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Opportunities arising from disruption in the automotive sector:

A UK perspective

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Executive Summary

This report provides an overview of the transformational forces in the automotive sector at a global level and their implications for the UK. The sector is currently going through a non-linear disruption driven by technology, climate change, geopolitics and demographics.

Climate change has led to regulatory mandates in both the EU and UK, forcing the industry to move towards electric vehicles (EVs) – although its traditional core competencies and supply-chain capabilities were based on the internal combustion engine (ICE). The US initiated a market and innovation-driven approach towards electromobility and artificial intelligence (AI), which was followed by China.

China itself used its market size, government support and supply-chain network to become a dominant player in EVs, and is quickly catching up in AI, including AI-enabled automated vehicles (AVs). The EU has found itself in a defensive situation, suffering from competitive inferiority both in its supply chain and in its available product and service portfolio.

In this report, both UK and non-UK roadmaps are analysed to find out whether the UK is well prepared for the future of mobility. In general, we can say that the right policies and regulations are in place to support the mass electrification and full automation of the automotive sector. However, due to a shrinking manufacturing base and dependency upon the EU market – which faces substantial competitiveness issues in the electric-vehicle supply chain and in the adoption of fully automated driving – the UK risks becoming less significant in the automotive sector from a global perspective, and ultimately losing strategic relevance.

Meeting the targets of the zero-emission vehicle (ZEV) mandate is a major concern, because of the low level of EV adoption and the lack of deployment projects involving AI-enabled fully automated vehicles. The missing demand for EVs is driven by a lack of affordable and innovative vehicles produced in the UK and EU that are available to the consumer. This has implications for the available private funding for necessary expansions, and for the transformation of the supply chain and charging infrastructure.

Nevertheless, the use of privately owned vehicles remains dominant for the average UK household. There are no incentives to shift mobility behaviour towards the use of commercially operated zero-emission, AI-enabled automated vehicle fleets.

In general, the average weight of electrified vehicles is too high, and the use of smaller zero-emission urban vehicles is not supported through incentives. This fact is influencing the lifecycle energy performance of vehicles and their operation, as well as non-tailpipe pollution such as tyre emissions and inequalities regarding passenger survivals rates in vehicle-to-vehicle collisions. The waste of space caused by parking is widely accepted in the UK, and not regulated – although automated driving technologies are becoming available to tackle this.

A key opportunity for the UK automotive sector is to further develop R&D and manufacturing competences in battery-cell core components, as well as in AI chip design and AI algorithm development. The UK could take the lead in developing a software-defined vehicle (SDV) ecosystem that could be an alternative to platforms recently developed in China. Most important is the development of a highly flexible AI-enabled system infrastructure for mobility, which would be compliant with all relevant sourcing rules that may be considered for geopolitical reasons. In addition there is also an opportunity for the UK to develop a lead position in silicon carbide (SiC) power electronics chip manufacturing process technology, which is highly relevant for the design and manufacturing of EVs.

Another substantial opportunity is in developing a large-scale deployment of fully automated zero-emission mobility services in urban environments, with commercial fleet operators complementing public transit solutions.

A key suggestion from this preliminary work is to consider the implementation of collaborative platform initiatives to address the competitiveness of the UK automotive sector in an ecosystem approach. These programmes would address core automotive system components, core development processes, and the impact on waste, health and usage behaviour to build products and services that are globally competitive. Universities, fleet operators, automotive OEMs, suppliers and government agencies should be considered key stakeholders.

The goal of the platform initiatives would be to establish a highly competitive automotive ecosystem in the UK – one that is ready for the future of mobility, and that will attract and retain top talent.

List of abbreviations

ADAS: Advanced Driving Assistance System
ADS: Automated Driving Systems
AI: Artificial Intelligence
APC: Advanced Propulsion System
AV: Automated Vehicle
BEV: Battery Electric Vehicle
CAM: Connected and Automated Mobility
CAV: Connected Automated Vehicle
DCU: Domain Control Unit
ECU: Electronic Control Unit
E/E: Electric/Electronics
EPA: Environmental Protection Agency
FCEV: Fuel Cell Electric Vehicle
FMVSS: Federal Motor Vehicle Safety Standard
GBP: UK Pound
GVA: Gross Value Added
HPC: High Power Charging
ICE: Internal Combustion Engine
IRA: Inflation Reduction Act
L2: SAE Level 2
L2+: Advanced SAE Level 2 (not standardised)
L3: SAE Level 3
L4: SAE Level 4
LCA: Lifecycle Assessment
LFP: Lithium Iron Phosphate
NEV: New Energy Vehicle
NHTSA: National Highway Traffic Safety Administration
NIST: National Institute of Standards
NUIC: No User In Charge
ODD: Operational Design Domain
OEM: Original Equipment Manufacturer
OS: Operating System
PMT: Personal Miles Travelled
PRC: People's Republic of China
SDV: Software-Defined Vehicle
SMMT: Society of Motor Manufacturers and Traders
TCA: Trade and Cooperation Agreement
UN: United Nations
UNECE: United Nations Economic Commission for Europe
VCS: Vehicle Connectivity System
VMT: Vehicle Miles Travelled
WLTP: Worldwide Harmonised Light Vehicles Test Procedure
ZEV: Zero Emission Vehicle
ZLEV: Zero and Low Emission Vehicle

Introduction

The overall revenue of global automotive manufacturing companies has plateaued at around $2.5 trillion over the past five years. The automotive sector is now experiencing a major structural transition, triggered by technology, climate change and geopolitical trends.

For decades, the motor vehicle has been a mechanical-centric, manually driven system propelled by a combustion engine in a predominantly safety-centric regulatory environment. It is now rapidly moving to an automated and data-driven software-centric operating system, based on a battery-powered electrified powertrain that is regulated for climate impact and the use of AI, as well as cybersecurity risks.

The new US administration is challenging both climate and AI-related regulations and moving to a domestic-centred approach that prioritises value creation in the US, using tariffs as a tool to influence supply chains and local production.

China is facing a hyper-competitive domestic market in which consolidation among dozens of car brands is likely, and where enormous production capacity is pushing car manufacturers towards export to find new customers. It is also highly successful in the development of innovative and cost-competitive electrified, connected and AI-enabled vehicles. China's massive supply chain poses a substantial challenge to the EU, while the US is restricting Chinese original equipment manufacturers (OEMs) and suppliers from accessing its market.

Although the EU is raising tariffs against Chinese battery electrical vehicle (BEV) imports, its trade dependency on the Chinese automotive market is substantial. The trade tensions between the US and China make it necessary to pursue more flexible localised sourcing strategies, which lead to higher cost.

This report is about the implications of this landscape for the future shape and competitiveness of the UK's automotive sector. It presents key findings from an analysis of the sector and a series of recommendations for policymakers to establish an innovation ecosystem for the automotive sector. This anticipates the design of new software-centric system architectures and new business models for mobility, and leverages the UK's strengths in information technology and its pool of software talent in research, education and industry.

Key market and regulatory forces

Key market and regulatory forces include:

(i) **Global zero-emissions mandates** that seek to ban the sale of pure ICEs (Internal Combustion Engines) as early as 2030.

(ii) **The UK Automated Vehicles Act 2024** and the UN regulations for automated driving systems (ADS)planned for 2026, are expected to provide a foundation for the scaled adoption of self-driving vehicle technology.

(iii) A shift in competitiveness due to the accelerated **adoption of zero-emission vehicles (ZEV) in China** (the world's largest automotive market).

(iv) The **slow down of electric vehicle adoption in the EU** (the third-largest automotive market in the world behind China and the US, and the second-largest automotive market for EVs behind China).

BOX 1. AUTOMOTIVE SECTOR CO_2 EMISSIONS

China was the highest emitter of CO_2 in 2024, with a global share of more than 30%. It has committed to becoming carbon neutral by 2060 – a goal it may achieve earlier. The country's automotive sector accounts for about 10% of its CO_2 emissions.

The US was responsible for around 13% of global CO_2 emissions in 2024. The transportation sector accounts for about 28% of CO_2 emissions in the US.

The EU share of global CO_2 emissions fell from 15.2% in 1990 to around 6% in 2023. The main CO_2 emitters in the EU are Germany, France, Italy, Poland and Spain. The transportation sector in the EU accounts for around 25% of its CO_2 emissions, and road transportation has by far the largest impact. Europe's goal is to achieve carbon neutrality by 2050.

Zero-emissions mandates

Many jurisdictions are adopting ZEV mandates. Broadly, these impose rules on vehicle fleet composition, gradually increasing the proportion of zero-emission vehicles. For example, California has adopted a ZEV rule for 2035, and the EU has adopted a similar regulation for the same year. The EV market share in California is currently around 25%, and in Europe it is estimated to be between 13% and 22% in 2024. The UK has already achieved close to 20%, only slightly behind government targets of 22% for 2025. The EV market share in the US stands at 8% for 2024, but growth dynamics are evolving due to more rapid consumer adoption and recent political developments arising from the Trump administration.

The most advanced European country in terms of adoption is Norway, which had achieved an EV market penetration of 89% in 2024, and is on track to reach its strategic goal of becoming the first country in the world to sell 100% zero-emission vehicles by 2025[A].

[A] Tesla has the highest market share in Norway's EV market with 19%, followed by Volkswagen, Toyota, Volvo and BMW. Chinese OEMs (MG, BYD, XPeng) have a combined market share of close to 10%[1] but this proportion is increasing.

[B] The UK is the second-largest automotive market in Europe after Germany, but car ownership in the UK overall (except London) has only increased slightly over the past 20 years, from 1.16 to 1.3 per household. In London it decreased from 0.82 to 0.76.[3]

The UK ZEV mandate - implications

The UK ZEV mandate seeks to achieve a battery electric vehicle (BEV) minimum share of 22% for all manufacturers in 2024. By this time, each original equipment manufacturer (OEM)'s sales mix had to reach this share in BEVs or other emission-free vehicles such as fuel-cell electric vehicles (FCEVs). The minimum share will increase stepwise to 80% by 2030. Manufacturers failing to achieve this threshold will be fined £12,000 (reduced in 2025 by 20% from £15,000) for each additional car that is non-compliant.

Based on new registrations in the past 12 months, and even with a current BEV share of 18%, OEMs were originally facing potential fines of £2.4 billion under the ZEV mandate. Ford and Toyota the worst affected, as per Figure 1. To avoid these fines, manufacturers will need to convince significantly more private buyers to opt for electric vehicles or request flexibility in the application of the regulations: such as extended hybrid sales, credit borrowing, and the ability to transfer credits between car and van sales. The Government has recently made changes to the ZEV Mandate in response to the US imposition of global tariffs and reduced the fines. These increase the flexibility of the mandate up to 2030 through extended trading of credits and allow hybrid vehicles to be sold until 2035[2].

There are currently 41 million vehicles registered in the UK, of which slightly more than one million are electric, and more than three times more used cars than new cars are sold in the UK annually.[B] It would therefore take several decades for the complete vehicle fleet to be emission free.

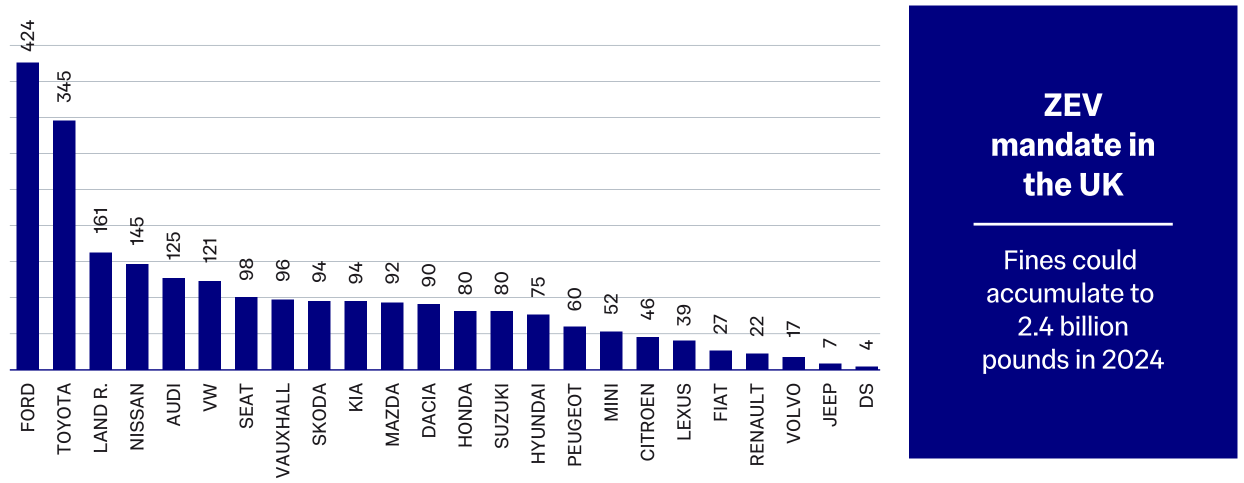
In order to accelerate the conversion to a zero-emission fleet, it is necessary to decommission ICE vehicles earlier than at the end of their lives, and replace them with emission-free vehicles.

Given that the average age of a vehicle in the UK is roughly 10 years[4] and the average age of commercial fleet vehicles is significantly lower[5], one way of achieving this would be to shift from a model of personally owned cars, held for many years, to a model of mobility services provided by commercial fleets. This could accelerate the transformation towards a zero-emission vehicle fleet, assuming that personally owned vehicles are scrapped when replaced through fleet vehicles.

It is also possible that the market will respond by stimulating consumer demand through the importation of affordable Chinese EVs. Since the average transaction price of a new vehicle in the UK is nearly double that of China, it could be highly lucrative for Chinese OEMs to sell or even manufacture vehicles in the UK. However, growth in a mass market may also be constrained by limitations in the public infrastructure for EV charging – public charging stations cost significantly more than charging at home, by a factor of two to three. Just over 70,000 public charging stations are currently available in the UK, about 40% fewer than in Germany, where around half of electric-vehicle charging takes place at home[6]. In densely populated urban areas where on-street parking predominates, affordable home charging is difficult to achieve without subsidised installations in street lighting infrastructure.

Projected fines by brand (mill. GBP)

Figure 1. Originally projected fines through ZEV mandate



Source: Data Force

Automation

Full automation of vehicles could be a path towards accelerating the transformation of the UK vehicle fleet to zero-emission – particularly when combined with a transition from personally owned vehicles to mobility services provided by commercial fleet operators due to more intensive vehicle utilisation. **This would require close integration with public transit services and private mobility service providers utilizing public private partnership models.**

To offer automated and sustainable mobility services at affordable rates to the majority of the population, energy prices would need to stay moderate and come from renewable sources, the cost of the vehicle platform would need to be low, and charging infrastructure would need to be abundant. Furthermore, automation of vehicles would require suitable standards and regulations to ensure safe and secure operation where collisions are kept below an acceptable threshold.

Reducing the cost as well as the development time of zero-emission vehicles and enabling their automation will require substantial innovation efforts in process development tools, sensor technology, AI algorithms, AI chips, configurable software platforms, high-performance computing capabilities in the vehicle and the backend, and new battery and charging technologies. In order to build complete user trust into AI-enabled driving, standardised methods of AI assurance need to be in place and implemented in the regulatory approval process. Another important consideration is the licensing of L4 technologies from specialised companies to OEMs.

Circular business models need to be created that enable the elimination of waste in resources and operation – in particular with respect to the size of the automated vehicle fleet and its supporting infrastructure, while also making sustainable automated services affordable to the market – safeguarding the right to mobility.

BOX 2. KEY PLAYERS IN AUTOMATION

Both Tesla and XPeng are pushing end-to-end AI for autonomous driving, which takes raw sensor data and uses it for vehicle control. The system combines the traditional modular approach of perception, prediction and planning into a single system that can be trained. This technological approach has made substantial progress in the number of miles driven between user interventions. The hope is to make the system completely intervention-free, to enable unsupervised automated driving without geofencing.

Waymo has indicated that it is exploring the use of end-to-end AI technologies[7], but that these will be integrated with the existing modular approach (based on perception, localization, planning, control, and prediction). This strategy is also being followed by others such as Zoox and Nuro. Nuro is an example of a company that offers a licensing model[8]. Operators such as Moia, owned by the Volkswagen Group, also offer to license their L4 operational platform[9] to third parties. The UK has companies such as Oxa and Wayve, offering L4 technology that can be integrated into other OEMs.

