White Paper

ICV Roadmaps:

A Worldwide Perspective

The International Communication and Cooperation Committee of ICV Roadmaps

China Society of Automotive Engineers

China Industry Innovation Alliance for Intelligent & Connected Vehicles

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Executive Summary

Intelligent and connected vehicles (ICVs) have become a strategic focus for the global automotive industry. Major leading auto powers are accelerating the development of the ICV industry through introducing innovative policies and regulations, exploring development paths, encouraging technology innovation, promoting testing and demonstration, and improving infrastructure construction.

The industry is at a key stage toward large-scale deployment, and there are many common challenges globally on the above topics. In this context, the ICV roadmaps have become an important measure to forge consensus among all sectors. Diverse roadmaps have been released from different countries and regions, led by respective industry organizations as well as governments, playing a crucial role in the alignment among all sectors.

To explore the realization path and its corresponding innovation mechanism by starting from the exchange and cooperation on these roadmaps and lay a solid foundation for further global alignment, the China Society of Automotive Engineers (CSAE) and China Industry Innovation Alliance for Intelligent & Connected Vehicles (CAICV) have initiated the motion to establish the International Communication and Cooperation Committee of ICV Roadmaps, together with organizations, institutions, and enterprises all around the world, including 5GAA, ACEA, BMW, CAAM, CAERI, CAICT, CATARC, Changan Auto, CICT, DFM, Drive Sweden, ERTICO, ERTRAC & CCAM Partnership, FISITA, GAC Motor, GM, Huawei, KSAE, RIOH, RIRS, SAE International, VDA, Volkswagen, and Zenzic.

This white paper is therefore written as a first step toward the ongoing, collaborative initiative. It outlines the main contents of these diverse ICV roadmaps, drawing on input from the corresponding committee members. This paper then synthesizes the expected conclusions and respective characteristics among them, and the best practices of the roadmaps above, with excellent insights provided throughout by our keen participants.

1. Introduction to Current ICV Roadmaps

This chapter is a non-exhaustive compilation of the roadmaps below (in alphabetical order by country/region), with their respective background, vision, contents, objectives, milestones, and other insights.

Roadmap	Country/Region	Organization
Technology Roadmap for Intelligent Connected Vehicles 1.0 (2016) Technology Roadmap for Intelligent Connected Vehicles 2.0 (2020) Innovative Application Roadmap for Intelligent Connected Vehicles (2021)	China	CSAE & CAICV
Study on Technical Development Roadmaps for Collaborative Automated Driving Draft 2.0 (2021)	China	CHTS
C-V2X Industry and Technology Development Roadmap (2022)	China	CIC
Automated Driving Roadmap (2015, 2017) Connected Automated Driving Roadmap (2019) Connected, Cooperative, and Automated Mobility Roadmap (2022)	Europe	ERTRAC
CCAM Roadmap for 2030 (2020) CCAM RoadMap 2020-2035 (2022)	Europe	ERTICO
A Visionary Roadmap for Advanced Driving Use Cases Connectivity Technologies and Radio Spectrum Needs (2020, 2022)	Europe	5GAA
Public-Private ITS Initiative/Roadmaps (2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021) Future of transportation society utilizing digital technology (2022) Roadmap for the Realization and Spread of Unmanned AD Services (2020)	Japan	Cabinet Office

Drive Sweden's Outlook for the Transport System (2022)	Sweden	Drive Sweden
UK Connected and Automated Mobility Roadmap to 2030 (2019, 2020)	UK	Zenzic

Technology Roadmap for Intelligent & Connected Vehicles 2.0, CSAE & CAICV

CSAE and CAICV released the Technology Roadmap for Intelligent & Connected Vehicles and its updated 2.0 version in 2016 and 2020. This roadmap clarifies the key technology architecture, developmental vision, general development objectives, developmental milestones of different vehicle types, and various key technologies sub-roadmaps of China's ICV industry toward 2035, strongly supporting the construction of industrial technology development system and the formulation of China's ICV national development strategy.

