in the legislative proposal No. 8395.

Cybersecurity and Digital Trust

Digitalisation is profoundly transforming the automotive and smart mobility sector. Since 2018, with the mandatory adoption of the eCall system (emergency call), **all new cars are connected by default.** An increasing number of means of transport rely on a growing number of IT systems to **supervise, control, and command critical functions** such as propulsion, braking, or steering, but also to **offer new services** such as dynamic navigation, personalised assistance, fleet management, or infotainment. Moreover, **Over-The-Air (OTA)** updates are increasingly used by manufacturers to refresh their products' offerings.

The diversity and complexity of connections, coupled with the growing number of stakeholders (manufacturers, suppliers, service providers, infrastructure managers, public authorities, etc.), **multiply the risks of cyberattacks** that could directly impact the operational safety of vehicles.

The Government will promote the **development of cybersecurity expertise** to support the deployment of cooperative, connected, and automated driving and **promote the highest applicable standards** in this area, across both the public and private sectors.

In its stated ambition to become a true "**European Trusted Information Center**", Luxembourg is committed to developing services and structures that foster **strategic synergies** between cybersecurity actors. The goal is clear: to **maximise collective benefits** by facilitating cooperation, sharing critical information, and aligning efforts to face digital threats. European regulations (such as **NIS2, DORA[41], and CRA**) call on all actors, to varying degrees, to promote cybersecurity information exchanges as a key lever to strengthen collective resilience.

In this context, the **Luxembourg House of Cybersecurity (LHC)**, leveraging its expertise, will establish an exchange **infrastructure dedicated to the automobility sector.** This platform will allow stakeholders to collaborate actively on several key areas: threat intelligence and analysis, proactive attack detection, identification of technological vulnerabilities, and the definition of coordinated responses for prevention, detection, and mitigation.

Beyond these exchanges, the LHC also plans to offer enhanced support in risk analysis, compliance audits, and penetration testing with each system evolution. It will play a central role in **data security** and the dissemination of best practices, thereby contributing to **enhanced collective resilience.**

By fostering these synergies, Luxembourg aims not only to strengthen the security of its infrastructures but also to **position its stakeholders as European leaders in collaborative cybersecurity.**

Luxembourg will also ensure **linkages between international decision-making bodies on technical regulation and those involved in standardisation activities.**

The country possesses **recognised expertise in cybersecurity related to homologation**, particularly at the level of its technical services and the SNCH, the national authority for type approval. Experienced professionals are available to guide and support businesses throughout the process, including assistance with the selection of the appropriate testing laboratories. Furthermore, **access to standardisation activities (as an expert) is free of charge in Luxembourg** and coordinated via ILNAS[42].

Directive NIS2

As part of its compliance with European requirements regarding the **resilience of critical infrastructures**, Luxembourg transposes Directive (EU) 2022/2557[43] on the resilience of critical entities (*"CER Directive"*) and Directive (EU) 2022/2555[44] on cybersecurity (*"NIS2 Directive"*) through the **legislative proposals No. 8307[45] and No. 8364[46]**. These legislative instruments aim to strengthen the **security and continuity of essential services**, particularly in the **transport and digital infrastructure sectors.** They cover **risk anticipation and define resilience obligations** in terms of technical, security, and organisational measures (CER Directive) as well as cybersecurity measures (NIS2 Directive) that critical entities must take to ensure their resilience.

The NIS2 Directive thus constitutes an **essential framework for strengthening cybersecurity** for entities operating in critical sectors, notably in the transport sector (Annex I of the Directive), including **operators of Intelligent Transport Systems** (ITS), as well as automotive manufacturing (Annex II), including **manufacturers of motor vehicles for passenger or freight transport**, and **components and accessories** (according to NACE Rev. 2, section C, division 29), two domains closely linked to automated driving.

In this context, the national legislative proposal transposing the NIS2 Directive **provides for the designation of the ILR** *(Institut Luxembourgeois de Régulation)* **as the competent authority in Luxembourg**, responsible for overseeing and monitoring compliance with the obligations outlined by NIS2. Depending on their size and sector of activity, entities will be classified as either "essential" or "important," which determines the nature and intensity of the supervision applied. Among the priorities is the **obligation for entities to self-register** with the ILR, thereby ensuring clear identification of all actors subject to the directive.

The ILR plays a central role in **supervising the implementation of essential cybersecurity measures**, including governance, risk management, information systems protection, and incident management. In addition to these security measures, **entities must report any significant incident within 24 hours of its detection.** The ILR will be equipped with a **comprehensive supervisory framework** tailored to these challenges.

A **cybersecurity risk assessment related to automated and connected vehicles** has been initiated under the guidance of the European Commission. The ILR represents Luxembourg alongside other Member States (e.g., FR via ANSSI, DE via BSI) with support from experts from both the private and public sectors. An evaluation of the risk impact and probability has been conducted, and **recommendations are currently being drafted.**

Cyber Resilience Act (CRA)

The *Cyber Resilience Act* (CRA)[47] aims to **strengthen the cybersecurity of digital products commercialised in the European Union**, and thus has significant implications for the automated driving sector.

Manufacturers are required to **integrate cybersecurity from the design phase of automated systems.** This includes identifying and managing security risks, protecting against known vulnerabilities, and implementing **mechanisms for secure updates throughout the product's lifecycle.** In the event of a security breach, manufacturers must notify the competent authorities within 24 hours and promptly take corrective measures. This enhances the sector's responsiveness to cyber threats. The CRA also imposes **shared responsibility between manufacturers and their suppliers.** Each software or hardware component integrated into an automated vehicle must meet cybersecurity requirements, encouraging better coordination across the supply chain.

AI Act

The *EU Artificial Intelligence Regulation* ("AI Act" or "AIA")[48] adopts **a risk-based regulatory approach**, whereby high-risk AI systems (HRAIS) are subject to the strictest obligations. High-risk systems are those likely to significantly affect the health, safety, or fundamental rights of individuals. Among these are **critical infrastructure systems**, including AI systems used as **safety components in the management and operation of critical digital infrastructure**, as well as systems **related to road traffic management.**

While many AI systems used in automated vehicles will likely fall under the HRAIS category, the AIA recognises that **automated driving systems are already regulated by other EU legislations**, such as the *Type approval regulation*[25] or the *General Safety Regulation* (GSR II)[49]. Where high-risk AI requirements are already embedded in sector-specific legislation, the AIA allows providers of AI systems deployed in or related to automated vehicles to **benefit from AI regulatory sandboxes**, subject to certain conditions. However, **specific transparency obligations or voluntary codes of conduct** may also apply.

The legislative proposal No. 8476[50], implementing certain provisions of Regulation (EU) 2024/1689, foresees that national competent authorities can establish an AI regulatory sandbox.

This bill will allow the Government Commission for Data Protection (CGPD) to propose a regulatory sandbox for AI in line with the AI Act. This will enable integration within the secure processing environment established by the CGPD under the legislative proposal No. 8395, in accordance with European regulations on data reuse.

In its guidance mandate, the National Commission for Data Protection (CNPD) proposes **an AI regulatory sandbox** in line

The national Critical Entity Resilience Law (CER) will in the future serve as the foundation for identifying critical infrastructures and entities among operators of intelligent transport systems, within an increasingly automated and interconnected mobility environment. The cybersecurity obligations set out by NIS2 apply to all intelligent transport system operators, regardless of whether they are designated as critical entities or not.

Other obligations arising from Regulation (EU) 2024/1689, which establishes harmonised rules regarding artificial intelligence, and Regulation (EU) 2024/2847, which concerns horizontal cybersecurity requirements for products containing digital components, further strengthen the overall security framework for automated driving.

with the provisions of the AIA. The *"Sandkëscht"* programme encourages a collaborative and proactive approach to managing emerging challenges related to data privacy and the use of AI. Focused on personal data protection, this initiative follows a structured plan over a defined period, **encouraging innovation while building public trust** in new technologies through a dedicated environment for testing and understanding the legal implications of new technologies and their use.

The exact obligations of the various stakeholders in the automotive sector **could be clarified by future amendements to sector-specific legislation**, by incorporating provisions applicable to automated vehicles. Luxembourg will continue to monitor and support these developments.

Artificial Intelligence

Luxembourg aims to become a leading **innovation hub with a strong European and international influence in the field of human-centric AI**, built on trust, competitiveness, collaboration, and societal impact. The *Luxembourg AI Strategy*[29], presented under the "Accelerating Digital Sovereignty 2030" initiative, outlines six key levers to ensure the success of AI in Luxembourg.

As a high-potential application of AI, **automated driving will rely heavily on these levers and the cross-cutting actions** envisaged to strengthen the AI ecosystem in Luxembourg. **Synergies between these activities and those of the automotive and smart mobility sectors will continue to be pursued** to promote and support efforts by key stakeholders to ensure the deployment of this transformative technology.

Indeed, the **core components of artificial intelligence are directly applicable to automated driving.** However, certain aspects will require further development to address the specific constraints of this domain. **Examples of how these AI components apply to automated driving are outlined in the adjacent text box.** These capabilities make AI a strategic pillar for ensuring the safety, robustness, and efficiency of tomorrow's automated mobility systems.

While automated vehicles can bring numerous benefits, **the use of AI in automated driving systems also introduces new risks.** The preceding section on the AI Act provides insights into the **regulatory framework for AI** within the European Union, and by extension in Luxembourg.