The emergence of China and implications for established OEMs

Of the estimated 1.5 billion cars on the road globally, 20% are in the US, 17% in Europe and 30% in China. Most of China's growth has occurred since the 2000s, such that in 2024 it was the global leader both in vehicle sales and ownership. In 2023, China became the largest exporter of vehicles worldwide.

The Chinese government (both central and local) has been very active in supporting the transformation of its automotive market to electrification – contributing to China's long-term development into a net-zero society, and producing a significant edge over European manufacturers in terms of innovation. The Chinese automotive industry (both legacy and new) has strengthened its domestic position with highly competitive products and pricing. It is now addressing the global market, especially Europe.

European legacy automotive OEMs are predominantly driven by economic performance parameters such as market share, profit margins and stock price. Innovation is often driven top-down, from high-end premium models to volume models. In particular, German car manufacturers have developed a strong and longstanding market position in the premium ICE vehicle segment, with performance, safety and comfort features at an excellent production quality level producing high profit margins through high prices. However, the established automotive OEMs are now being challenged by new players backed by large technology companies, as well as new OEMs that are software driven, such as XPeng. These embrace full electrification and automation, and have significant financial capacity to fund innovation and new business models. Furthermore, these new Chinese OEMs are able to develop vehicles 30% faster than legacy automakers[10], surpass the vehicle specifications of competitors and implement new innovations faster.

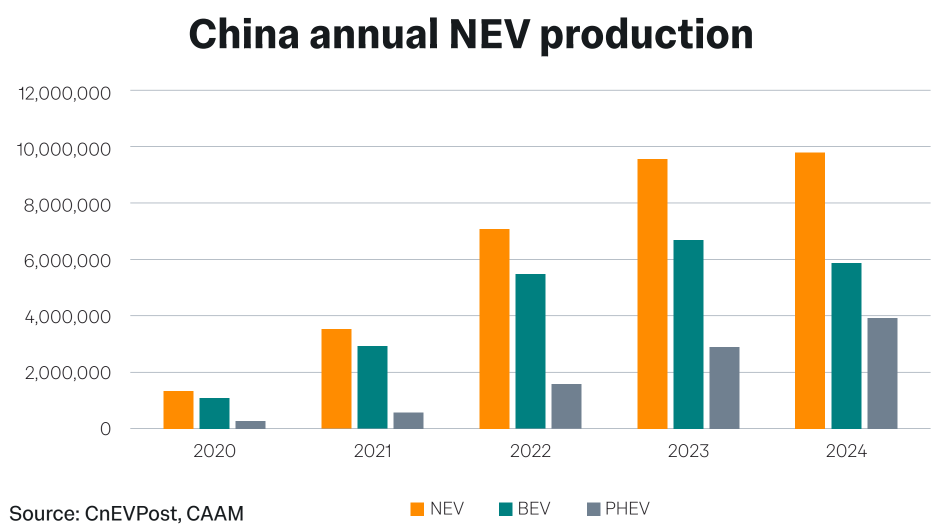
BOX 3. CHINA INVESTS IN BATTERY SWAPPING

China aims to have 16,000 battery-swapping stations by 2025[11]. This technology has been pioneered by NIO, a Chinese OEM which has partnered with other Chinese OEMs such as Changan, Chery, Geely and GAC to build interoperable stations. The leading Chinese battery manufacturer CATL has announced the target of establishing an additional 10,000 battery-swapping stations by 2030. Through standardisation battery-swapping has become an alternative to conventional charging while substantially reducing charging time.

Tesla's entry into the Chinese market with local manufacturing in 2019 has contributed substantially to the acceleration of Chinese OEMs' ability to compete with Tesla vehicles on performance and price. This is particularly notable in the case of emerging new energy vehicle(NEV) players such as BYD, Li Auto, XPeng, Xiaomi and Nio. China's initial goal of achieving a NEV market share of 20% by 2025 has already been surpassed with more than 12 million NEVs produced in 2024 (Figure 2).

Tesla has expanded the production capacity of its Shanghai Gigafactory to almost a million vehicles a year, and uses the plant for exports, including to Europe. The NEV players are increasingly competing with German premium manufacturers such as Audi, BMW and Mercedes, and BYD closed the gap in global battery electrical vehicle (BEV) sales with Tesla in 2024[12]. Interestingly, although Tesla and BYD are competing on vehicle sales, they collaborate strategically: Tesla uses LFP batteries made by BYD in vehicles produced both in Gigafactory Shanghai and in Gigafactory Berlin. China is for the foreseeable future the dominant player in global EV battery production where its share will decline from 78% in 2023 to 58% in 2030[13].

Figure 2. NEV production in China



Source: CnEVPost, CAAM

Slower EV adoption and other European automotive sector challenges

European legacy automotive OEMs are facing significant challenges. Weakening profits are making it more difficult to sustain investments in full electrification and full automation.

First, despite the efforts of European OEMs to invest in their zero-emission product portfolio, consumer demand for EVs has slowed down substantially in the EU, questioning the ability to meet emission regulation requirements by 2035. This is due especially to the following factors:

- A delayed build-out of EV charging infrastructure[14].
- Higher end-user price levels of EVs, compared with ICEs.
- Introduction of tariffs on BEVs manufactured in China and imported to the EU leading to limitation of affordable vehicles available to the consumer.
- A lack of government incentives to purchase EVs (e.g. Germany dropped its subsidies completely in late 2023).
- High prices of electric energy due to the impact of sanctions on energy imports from Russia.

Second, sales and profits of European OEMs in the China market are rapidly weakening, while competition in home markets from Chinese OEMs in Europe is intensifying, despite the EU's imposition of duties on imports of BEVs from China for a period of five years from 2024[15]. In addition to competition from China, the new US administration is enforcing local engineering and production in a major reindustrialisation effort, bolstered by the use of tariffs on imported vehicles and automotive parts. The US legacy automotive industry is also primarily focused on the domestic market and is largely protected from Chinese competition.

Third, there are substantial technology competitiveness challenges for the European car industry in the EV supply chain and SDV sector, which need to be addressed:

- Lack of critical mass of battery cell production capability due to slow speed in scaling up.
- Dependency on Chinese battery production machine equipment and suppliers.
- Lengthy product development cycles.
- European OEM's failure to focus fast enough on dedicated AI chip design and AI algorithm development to support automated driving, leading to a dependency on US tech companies.
- A lack of regulatory frameworks to test and deploy highly and fully automated vehicles.

China has also issued data regulations related to exporting and processing data from connected vehicles, for example, data from vehicles operated in China needs to be stored within China's borders, cross-border data transfers need to go through a security review and be approved, and automakers must establish domestic data centres to process local data. One of the key implications of this requirement is the need to train AI-based advanced driving assistance system/automated vehicle (ADAS/AV) systems locally and utilize vehicle data collected domestically.

The 2024 Draghi report highlights several of these shortcomings in the European automotive sector18, notably high production costs (about 30% higher in the EU than in China), lagging technology capabilities, supply chain dependencies, and declining brand value. The report does not comment on battery capacity, vehicle weight or the SDV. Draghi recommends measures to lower energy and labour costs and increase automation. The report also provides examples of innovation opportunities in affordable electric and autonomous vehicles, circularity in the value chain, and further developing the charging infrastructure.

A specific EU action plan for the automotive sector covering all stages of the value chain is recommended. An industrial action plan for the European Automotive Sector has been published in March 2025[19]. The action plan elaborates on innovation and digitalisation, clean mobility, competitiveness and supply chain resilience, skills and social dimension, level playing field and business environment.

Given the strong trade relationships between the UK and the EU in the automotive sector, the call for action outlined in the Draghi report and the industrial action plan could also provide an opportunity for the UK to take part in the effort, with both R&D and manufacturing implications. Examples are:

- **Engagement of the UK in joint regulatory sandboxes and cross-border testbeds to support the creation of a single market for autonomous driving including a unified vehicle test regime and aligned regulatory vehicle approval frameworks.**
- **Engagement in a joint SDV platforming and participation of UK companies in the supply chain of solution providers.**
- **Participation of UK public and private funding vehicles in a TechEU investment programme.**
- **Participation in a joint framework for smart and bidirectional charging.**
- **Alignment on local content regulations.**

The US perspective and national security risk concerns

The US has recently issued a 'final rule'[20] to be applied to passenger vehicles. This addresses the hardware and software integrated into the vehicle connectivity system (VCS) and the software integrated into the automated driving system (ADS), as well as any automotive systems in general that allow external connectivity or automated driving capabilities. These may not be designed, manufactured or supplied by persons with close ties to China or Russia. The software ban will apply to vehicles from model year 2027 onward, and the hardware ban to vehicles from model year 2030 onward.

Any consideration of national security risks in the development and deployment of automotive systems needs to take into consideration the sensing of data in specific geographical areas, and its processing through data centres. In addition, the use of AI malware could enhance cyberattacks on automotive vehicle and related infrastructure in the future[21], and make detection more difficult by adaptively changing the attack vector and masking the behaviour of the attacker. Prevention and mitigation strategies for AI-enabled cyberattacks need to be considered in suitable automotive technology roadmaps.

The road ahead

The automotive sector is at a crossroads. The current evolutionary development approach involves gradual electrification and automation of predominantly self-owned vehicles. A radical development approach would establish full automation and electrification, with mobility provided as a service through a fleet operator, and where traditional ownership is no longer needed. **Both these directions pose important challenges for European legacy automotive OEMs.**

The global context for the automotive sector requires OEMs and suppliers to develop market-specific system architectures, sourcing strategies and operational models that are compliant with local rules and regulations. **There is no one-size-fits-all approach.**

From a UK perspective, the future direction for the automotive sector needs to take into account geopolitics and matters of national security, especially in relation to critical supplier relationships such as battery components, microelectronics and software, as well as data collection, data processing and data transfer. **The UK maintains trade relationships with all major automotive markets, and needs to find a flexible approach that can both embrace value-creation opportunities and reduce risks of potentially harmful security or trade tensions.**

Review of UK automotive sector roadmaps

A number of automotive and mobility roadmaps and future-looking reports have been published by UK and non-UK organisations. In this section we review a selection of them and highlight salient points.

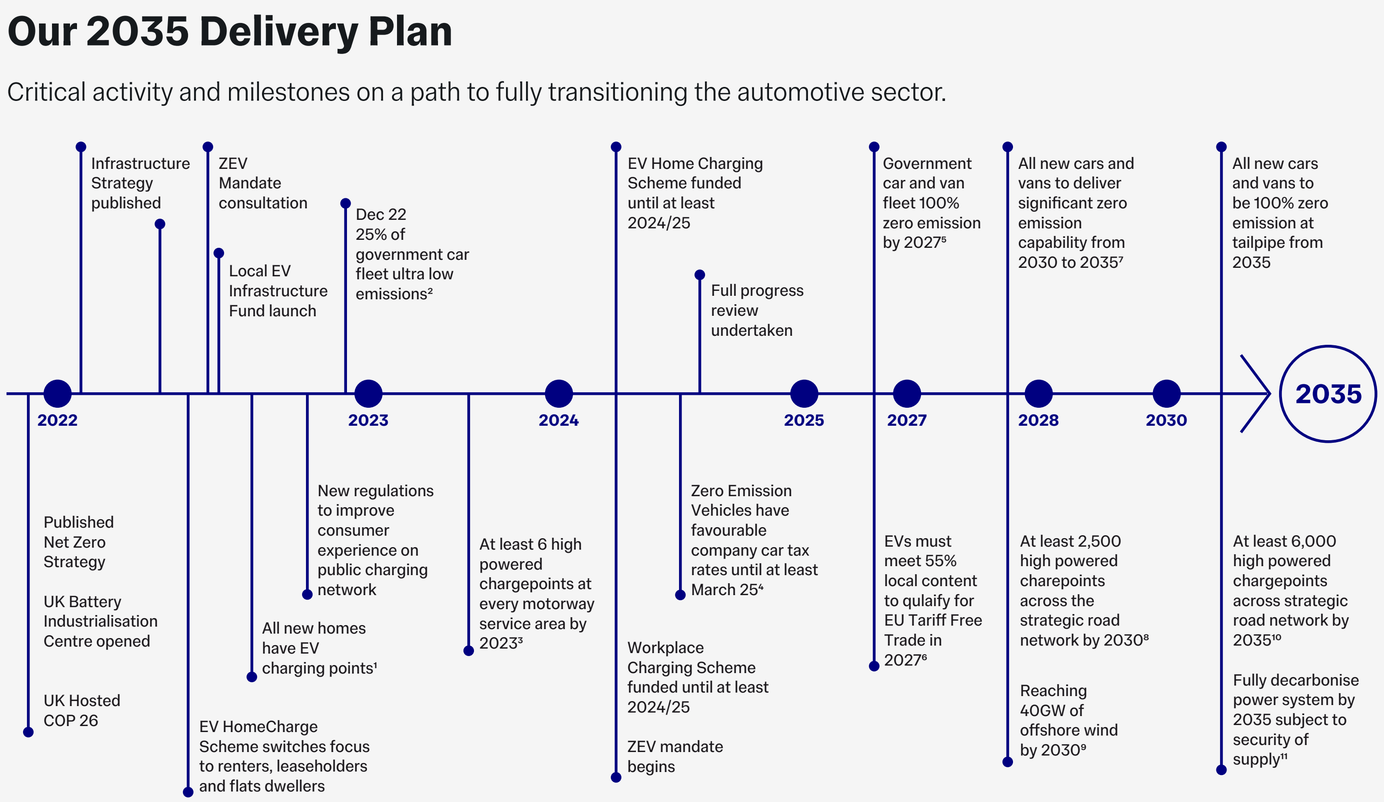
Automotive Roadmap: Driving Us All Forward (2022)

In 2022, the UK government published an automotive roadmap which primarily addressed the 'Green Transformation'. It provided the foundations of the ZEV mandate mentioned previously, and provided a timeline until 2035 (Figure 3).

The ZEV mandate came into effect in January 2024[22]. Its timeline was synchronised with the California and EU ZEV mandates to ban the sale of CO_2-emitting vehicles by 2035. Due to pressure from the automotive industry within both the UK and the EU, the emission goals have been relaxed but the overall timelines to ban the sale of ICE vehicles has not been changed[23].

From a UK perspective, a slowdown of EV adoption in the EU[24] is problematic for meeting the goals of the ZEV mandate, as the EU is the most important automotive export market. At the same time, to increase EV sales in the UK, vehicles need to be affordable to consumers, and EU manufacturers have a limited selection of affordable EV models. This could open the door for Chinese OEMs to increase export efforts to the UK (providing a wider consumer selection of affordable EVs) and even to consider local production of vehicles and batteries. Importantly, in contrast to the EU, the UK government has no plans to raise tariffs on EVs imported from China[25].

Figure 3. Automotive Roadmap, Driving Us All Forward



Source: UK Government (Automotive Roadmap, Driving Us All Forward, March 2022)

After Brexit, the UK and EU concluded a Trade and Cooperation Agreement (TCA) concerning the rules of origin for electric vehicles and batteries (Figure 4). Vehicles and batteries that do not meet these requirements face a 10% tariff at either the EU or UK border. The original threshold increase has been shifted from 1 January 2024 to 31 December 2026 as the EU and UK EV supply chain has not made sufficient progress.

As the US is investing heavily in strengthening its domestic EV supply chain, supported by the US Inflation Reduction Act (IRA)26, and China has the strongest EV supply chain worldwide, building a competitive EU supply chain has proven to be challenging. Both the UK and EU may benefit from investments of Chinese OEMs and suppliers in an UK-EU EV supply chain.