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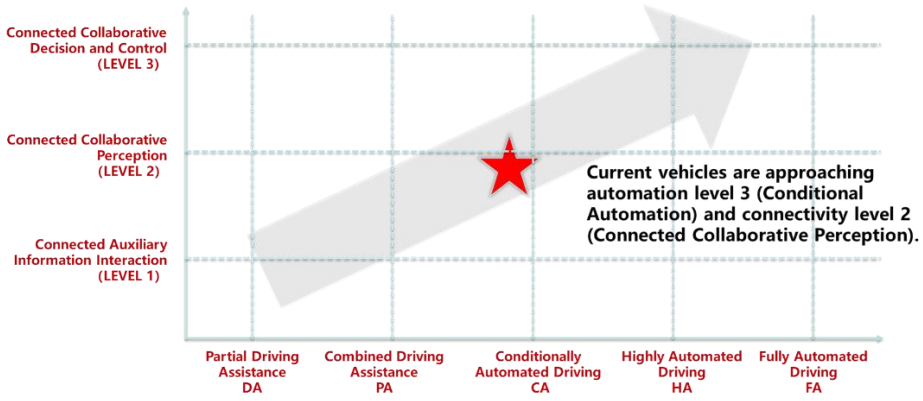
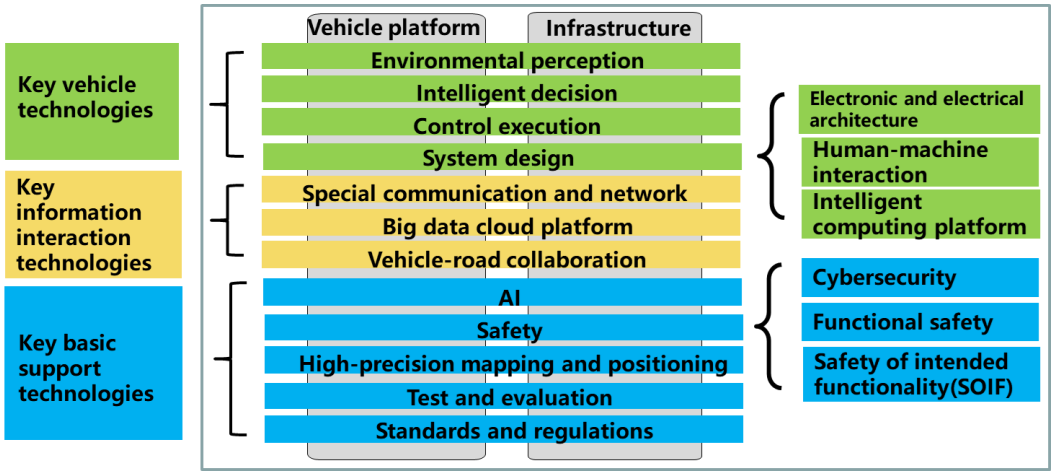
  CSAE & CAICV
- Contents
  - Automation Level and Connectivity Level

    This roadmap defines the classifications of automation level and connectivity level of ICVs for the first time, using 5 levels of automation and 3 levels of connectivity, and points out that fully autonomous driving will be realized by the convergence of automation and connectivity.