Examples of AI Components in Automated Driving

MACHINE LEARNING enables automated driving systems to identify patterns in real-world traffic data. By relying on statistical algorithms, these systems can **improve their ability to recognise various situations** that may arise on the roads, anticipate the diverse behaviours of road users, and a**dapt their driving behaviour** based on accumulated experience.

DEEP LEARNING relies on multilayer neural networks capable of **processing massive volumes of unstructured data**, such as images or LIDAR signals. This technology is essential for the vehicle's **visual perception**, particularly for object detection, scene segmentation, and **contextual understanding** of the road environment.

SIMULTANEOUS LOCALISATION AND MAPPING (SLAM) enables the vehicle to **precisely position itself** within its environment while simultaneously building a real-time map. This capability is crucial for **navigating unmapped or dynamic areas**, ensuring reliable driving even in the absence of satellite positioning systems (e.g., GPS or Galileo) or in dense urban environments.

SYMBOLIC AND LOGICAL REASONING complements statistical approaches by **integrating explicit rules, such as traffic regulations or right-of-way priorities.** It enables the vehicle to make consistent decisions in **regulated or ambiguous situations** by combining formal logic with contextual interpretation.

PLANNING AND CONTROL ALGORITHMS generate optimal trajectories, taking into account the vehicle's **physical constraints**, **traffic rules**, and **safety objectives.** They ensure smooth, comfortable, and responsive driving by continuously adjusting the vehicle's speed, direction, and manoeuvres.

REINFORCEMENT LEARNING allows driving systems to improve through **trial and error in simulated environments.** This approach is particularly useful for developing driving strategies in complex or rare scenarios, optimising long-term decisions based on the rewards obtained.

ARTIFICIAL INTELLIGENCE INFERENCE is another essential lever for the development and optimisation of automated driving systems. It allows automated vehicles to perceive their environment in real time, accurately identifying and classifying objects, road users, and traffic signals, while understanding complex scenes. Through predictive analysis, these systems can **anticipate the behaviours** of other road users, plan safe trajectories, and **dynamically respond to unforeseen events**, such as emergency braking, a sudden obstacle, or deteriorating weather conditions. Inference also allows for the **fusion of data from multiple sensors** (cameras, LIDAR, GPS, etc.) to enhance the reliability of the decisions made by the vehicle. Finally, it plays a key role in continuous learning and performance improvement by facilitating the **analysis of incidents or near-accidents** and adapting learning models through retraining or federated learning.

Lastly, **ONBOARD AI** and **EDGE COMPUTING** allow for the local execution of AI models directly on the vehicle, **without relying on a cloud connection.** This capability ensures **low latency and high reliability** for critical decisions, while strengthening **data security and privacy.**

Establishing Test Environments / Living Labs

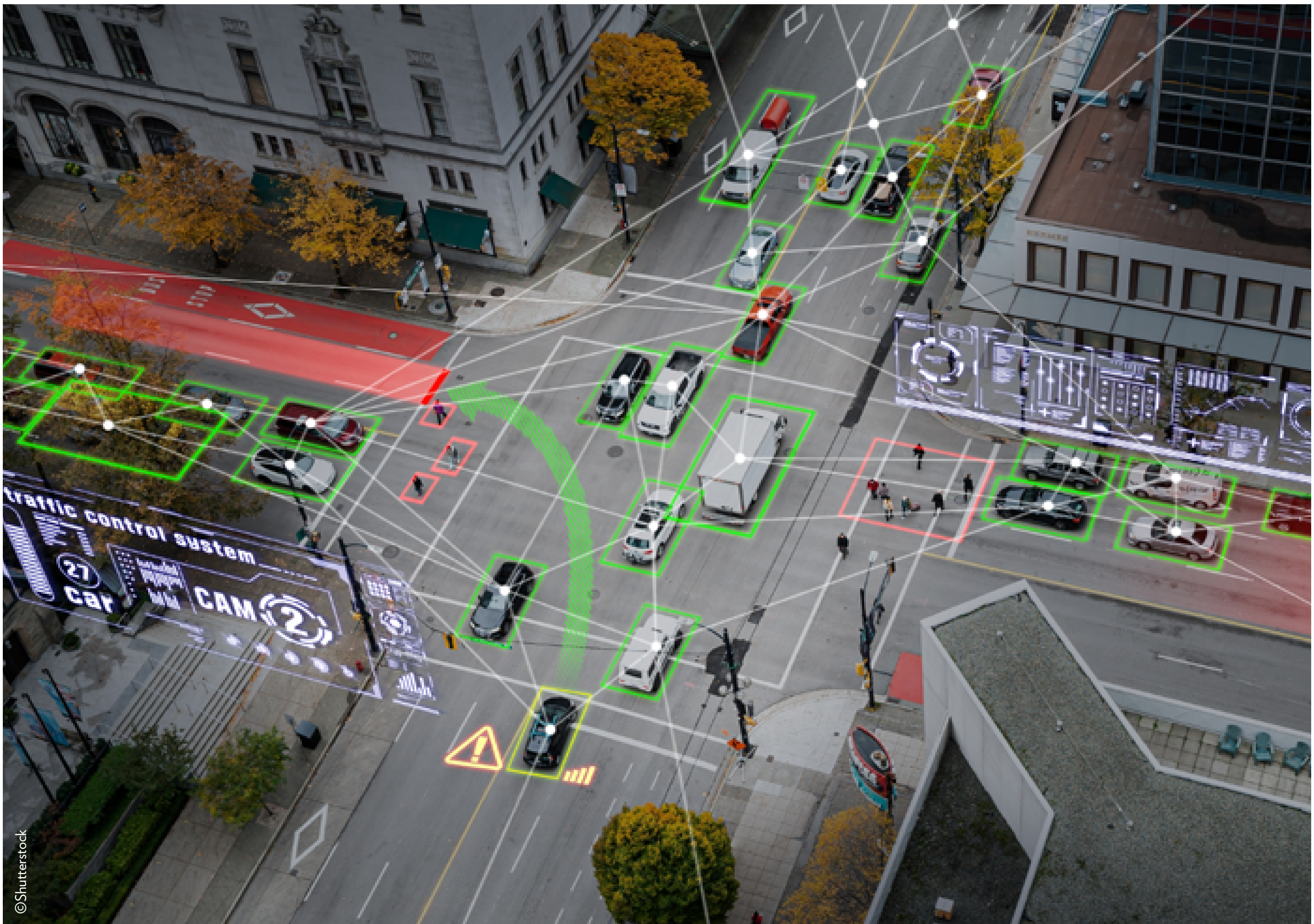
The **secure and efficient development of automated driving relies on the establishment of suitable testing environments** that cover the entire development and experimentation chain, from virtual simulation to open-road testing.

At the European level[51], initiatives such as the CCAM Partnership (Connected, Cooperative, and Automated Mobility) and platforms like Testfeld Niedersachsen (Germany), Aldenhoven Testing Center (Germany), UTAC Linas-Montlhéry (France), Living Lab Testtrack A270 (Netherlands), Digitrans (Austria), or ZalaZONE (Hungary) highlight the importance of **combining closed test infrastructures, intermediate environments, and real-world living labs.**

In Luxembourg, while **testing facilities such as the two sites of the Centre de Formation pour Conducteurs (CFC) or the Goodyear Testing Circuit** exist, they were not initially designed to fully meet the specific requirements of automated driving experimentation and validation, particularly concerning complex scenarios or connectivity (see box).

To support the growth of automated driving in Luxembourg, it will therefore be essential **to build upon existing structures** (including living labs on public roads), **while ensuring the development of intermediate environments** that allow for a progressive transition between closed-circuit tests and real-world testing. **A structured, scalable, and interoperable experimentation framework**, aligned with European standards, is necessary. This gradual approach will help reduce the complexity of test environments, especially on open roads, where situational variability can compromise reproducibility and safety.

The **establishment of collaborations with existing test sites** in the Greater Region and its surrounding areas represents a strategic opportunity for Luxembourg and should be pursued. **Targeted partnerships with different infrastructure operators** will allow access to advanced testing environments, enable resource pooling, and foster cross-border interoperability. They also provide an effective means of testing complex scenarios in diverse contexts, while **strengthening synergies in research, standardisation, and validation.** Such cooperation will support Luxembourg's integration into European innovation networks for automated mobility.