Figure 4. Minimum level of EU/UK manufactured content to access zero tariffs

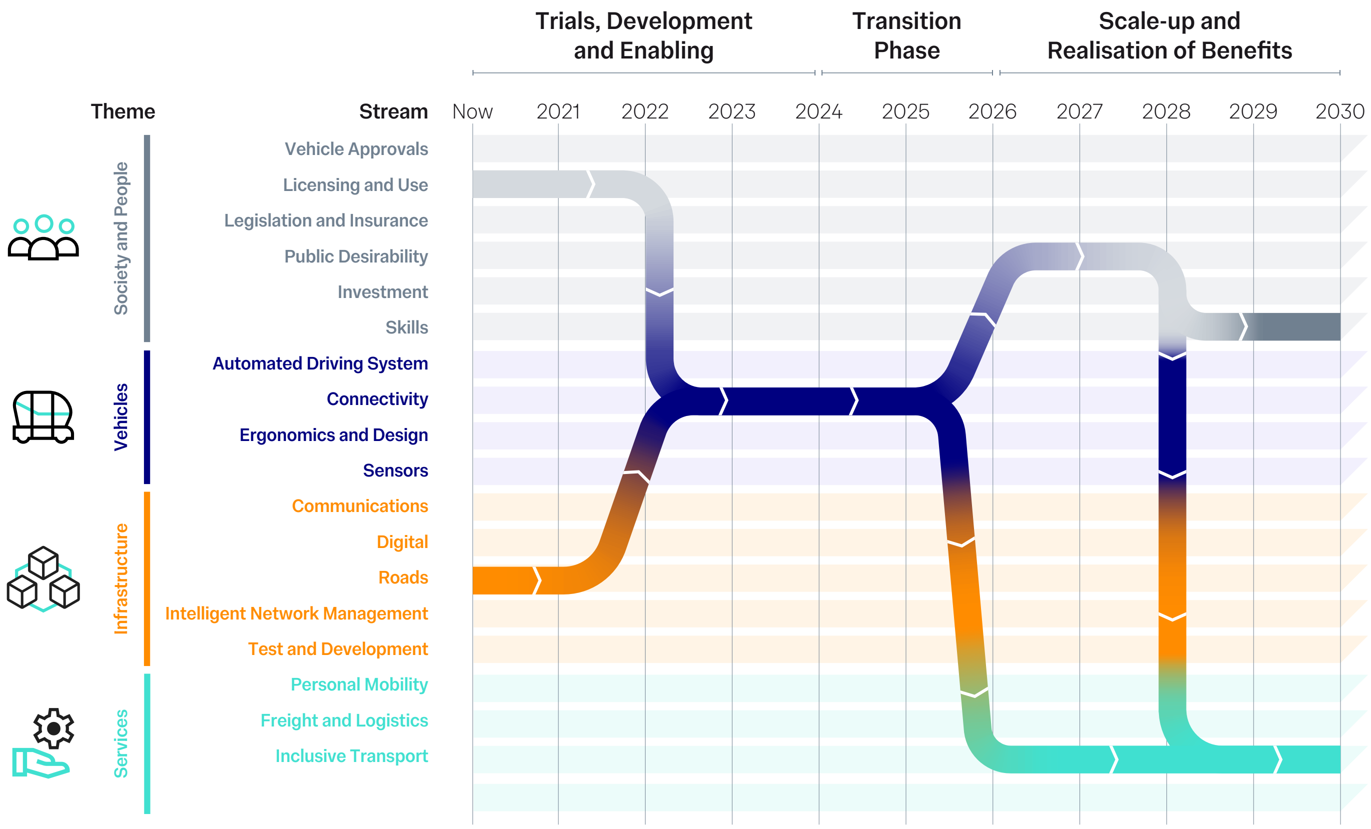
	1 May 2021 to 31 December 2023	1 January 2024 to 31 December 2026	From 1 January 2027
Vehicle value	40%	45%	55%
Battery pack	30%	60%	70%
Battery cell	30%	50%	65%

Source: EU-UK TCA (EU-UK rules of origin for electric vehicles and batteries)

UK Connected and Automated Mobility Roadmap to 2030 (2019/23)

Zenzic was created by government and industry to champion the UK Connected and Automated Mobility (CAM) ecosystem and lead the UK in accelerating the self-driving revolution. A major achievement was reached in 2019, when Zenzic published the 'UK Connected and Automated Mobility Roadmap to 2030' (Figure 5), which identified a total of 500 milestones to be passed in order to get connected automated vehicles (CAVs) on the road by 2030[27].

Figure 5. UK Connected and Automated Mobility Roadmap to 2030.



Source: Zenzic

In 2023, Zenzic updated the 2030 roadmap with more information about personal mobility and public transport vehicles (Figure 6) as well as verification, validation, assurance, and infrastructure and data services (Figure 7)[28]. The updated roadmap also refers to off-highway vehicles, which are being deployed now as there is not the same regulatory barrier. The AV (Automated Vehicles) Act[29] only applies to on-road vehicles.

According to the roadmap, commercial deployment pilots should be implemented in the 2023-2026 timeframe, both for personal mobility vehicles and public transport vehicles. Such developments are well under way at scale in the US and China[30, 31], but to a lesser degree in the EU[32] and the UK[33].

Figure 6. UK Connected and Automated Mobility Roadmap to 2035

Product, services, solutions	Short term (2023–26)	Medium term (2027–30)	Long term (2031+)
Personal mobility vehicles and services	**Commercial deployment pilots** • Introduction of No-User-In-Charge vehicles (NUiCs) in specific use cases such as automated lane-keeping systems (ALKS), valet parking as optional feature in privately owned vehicles • Deployment trials to support the development of service/business models for personal mobility • Identification of training and skills required for this service • Identification of the CAM supply chain requirements for this service	**Commercial service models ready for investment** • Deployment of personal mobility vehicles for personal ownership and services such as sharing and car clubs within identified ODDs • Manufacturing of vehicles ready for NUiCs at scale • AI-enabled load route/task planning • Partnership between operators and vehicle providers • Cost-effective technology/product solutions (e.g. for sensors, HD mapping, road infrastructure) • End-to-end CAM skills pipeline established	**Monitoring and refinement followed by expansion of the ODDs** • Integrated business case enabling efficient transport of people
Public transport vehicles and services	**Commercial deployment pilots** • Partnerships between operators, local authorities and technology or solution providers • Deployment trials to support the development of service models for public transport • Development of mobile applications needed to access the service • Identification of training and skills required for this service • Identification of the CAM supply chain requirements for this service	**Commercial service models ready for investment** • Deployment of public transport services, and services within identified ODDs • Manufacturing of vehicles ready for NUiCs • AI-enabled load route/task planning • Cost-effective technology/product solutions (e.g. for sensors, HD mapping, road infrastructure) • End-to-end CAM skills pipeline established	**Monitoring and refinement followed by expansion of the ODDs** • Integrated business case enabling efficient transport of people

Source: Zenzic

Various issues need to be considered if commercial service models for ADS are to become scalable:

(i) Automated vehicle fleets must be able to operate with 'zero interventions' over the designated operational design domain (ODD), with a scenario set that covers all imaginable driving situations – including edge cases reflecting rare occurrences at the boundaries of the operational parameter spectrum.

(ii) Passenger-carrying services should offer a 'human-like' driving experience.

(iii) Operational risks should be assessed through standardised test methods and certified test infrastructures.

(iv) Physical and digital infrastructure must be in place to allow proper monitoring of the automated vehicle fleet and keep operations safe and secure.

(v) Special attention needs to be given to AI-enabled ADS, which must be trained on sufficient data to deliver the right response in a specific situation. Although we always want to achieve collision-free mobility, the risk needs to minimised if impact cannot be avoided in a specific scenario setting.

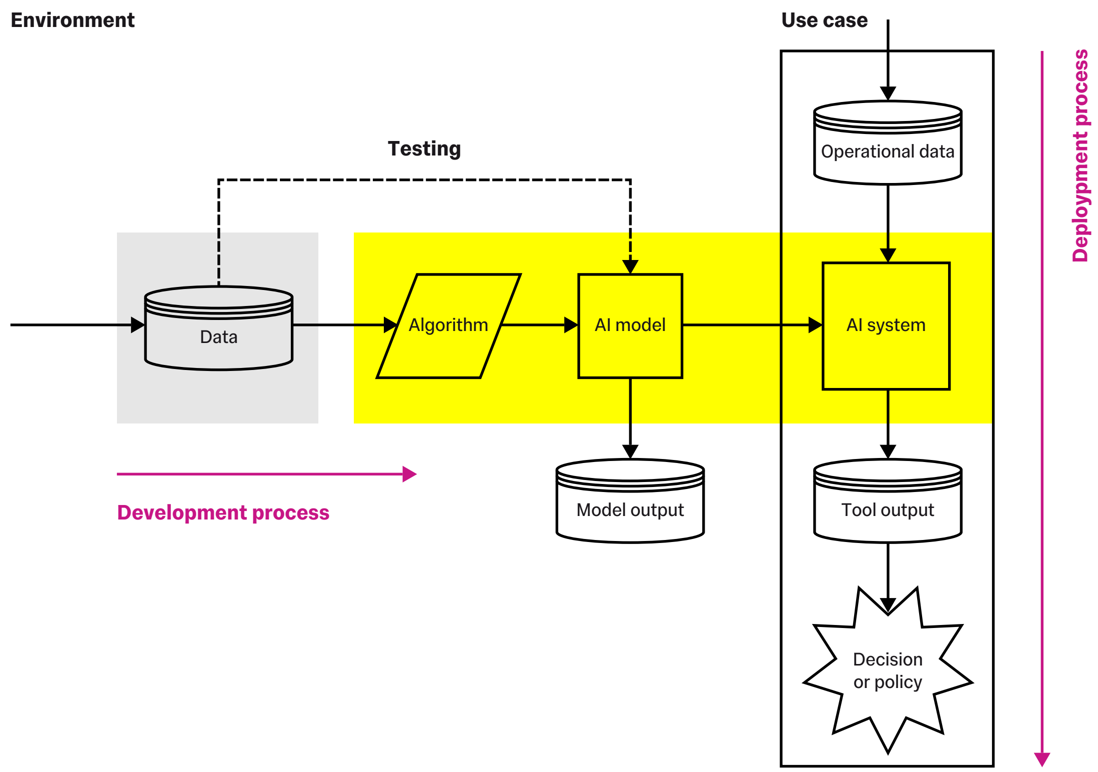
Ideally, ADS should also be able to learn over its operational lifecycle. The UK government published a guidance document on AI assurance in 2024[34], which provides more information on how to measure, evaluate and communicate the trustworthiness of an AI system. The end user must be able to trust AI-enabled ADS to be at least as safe as a human-operated vehicle. The decision-making component of an AI-based system therefore needs to be sufficiently trained to deliver trustworthy behaviour during deployment (Figure 8).

Figure 7. UK Connected and Automated Mobility Roadmap to 2035

Product, services, solutions	Short term (2023–26)	Medium term (2027–30)	Long term (2031+)
Verification, validation and assurance services	**CAVs framework in place** ▪ Pre-certification validation (within organisation) ▪ Primary legislation in place ▪ Consultation for secondary legislation – research to support assurance standards, and product development assurance ▪ CAM ecosystem to collaborate to focus on the public perception of CAM and its benefits	**Framework for the life cycle of CAM services** ▪ Secondary legislation in place for commercial service models ▪ Whole-life assurance (includes aftermarket services of maintenance and replacements)	**Monitoring and refinement followed by expansion in CAM deployment areas** ▪ Legislation and regulations to support the integrated business case, enabling efficient transport of people and goods
Infrastructure and data services	**Framework for the federated data architecture** ▪ Defining the data requirements ▪ Compiling, developing and building federated digital architecture ▪ Real time digital twins of the operating environment, including HD mapping	**V2X (vehicle-to-everything) connectivity and data availability** ▪ Regulatory information digitised with agreements in place to share the required data ▪ Vehicle-to-vehicle (V2V) connectivity between different vehicles (owned by different providers) ▪ Vehicle-to-infrastructure (V2I) connectivity between roadside infrastructure, vehicles and applications utilised to run services	**Seamless passenger connectivity** ▪ Connectivity with Electric Vehicle (EV) charging infrastructure ▪ Ubiquitous connectivity for the services enabled with connectivity ▪ Geographic Information System (GIS)/digital/data platforms driving services (public and commercial)

Source: Zenzic

Figure 8. Development and deployment of AI-based systems



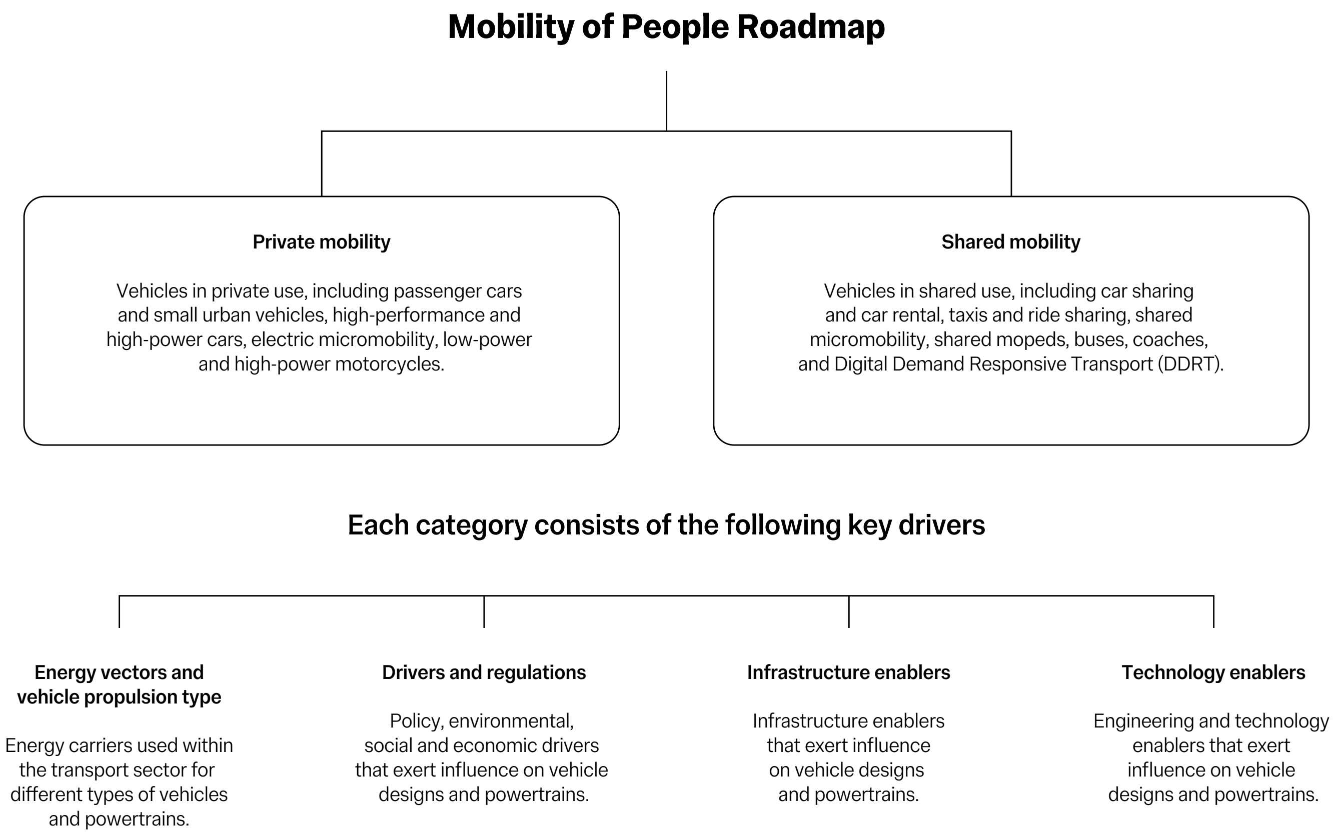
Source: UK Government, Department for Science, Innovation and Technology. Introduction to AI Assurance, February 2024.

Importantly, the Zenzic 2035 strategic level roadmap does not provide specific answers on how to deal with AI-based systems, but it explains how to deal with any changes in the operation of an AV which can include AI (described in their latest roadmap update on verification, validation and assurance[28]).

Advanced Propulsion Centre Mobility Roadmaps (2024)

In 2024 the UK's Advanced Propulsion Centre (APC) issued roadmaps on mobility options on behalf of the Automotive Council UK[35] in 2024. These reflect on the evolving landscape across the mobility and transport ecosystem and highlight the critical role that the automotive industry will play in the landscape. The two system-level roadmaps cover 'Mobility of People' (Figure 9) and 'Mobility of Goods'.

Figure 9. Mobility of People Roadmap



Source: APC UK

The most relevant aspects of the system-level (mobility of people) roadmap in terms of transformation from the status quo are:

(i) Mass electrification after 2035 is forecast and small BEVs will become commonplace in urban areas.