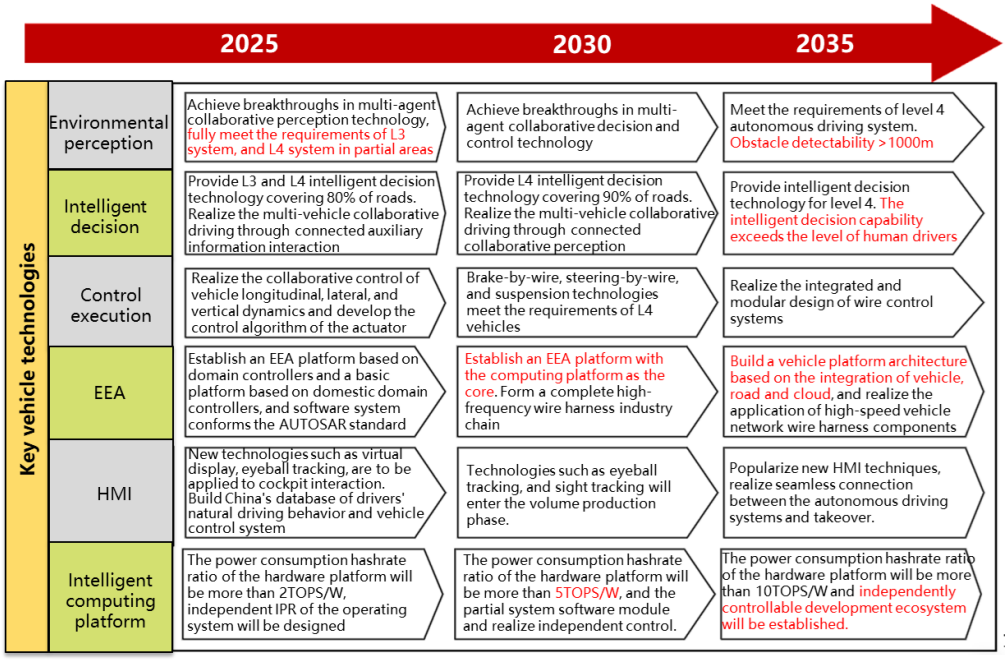
  - Technical Architecture

    As ICVs involve technologies in multiple fields such as automobiles, communications, and transportation, the technical architecture of ICVs is proposed as "three horizontal and two vertical". "Three horizontal" refers to vehicle technologies, information interaction technologies, and basic support technologies while "two vertical" refers to the vehicle platforms and infrastructure that support the development of ICVs.



- 3 Stages of Industrialization

In terms of the industrialization process, the roadmap divides the industrialization goals toward 2035 into 3 stages: the development period (2020–2025), the promotion period (2026–2030), and the maturity period (2031–2035). The development status and future routes of key technologies in the technical architecture are comprehensively analyzed. Taking key vehicle technologies as an example, relevant technologies need to meet the requirements according to these 3 periods: by 2025, the environment perception system will meet the requirements of level 3 and level 4 in specific scenarios in distance, accuracy, etc.



- Vision

To drive the mobility of society towards a direction of sustainability and meet people's expectations for a better life, demonstrated by safety, efficiency, energy conservation,

emission reduction, comfort and convenience, and user-friendliness.

- Objectives

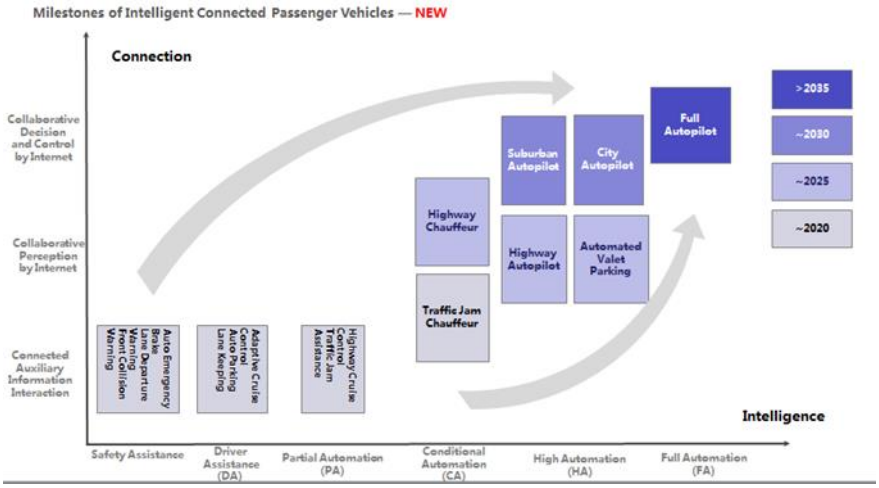
  By 2025: Level 2 & Level 3 ICVs account for more than 50% of new cars. Level 4 ICVs begin to enter the market. The C-V2X terminal equipment rate for new vehicles reaches 50%. The connected collaborative perception technology is to be applied in some scenarios including highways, some urban roads, and closed areas.