Aerial view of a smart urban intersection where connected and automated vehicles equipped with vision and positioning systems are on the road

*A **test environment primarily dedicated to the experimentation and validation of automated driving** typically offers various technical, functional, and organisational components to cover the full range of test scenarios, from simulation to real-world experimentation. Its components typically include:*

1. Modular Physical Infrastructures

- *Simulated urban areas (intersections, roundabouts, pedestrian crossings, traffic lights, bus stops, etc.);*
- *Highway segments (multiple lanes, entrances/exits, tunnels, bridges);*
- *Rural environments (narrow roads, tight turns, lack of markings);*
- *Variable conditions (night-time lighting, simulated weather, different road surfaces).*

2. Connectivity and Intelligent Systems

- *V2X networks (5G/6G or ITS-G5 antennas, RSU (Roadside Units), DSRC/C-V2X communication);*
- *Traffic lights and intelligent signs (interoperable with onboard systems);*
- *Dynamic signage systems (VMS, LED markings, connected beacons).*

3. Simulation and Virtual Testing Platforms

- *High-fidelity simulators (to test algorithms before physical deployment);*
- *Digital twins (virtual replicas of the test site for continuous validation);*
- *Scenario generation tools (including extreme or rare cases).*

4. Measurement, Tracking, and Analysis Systems

- *Tracking sensors (fixed LIDAR, cameras, radars for trajectory analysis);*
- *High-precision positioning systems (GNSS RTK, UWB beacons);*
- *Data collection and analysis platforms (for validation, traceability, and continuous improvement).*

5. Organisational and Regulatory Framework

- *Safety and oversight procedures (risk management, emergency stop zones);*
- *Access to regulatory authorities (e.g., for certification or regulated testing);*
- *Collaborative spaces (for R&D teams, demonstrations, training).*

6. Integration into a Living Ecosystem

- *Connection to living labs (urban districts, open roads, test fleets);*
- *Intermediate environments (semi-open zones with partial traffic control);*
- *Interfaces with citizens (for social acceptance and structured feedback).*

Living Lab Bissen

The **AutoMobility Campus** is a 14-hectare special activity zone specifically dedicated to R&D activities in the automotive and smart mobility sectors. The Ministry of the Economy has invested in the construction of an incubator and a modular parking facility, both designed in accordance with circular economy principles. A convention with Technoport has been concluded, focusing on the joint development of a strategic concept and mandating Technoport to **manage the incubator and provide services to hosted companies.** In parallel, a convention with the municipal administration of Bissen has been prepared for the implementation of a ***"Living Lab Bissen"***, following a co-funded mobility study under the Mobility Management programme. In parallel, the BISTWIN project is underway in collaboration with LIST to develop a ***"Mobility Digital Twin"*** of the territory of the Bissen municipality, enabling the virtual testing of various measures and scenarios, allowing for impact assessment to support informed decision-making.

Cross-Border Digital Testbed France-Germany-Luxembourg

As part of its **strategic cooperation efforts**, Luxembourg will continue its commitment to the development of the **cross-border digital testbed France-Germany-Luxembourg**, with the objective of bringing together expertise and ongoing efforts from the triple helix of actors: industry, research, and public institutions.

Established in 2017, this trilateral cooperation aims to create **a shared understanding of the regulatory and societal acceptance challenges related to connected and automated driving.** It facilitates **joint testing of interoperability and**

cross-border continuity issues through various use cases (e.g. sensor perception, vehicle connectivity), and addresses **economic and legal challenges** posed by tri-national models (e.g. data exchange, public acceptance, perception, and user behaviour).

In its *Action Plan to Stimulate Innovation, Sustainability, and Competitiveness in the Automotive Sector*, the European Commission plans to launch **large-scale automated driving demonstrations** starting in 2026, through three testbeds and regulatory sandboxes. With multiple previous projects, notably in the context of the first 5G corridors, its diversified infrastructure, and ongoing cooperation with associated Member States, the **cross-border testbed is well-positioned to be part of this strategic initiative.**

Test Environment Planning via 5G Mapping

Creating test environments for automated driving typically relies on **reliable and high-performance connectivity.** In this regard, the mobile coverage maps provided by the Luxembourg Institute of Regulation (ILR) and the Géoportail Luxembourg platform play a key role. By providing an overview of 5G coverage, **these tools help assess the feasibility of optimal automated vehicle operation** in specific areas such as motorways, urban zones, campuses, etc. They enable companies to **better plan their trials and ensure optimal conditions** for the development of innovative mobility solutions.

SPS Lux Service

The SPS Lux (Luxembourg Satellite Positioning Service) provides **real-time high-precision GNSS** (Global Navigation Satellite System) positioning, based on a network of reference stations distributed across the national territory. This **service, available free of charge in Luxembourg, is a strategic asset for automated driving**, enabling centimetre-level vehicle localisation, which is essential for secure navigation, lane detection, and precise manoeuvre execution. Its integration into automated driving systems also supports open-road testing, V2X cooperative scenarios, and trajectory optimisation. As a publicly operated infrastructure provided on a best-effort basis, SPS Lux offers a strong foundation for the development of advanced mobility services, promoting interoperability with European initiatives related to precise geolocation.

Through specialised correction service providers, an **on-demand service** extends the intelligent use of data from existing GNSS CORS (Continuous Operating Reference Stations) networks **beyond national borders, offering transparent inter-provider compatibility** at an international level. This helps overcome existing limitations in GNSS correction services (e.g., access, usage, or user support).

Testing and Experimentation Facilities (TEF)

CITCOM.AI is a European platform designed to facilitate the adoption of artificial intelligence in smart cities and communities. It provides a **secure and controlled environment where municipalities and solution providers can test AI-based technologies before their large-scale implementation.** The aim is to ensure regulatory compliance, security, and effectiveness of the tested solutions—including those related to automated driving. Services offered include experimentation with data space technologies, local toolkits for Digital Twins, data analysis, and AI model evaluation. CITCOM.AI plays a key role in the digital transformation of cities by reducing risks associated with AI adoption and fostering reliable, sustainable, and interoperable solutions.

SMARTSPIRES is a €3.1 million initiative co-funded by the EU's Connecting Europe Facility (CEF), which **transforms the Belval campus in Luxembourg into a true living lab for smart cities.** The initiative aims to demonstrate how dense 5G connectivity, combined with edge computing infrastructures, can enable the deployment of innovative AI- and IoT-based services with minimal latency. The project plans to install at least three smart towers equipped with advanced technologies: 5G connectivity, local computing capabilities, IoT sensors, and other devices, to support real-world use cases. Led by a public-private consortium, SMARTSPIRES aims to showcase how digital infrastructures can enhance the safety, sustainability, and efficiency of urban services – including those related to automated driving, for the benefit of citizens and local authorities.

4. Supporting mechanisms and other services

National Funding

Private companies benefit from a range of instruments offered by the Ministry of the Economy, which support **research, development, and innovation (RDI) projects** such as experimental development, fundamental research, and industrial research.

These instruments support innovation in emerging technologies, including those described in the "Concept overview" chapter, and particularly those based on AI or requiring the use of high-performance computing (HPC). These funding mechanisms often follow a bottom-up approach based on projects submitted by economic actors; however, innovation in the field of automated driving could also benefit from a top-down framework. Consequently, the introduction of **thematic calls** with **adjusted financial aid rates** will be considered to encourage this specific area of innovation among private companies.

Funding for high-quality public research projects related to automated driving is available through the programmes of

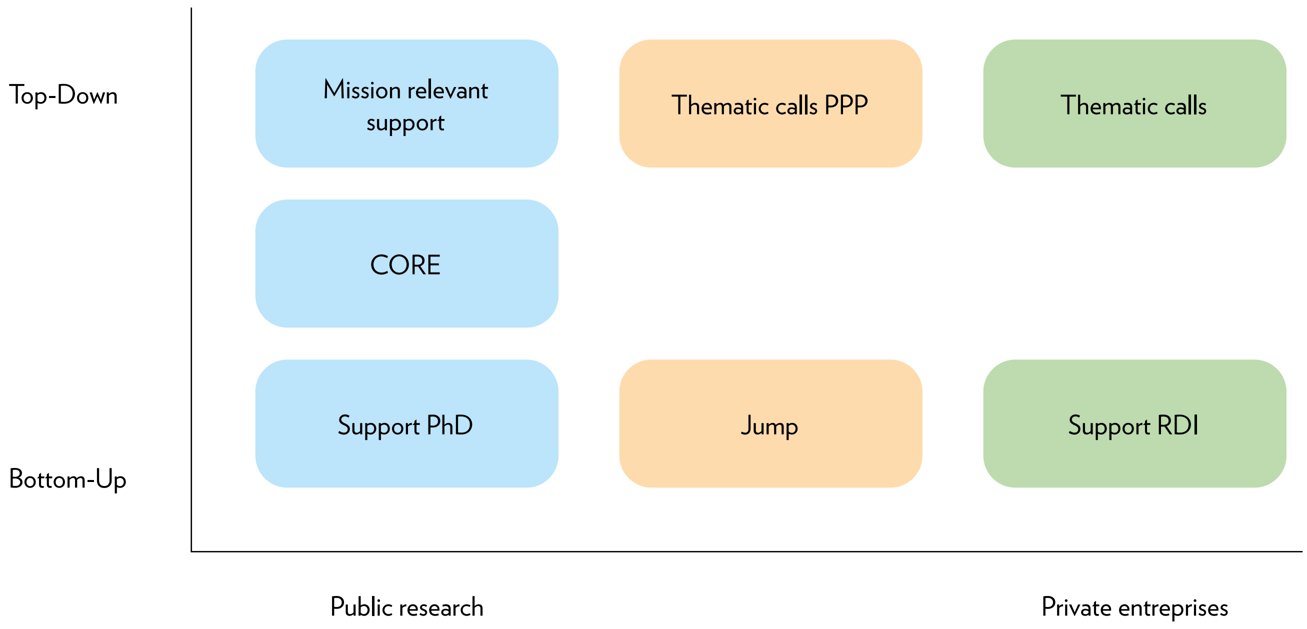


Figure 2. Overview of top-down and bottom-up funding mechanisms

the National Research Fund (FNR), particularly its flagship CORE programme. Additionally, the Ministry of the Economy, the Ministry of Research and Higher Education, and the FNR **encourage collaboration between public research institutions and private companies** through joint thematic calls for Public-Private Partnership (PPP) projects. These initiatives aim to foster technology and knowledge transfers between academia and industry in strategic areas such as automated driving.