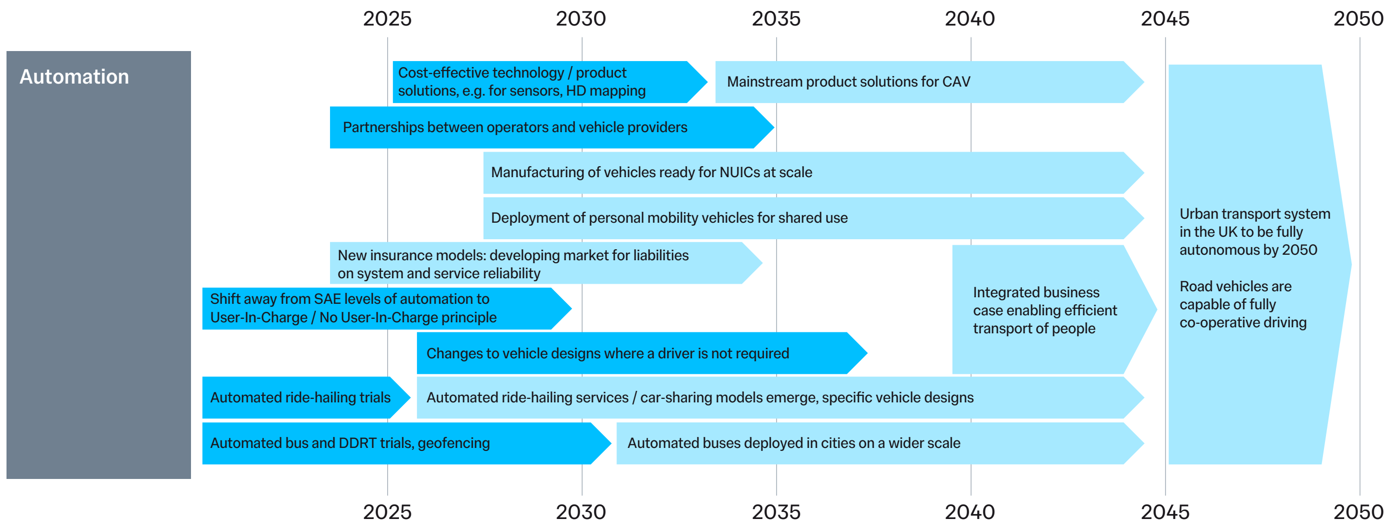
(ii) Safety regulations are continuously developed, with the goal of collision-free driving.

(iii) Personal ICE ownership could become prohibitively expensive in the future. Ownership could be replaced by usage-based business models.

(iv) Automated parking will initiate wider adoption of driving automation, and we will see the scaled manufacturing of NUIC (no user in charge) vehicles by the end of the decade.

(v) Although creating a truly carbon-free transportation fleet is the 'generational task' considered in the roadmap, automated mobility will enable new business and operational models that are substantially more resource-efficient and safe (Figure 10).

Figure 10. Infrastructure and technology enablers



Source: APC UK

Assessment of UK-based roadmaps

- The UK-based roadmaps issued by the government in collaboration with the automotive industry that are most relevant in influencing the future of automotive are the ZEV mandate and the 2035 Connected and Automated Mobility roadmap. The roadmaps on mobility created by APC UK are very helpful in understanding the long-term implications of known technologies, including policy, business-model and infrastructure impacts.

- In general, **the roadmaps suggest that the UK is strategically well positioned for both the green and the digital transformation of automotive mobility.** However, the key innovation forces for the transformation are emerging in the US and Chinese markets: China is driving the green transformation and the US is driving the digital transformation. In the future, India may play a more important role in engaging with both transformations, due to its huge population, strong engineering and IT-skilled workforce, and general economic progress.

- **The weakness of the EU in building up competitive EV supply chains, as well as the delayed implementation of larger-scale AV commercial deployment projects, is a major concern.** This has potential economic implications for the UK, due to its strong trade relationships with European automotive OEMs.

- What the UK could do better is to **focus not only on making the domestic vehicle fleet carbon free for new vehicles sold on the market, but also accelerating the complete transformation process.** This requires addressing and measuring the overall sustainability impact of mobility in terms of waste, carbon footprint of manufacture and raw materials (not just tailpipe emissions), low cost zero carbon electricity generation, affordability, productivity and health. Connectivity and automation of mobility can help to further accelerate this transformation process. However, transformational projects need to be assessed, evaluated, and potentially bundled for optimal sustainability impact.

- What has not been addressed in any mobility-related UK roadmap mentioned thus far is the **risk that quantum technology could endanger the safe and secure operation of connected and automated vehicle systems in the future.** However, there is substantial effort on the way in UK to deploy quantum resistant cryptography.

Review of non-UK automotive sector roadmaps

Deloitte Future of Mobility (2016)

In 2016, Deloitte published a 'Future of Mobility' roadmap (Figure 11)[36]. This suggested that shared and personally-owned autonomous vehicles would begin to be introduced from the early 2020s and by 2025 over 10% of total miles driven would be shared driver-driven. The general trajectory of transformation towards automation still seems reasonable but the big unknown is how the ratio between personally owned autonomous vehicles and shared or temporarily shared autonomous vehicles will change. It is safe to say that Deloitte's 2016 predictions concerning the transformation to automated mobility have proven too optimistic in 2025 (see Box 4).

BOX 4. DRIVEN AND SELF-DRIVEN AUTONOMOUS VEHICLE

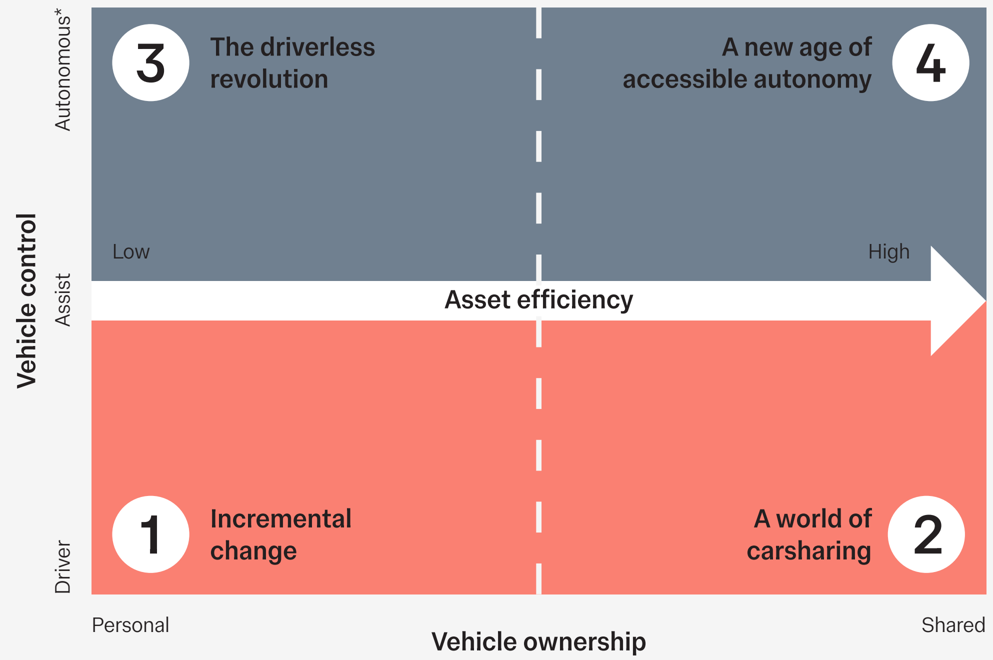
In 2024, the total number of Uber drivers worldwide was around 7.8 million. Assuming that Uber is a dominant player in shared driver-driven services, that the US market has more than 50% of the overall revenue, and that the average Uber driver drives 140-200 miles per day for around two days a week, this would result in 50 billion miles driven – a small fraction of the annual three trillion annual VMT (vehicle miles travelled) reported by the US Federal Highway Administration.

The Waymo fleet in the US currently drives one million miles per week with a fleet of less than 1,000 vehicles. This amounts to around 50 million miles per year. Even with a fleet of one million fully automated robotaxis, this would result in only about 10% of the miles driven by the Uber fleet. Waymo started its robotaxi service in 2020 in Phoenix, Arizona, but there are so far no personally owned autonomous vehicles on the market (in spite of Tesla introducing full self-driving in 2022).

Figure 11. Future mobility scenarios

Extent to which autonomous vehicle technologies become pervasive:

- Depends upon several key factors as catalysts or deterrents - e.g., technology, regulation, social acceptance
- Vehicle technologies will increasingly become "smart"; the human-machine interface shifts toward greater machine control



Extent to which vehicles are personally owned or shared:

- Depends upon personal preferences and economics
- Higher degree of shared ownership increases system-wide asset efficiency

Note: Fully autonomous drive means that the vehicle's central processing unit has full responsibility for controlling its operation and is inherently different from the most advanced form of driver assist. It is demarcated in the figure above with a clear dividing line (an "equator").

Source: Deloitte, Future of Mobility (2016)

Accenture Circular Economy (2020)

At the 2020 World Economic Forum in Davos, Accenture introduced a roadmap[37] for the automotive circular economy, based on five circularity levels (Figure 12). Accenture highlights the inefficient use of cars by private owners; business models that are used to sell cars as a product rather than mobility as a service; production methods that are volume-driven; and regulatory frameworks that do not account for life-cycle emissions and the use of materials. The report defines the circular car in terms of maximising the value for society, the environment and the economy, while efficiently using resources and public goods. Carbon efficiency is defined as 'life-cycle CO_2 emissions per passenger kilometre' and resource efficiency as 'non-circular resource consumption per passenger kilometre'. The stated goal is to reduce carbon emissions by up to 75%, and non-circular resource consumption for a BEV by up to 80% by 2030.

Figure 12. Levels of circularity

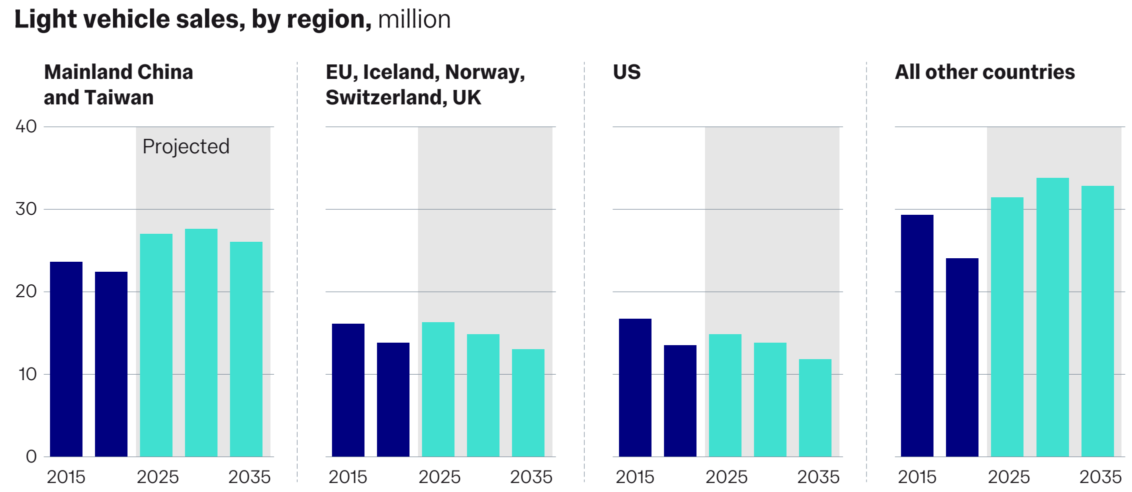
Levels of circularity	0	1	2	3	4	5
	No circularity Past	**Low circularity** Today	**Moderate circularity** 2025	**High circularity** 2030	**Full circularity** 2035	**Net positivity circularity** 2040
	Classic make-use-waste mentality	Silo optimization and sales focus	Product improvement and better coordination	Aligned incentives and life-cycle optimization	Full circular value chain in as-a-service models	Ecosystem optimization
Energy	Carbon-intensive fuels	Renewable energy in component production and assembly	Alternative drivetrains; low-carbon production	Carbon-neutral use phase; low-carbon materials	Carbon-neutral production and materials	Full energy grid integration of vehicles
Materials	Linear value chain	Production scrap looping	Recycled content increased	High-quality recycling loops	Full "at level" recycling and transparency	Upcycling of waste
Lifetime	Sales-driven model	Repair networks and used car markets	Increased reman in aftermarket	Modular design for upgradability and reman	Purpose-built vehicles	Second-life applications
Use	Private ownership	Private ownership and leasing	On-demand services (cities); subscriptions	Fleets dominate: vehicles and mobility on demand	Mobility on demand in breathing fleets	Optimized mobility system

Source: Accenture

McKinsey The Future of Mobility (2023)

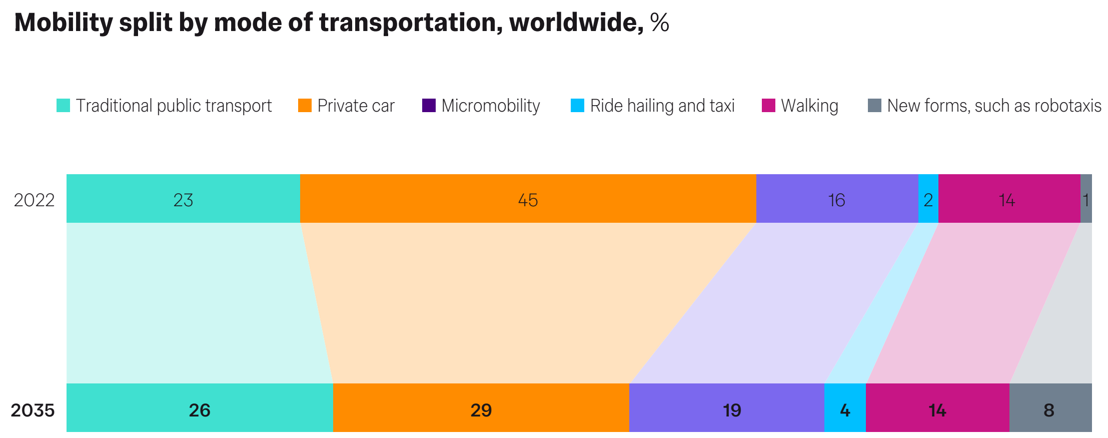
The McKinsey report on 'The Future of Mobility' was published in 2023[38]. According to the study, private car sales will peak by the end of the decade and decline by 2035 to the same level as in 2015. Passenger miles travelled (PMT) in private cars will also drop by 15% by 2035 (Figure 13). New modes of mobility such as autonomous robotaxis will gain an increased share of PMT (Figure 14). Should this trajectory be followed, the impact will be most dramatic in the US, the most car-dependent country in the world.

Figure 13. Light vehicle sales by region



Source: The Future of Mobility, McKinsey Quarterly, April 2023.

Figure 14. Mobility split by mode of transportation

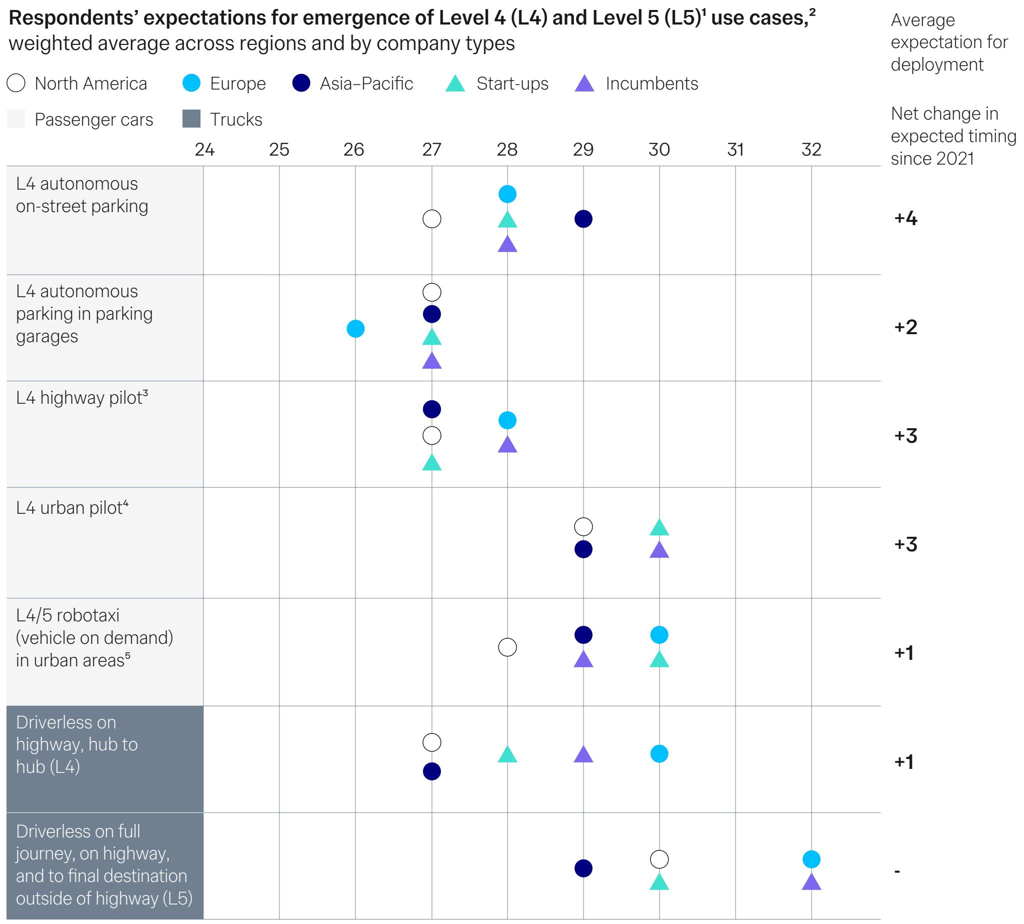


Note: Figures may not sum to 100%, because of rounding.
Source: The Future of Mobility, McKinsey Quarterly, April 2023.