  By 2030: Level 2 & 3 ICVs account for more than 70% of new cars. Level 4 ICVs is 20%. A new vehicle equipped with a C-V2X terminal is popularized. Vehicle-road-cloud integrated ICV with collaborative decision-making enters the market.

  By 2035: China's ICV technology and industrial system is comprehensively built.

- Milestones

  With the high coupling of intelligence and connectivity, milestones jointly promoted by vehicle, road, and cloud are formulated for passenger vehicles, freight vehicles, and passenger service vehicles respectively, by analyzing the schedule of technology industrialization, marketization, and commercialization of ICVs within urban roads, suburban roads, highways, and limited scenarios. For example, the milestones of passenger vehicles are shown below.



Innovative Application Roadmap of ICV, CAICV

The Innovative Application Roadmap of ICV was compiled by CAICV in 2022, to further explore the industrialization process of high-level automated driving ICVs and promote the deployment of automated driving in various scenarios. This roadmap targets the popularization of vehicles, facilities, and related services in 11 typical scenarios by 2025, with

respective development paths and timelines.

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- Classification of main scenarios
  First, this roadmap combines the characteristics of the road and ADAS/ADS applications and classifies the main application scenarios of the current ICVs according to the driving environment and different driving speeds.

Environment	Characteristics	Speed	Scenarios
Enclosed area	Belonging to internal facilities with entrances and exits	Low	Parking
			Port or factory
			Mine
Confined area	Vehicles or pedestrians are restricted to a certain extent	Low	Robobus
			Delivery
			Sanitation car
		Medium	Cruiser
			BRT
Urban road	Arterial road and sub-arterial road	Medium	Robotaxi
Highway	Speed at 60km/h and above	High	HWP
			High-speed logistics

Based on the classification method, the 11 typical scenarios are sorted out and classified into 4 categories: passenger vehicles, urban mobility, freight vehicles, and civilian unmanned vehicles.

This roadmap further focuses on the general objectives, visions, milestones, and development path of ICV technology innovation and application for the short-term (2021-2022), medium-term (2023-2025), and long-term (2026-2030), and clarifies innovation and development needs, including the function, regulations, standards,

testing requirements, and other aspects under these scenarios.

- Vision

  To satisfy the increasing demands for low-carbon mobilities, multi-scenario commercial operations, and safety & efficiency of transport through the continuous popularization of ICVs.

- Objectives

  By 2022: Actively explore multi-scenario applications in Tier-1 cities, and then perfect their business models based on demonstrations.

  By 2025: Further, explore innovative applications in Tier-1 and Tier-2 cities, and then extend usage scope and partially operate commercialization.

  By 2030: Innovative applications are widely used in most cities, which account for a significant section of overall transport. In addition, all of the applications will gradually execute commercialization operations.

- Milestones

  The milestones of these 11 scenarios are set for 3 different periods towards 2030, focusing both on broad applications and driver needs, with more details as follows.

Types	Speed	Domain		Short term (2021-2022)	Medium term (2023-2025)	Long term(2026-2030)
Passenger vehicles	Low	Parking	Application	Hundreds of parking lots	Nearly one thousand parking lots	thousands of parking lots
			driver :	Remote monitoring		None
	medium	Robotaxi	Application	Thousands Robotaxi	Thousands Robotaxi	Commercial
			driver :	Monitor	Monitor	None
	High	HWP	Application	Part of highway	Most highways	All highways
			driver :	Driver monitoring	Driver monitoring& Remote monitoring	Remote monitoring
Urban mobility	Low	Robobus	Application	Demonstration	Commercial attempt	Commercia
			driver :	Monitor	Remote monitoring	None
	medium	BRT	Application	Demonstration	Commercial attempt	Commercia
			driver :	Driver monitoring	Driver monitoring	Monitor
Freight Vehicles	Low	Port or Factory	Application	Hundreds truck	Thousands truck	Most of the port
			driver :	Monitor	Monitor	None
		Mine	Application	Mining transport unmanned	The whole mining area unmanned	The whole mining area unmanne
			driver :	Monitor	Remote monitoring(1:N)	Remote monitoring(1:N)
	High	High-speed logistics	Application	Part of highway	Most highways	All highways
			driver :	Monitor	Monitor	None
Civilian Unmanned Vehicle	Low	Delivery	Application	Hundreds of campuses & Several urban roads	Thousands of campuses and hundreds urban roads	Wide application
			driver :	Monitor in urban road		None
		Sanitation car	Application	Hundreds of campuses & Several urbn roads	Thousands of campuses and hundreds urbn roads	Wide application
			driver :	Monitor in urban road		None
	medium	cruiser	Application	几Hundreds of campuses & Several urbn roads	Thousands of campuses and hundreds urbn roads	Wide application
			driver :	Monitor in urban road		None