To support the **commercialisation of academic research outcome**s, the entire value chain is covered through the **integrated deployment of support instruments** across different stages. The FNR offers a competitive funding instrument (JUMP programme) designed to bridge the technical and financial gap between research discoveries and market entry. This financial support aims to advance the development of cutting-edge solutions from applied research, particularly those with commercialisation potential via the creation of spin-off companies. A complementary funding tool, the Entrepreneur in Residence bonus (EiR-bonus), is implemented under the FNR–MECO collaborative programme. Additionally, a **dedicated aid scheme for the creation of spin-offs** from public research institutions in Luxembourg is available. Its objective is to increase the likelihood of a successful fundraising from the first round by partially covering the financing needs up to this critical milestone.

To **encourage the market launch of results from academic research**, the entire value chain is covered by a seamless integration of support instruments at various stages. The FNR offers a competitive funding instrument (JUMP programme) designed to bridge the technical and financial gap between research discoveries and their market launch. This financial support aims to advance the development of cutting-edge solutions from applied research, particularly those with the potential to be commercialised through the creation of spin-offs. A complementary funding tool, the Entrepreneur in Residence bonus (EiR-bonus), is implemented as part of the collaborative FNR-MECO programme. Additionally, a scheme to **support the creation of spin-offs from public research** aims to help Luxembourg-based research organisations increase their chances of securing early-stage funding.

To lower barriers to entrepreneurship, the Ministry of the Economy offers a **specific aid scheme for start-ups or young innovative businesses.** This scheme supports business ventures under the age of 5 years that have recently received capital injection (typically through a fundraising or private investment). The aim is to facilitate their transition into a growth phase by accelerating product development, boosting marketing and sales activities, and supporting international expansion. This co-matching instrument makes private investors' participation more attractive and less risky.

The **Fit4Start programme** is the Luxembourg's most comprehensive national seed funding initiative, supporting early-stage businesses in key strategic sectors. The programme includes initial financial support and incentives to raise private capital, alongside personalised coaching that covers business and technical aspects, with a focus on data valorisation and high-performance computing, AI, and disruptive technologies.

Person analysing statistics using a tablet and a laptop

The upcoming **Fit4Scale** programme will provide young enterprises with the support needed to scale up and expand into new markets. Special editions for young companies specialising in automated driving technologies will be planned to further strengthen the associated ecosystem.

Another essential pillar of a supportive start-up ecosystem is **access to investment.** A range of funds is already available to finance start-ups at the seed stage, including the *Digital Tech Fund* (ICT sector), *Orbital Ventures* (space sector), and the *Luxembourg Future Fund* (AI, cybersecurity, new space technologies, and energy resilience).

An **investment aid for research infrastructures** (i.e., facilities, resources, and services used by the scientific community to conduct research in their areas of expertise in Luxembourg) that engage in economic activities is also available, provided the access to these infrastructures is open to multiple users on a transparent and non-discriminatory basis. This definition encompasses scientific equipment and research materials, reference resources like collections, archives, and structured scientific information, enabling ICT-based infrastructures such as grid networks, computing infrastructure, software and communication systems, as well as any other resources required for conducting research. These infrastructures can be located at a single site or distributed across several countries as part of an organised network of resources.

Luxembourg will also evaluate the opportunity to join the initiative for the establishment of a future **Important Project of Common European Interest** (IPCEI) on *clean, connected and automated vehicles*, identified as a priority area by the European Commission. Active participation in this IPCEI would enable the mobilisation of public and private funding to accelerate the development of sustainable and interoperable solutions in the field of automated mobility.

Thanks to its dynamic smart mobility ecosystem, advanced digital infrastructure, and pilot initiatives in automated driving, Luxembourg is well-positioned to act as a niche player in key segments, while simultaneously strengthening its industrial and research capabilities.

European Funding

Beyond national support, Luxembourg actively encourages domestic stakeholders to pursue European and international funding opportunities (such as Digital Europe, Horizon Europe, or Eureka) and engage in collaborative initiatives and platforms related to cooperative, connected, and automated mobility (CCAM). Leveraging its strengths in interinstitutional coordination and its strategic location within the Greater Region, Luxembourg offers an ideal position to contribute to collaborative European projects, particularly through the cross-border digital testbed.

Support services for identifying the most appropriate calls, as well as assistance for preparing applications, are provided by **Luxinnovation** in its role as the **National Contact Point** (NCP), alongside access to specific co-financing mechanisms, are part of the support infrastructure put in place to facilitate participation in those kind of projects.

Horizon Europe, the EU's current framework programme for research and innovation (2021–2027), provides significant funding opportunities for cooperative R&I projects in automated driving, particularly through **Cluster 5 (Climate, Energy and Mobility).** This includes topics such as connected and automated mobility (CAM), digital transport infrastructure, vehicle-to-everything (V2X) communication, artificial intelligence for mobility, and system integration.

Under Horizon Europe, the **co-programmed partnership on Connected, Cooperative and Automated Mobility** (CCAM) plays a central role in coordinating EU-funded research and innovation in this field. It brings together industry, academia, public authorities, and user groups to create a common R&I agenda and ensure deployment readiness.

The **successor of Horizon Europe** (FP10), set to begin in 2028, is currently in its early conceptual stages. However, continuity in supporting smart and sustainable mobility, digitalisation, and automation is expected. In March 2025, the European Commission adopted an *Industrial Action Plan for the European automotive sector* which explicitly promotes autonomous driving by enabling large-scale cross-border testbeds and deploying *European Automated Driving Corridors* from 2026 onward. The Action Plan also introduces a *European Connected & Autonomous Vehicle Alliance* (ECAVA).

The programme is set to provide €1 billion for the automotive sector between 2025-2027, including relevant activities funded through the **European Innovation Council** (EIC). In the future, dedicated partnerships for specific activities could be grouped into a Joint Undertaking dedicated to the automotive sector, with implications for the next multiannual financial framework (MFF) proposal.

Luxembourg is actively involved in defining the **Strategic Transport Research and Innovation Agenda (STRIA)**, which provides a long-term policy framework for transport innovation in the EU. STRIA identifies key priority areas – including connected and automated mobility – and promotes alignment between EU, national, and regional initiatives. It supports cross-sectoral coordination and ensures that R&I investments contribute effectively to the EU's wider goals of decarbonisation, digitalisation, and competitiveness.

Luxembourg is also a member of the **European Road Transport Research Advisory Council** (ERTRAC), which provides strategic input to the European Commission and coordinates research priorities across industry and academia. It plays a key role in shaping the research agenda of the CCAM Partnership and Horizon Europe. ERTRAC's roadmaps on automated driving, safety, and digitalisation serve as valuable guidance documents for aligning national research and innovation (R&I) efforts with EU strategies.

The **EIT Urban Mobility** is highly relevant to automated driving as it serves as an innovation and deployment platform for smart and sustainable mobility solutions in urban environments, including automated vehicles. It can be particularly interesting for funding SMEs and startups, offering equity investment via its venture arm and facilitating public-private partnerships.

Actors in Luxembourg can also leverage several **European territorial cooperation programmes** to support the development of projects related to connected and automated driving (such as *Interreg Grande Région, Interreg North-West Europe, Interreg Europe, Interact, URBACT,* and *ESPON*). These programmes offer co-financing opportunities for cross-border projects, applied research, demonstration, or networking, particularly in the fields of smart mobility, technological innovation, and sustainable urban development. For example, **Interreg Grande Région** allows the development of pilot projects between Luxembourg, Lorraine, Wallonia, Rhineland-Palatinate, and Saarland, while **Interreg Europe** and **URBACT** facilitate the exchange of best practices and the strengthening of institutional capacities.

The **National Contact Point for Interreg in Luxembourg** is managed by the **Ministry of Spatial Planning** (Department of Territorial Cooperation), which assists project holders in the preparation, structuring, and management of applications. These instruments serve as a strategic lever to embed automated driving into a coherent and innovative regional dynamic.

AutoMobility Campus and Incubator

In addition to financial aid, various facilities, services, and advisory support are provided at different stages of the company development journey.

The **AutoMobility Campus** is a site dedicated to research, development, and innovation (RDI), with the objective of enhancing the international attractiveness and national competitiveness of the automotive and mobility sectors, while fostering closer collaboration among key stakeholders from public research, start-ups, established companies, and other professionals in the field. The Campus is designed to act as a catalyst for innovation and to attract talent in sustainable and digital technologies within the targeted sectors.

The AutoMobility Campus is designed to act as a catalyst for innovation and to attract talent in sustainable and digital technologies within the targeted sectors.

Managed by Technoport within the premises of the Campus, the **national incubator** aims to welcome not only young innovative enterprises (such as start-ups, scale-ups, or spin-offs) but also any company focused on innovation, research, and the development of new technologies, particularly in the field of automated, cooperative, and connected driving, as well as in sustainable mobility. In addition to access to fully equipped workspaces (modern offices, meeting rooms, workshops, and other shared spaces designed to encourage collaboration and synergies), Technoport offers a range of mentoring and advisory services to hosted businesses. Thes include training programmes, networking events, investor matchmaking, and all other services related to the creation and growth of these companies.