McKinsey, Spotlight on mobility trends (2024)

In 2024, McKinsey published the results of a survey on mobility trends[39] which included an assessment of the market adoption of ADS (Figure 15). McKinsey found that the timelines for adoption that were produced in 2021 were overoptimistic, and should be extended by two to three years. It estimated that vehicles with L4 capability (unsupervised self-driving) will begin to occur at scale around 2027-28.

Figure 15. Emergence of L4 and L5 use cases



¹L4 vehicles are fully autonomous within controlled environments, such as robotaxis restricted to use within a city. L5 vehicles are autonomous under all conditions.
²Question: In your estimation, what is the rollout (i.e., commercial availability of vehicles or service) timeline for autonomous driving across use cases in your region?
³Driver can use time on highways for work or leisure activities using in-car or own solutions but needs to take over at highway exits.
⁴Driver can use time on highways in urban environments for work or leisure activities using in-car or own solutions, but there might be certain situations in which the driver needs to take over.
⁵Robotaxis are driving everywhere in fully automated mode with no driver and are accepting and conducting transportation requests (goods, passengers). Passenger can use the travel time for work or leisure activities.

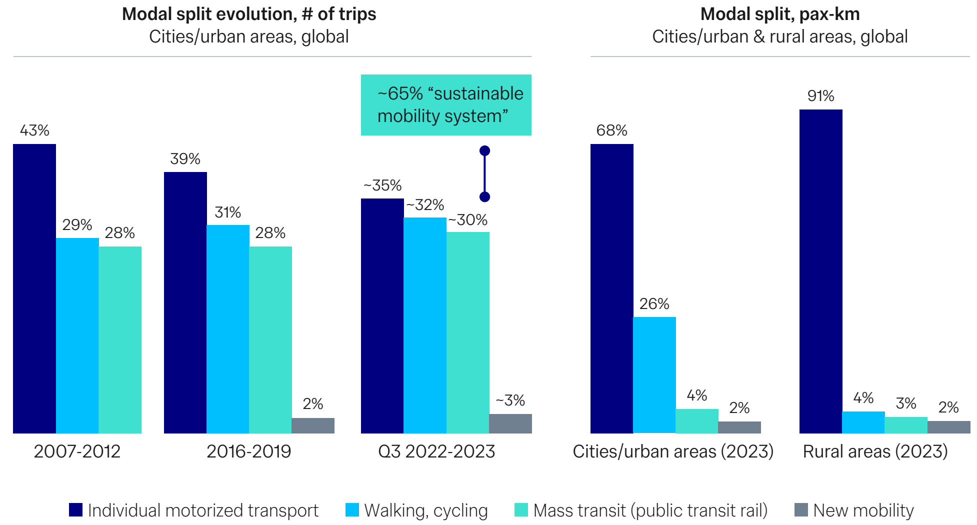
Source: McKinsey Center for Future Mobility Survey of global decision makers, 2023
(n = 86, 40 from North America, 37 from EU, 3 from China, 6 from other) and 2021
(n = 75, 31 from North America, 33 from EU, 11 from Asia–Pacific)

Source: McKinsey Center for Future Mobility, Spotlight on mobility trends, March 2024

Arthur D. Little and POLIS. Future of Mobility 5.0 (2024)

In 2024, Arthur D. Little and POLIS – a European network of cities and regions promoting sustainable mobility – published the results of a comprehensive survey on the future of mobility[40]. This showed that individual car transport is still a dominant form of mobility when it comes to passenger kilometres (pax-km) (Figure 16). Globally, the number of individual car trips grew by more than 30% over a five year period, propelled by fast-growing economies (e.g. India, Vietnam, Thailand and Mexico) while the use of public transport decreased slightly.

Figure 16. Global change in mobility patterns

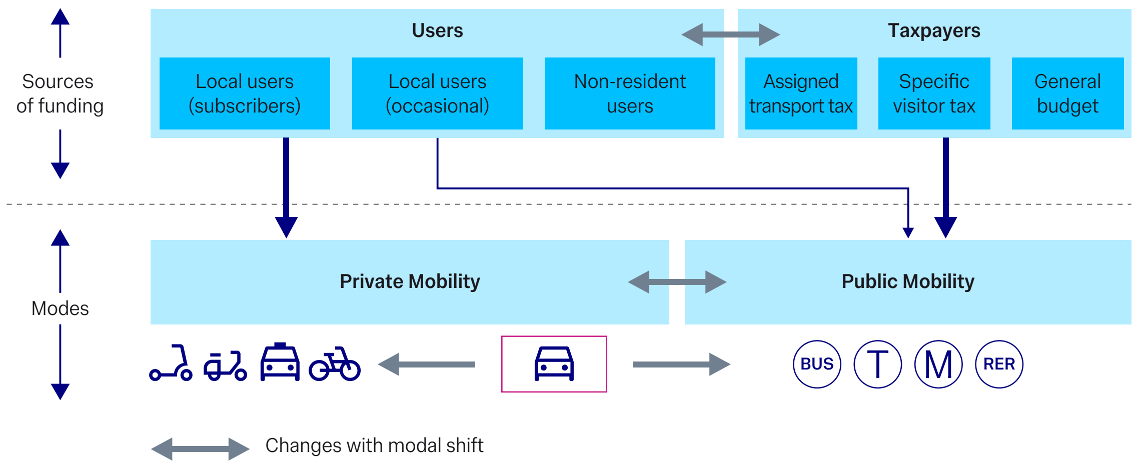


Note: New mobility includes shared and micromobility (car sharing, bike sharing, e-scooter sharing, etc); individual motorized transport includes taxi and ride-hailing; private mobility devices are not accounted for Source: ADL, The Future of Mobility 5.0 (2024)

A key issue highlighted by the study is the funding mechanisms that support mobility (Figure 17). Public transport systems are all subsidised, typically through the taxpayer. Households fund mobility through purchasing private mobility or by paying for public transportation or shared mobility services. Companies pay for mobility by assigning private vehicles to an employee or subsidising the use of shared mobility services or public transportation.

Private mobility accounts for a significant share of household budgets. Increasing the distance between home and work could reduce expenditure on housing, but will increase expenditure on mobility. The increased popularity of the 'city of proximity' concept is highlighted in the study, but its proper implementation comes with challenges such as the need to coordinate between multiple stakeholders such as planning and transport authorities, transport providers, and local politicians.

Figure 17. Funding mechanisms of public and private mobility



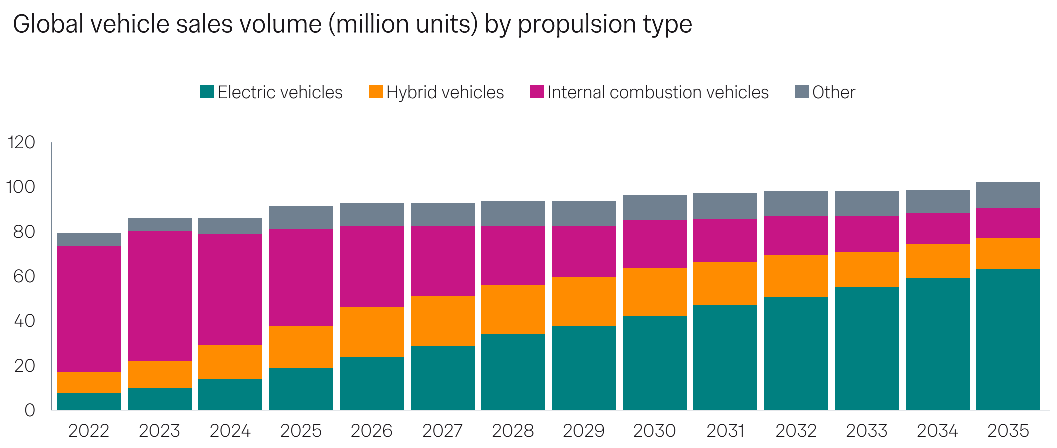
Source: ADL, The Future of Mobility 5.0 (2024).

S&P Global EV Adoption(2024)

An article published by S&P Global in 2024[41] highlights China's lead in affordable electric mobility. Although there is currently a contraction of BEV sales in all major markets, the long-term trend indicates a clear shift towards electric vehicles globally (Figure 18).

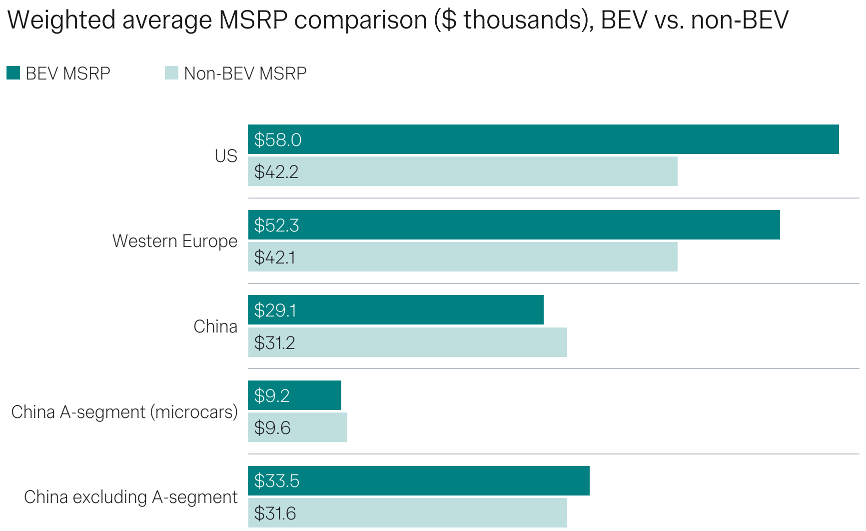
S&P points out that consumer reluctance in EV adoption is heavily influenced by cost. Globally, China is leading in BEV market penetration (25% in Q1 of 2024) due to low manufacturing cost, government support and a large portfolio of available products. In China, BEVs have almost achieved cost parity with ICE vehicles (Figure 19). In contrast, legacy OEMs from Europe and the USA are forced to use the cashflow from ICE models to shoulder investments in the transformation to a BEV product portfolio that has lower margins, and where priority is given to models in the premium segment to compensate for margin loss – but with limited potential in volume growth.

Figure 18. Growth in EV as a share of global vehicle sales.



Data compiled May 14, 2024.
Hybrid cars include hybrid electric vehicles, plug-in hybrid electric vehicles and mild hybrid electric vehicles.
Other includes fuel-cell electric vehicles, range extenders and other propulsion types.
Source: S&P Global Mobility.
© 2024 S&P Global.

Figure 19. Price comparison between BEV and non-BEV



Source: S&P

Roadmaps analysis

If we compare the different roadmaps, we can conclude that **there is a general consensus that the global fleet of new vehicles that are sold will decarbonise over the next 10 years, with the speed of the transformation driven both by regulation and by market forces.** China is clearly in the lead in terms of decarbonising the vehicle fleet.

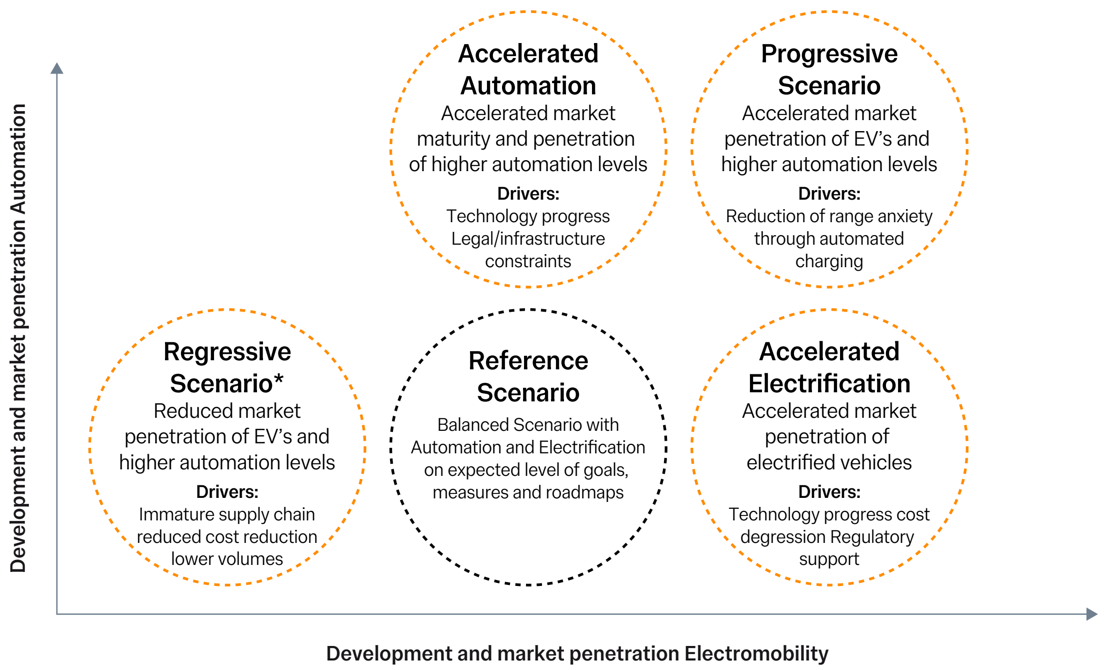
However, given that private car ownership is still dominant among mobility users, **the key issue is how to incentivise consumers to give up personally owned cars and switch to a mobility-as-a-service model.** Such a switch would require either substantial investments in public transport, which is predominantly funded through the taxpayer; or technological innovation to fully automate vehicles that are managed by commercial fleet operators, and which can operate with higher carbon and resource efficiency compared with private car use; and a combination of incentives and other measures such as use of local planning regulations to implement housing projects that do not allow private car ownership, e.g. in some Swiss cities[42] and elsewhere.

It should be noted that **none of the roadmaps reviewed here consider the increasing implications of geopolitics in the sourcing of raw materials, technical hardware components and software solutions.**

Implications for the UK

Four scenarios describing the future of automotive value creation were outlined in a German government report[43] (Figure 20). The scenarios are shaped by the extent to which the sector has made progress towards electrification and automation. Thus the 'progressive scenario' involves a high degree of development and market penetration on each dimension. We have also incorporated a fifth 'regressive' scenario in which there is only limited progress in electrification and automation. The scenarios can help to assess the UK's future mobility readiness.

Figure 20. Electrification and automation readiness



Source: fka, Roland Berger, IPE (*regressive scenario added)

Electrification

In the UK context, the reference scenario would suggest that the ZEV mandate will be fulfilled by 2035 by all active automotive OEM market participants. The ZEV mandate allows OEMs to bank, borrow or transfer carbon credits to avoid penalties for missed emission targets. As the UK does not impose tariffs on BEVs imported from China (unlike the EU) this may help to fill gaps in the range of affordable competitive EV products on the UK market. However, both the EU and the UK market are currently moving towards a regressive scenario, i.e. stagnating EV sales and little progress on automation. The key question is whether the slow down of EV adoption is temporary and will then accelerate again when more affordable EVs become available on the market.