Study on Technical Development Roadmaps for Collaborative Automated Driving (Draft 2.0), CHTS

China Highway & Transportation Society (CHTS) released the *Study on Technical Development Roadmaps for Collaborative Automated Driving (Draft 2.0)* in 2021. This technology roadmap systematically sorts, updates, and improves the definition connotation,

technology architecture, and the current development status of the CAD system. The expected development goals, visions, and development paths of CAD technology for 2025, 2035, and 2045 are also formulated to support the construction of the technology system and the formulation of the CAD development strategy in China.

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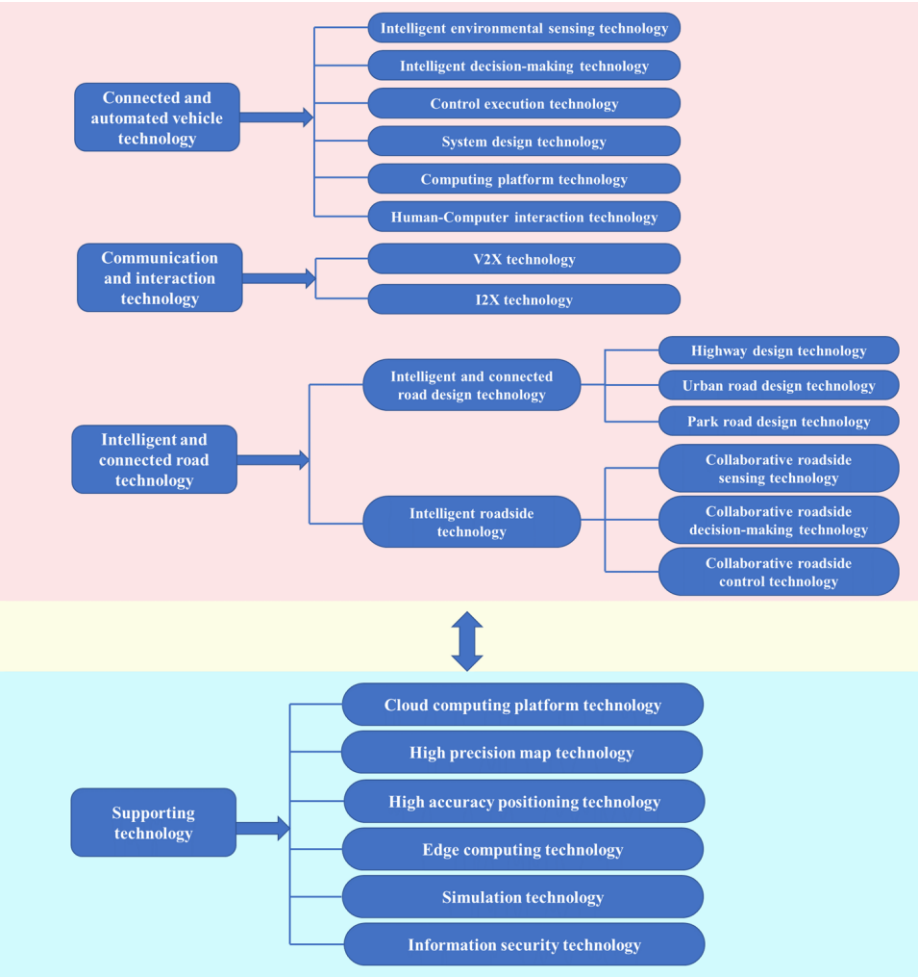
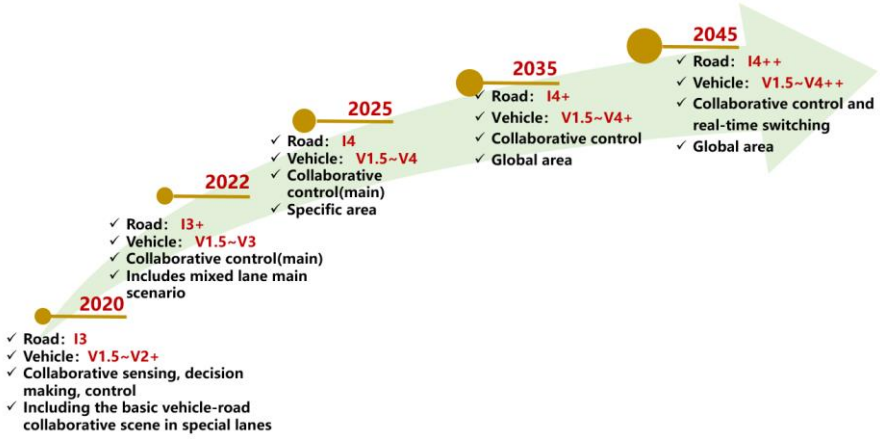
  This technology roadmap sorts, updates, and improves the definition connotation, technology architecture (as shown below), and the current development status of relevant technologies of collaborative automated driving systems.