5. Research, Development and Innovation (RDI)

Efforts to support research activities in the field of automated and connected driving, as outlined in the section on the Development of Scientific Competencies, should continue. Particular focus should be placed on expanding activities in areas where Luxembourg already possesses significant expertise, such as automated systems, connectivity, and modelling and simulation. The technologies developed in these domains are not limited to automated driving—they also have applications in other sectors such as defence and space, where synergies should be actively explored.

The topics of "Automated and Intelligent Systems", "Future Computing and Communication Systems", as wells as "Fundamental Tools, Data-Based Modelling and Simulation" are already part of the priority research areas defined under the National Research and Innovation Strategy

The topics of **"Automated and Intelligent Systems"**, **"Future Computing and Communication Systems"**, as wells as **"Fundamental Tools, Data-Based Modelling and Simulation"** are already part of the priority research areas defined under the *National Research and Innovation Strategy*[17]. Adopted by the government in late 2019, this strategy outlines the top-level interdisciplinary research domains considered crucial for the societal, ecological, and economic development of the country.

Within these priority domains, specific research priorities are defined, which directly apply to most of the funding programmes of the National Research Fund (FNR), particularly its flagship CORE programme. Funding for high-quality research projects related to automated driving is therefore both possible and encouraged within this framework. In line with the government programme, the national strategy is regularly updated to reflect new developments, especially in the field of digital technologies.

To encourage collaborations between public research institutions and private companies, thematic project calls focused on automated driving and Public-Private Partnerships (PPP) in collaboration with the FNR, the Ministry of the Economy, and Luxinnovation may also be considered. The principles of this support mechanism are outlined in the section on National Funding.

Recent Research Projects

As part of the government's **5G strategy**, three project calls have been initiated to promote the deployment of 5G technology. These calls were primarily focused on demonstrating the feasibility of 5G applications in domains such as "Smart Environments", "Smart Cities", "Industries 4.0", and "Technologies".

A key target across these calls was the development of proofs of concept in the field of automated driving. Some projects have been successfully concluded, while others are still ongoing.

Completed Projects:

The **5G-PLANET** project served as an awareness-raising platform showcasing 5G technologies and the opportunities they can offer to the automotive sector. The project promoted how 5G networks can be used to deploy intelligent transport systems and enable vehicle connectivity. The project included three demonstrators addressing frequently asked questions like: What does mobility involve? What is 5G? What role does 5G play in connected mobility?

Ongoing Projects:

The project **PASTA-5G-V2X** aims to achieve 5G coverage across all inhabited areas. It addresses the challenge of 5G network dead zones. In parallel, technological advancements in vehicle-to-everything (V2X) communication are expected to deliver benefits for road safety and traffic management. The consortium, composed of IEE S.A. and LIST, is focusing primarily on the development of transparent antennas for V2X communication using 5G technologies.

The project **5GDrive** is led by SnT at the University of Luxembourg. In collaboration with POST Luxembourg and Ohmio, this project aims to develop and validate a driving system for automated vehicles using cutting-edge 5G technology. This unique initiative combines industrial and experimental research to harness 5G's potential for real-time high-definition transmission of video and sensor data, as well as remote vehicle control, ensuring the low latency and high bandwidth essential for the operational success of automated vehicles.

Participation in European Projects

Luxembourg is actively involved in several major European projects related to automated mobility. It has participated in **5G-MOBIX** and **5GCroCo**, which tested connected and automated driving scenarios in a cross-border context, as wells as in **L3Pilot**, one of the largest European projects to evaluate Level 3 and Level 4 automated driving functions on European roads in real-world conditions. Other examples include the European project **PAsCAL** focused on the social acceptability of autonomous vehicles, which **LIST** coordinated and **IN2CCAM** where it contributed to the impact assessment and analysis, aiming at accelerating CCAM services for more transparent traffic management across Europe, with the goal of making roads safer, more sustainable, and more accessible. The **SnT** at the University of Luxembourg continues applied research on onboard perception, cybersecurity for autonomous vehicles, and validation of autonomous systems, in collaboration with industrial partners. The **LISER** contributes to the analysis of territorial and social impacts of automated mobility, particularly in cross-border regions.

Participation in the Development of Future Projects

Beyond current initiatives, Luxembourg is actively positioning itself for the next major milestones in automated mobility. It is notably involved in the preparation of Horizon Europe projects, such as the action to support **large-scale CCAM deployments** and the definition of a **flagship large-scale demonstration project.** These initiatives aim to structure the future deployments of automated driving in Europe by integrating technological, societal, and regulatory dimensions.

6. International Cooperation / Participation in International Initiatives

The success of connected and automated driving will depend on market conditions, technological advancements, and regulatory adaptations. Through its geographical position, continuous investments, and proximity to key actors, **Luxembourg is well placed to act as a pilot market in this context.** Beyond its limited domestic market, the country stands out for its business-friendly climate, stable economy, and qualified, multilingual workforce, **making it a reliable, established gateway and a natural hub to serve the broader European market** and beyond. Indeed, Luxembourg has long advocated for open markets, regulatory reliability, cross-border technological investments, commercial openness, and international partnerships.

At the **European level**, Luxembourg will continue its **commitment to various forums and technological platforms related to automated driving**, including the *European Forum for Automated Transport* (EFAT) and the *CCAM State Representatives Group* (SRG), and their future iterations. The exchange of perspectives and best practices between Member States allows European countries to advance collectively. Such coordination and collaboration is crucial, given the international competition in the field of automated transport.

Luxembourg will also monitor developments from the *European Connected and Autonomous Vehicle Alliance* and the *Automotive Joint Undertaking* (JU) – two initiatives announced by the European Commission as part of its *Action Plan to Stimulate*

Person wearing a virtual reality headset next to a robot in a science laboratory

Innovation, Sustainability, and Competitiveness in the Automotive Sector. Their goal is to bring together the key stakeholders in the automotive sector across Europe to guide policy measures and align resources from industry and public funding to support research and innovation activities for the next generation of connected and automated vehicles across the entire value chain.

Further details on R&I support mechanisms are provided in the European Funding section of this strategy.

To promote a high level of safety for new vehicles, **Luxembourg will continue its participation in Euro NCAP**, specifically focusing on efforts to promote automated driving while raising awareness about both the benefits and the limitations regarding safety. With the emergence of vehicles featuring varying levels of automation, Euro NCAP's actions to **clearly distinguish between assisted and automated driving**, and its efforts to **improve human–machine interface (HMI) design**, are increasingly important to ensure adequate consumer information. Similarly, Euro NCAP's initiatives to encourage technologies that enhance driver awareness and support automated driving systems through **connectivity services and the sharing of road safety data** are fully aligned with the objectives of this strategy.

Luxembourg **also maintain its active participation in ERTICO** – ITS Europe, the leading European platform for smart and connected mobility. Several national actors are already involved, including LIST, Ponts et Chaussées, and LNDS. This collaboration helps highlight Luxembourg's initiatives, contribute to deployment efforts for automated and cooperative systems (C-ITS), and ensure alignment with European standards. Luxembourg intends to strengthen its contribution to thematic working groups, particularly those related to automated driving, mobility data, and cross-border corridors.

Luxembourg is a recognised and active member of the **Gaia-X** AISBL, **a European initiative aiming to create an open, secure, and sovereign data infrastructure** to promote data or cloud service interoperability while complying with European standards. Luxembourg plays an important role, with a national representative sitting on the board of directors. **LNDS, as the official Gaia-X national hub in Luxembourg**, contributes to the goal of developing a federated European data infrastructure by promoting transparency, controllability, portability, and interoperability of data and services.

LNDS can support organisations based in Luxembourg – startups, public sector entities, and research centres – in exploring the use or creation of data services based on European values. Through LNDS, Luxembourg actively contributes to a growing number of international projects and initiatives, including those related to mobility data such as *International Data Space Association, FIWARE Foundation, MyData Global, and Big Data Value Association* (BDVA). It is worth noting that LIST co-leads the "Mobility and Logistics" Task Force within the BDVA.

The European Digital Infrastructure Consortium (EDIC) is a new European legal instrument aimed at facilitating multi-country projects. Each project adresses a strategic topic of common interest to Member States and enables shared progress at the European level. In addition to its involvement with other EDICs, **Luxembourg is currently participating in discussions regarding the creation of an EDIC dedicated to Mobility and Logistics** (M&L), aiming at accelerating the **transposition of a *European Mobility Data Space*** (EMDS)[52]. Associated with this initiative, the multinational project "Boost EDIC M&L", co-financed through the Digital Europe Programme (DEP), will support the implementation of a common European data infrastructure and services for the mobility and transport sector. LIST is part of the selected consortium, with one of its objectives being to enhance the availability of data for mobility services and applications – including those related to automated driving.

Meanwhile, the multinational project **"CitiVerse EDIC"** aims to build a European ecosystem of advanced AI solutions for cities. Through its participation, Luxembourg benefits from collaborative efforts to improve resource management, urban innovation, and sustainability through AI-powered solutions that address potential threats and challenges.