Strengthening local EV supply chains in both the UK and EU will require sufficient consumer demand for EV adoption. This correlates to pricing level, affordable product offerings, and innovative product content that can stimulate consumer interest. Analysing market data in the context of the ZEV mandate for 2024 in more detail[44] reveals the following:

- In 2024, 1.95 million new vehicles were sold in the UK, of which 382,000 were BEVs. Overall growth came from businesses purchasing or leasing vehicles, whereas the market demand from private buyers fell by 8.7% to 746,000 units. Only one in 10 private buyers decided to purchase a BEV, and some OEMs had to discount their BEVs substantially to find buyers. The BEVs sold in the UK constitute about 18% of the market, which is lower than the 22% required by the ZEV mandate. However, as a result of the flexibility of the accounting principle of carbon credits, no OEM will have to pay a fine for missing the target in 2024. The target for 2025 is 28%, and each vehicle sold that does not meet the quota will attract a fine of £12,000 (recently reduced by 20% from £15,000 by UK Government).

- Around 426,000 cars were built in the UK during 2024. Of these, 309,917 were shipped worldwide (74.5%), of which 55.4% went to the EU[45]. This strong dependency of the UK on the EU market influences also the speed of the EV supply chain build out.

- It is estimated that between 160,000 and 200,000 full electric vehicles will be produced by 2030 from the OEMs Renault-Nissan, BMW with Mini, Tata with Land Rover, Toyota and Stellantis[46]. This represents only around 10% of the current market size and about 50% of the current UK production volume. Including commercial vehicles, the overall estimated UK production of electrified vehicles in 2035 will be less than 500,000 units – unless non-UK OEMs (e.g. from China) consider relocating production to the UK which would require investments in EV supply chain localisation.

- A contraction of the UK vehicle manufacturing base is in sharp contrast to the underlying economic projections of the UK battery strategy to build a domestic battery supply base[47]. This assumes that UK vehicle production levels reach pre-pandemic numbers of more than 1.5 million vehicles, fulfilling the ZEV mandate and justifying the creation of more than 100 GWh capacity in domestic battery production. Whatever the true demand for UK battery production capacity by 2035 might be, it is important to build domestic R&D and manufacturing capabilities for battery cells, which are the most valuable components in an EV battery.

- Regarding EV public charging infrastructure, it is estimated that about 300,000 charging stations will be needed by 2030 in the UK, in accordance with the ZEV mandate[48]. The current rate of installation is not sufficient to reach this goal. Private-sector investment in charging infrastructure is correlated to confidence that EV adoption will take place, and requires market data to support the investment decision.

In summary, the challenge for both the UK and the EU is that the **lack of consumer demand for EV adoption and shrinking estimates of EV manufacturing volume do not encourage private investors to intensify their efforts**, but rather to postpone timelines for implementation and to wait for clear market signals to justify investment.

The UK is ready with policies and regulations to support the mass electrification of the automotive sector. However, the current speed of EV market adoption, the build-up of an EV supply chain and the development of EV infrastructure are behind target. **Increasing EV adoption will depend on the availability of competitive and attractive EV products – something that requires action by the OEMs, and which is market driven. Government-backed investments in R&D to strengthen knowledge in EV products and infrastructure will also require an export strategy, as domestic demand is limited.** The picture is not wholly regressive for the UK. Tata Motors plays an important role in the UK as the owner of JLR and is supporting an electrification strategy that requires a UK-based EV supply chain[49] (see Box 5).

BOX 5. TATA MOTORS ELECTRIFICATION STRATEGY

In 2025, JLR will introduce Jaguar as an all-electric brand; by 2030, all JLR nameplates will have a BEV variant; and by 2039, JLR aims for net-zero carbon in its products, operations and supply chain. In this context, the investment of Agratas, Tata Group's battery arm, is highly relevant. It has announced the intention to build a UK-based 40 GWh battery plant to create batteries for Tata Motors and JLR, as well as for energy storage, two-wheelers and commercial vehicles[47].

Tata Motors is the market leader in electric vehicles in India. It has a current market share of more than 50%[50], followed by JSW MG Motors – an Indian joint venture with Chinese SAIC Motors, which has the largest market share in the UK of all Chinese OEMs.
The Indian EV market in 2024 was only about 25% of the size of the UK's, but the overall size of the Indian automotive market was around four million units in 2024 – approximately twice the size of the UK's. However, the Indian government has the aggressive goal of making 30% of all vehicle sales electric by 2030[51], by which time domestic sales could reach 10 million units. Building an EV supply chain in the UK could thus have a strategic impact on the electrification of India's automotive industry, with substantial high-growth potential to export as well as desire to transfer knowledge gained in the UK[52].

Automation

The key problem for the adoption of L4 or full ADS is to find a viable business model that allows the ecosystem to make the operation profitable, while assuring its safe and secure operation to limit liability and insurance risks. The technical viability of L4 has been proven (e.g. major deployments of Waymo in US cities) and foundational regulatory frameworks are fundamentally in place (e.g. EU 2022/1426). A major technical hurdle is the non-linear increase of test efforts for highly and fully automated driving which requires extensive use of virtual engineering and synthetic test data generation.

It is important to note that systems developed for fully automated driving can also be used for lower automation levels, and that this currently represents a significantly larger market. Systems such as Full Self Driving (FSD) from Tesla have been tested and deployed as L2+ systems, under which the driver must take over whenever required by the driving situation. The industry has discovered that applying systems developed for L4 as L2+ systems can reduce development and operational costs, as users need to pay a subscription fee or buy the feature as an option[53].

From an UK perspective it is important to ensure that consumer adoption is following investments in technology and regulatory readiness for automated driving.

The UK government has invested more then £600 million since 2015[54] in CAM initiatives and announced the Automated Vehicles Act in 2024[28].

The EU – the most important export market for the UK automotive industry – made a range of ADAS mandatory by 2024[55]. The UK has not yet followed this approach[56] due to concerns of distraction and usefulness of some of the safety features.

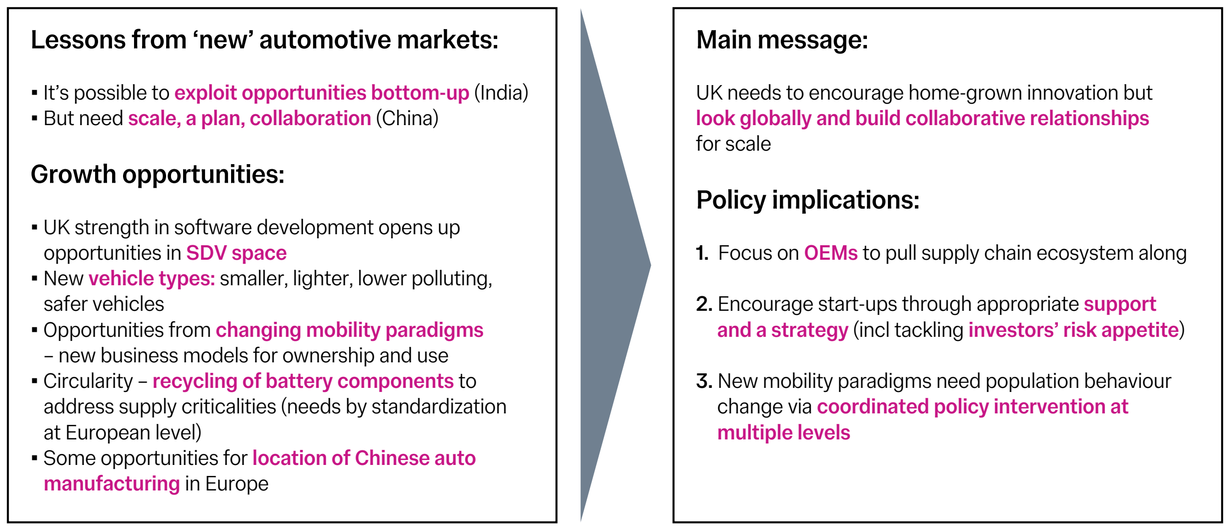
As with vehicle electrification, the UK is ready from a regulatory perspective to support fully automated driving in the near future, but is lacking concrete policies to stimulate consumer demand for L4 systems and even for lower-level automation systems.

Risks and opportunities regarding UK's Future Mobility Readiness

Recent discussions with representatives from UK Government (see Figure 27) suggest that new markets show substantial potential to accelerate the sector transformation towards electrification and automation. This opens the door both for allocating R&D and manufacturing capabilities of new OEMs in the UK, as well as providing locally developed innovative solutions through suitable global partnerships into existing and new markets.

The UK automotive ecosystem may benefit from collaborative platform initiatives which address: core automotive system components, core development processes, impact on waste, carbon footprint, health and end user behaviour. Addressing these in context will ensure the ecosystem is highly competitive in terms of product price, quality of service and policy robustness.

Figure 27. Automotive sector UK growth opportunities



Source: James Barlow, Imperial London, CSEP

Key stakeholders to engage in such collaborative efforts are universities, fleet operators, automotive OEMs, suppliers and government agencies, and future customers.

The ultimate goal is to establish a hyper-competitive automotive ecosystem in the UK which is ready for the future of mobility and attracts and retains top talent in the UK.

The collaborative platform initiatives should also provide the foundation for generating more GVA for the automotive sector in the UK, by focusing on key components in the vehicle that add substantial value to the product and by providing optimal economic value to the end user. This would support policy-driven behaviour changes that lead to waste minimisation, health optimisation and in general an improvement of affordable sustainable mobility access.

A major risk for the UK is the deindustrialisation of its automotive manufacturing base due to the substantially lower cost base of the Chinese automotive supply chain (in both ICE and EV production) and the willingness of the UK consumer to consider switching to Chinese OEM brands when there is a significant price advantage[57]. In contrast to the EU, the UK does not yet impose tariffs on electric vehicles imported from China.

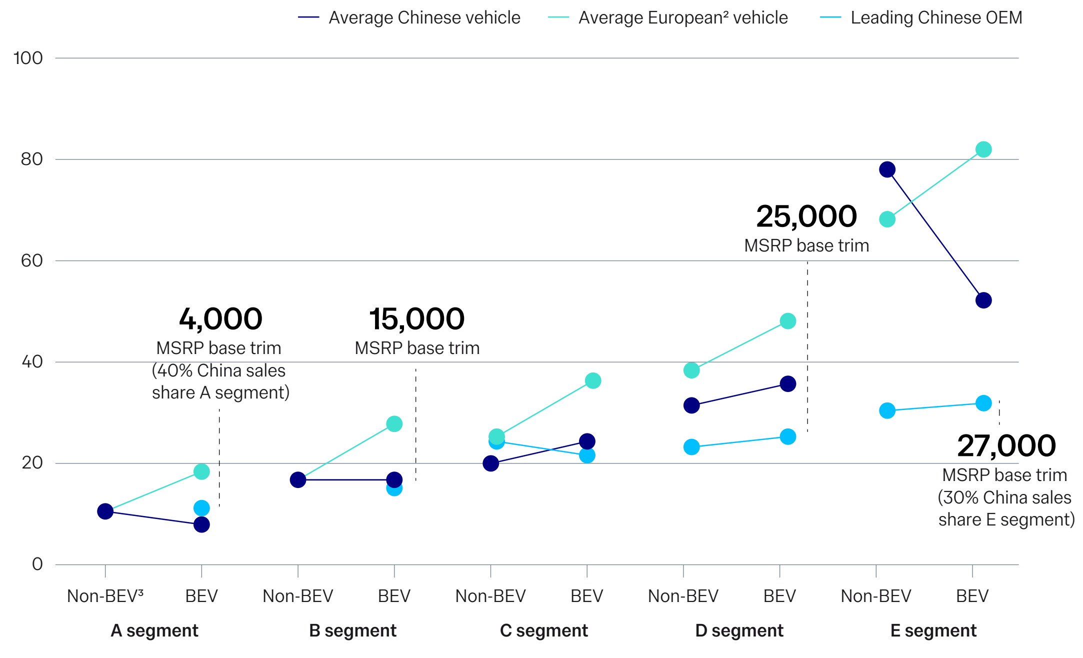
China has demonstrated (Figure 21) that it has been able to develop a highly attractive and price-competitive EV product portfolio both for its domestic market and for export. Fierce domestic competition has forced Chinese OEMs to be extremely price competitive, particularly with EVs, which led to a highly integrated EV supply chain to deliver components at scale. Thus Chinese OEMs can offer, in all vehicle categories, products at a price level which is lower than their European counterparts. It can also offer EVs at prices that are lower or on par with comparable ICE vehicles.

This is an incentive for Chinese OEMs to consider local production of both EVs and batteries in the UK – either to circumvent EU tariffs or to strengthen their strategic approach and create domestic manufacturing capabilities in the European market, once their brands are more accepted by European customers in terms of quality, innovation and price. This should not only be viewed as a threat, but also as an opportunity to secure UK-based jobs and keep value creation in the country.

A major opportunity is to utilise R&D capabilities in the UK, supported by its strong university-based research ecosystem – implementing technology centres to develop innovations for the future of mobility and to attract foreign OEMs. First, the UK could build strong capabilities in designing and manufacturing EVs with deep integration in a domestic EV supply chain that can collaborate with EU partners. Second, the UK could leverage local competence in chip design and software design, paired with regulatory and standardisation knowledge which can be made available for software-enabled automated vehicles.

Figure 21. Vehicle portfolio – price/volume segmentation

Volume-weighted average estimated MSRP,[1] by segment and powertrain, in April 2023, € thousand



Source: McKinsey Center for Future Mobility, Spotlight on mobility trends, March 2024

[1] Manufacturer's suggested retail price. Excludes value-added tax, other taxes, and add-on equipment (e.g., leather seats, color options).

[2] EU, European Free Trade Association, and UK; MSRP calculated as average of Germany and UK.

[3] Non–battery electric vehicle. Includes full hybrid electric vehicles (EVs), fuel-cell EVs, internal-combustion-engine vehicles, mild hybrid EVs, plug-in hybrid EVs, and range-extended EVs.

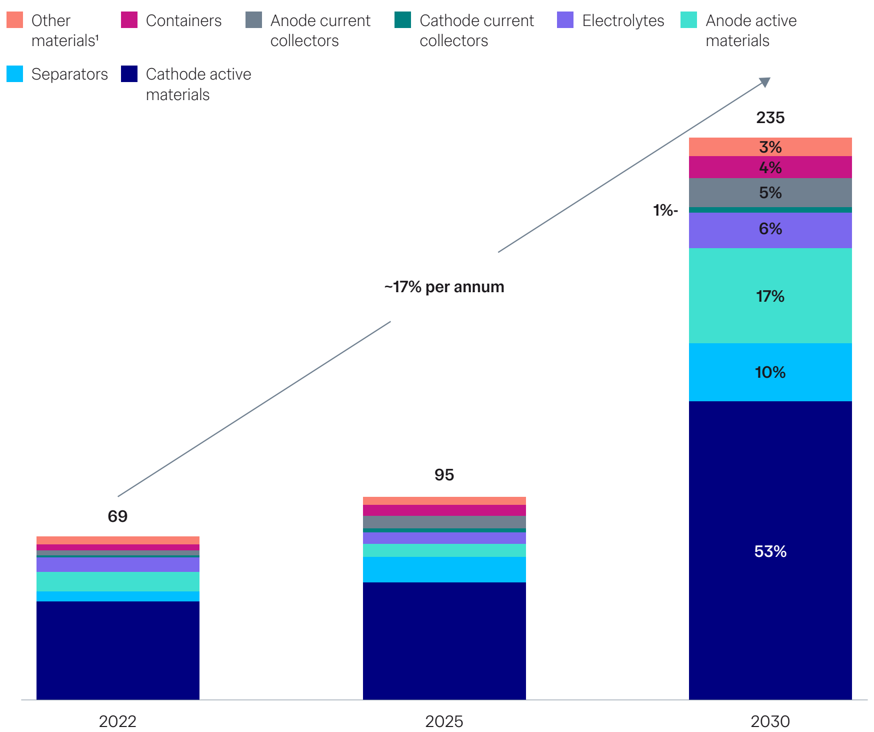
The following list indicates areas of high value and high priority opportunities in the UK:

(1) Batteries
McKinsey pointed out in an article published in 2024[58] that the core components of a battery cell amount to about 60% of its cost. Four battery cell components – cathode, anode, separators and electrolytes – are the main drivers of cell performance (energy density, cycle life, charging rate and safety). Asia currently produces more than 90% of these components globally. Innovations in new cathode materials and solid-state electrolytes will provide opportunities, as will finding ways to decarbonise the production of cell components. According to the McKinsey report, the global revenue pool of cell components could reach $235bn by 2030 and presents a substantial business opportunity (Figure 22).

In addition to the manufacturing of cell components, the mining and refinery of raw materials could provide a profitable opportunity. The UK's Lithium future demand is expected to reach up to 15 kt/yr by 2030 and up to 25 kt/yr by 2040[59] for EV battery applications. The UK has two advanced Lithium production projects that propose to extract Lithium from Cornish granites that are led by British Lithium and Cornish Lithium respectively. Tees Valley Lithium and Green Lithium are also new players in the production of battery grade Lithium[60]. British Lithium has announced production plans of 3.9 kt/yr Li (or 20.8 kt/yr of Lithium Carbonate Equivalent (LCE)) over a 25-30 year mine life from a 161 Mt ore resource at 2495 ppm Li grade[61, 62]. Cornish Lithium has announced an annual production plan of 2.9 kt/yr Li (produced as 10 kt/yr of lithium hydroxide - LiOH) from its 51.7 Mt Trevalour ore resource at 0.11% Li over a 15-20-year mine life[63] with production anticipated to start in 2027. Cornish Lithium is also investigating the extraction of Lithium from brines containing 220 mg/l of Lithium[64], and have announced the possibility of producing up to 9.4 kt/yr (50 kt/yr LCE)[60]. These numbers suggest that British Lithium and Cornish Lithium could provide up to 45% of the UK's anticipated lithium needs by 2030, and that if lithium extraction from brines at Cornish Lithium proves positive before 2040, then both companies could deliver 53% of the UK's anticipated needs by 2040. The British Geological Survey (BGS) has produced evidence that the UK could hold as much as 15.8 Mt of lithium resources[65], enough to provide the UK's 2040 annual needs for over 600 years. Furthermore, BGS suggests that after St Austell granite, the next most promising area for exploration could be the Northeast of Scotland in the Glenbuchat spodumene bearing pegmatites[65]. Exploration is required to determine if this high-level geological evidence can be converted into geological resources and investigated further to determine their economic viability for extraction. Such exploration and research should be conducted as it paves the route towards the UK's possible self-sufficiency in Lithium production for its mobility needs.

Figure 22. Battery Cell Components

The global revenue pool of cell components is expected to reach $235 billion in 2030.



Source: McKinsey – The battery cell component opportunity in Europe and North America (April 2024)

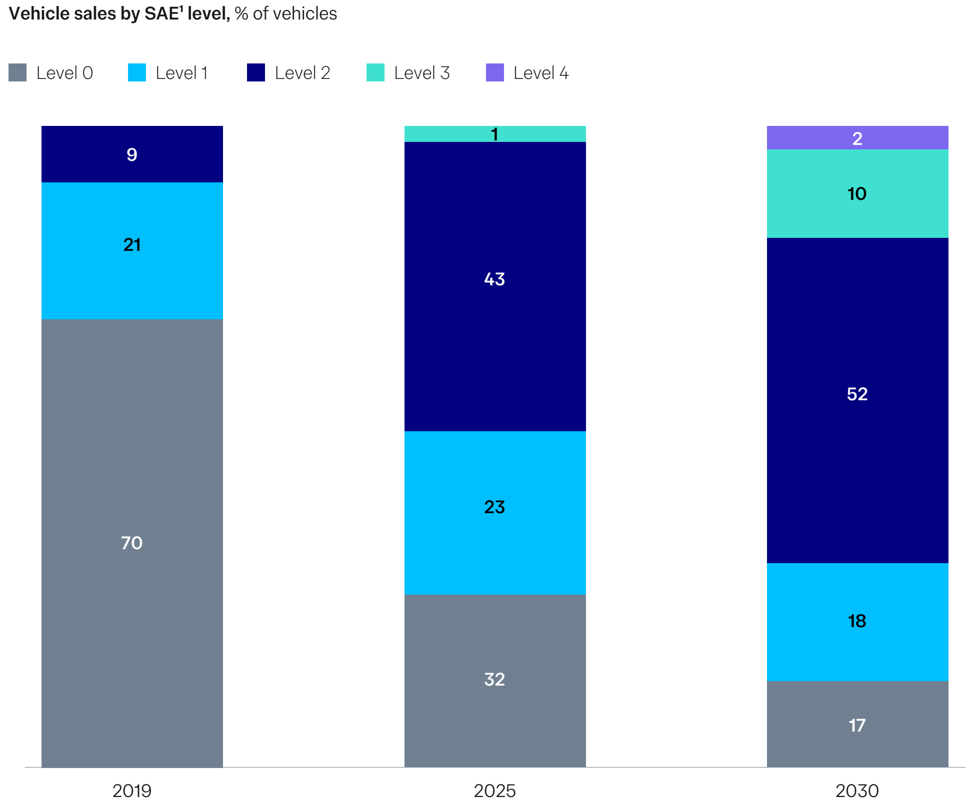
(2) Another area of opportunity is in the **market development of automotive software and E/E66 for driver assistance systems, ADS** (Figure 23) and power control systems. (e.g. www.weetiq.com, who supply Bosch). Considering the complete spectrum of automotive software and E/E, we predict that the market size will almost double between 2020 and 2030, with particularly strong growth in the segments of software (functions, OS and middleware); system integration, verification and validation; electronic control units and domain control units (ECU/DCU); and sensors and power electronics (Figure 24). The E/E architectures are moving from distributed and domain-based towards centralised structures. The development of ADAS/AV, as well as infotainment systems, is accelerating the use of DCU (Figure 25). The use of end-to-end AI will contribute to the use of centralised system architectures, with vehicle-side high power charging (HPC) being the core of an automotive ethernet-enabled E/E system.

Centralised system architecture is the centrepiece of the SDV approach to upgrading a car throughout its complete lifecycle, implementing new functions and closing safety and security gaps.

(3) Customised AI chips are being developed for automotive OEMs, and these are strategically relevant – particularly for automated driving. **AI chips and algorithms represent the biggest value-creation opportunity for the UK to leverage its R&D capabilities and create IP that can be licensed within the automotive ecosystem, not only domestically but at an international level.** However, geopolitics and national security concerns need to be considered in this regard. From a UK perspective this means developing system architecture capabilities that allow dual use and avoid critical dependencies on technologies and supply chains from incompatible trade partners. An example for dual use is Agentic AI.

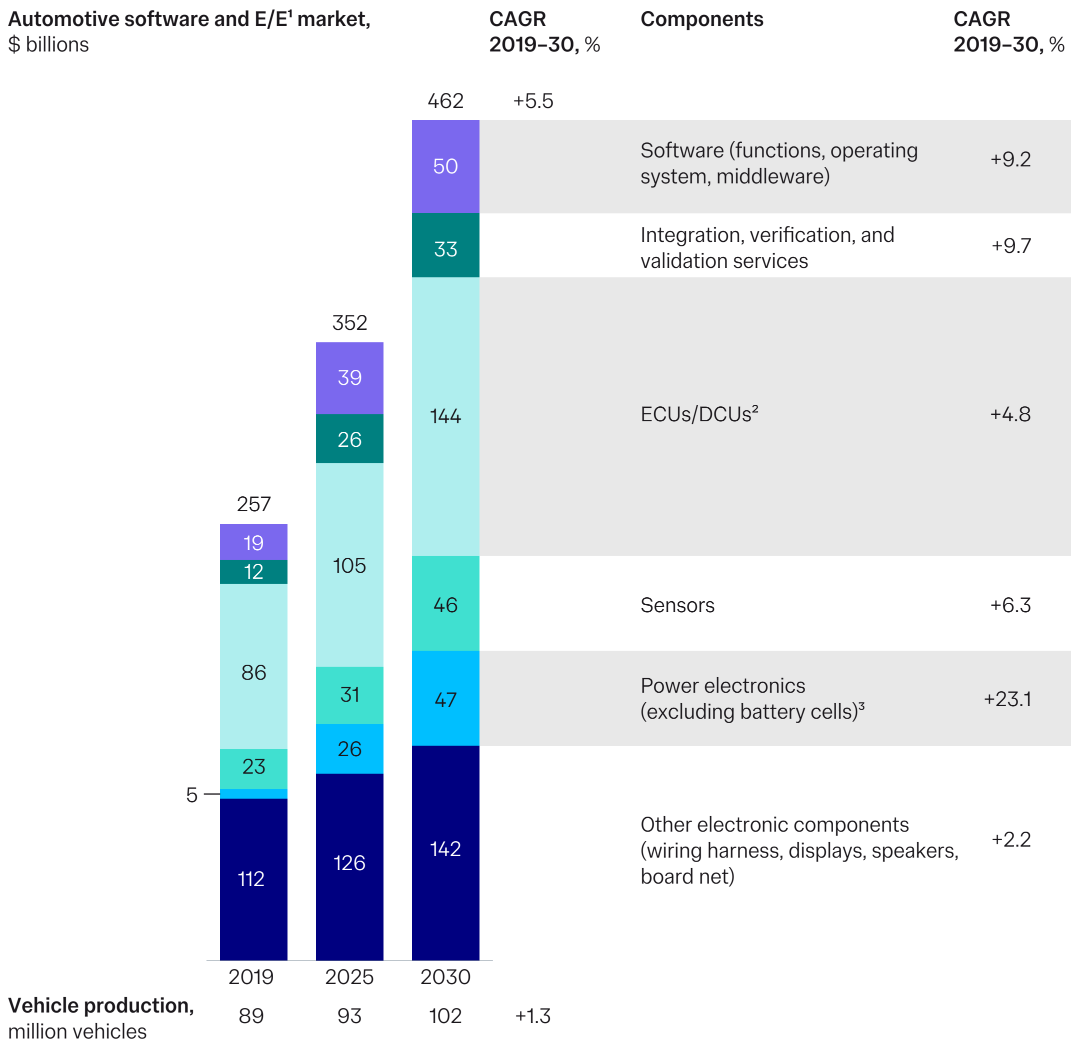
Figure 23. ADAS/AV systems

Consumer demand will propel the rapid growth of autonomous-driving and advanced driver assistance systems (AD/ADAS) vehicle sales.



Note: Figures may not sum to 100%, because of rounding.
¹Society of Automotive Engineers
Source: McKinsey Center for Future Mobility Current Trajectory Scenario
Source: McKinsey – Outlook on the automotive software and electronics market through 2030 (January 2023)

Figure 24. Automotive Software and E/E



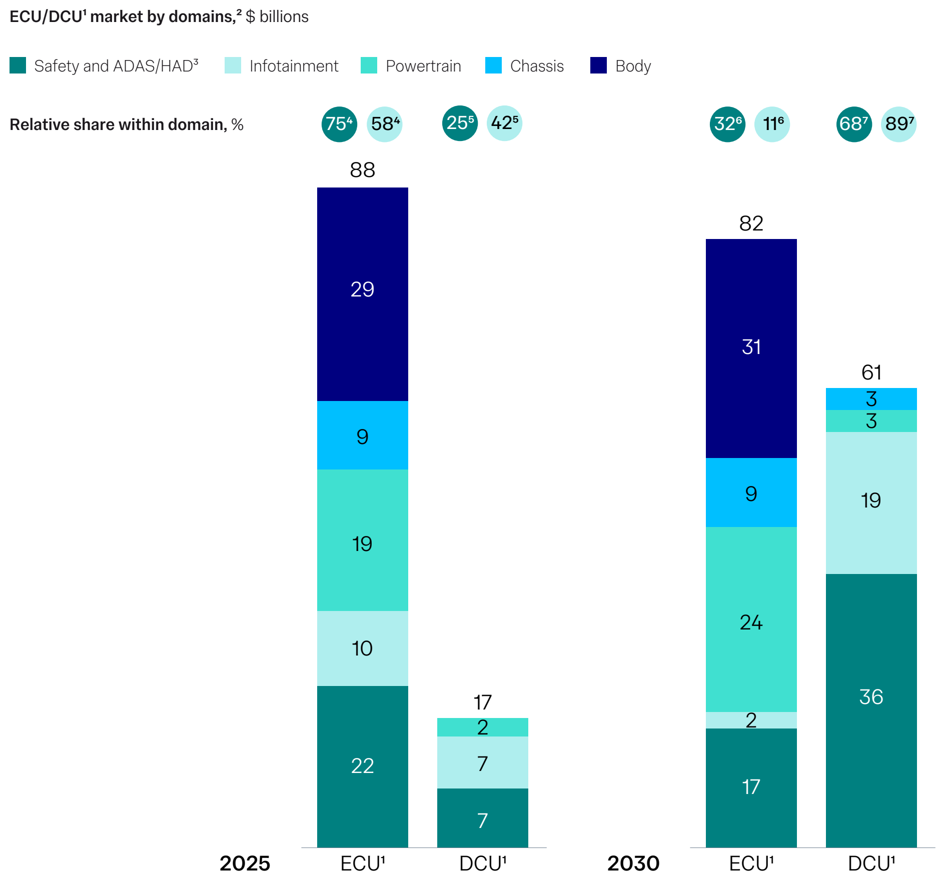
Source: McKinsey – Outlook on the automotive software and electronics market through 2030 (January 2023)

(4) With respect to the use of AI in the context of safety-critical systems such as a vehicle, there is increasing awareness of the risk of cyberattacks that manipulate the behaviour of AI systems[67]. The increasing vulnerability of AI-systems to these attacks might be addressed through the use of quantum cryptography. Quantum technology could also help to improve vehicle sensing, decision making and the encryption of critical training data in the context of driving automation[68]. **The UK is investing heavily in quantum-based technologies, and the knowledge being created could be utilised in the automotive sector.**

(5) The UK could pioneer **the use of new business models in automotive innovation, given the proximity of major financial and insurance companies that are crucial in funding automated and zero-emission fleet operations.** The UK also has metropolitan areas where those models could be trialled and validated at scale. The flexibility of the work environment, as well as the UK's rapidly ageing society, requires mobility models that are no longer based on car ownership. Over decades, a transportation infrastructure has evolved that requires widespread space for the parking of vehicles and the widely unrestricted use of roads. The full automation of vehicles, both in driving and charging, enables a more sustainable use of vehicles that is no longer based on personal car ownership but on a mobility service model. This could be delivered through a commercially operated fleet that optimises the circular consumption of space, energy and material, and ensures maximum safety and security for its users. An interesting opportunity could be to link the development of small EVs with automated driving technology to meet mobility needs in lower density suburbs or rural areas, making them available under a mobility-as-a-service model that complements public transit services. The UK could also introduce policies to incentivise the use of ADS for parking, urban and highway use (such as lower insurance rates, privileged lane access, and privileged parking and charging), in a similar way to how Norway has incentivised the adoption of EVs. Furthermore, the UK could pioneer new policies for government and businesses that encourage the use of sustainable and automated mobility services instead of personally assigned company cars.

Figure 25. ECU/DCU

Autonomous vehicles and infotainment will become the earliest adopters of domain control units.



Source: McKinsey – Outlook on the automotive software and electronics market through 2030 (January 2023)

UK automotive ecosystem SWOT analysis

Based on our assessment of the various automotive roadmaps and global geopolitical, technology and market trends, the following section discussed the strengths, weaknesses, opportunities and threats facing the UK automotive ecosystem (see Figure 26). In summary, the UK has the potential to provide leadership in sustainable and automated mobility, thanks to the 2035 ZEV mandate and the Automated Vehicle Act (2024). These offer the automotive sector a degree of regulatory clarity and flexibility.

However, weaknesses persist. Current policies do not adequately address the trend toward larger electric vehicles in cities by incentivising smaller, more sustainable options. There is also limited support for shared mobility services, automated charging and parking solutions in urban areas, or the adoption of driver assistance technologies. Tyre emissions – a growing environmental and health concern – remain largely unaddressed.

Opportunities exist for the UK to enhance its strengths by promoting small, safe electric vehicles in urban settings, encouraging car-free housing linked to multimodal mobility services, and pioneering fully automated transport solutions. The UK's research capabilities in automotive software development could potentially be leveraged to attract global talent to develop cutting-edge innovations, helping to support leadership in the SDV field.

The sector faces threats, notably falling behind in vehicles manufacturing due to competition from more cost-efficient producers, particularly China. Cybersecurity risks could impact the reliability of zero-emission and automated mobility infrastructure, although this also represents an opportunity for the UK's software industry.