The *Data for Road Safety* (DFRS)[53] ecosystem, created in 2017 by European transport ministers, the European Commission, and industry representatives, is an example that clearly demonstrates the **added value of combining data from vehicles and infrastructures.** While vehicles can detect safety-related incidents with minimal latency, vehicle-only data is insufficient to manage the full lifecycle of the corresponding information in the ecosystem. This is more effectively achieved through infrastructure integration.

4

Conclusions

Part 4

Conclusions

Reminder of the Strategic Vision

Luxembourg aspires to position itself as a **leading European centre of competence** in the field of **connected and automated driving.** Through this strategy, the country aims to become a **reference hub for research, development, and technological innovation**, by actively supporting relevant initiatives, strengthening national scientific expertise, and attracting the talent required to implement these future-oriented technologies.

Automated driving is fully aligned with Luxembourg's **economic diversification priorities**, particularly within the **smart mobility sector.** By focusing its efforts on this domain, Luxembourg seeks to **strengthen its economic position, build a dynamic ecosystem, attract targeted investments, establish innovative value chains, foster the emergence of new mobility services**, and **generate sustainable employment opportunities** – both within the automotive and mobility sectors and beyond.

To achieve these objectives, the strategy encourages promotes the establishment of **close partnerships between universities, research centres, and industry**, to stimulate innovation and accelerate the development of automated driving technologies. S**trengthening scientific and technical skills** is a key priority, supported by **training programmes** and **talent development initiatives**, in particular through participation in **European programmes.**

Luxembourg will also develop **suitable environments for testing**, including **real-world living labs** and **controlled experimental sites**, enabling the simulation, evaluation, and optimisation of automated systems prior to their large-scale deployment.

Connectivity and the digitalisation of transport are identified as key enablers for the development of automated vehicles. Leveraging its **advanced digital infrastructure**, Luxembourg will continue to expand its digital ecosystem, integrating **next-generation communication technologies** while ensuring a **high level of interoperability.**

Furthermore, the strategy places particular emphasis on **data governance, cybersecurity**, and **artificial intelligence.** These dimensions are aligned with the national initiative *"Accelerating Digital Sovereignty 2030"* and will be complemented by a **specific regulatory framework** to ensure **data protection, economic security**, and the **responsible use of AI** to enhance the performance of automated systems.

The seamless **integration of automated vehicles into a multimodal mobility system** is a central objective. Luxembourg will ensure **effective coordination various different modes of transport**, both nationally and across borders, to deliver a **smooth, accessible, and efficient travel experience.**

Finally, the strategy takes into account the **societal and ethical dimensions** of automated driving. Efforts will be made to ensure that these technologies **benefit society as a whole, respect fundamental values**, and contribute to a **positive social impact. Awareness-raising initiatives** will be implemented to **build public trust** and **foster the acceptance** of future automated mobility services.

To this end, an **Interministerial Committee** has been established by the Government Council to ensure the **integrated and participatory coordination** of the various work items. The implementation of the strategy will be monitored through a transversal approach, involving all relevant institutions.

Perspectives

On the path to achieving the goals of the *European Green Deal* and the *2030 Agenda for Sustainable Development*[1], the use cases for automated driving will continue to expand, particularly through the implementation of the Action Plan to Stimulate Innovation, Sustainability, and Competitiveness in the Automotive Sector and the outcomes of Horizon Europe. The decade leading up to **2030** is thus expected to mark the **technological maturity** of automated mobility, delivering **societal benefits at scale.**

Given the continuous evolution of mobility systems, the **landscape of passenger transport** will no longer be confined to traditional categories such as private cars, taxis, or buses. New forms of transport are emerging, driven by the rise of **electrification, vehicle automation**, and the **digitalisation of services.** In the passenger transport sector, the concept of **multimodality** is expanding to include a wide range of subcategories – from **on-demand shuttles** and **organised carpooling** to **car sharing, electric bike fleets**, and **automated transport offerings** such as **local shuttles** or **robotaxis.**

By **2028**, Luxembourg will be positioned as an **ideal environment** for the **gradual and controlled deployment of automated driving**, thanks to its **unique geographic, demographic, and economic characteristics.** Its **compact size, dense and well-maintained road network** at the heart of Europe, and **proximity between urban, peri-urban, and rural zones** allow for **real-scale experimentation** in varied contexts, while facilitating the **progressive scaling** of future technologies.

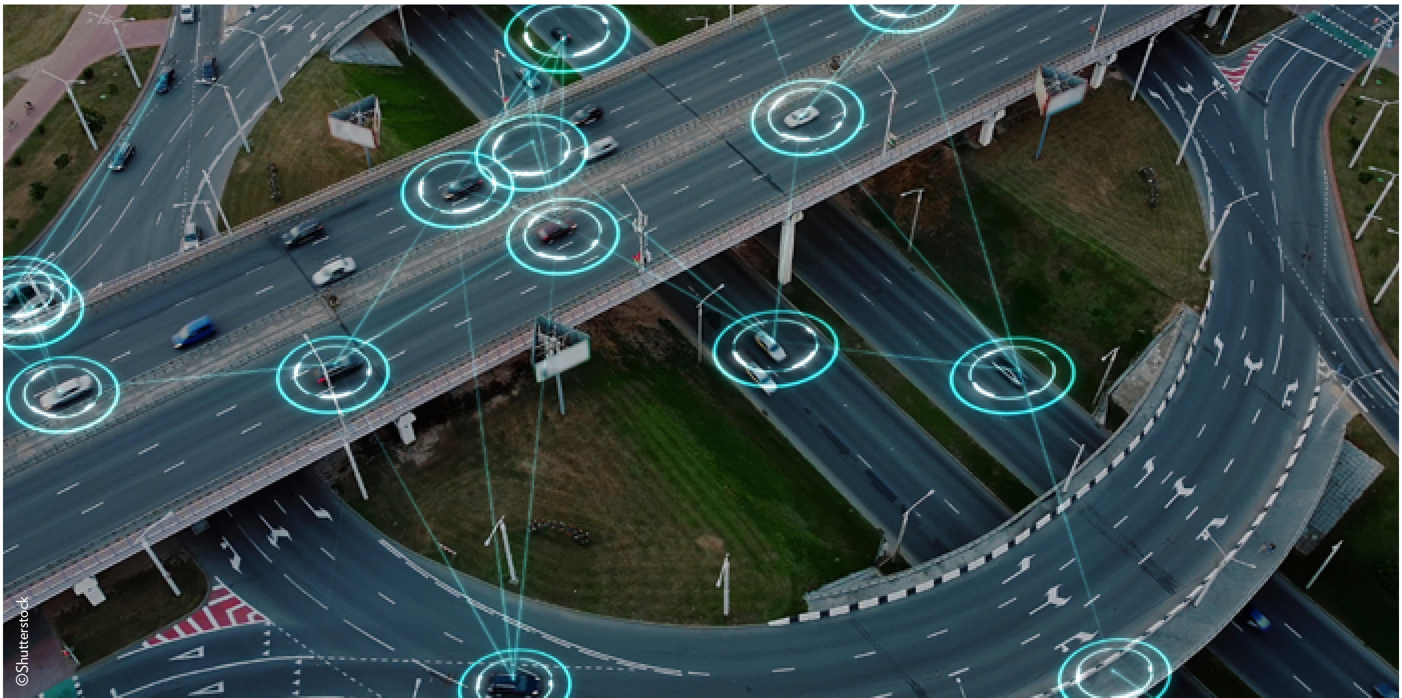
These **experimental phases** will help reach a better understanding of the **evolving dynamics of different transport modes**, and ultimately determine the **functional or contextual niches** where each can demonstrate its **legitimacy and relevance.** In this sense, authorities will leverage insights gained from these experimental phases to **lay the groundwork for future legislation** on automated driving on public roads. These efforts will also result in a stronger ability to **accompany the development of new regulatory provisions.** Regular **public and sectoral consultations** will ensure **greater legitimacy** and **better alignment with real-world needs.**

The **anticipated timeline** for the potential **widespread adoption of automated mobility services** is around **2028–2029**, subject to achieving **sufficient technological maturity** – particularly in terms of **road safety**, and a **clearly established level of social acceptance.** This **phased approach**, built around **experimentation, structured social dialogue**, and **gradual legislative adaptation**, represents a **pragmatic response** to the challenges posed by automated mobility, as outlined in the *National Road Safety Plan*.

To ensure **large-scale deployment and services of high quality** within the Single Market, the creation of a **framework for automated** (and connected) **driving at European level** will have been essential. This framework will enable the **cross-border use of new mobility solutions**, contributing to greater cohesion across the regions. **Advanced artificial intelligence (AI) applications**, based on vast amounts of data, will also have been supported while prioritising **socio-economic and ethical considerations**. The integration of AI-based decision-making systems will have been a decisive factor.

From an **economic perspective**, Luxembourg with its **dynamic ecosystem in finance, information technology, and logistics**, will have supported **innovation and investment in automated vehicles** and smart infrastructures. Politically, the country's **agile governance** and **strong commitment to smart mobility**, as demonstrated by its **involvement in European and cross-border initiatives**, will reinforce its leadership.

This transition will require **close and continuous coordination** between **public and private stakeholders, ongoing regulatory adaptation**, and **active citizen engagement** to ensure the development of **attractive mobility solutions** that generate sufficient demand.



Aerial view of a motorway interchange with connected and automated vehicles travelling on different lanes

Glossary

Some of terms and definitions below are taken or adapted from the *Taxonomy for Connected Cooperative and Automated Mobility (CCAM)*[54].

Term	Definition
ADS (Automated Driving System)	The *Automated Driving System* refers to the hardware and software collectively capable of performing the entire dynamic driving task continuously within a specific Operational Design Domain (ODD).
ALKS (Automated Lane Keeping Systems)	The *Automated Lane Keeping System* is a driver-activated system that keeps the vehicle in its lane at speeds up to 130 km/h by controlling the vehicle's lateral and longitudinal movement for extended periods without the driver's intervention. It is based on UN Regulation No. 157 regarding lane-keeping system approval.
CCAM (Cooperative, Connected and Automated Mobility)	*Cooperative, Connected and Automated Mobility* is a generic term encompassing smart mobility, intelligent transport systems, and cooperative intelligent transport systems.
Cloud computing	*Cloud computing* refers to the use of memory and computing power from computers and servers spread across the world, linked by a network.
D2D (Device 2 Device)	*Device-to-Device Communication* is a method by which devices communicate directly with each other without relying on a central base station or network infrastructure. This direct communication can offer several advantages, including reduced latency, increased data throughput, and improved network efficiency.
DCAS (Driver Control Assistance Systems)	*Driver Control Assistance Systems* refers to all hardware and software capable of helping the driver control the longitudinal and lateral movements of the vehicle. Based on UN Regulation No. 171 on driver assistance systems.
DDT (Dynamic Driving Task)	*Dynamic Driving Task* refers to all operational and tactical real-time functions needed to drive a vehicle in road traffic, excluding strategic functions like route programming or destination selection. Key sub-tasks include vehicle lateral and longitudinal control, environment monitoring, response execution, and manoeuvre planning.

DSSAD (Data Storage System for Automated Driving)	This system clarifies "who was invited to drive" and "who was actually driving" (which may differ, especially during transition periods) by storing data that provides a clear picture of the interactions between the driver and the highly automated driving system.
Edge computing	*Edge computing* is a distributed computing architecture where data processing is done near the source, i.e., at the network's edge, rather than in a centralised data centre. It reduces latency, saves bandwidth, and improves application performance.
EDR (Event Data Recorder)	This system records data required for effective accident investigations and safety equipment performance analysis (e.g., advanced restraint systems). These data help understand accident circumstances and lead to safer vehicle designs.
GNSS (Global Navigation Satellite System)	The *Global Navigation Satellite System* refers to a constellation of satellites providing positioning and synchronisation data to GNSS receivers, which use this data to determine location.
ITS (Intelligent Transport Systems)/ **C-ITS** (Cooperative-ITS)	*Intelligent Transport Systems (ITS)* refers to the application of information and communication technologies to improve transport safety, efficiency, and sustainability. *Cooperative-ITS (C-ITS)* focuses on communication and cooperation between vehicles, transport infrastructure, and road users to optimise network performance.
ODD (Operational design domain)	The conditions under which a given automation system or its components are specifically designed to function. This includes environmental, geographical, and temporal restrictions or the presence/absence of certain traffic or road-related features.
OEDR (Object and event detection and response)	Refers to the sub-tasks of the dynamic driving task, including monitoring the driving environment (detection, recognition, and classification of objects/events and preparing a response), and executing a response to those objects/events.
OTA (Over-the-air update)	This technology allows for updating a vehicle's software remotely, without needing to connect it to a computer or visit a dealer. OTA updates are typically sent via the internet (e.g., through the vehicle's mobile network) and improve functionality, performance, or fix errors in the software system.
Privacy by default	The *Privacy-by-Default* principle is part of the GDPR (Article 25). It means that product or service settings must, by default, offer the highest level of privacy protection for users.
Privacy by design	The *Privacy-by-Design* principle involves integrating personal data protection and privacy from the initial design phase of a product, service, or system, and throughout its lifecycle. It is a proactive, preventive approach aiming to minimise privacy risks before they occur, rather than addressing them retroactively.

Remote driving	*Remote Driving* refers to the real-time execution of part or all of the dynamic driving task and/or failsafe driving task (including braking, steering, acceleration) by a remote driver. A responsive remote operator ready for remote fallback becomes a remote driver once they take over when necessary to execute the fallback plan. The remote operator performs or completes the OEDR and has the authority to cancel the ADS for the purpose of controlling the lateral and longitudinal movements of the vehicle. Remote driving is not driving automation. Remote driving of a vehicle by a human being is sometimes referred to as "teleoperation". However, the term "teleoperation" is not consistently defined in the literature and, in order to avoid confusion, is not used in this document.
Remote operator	The *Remote Operator* is the person located outside of the vehicle that performs the dynamic driving task without using the vehicle's built-in input devices (if available) to control the longitudinal and lateral movement of the vehicle. The operation of the vehicle can occur with or without direct vision.
Remote surveillance	*Remote Surveillance* refers to the practice of monitoring and observing of vehicles with autonomous driving functions and their surroundings from a remote location using various technologies. This surveillance is typically performed to ensure the safety, security, data collection and proper functioning of the automated mobility system.
Sandbox (ou Bac à Sable)	A *Regulatory Sandbox* typically refers to regulatory tools that allow the testing and experimentation of new and innovative products (e.g. automated vehicles), services, or business models under the supervision of a regulator for a limited period of time.
SLAM (Simultaneous Localization and Mapping)	*Simultaneous Localization and Mapping* is used in robotics – including for automated vehicles – to build a map of an unknown environment while simultaneously locating the vehicle within that map. In other words, the SLAM system solves two problems at once: localising the vehicle and mapping its surroundings.
V2X (Vehicle-to-everything)	This term refers to wireless communication between a vehicle and any other entity, including other vehicles (V2V), infrastructure (V2I), networks (V2N), charging infrastructure (V2G), or other road users (e.g., V2P).

References

1. United Nations, (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. Resolution adopted by the General Assembly on 25 September 2015, A/RES/70/1. Available at: *https://www.un.org/sustainabledevelopment/sustainable-development-goals/* or *https://eur-lex.europa.eu/EN/legal-content/glossary/sustainable-development-goals.html*

2. Road safety, (no date). *Mobility & Transport - Road Safety* [online]. Available at: *https://road-safety.transport.ec.europa.eu/index_en*

3. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS (2020), *Sustainable and Smart Mobility Strategy – putting European transport on track for the future*, *COM/2020/789 final*

4. European Commission. (2020). *A Green Deal for Europe* [online]. Available at: *https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en*

5. European Commission. (2020). *A Europe fit for the digital age* [online]. Available at: *https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age_en*

6. Draghi, M. (2024). *Report on the future of European competitiveness*. European Commission. [online]. Available at: *https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en*

7. European Commission. (2025). *Questions and answers on the Commission unveiling the Action Plan to drive innovation, sustainability, and competitiveness in the automotive sector*. [online]. Available at: *https://ec.europa.eu/commission/presscorner/detail/en/qanda_25_636*

8. AUTOMOTIVE SKILLS ALLIANCE. (2025). *Homepage: AUTOMOTIVE SKILLS ALLIANCE*. [online]. Available at: *https://automotive-skills-alliance.eu/*

9. The Luxembourg Government. (2025). *The strategic initiative "Accelerating digital sovereignty 2030"*. [online]. Available at: *https://gouvernement.lu/en/dossiers.gouv2024_smc+en+dossiers+strategy-ads2030+strategy-ads2030.html*

10. Ministry of Mobility and Public Works. (2022). PNM 2035 - *National mobility plan* [online]. Available at: *https://gouvernement.lu/en/dossiers/2022/pnm2035.html*

11. Official Journal of the Grand Duchy of Luxembourg. (2024). *Arrêté du Gouvernement en Conseil du 25 octobre 2024 déterminant la composition et le fonctionnement du comité interministériel de coordination pour la conduite automatisée*. [online]. Available at: *https://legilux.public.lu/eli/etat/leg/agc/2024/10/25/a447/jo*

12. SAE International (2021). *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles - SAE International*. [online]. Available at: *https://www.sae.org/standards/content/j3016_202104/*

13. The Luxembourg Government. (2023). *Coalition agreement 2023–2028 "Lëtzebuerg fir d'Zukunft stäerken"*. [online]. Available at: *https://gouvernement.lu/en/publications.gouvernement2024%2Ben%2Bpublications%2Baccord-coalition%2Baccord-de-coalition-2023-2028.html*

14. The Luxembourg Government. (2019). *The Data-Driven Innovation Strategy for the Development of a Trusted and Sustainable Economy in Luxembourg*. [online]. Available at: *https://gouvernement.lu/en/publications/rapport-etude-analyse/minist-economie/intelligence-artificielle/data-driven-innovation.html*

15. The Luxembourg Government. (2018). *National Cybersecurity Strategy III*. [online]. Available at: https://gouvernement.lu/en/publications.gouv2024_hcpn%2Ben%2Bpublications%2Bstrategie-nationale-cybersecurite-3%2Bstrategie-nationale-cybersecurite-3.html

16. Ministry of Research and Higher Education. (2020). *National Research and Innovation Strategy*. [online]. Available at: https://gouvernement.lu/dam-assets/documents/actualites/2020/02-fevrier/25-mesr-strategie-recherche-innovation/mesr-strategy-research-innovation.pdf