Figure 26. SWOT analysis of the UK automotive ecosystem

Strengths	Weaknesses
• Well-defined policy milestones to make and sell carbon free new vehicles by 2035, with transparent rules for automotive OEMs. • Automotive OEMs have some flexibility to update their product portfolios towards BEVs, avoiding fines by being compliant with the ZEV mandate. • AV Act regulatory framework on which safety standards need to be applied to validate a highly or fully automated vehicle, and which liability rules need to be applied. **Questions** • What measures are needed to accelerate the replacement of used ICE vehicles with new or used BEVs and what the challenges in implementing them? • What regulatory gaps still need to be closed, or refinements made, in the light of the AV Act?	• Policies do not address trend towards larger and heavier (electric) vehicles or incentivise use of smaller vehicles in in urban environments. • Only limited measures to incentivise use of sustainable mobility services over personally-owned cars or company cars in densely populated urban areas. • Policies do not address use of automated charging and automated parking in dedicated urban zones to free up space and improve efficiency of charging infrastructure. • Policies do not address mandatory use of advanced driver assistance technology and does not incentivise use of highly or fully automated driving. • Policies do not address prevention of harm to health from tyre emissions. **Questions** • What measures are needed to replace the use of personally owned cars with multi-modal mobility service subscriptions and what the challenges in implementing them? • What measures are needed to free up space from street parking in densely populated urban areas and what the challenges in implementing them? • What measures and technologies can the UK put in place or in development to reduce tyre emissions?
Opportunities	**Threats**
• Incentivise use of small and light ZEV (with active and passive safety features) in urban environments. • Promote the use of affordable car-free housing in popular urban environments, with the option of accessing multi-modal mobility services that leverage zero-emission and automated driving technologies. • Pioneer policies to incentivise use of fully automated parking and driving. • Leverage UK's R&D strength and innovative capabilities in software and hardware systems for automotive sector. **Questions** • Does the UK have an attractive R&D and manufacturing ecosystem to develop and produce small electric vehicles for urban use? • What is needed to implement business models successfully for large-scale robotaxi and robo-delivery vehicles in UK urban environments? • How can top talent in automotive software and hardware design be attracted to and retained within the UK?	• Erosion of automotive industrial base due to lack of competitiveness in the EV supply chain and EV product offering. • Falling behind in efforts to lead in connected automated mobility (CAM) due to a lack of scaled deployments of automated driving systems. • Losing chance for leadership in reducing tyre emissions through innovative technology and policy frameworks. • Vulnerability to cyberattacks on critical infrastructure needed to for zero-emission and automated driving systems. **Questions** • What measures are required to compensate for UK cost disadvantage compared to China and bring new automotive solutions into production? • How to motivate automotive OEMs and fleet operators to develop and deploy fully automated driving systems in the UK? • How to motivate the tyre industry, automotive OEMs, and fleet and road operators to collaborate on reducing tyre emissions through innovation and standardization?

Key Insights

The critical analysis of automotive roadmaps within the context of standards and regulatory developments, resulted in the following recommendations:

Recommendation	Addressed to	Priority	Stakeholders to engage with	Purpose
Leverage capabilities in AI chip and algorithm design	DBT	Short term	AI research centres, automotive OEMs	To power electronics development, ensure global competitiveness for ADAS/AV systems, and form an SDV strategy to support the EU Industry Action Plan for the automotive sector.
Lead in developing a new operating system platform	DSIT	Short term	European OEMs, DSIT Digital Policy teams	To offer an alternative to Chinese automotive operating system platforms under open source, SDV principles. This will open the door for a dual use strategy to strengthen the defence sector.
Develop AI assurance to increase trust in ADS	DSIT / DfT	Short term	Standards bodies (BSI), AI safety researchers, vehicle OEMs, insurers	To ensure trust and safety in automated driving systems
Focus battery R&D on cell core components	DBT	Medium term	OEMs in US and China interested in accessing the EU market	To strengthen the UK's position in advanced battery cell manufacturing, as well as building towards a European EV supply chain
Explore the use of quantum computing and agentic AI in automotive	DSIT	Medium term	Automotive R&D teams	To test new computational methods for advanced mobility applications. Develop tools and processes that enable the automotive industry to create products and services in much shorter timeframes
Lead in developing technologies and methods to reduce tyre emissions	DEFRA / DBT	Medium term	Tyre manufacturers, materials scientists, automotive OEMs	To place the UK to lead in technology to reduce non-tailpipe emissions (largely from tyre wear) as part of sustainable mobility goals. This will reduce the automotive industry's impact on air quality.
Pilot alternative models to traditional car ownership	DfT	Medium term	Local authorities, fleet operators, mobility service providers, urban planners	To reduce car dependency and support shared, sustainable mobility as well as utilising the advantages of driving automation in urban centres and pooled mobility centres in rural areas. Enabling the transition to service centred mobility models.
Deploy automated parking, driving and charging systems at scale	DfT / DBT	Medium term	Fleet operators, charging infrastructure firms, OEMs, local authorities	To validate and scale sustainable, automated mobility with high vehicle utilisation, benefiting those without car access currently such as lower income households and those with accessibility issues.
Apply circular economy principles to automated sustainable fleets	DEFRA / DBT	Medium term	Automotive OEMs, fleet operators, circular economy experts, standards bodies	Reduce resource depletion in the automotive industry. Reusing vehicles through delegating fleet management to shared users or specialised fleet management companies can lead to smaller fleets and more efficient vehicle use. With increased automation and disrupted business models, the UK could be a world leader in applying circular principles to fleet operation and validate them with a standardised impact assessment.

Figure 27: Automotive sector UK growth opportunities

Automotive sector UK growth opportunities

Lessons from 'new' automotive markets:

- It's possible to **exploit opportunities bottom-up** (India)
- But need **scale, a plan, collaboration** (China)

Growth opportunities:

- UK strength in software development opens up opportunities in **SDV space**
- New **vehicle types:** smaller, lighter, lower polluting, safer vehicles
- Opportunities from **changing mobility paradigms** – new business models for ownership and use
- Circularity – **recycling of battery components** to address supply criticalities (needs by standardization at European level)
- Some opportunities for **location of Chinese auto manufacturing** in Europe

Main message:

UK needs to encourage home-grown innovation but **look globally and build collaborative relationships** for scale

Policy implications:

1. Focus on **OEMs** to pull supply chain ecosystem along
2. Encourage start-ups through appropriate **support and a strategy** (incl tackling **investors' risk appetite**)
3. New mobility paradigms need population behaviour change via **coordinated policy intervention at multiple levels**

Source: Professor James Barlow, CSEP

Annex A

The future of the UK automotive sector – key questions to be answered

This analysis of technological and market trends, international and UK-focused automotive roadmaps, national and international standards, and regulatory developments, suggests the UK is confronted with the threat of a substantial deindustrialisation of its automotive sector. Maintaining knowledge in vehicle design and manufacture will require a significant supply chain and manufacturing footprint, while the transformation towards a zero-emission vehicle fleet is dependent on achieving economies of scale and having access to a highly productive workforce.

A fundamental question is whether it is desirable for the UK to continue to maintain a strong automotive manufacturing base, or whether the focus should be redirected towards innovation in emerging technologies associated with mobility - leveraging its existing capabilities in software development.

We set out here a number of questions for the UK automotive sector that will shape its future direction.

1. Manufacturing competitiveness

European and US automotive OEMs have had substantial problems in keeping up with the speed of development of Chinese OEMs. Optimising development processes and using digital tools to accomplish highly virtualised vehicle development may help UK automotive OEMs to increase competitiveness.

Can the UK develop the process and tool capabilities to enable this, both on the vehicle product and mobility service side?

2. Transition to EVs

The UK is making substantial publicly supported investment in the build-out of public charging infrastructure. This is based on assumptions about how many EVs will be sold over the next 10 years. The automation of charging and parking, as well as technologies such as wireless power transfer, could lead to a development that requires substantially fewer charging stations – in particular, when personal car ownership is replaced by multi-modal mobility service subscriptions, starting in densely populated urban areas.

What policies are needed to change the approach from individual charging of personal EVs to collective automated charging in designated parking areas (which could also be used by fleet-operated cars)?

3. Shifting models of mobility

Personal car ownership is widely accepted and considered the norm. What can incentivise a massive change in user behaviour towards using mobility services on demand, once electric and automated vehicles are available at scale and at affordable rates?

What methods, supporting policies and initiatives are needed to implement a model in which sustainable and affordable mobility is available to everybody, at all stages of life?

4. Automated driving technology

The UK plans to have zero road fatalities by 2050. We are close to the point where fully automated driving technology becomes available at scale, and where collision avoidance becomes a primary safety target when moving through traffic.

What policies are needed to accelerate the adoption of fully automated vehicles in the overall fleet of registered vehicles without creating a social imbalance?

5. Software defined vehicle

AI-enabled vehicles need to provide users with a level of trust that is at least as high as that of a human-operated vehicle. Existing test methods for the quality assurance and operational risk assessment of vehicles were designed for human operation.

How do we adapt and transfer best practices for AI assurance of technical systems to standardised methods that are accepted by regulators and insurance companies for ADS?

Western OEMs have not reached consensus on the development of a common automotive operating system, in contrast to the Chinese automotive OEM ecosystem. This is a significant barrier to innovation.

What is the reason for the lack of collaboration between Western automotive OEMs to develop such a universal operating system? Could the UK fill this gap?

6. Security

Cybersecurity attacks could paralyse critical infrastructure such as energy networks, communication networks and connected, automated vehicle fleets.

What technologies, standards and policies are needed to protect zero-emission automated vehicle fleets from harm in the future?

7. Supporting UK automotive R&D capabilities

The UK has a unique landscape of research capabilities, comprising economic, political and technical knowledge. The combination of this knowledge is crucial in finding the right path towards the future of mobility.

How can the pool of talent in the UK be bundled to address the key issues in policy, technology and competitive economics to keep the domestic automotive sector internationally relevant?

8. Market adoption

The UK has a unique landscape of research capabilities, comprising economic, political and technical knowledge. The combination of this knowledge is crucial in finding the right path towards the future of mobility. The UK is also EU's largest market for vehicle exports including EU-made BEVs.

Which market trends are observed in the UK? Is the UK suitable as test market for the EU to identify market potential for new vehicle categories and new vehicle technologies?

Annex B

Analysis of the regulatory and standardisation environment in the automotive sector at national and international level

Emissions (tailpipe and non-tailpipe)

The EU is regulating CO_2 emissions of new passengers vehicles as follows:

2025-2029: 93.6 g/km (WLTP)
2030-2034: 49.5 g/km (WLTP)
2035: 0 g/km (WLTP)

OEMs receive a credit towards their emissions target if more than 25% of their total sales are zero and low-emission vehicles (ZLEV, which can emit up to 50 g/km).

Manufacturers can further reduce their emissions by adjusting their sales strategy to favour more efficient models, using mild-hybrid technology, and pool with lower-emitting manufacturers.

The US Environmental Protection Agency (EPA) finalised new motor vehicle emissions standards in 2024. These require an industry-wide average target for light-duty vehicles of 85 grams of carbon dioxide per mile in model year 2032 – almost a 50% reduction from the 2025 standard. For medium-duty vehicles, the target is 274 grams of carbon dioxide per mile in model year 2032, a 44% reduction from the 2025 standard. California has stricter regulation and mandates. By 2035, all new passenger cars, trucks and SUVs must be carbon-emission free.

China does have emission regulations that incorporate elements of the EU and US regulations, but does not have an explicit goal to be carbon free.

It is worth noting the creation of the Emissions Trading System 2 (ETS2) as an EU 'emission cap and trade' platform. This is planned to be fully operational by 2027 and is relevant for road transportation. Regulated entities must submit an annual emissions report. The carbon price is set by ETS2 and the system is intended to incentivise investments in low-emission mobility.

The UK has implemented the ZEV mandate, which requires all new vehicles sold in 2035 to be carbon-emission free. This needs to be viewed in the context of the UK's overall goal of being carbon-emission free as a society by 2050. Assuming the average life of a car on the road to be 15 years, the complete vehicle fleet should be CO_2-emission free by this time.

The UK removed incentives to purchase new electric cars in 2021. The ZEV mandate is linked to the UK Climate Change Act as well as to the California EV adoption approach.

The ZEV mandate came into effect in 2024. It sets a gradually increasing target for the sales proportion of zero-emission vehicles for each year, reaching 80% by 2030. A ZEV is defined as a vehicle that has zero CO_2 emissions at the tailpipe and a driving range of at least 100 miles under the Worldwide Harmonised Light Vehicles Test Procedure (WLTP). The battery warranty is expected to be eight years or 100,000 miles, and a battery replacement needs to be offered if the capacity falls below 70% during this timeframe.

The legislation requires 80% of new car sales (and 70% of new van sales) to be zero-emission by 2030. The goal to reach 100% by 2035 is not yet legally mandated.

As well as regulating emissions, the EU is aiming to reduce microplastic pollution through the regulation of tyre emissions[69]. After paint, tyres represent the largest known source of microplastics: 450,000 tons a year, including harmful chemicals. The EU's goal is to achieve a 30% reduction in tyre emissions by 2030. It is estimated that by 2050, 90% of the particulate emissions from road transport in Europe will originate from non-tailpipe sources – primarily tyres and brakes.

The UN has revised its R117 regulation regarding type approval for tyres. This requires the measurement of particle emissions from tyres. The EU will regulate emissions from tyres for the first time with the introduction of EURO7.

Automated Driving and Cyber Security

The United Nations Economic Commission for Europe (UNECE) is currently working on the regulation of ADS. This process is expected to be finalised by 2026. ADS are designed to operate a vehicle over sustained periods without driver interaction.

In 2024, the UK passed the Automated Vehicles Act. This requires self-driving vehicles to achieve a safety level at least as careful and competent as that of a human driver, and to pass rigorous safety checks before being allowed on roads. The legislation is targeted to allow self-driving vehicles to be on UK roads as early as 2026.

The US does not yet have a federal regulatory framework for self-driving vehicles, but has various regulations in place at state level. Vehicles without steering wheels and pedals currently need to operate on an exemption to the FMVSS (Federal Motor Vehicle Safety Standards), which must be granted by the National Highway Traffic Safety Administration (NHTSA).

The EU does have a regulation for the type approval of ADS (EU 2022/1426). This regulation also includes self-parking. The EU does not have a regulation in place for the deployment of self-driving vehicles.

China has regulations in place for the testing of self-driving vehicles, but does not yet regulate the type approval or deployment of self-driving vehicles (Figure 28).

UNECE addresses automotive cybersecurity regulations through UN R155, which addresses the implementation of a cybersecurity management system. It requires the OEM to perform threat analysis and risk assessments on a regular basis, and to monitor, respond to and learn from cybersecurity events.

Figure 28. Regulations and guidelines regarding testing self-drivingvehicles in China

Source: S&P Global Mobility © S&P Global

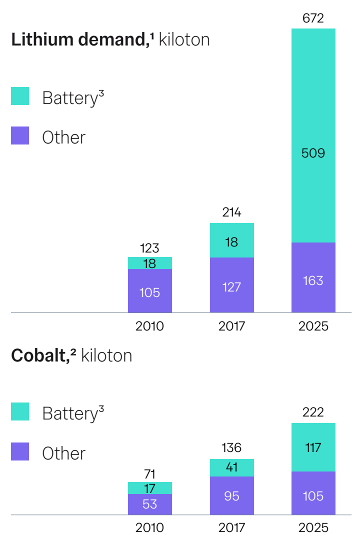
Battery Material and Circularity Lifecycle Aspects

Because of the EU ban on the sale of new ICE vehicles by 2035, the demand for battery materials will dramatically increase. It is estimated that the EU will need substantially more cobalt and lithium by 2030 (see Figure 29). The EU has updated its battery regulation, which now requires a digital record system containing key information over the lifecycle of a battery – a 'battery passport'. Any EV with a battery capacity of over 2 kWh is required to have a battery passport.

The European Commission has submitted proposals to the European Parliament to establish circularity requirements for vehicle design, and on the management of end-of-life vehicles to make the automotive sector more resource efficient. This includes the labelling of parts, components and materials used in the vehicles. The EU has integrated lifecycle assessment (LCA) principles into environmental policies and regulations.

Demand for lithium and cobalt will continue to evolve

Figure 29. Demand for lithium and cobalt



Source: Circularise – EU battery passport regulation requirements, March 2025

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