17. McKinsey & Co. report: *"Autonomous driving's future: Convenient and connected"* (January 6, 2023) Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-drivings-future-convenient-and-connected?cid=eml-web

18. European Union, (2023). *European Skills Agenda*. [online]. Available at: https://ec.europa.eu/social/BlobServlet?docId=26818&langId=en

19. European Commission. (2025). *Union of Skills*. [online]. Available at: https://commission.europa.eu/topics/eu-competitiveness/union-skills_en

20. Forum, I.T. (2017). *Managing the Transition to Driverless Road Freight Transport*. OECD iLibrary. [online]. Available at: https://www.oecd-ilibrary.org/transport/managing-the-transition-to-driverless-road-freight-transport_0f240722-en

21. *Projects AUTOPILOT, L3Pilot, or Hi-Drive. [online]. Available at:* https://cordis.europa.eu/article/id/401307-connected-and-automated-driving/fr

22. Ministry of Mobility and Public Works. (2025). *National Road Safety Plan 2024-2028*. (c.f. Measure 9 : *"Modifications nécessaires pour l'utilisation des assistants à la conduite et la conduite automatisée"*) [online]. Available at: https://gouvernement.lu/fr/actualites/agenda.gouvernement2024+fr+actualites+toutes_actualites+communiques+2025+01-janvier+30-backes-pnsr.html

23. Abdel-Aty, M., Ding, S. (2024). *A matched case-control analysis of autonomous vs human-driven vehicle accidents*. Nat Commun 15, 4931. [online]. Available at: https://doi.org/10.1038/s41467-024-48526-4

24. Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018 *on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles*, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC

25. Earth.org. article by Martina Igini: *"Environmental Pros and Cons of Self-Driving Cars"* (May 16th, 2022); [online]. Available at: https://earth.org/pros-and-cons-of-self-driving-cars/

26. Garus, A., Mattas, K., Albano, G., Baldini, G. and Ciuffo, B. (2025) *On the energy intensity of road transport in the presence of connected and automated mobility*, Publications Office of the European Union. [online]. Available at: https://data.europa.eu/doi/10.2760/8978379

27. Commission Implementing Regulation (EU) 2022/1426 of 5 August 2022 laying down rules for the application of Regulation (EU) 2019/2144 of the European Parliament and of the Council *as regards uniform procedures and technical specifications for the type-approval of the automated driving system (ADS) of fully automated vehicles.*

28. The Luxembourg Government. (2025). *Luxembourg's AI Strategy*. [online]. Available at: https://gouvernement.lu/fr/publications/rapport-etude-analyse/minist-digitalisation/2025-luxembourg-ai-strategy-en.html

29. The Luxembourg Government. (2025). *Luxembourg's Data Strategy*. [online]. Available at: https://gouvernement.lu/fr/publications/rapport-etude-analyse/minist-digitalisation/2025-luxembourg-data-strategy-en.html

30. Ministry of the Economy. (2025). *Attraction, retention and development of talent*. [online]. Available at: https://meco.gouvernement.lu/en/domaines-activites/talents.html

31. European Commission. (2023). *Homepage of Pact for skills*. [online]. Available at: https://pact-for-skills.ec.europa.eu/index_en

32. Calle, C. (2019). *Infrastructure Categorization*. Inframix EU Project. [online]. Available at: https://www.inframix.eu/infrastructure-categorization/

33. Shaping Europe's digital future. (2025). *Digital Decade 2025: Country reports*. [online]. Available at: https://digital-strategy.ec.europa.eu/en/library/digital-decade-2025-country-reports

34. The Luxembourg Institute for Regulation (ILR). (2025). *Plan d'allotissement et d'attribution des ondes radioélectriques au Luxembourg*. [online]. Available in French at: https://www.ilr.lu/wp-content/uploads/frequences-radioelectriques/ilr-fre-NTFA-20250526_Plan-des-frequences.pdf

35. European Commission. (2019). *European data strategy* [online]. Available at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en

36. Projet de loi n° 8395 *relatif à la valorisation des données dans un environnement de confiance*. [online]. Available in French at: https://www.chd.lu/en/dossier/8395

37. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 *on the protection of natural persons with regard to the processing of personal data and on the free movement of such data*, and repealing Directive 95/46/EC (General Data Protection Regulation)

38. Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 *on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport*

39. *eCall* [Commission Delegated Regulation (EU) No 305/2013, as amended by Regulation (EU) 2024/1084]; *information services on safe and secure parking areas* (Regulation (EU) No 885/2013); *minimum universal traffic information related to road safety,* free of charge for users (Regulation (EU) No 886/2013); *EU-wide multimodal travel information services* [Regulation (EU) 2017/1926, as amended by Regulation (EU) 2024/490]; *EU-wide real-time traffic information services* [Regulation (EU) 2022/670].

40. Interoperable Europe Portal. (2025). *Interoperable Europe Board*. [online]. Available at: https://interoperable-europe.ec.europa.eu/collection/governance-board

41. Regulation (EU) 2022/2554 of the European Parliament and of the Council of 14 December 2022 *on digital operational resilience for the financial sector and amending Regulations* (EC) No 1060/2009, (EU) No 648/2012, (EU) No 600/2014, (EU) No 909/2014 and (EU) 2016/1011

42. Institut luxembourgeois de la normalisation, de l'accréditation, de la sécurité et qualité des produits et service. [online]. Available at: *Portail Qualité - Luxembourg*

43. Directive (EU) 2022/2557 of the European Parliament and of the Council of 14 December 2022 *on the resilience of critical entities* and repealing Council Directive 2008/114/EC

44. Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 *on measures for a high common level of cybersecurity across the Union*, amending Regulation (EU) No 910/2014 and Directive (EU) 2018/1972, and repealing Directive (EU) 2016/1148 (NIS 2 Directive)

45. Projet de loi n°8307 sur la résilience des entités critiques et portant modification de la loi modifiée du 23 juillet 2016 portant création d'un Haut-Commissariat à la Protection nationale. Available in French at: https://www.chd.lu/fr/dossier/8307

46. Projet de loi n°8364 *concernant des mesures destinées à assurer un niveau élevé de cybersécurité* et portant modification de: 1° la loi modifiée du 14 août 2000 relative au commerce électronique ; 2° la loi modifiée du 23 juillet 2016 portant création d'un Haut- Commissariat à la Protection nationale ; 3° la loi du 17 décembre 2021 sur les réseaux et les services de communications électroniques. Available in French at: https://www.chd.lu/de/dossier/8364

47. Regulation (EU) 2024/2847 of the European Parliament and of the Council of 23 October 2024 *on horizontal cybersecurity requirements for products with digital elements* and amending Regulations (EU) No 168/2013 and (EU) 2019/1020 and Directive (EU) 2020/1828 (Cyber Resilience Act)

48. Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 *laying down harmonised rules on artificial intelligence* and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act)

49. Commission Delegated Regulation (EU) 2024/2220 of 26 July 2024 supplementing Regulation (EU) 2019/2144 of the European Parliament and of the Council by *laying down detailed rules concerning the specific test procedures and technical requirements for the type-approval of heavy-duty motor vehicles with regard to their event data recorder and for the type-approval of those systems as separate technical units* and amending Annex II to that Regulation

50. Projet de loi n°8476 portant mise en oeuvre de certaines dispositions du règlement (UE) 2024/1689 du Parlement européen et du Conseil du 13 juin 2024 *établissant des règles harmonisées concernant l'intelligence artificielle* et modifiant les règlements (CE) n° 300/2008, (UE) n° 167/2013, (UE) n° 168/2013, (UE) 2018/858, (UE) 2018/1139 et (UE) 2019/2144 et les directives 2014/90/UE, (UE) 2016/797 et (UE) 2020/1828 (règlement sur l'intelligence artificielle) et portant modification de : 1° la loi du 1er août 2018 portant organisation de la Commission nationale pour la protection des données et du régime général sur la protection des données ; 2° la loi modifiée du 23 décembre 1998 portant création d'une commission de surveillance du secteur financier ; 3° la loi modifiée du 7 décembre 2015 sur le secteur des assurances. Available in French at: *https://www.chd.lu/de/dossier/8476*

51. Connected Automated Driving. (2021). *Test sites map - Connected Automated Driving*. [online]. Available at: *https://www.connectedautomateddriving.eu/test-sites/*

52. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS (2023). *Creation of a common European mobility data space*. *COM/2023/751 final*

53. Data For Road Safety. (2023). *Partners Safety Related Traffic Information Ecosystem*. [online]. Available at: *https://www.dataforroadsafety.eu/*

54. As developed under the FAME PROJECT, funded by the European Union Horizon Europe Work Programme. [online]. Available at: *https://taxonomy.connectedautomateddriving.eu/*

Title of the publication
Automatiséiert Fueren 2028 – Luxembourg Strategy for Automated Driving

Publisher
Le Gouvernement du Grand-Duché de Luxembourg
33, boulevard Roosevelt
L-2450 Luxembourg

Author
Government of the Grand Duchy of Luxembourg

Photo credits
Adobe Stock, Shutterstock, SIP Claude Piscitelli, MMTP, CFL

Layout
brain&more

Printing
Imprimerie Centrale

September 2025

LUXEMBOURG

LET'S MAKE IT HAPPEN