It also formulates the collaborative automated driving system (overall system), intelligent connected road system, connected and automated vehicle system, intelligent

communication system, and intelligent support system for 2025, 2035, and 2045 based on the analysis of the current situation and development trend of the relevant technology industry.



These expected development goals, visions, and development paths of the collaborative automated driving technology for 2025, 2035, and 2045 are formulated to support the construction of the autonomous driving industry technology development system and the collaborative automated driving development strategy of China.

- Vision

  To provide a reference point for decision-making on the sustainable development and rapid transformation and upgrading of the intelligent transportation and automated driving-related industries of China.

- Objectives

  By 2025: The technology demonstration of the overall system of S4 level in closed scenarios such as special lanes and other major roads (highway, bus, freight) is realized. The road infrastructure level reaches I4 and vehicles reach V3, realizing basic holographic and omni-temporal sensing and data fusion. The information from sensing and prediction combined with collaborative optimization decisions and control technologies to complete the calculation of decision and control commands through onboard devices. The vehicle executes control commands to realize multi-level (key node level, road section level, traffic corridor level, and global macro level) and multi-group (individual vehicle, fleet, etc.) collaborative automated driving under a limited environment.

  By 2035: The technology demonstration of the overall system level of S4+ on open roads is realized. The road infrastructure level reaches I4+, the vehicle level reaches V3+, and road-led collaborative control (road-led) is realized which in turn leads to realizing

holographic collaborative sensing and data fusion of vehicles and roads and building holographic and full-time-space high-precision maps under limited environments. Research intelligent information traffic mining technology, correlate and predict various traffic information, provide early warning and control instructions for vehicles of collaborative automated driving, and improve the level of automated driving comprehensively. Combine with collaborative optimization technology, and complete the calculation of decision and control instructions through deployed roadside devices. Both vehicles and roads can gain control functions (road-based) to realize collaborative automated driving at multiple levels (key node level, road section level, traffic corridor level, and global macro level) and multiple groups (individual vehicles, fleets, etc.) in complex environments.

By 2045: Realize the overall system of S4++. The road infrastructure reaches I4++ and the vehicle level reaches V4. Based on the continuous global deployment of roadside perception, realize holographic collaborative perception and data fusion of vehicles and roads, and build holographic and all-time real-time high-precision maps. Achieve accurate judgment of microscopic behaviors of roads and vehicles with multi-level and multi-target, and complete the calculation of decision and control commands through deployed roadside devices. Both vehicles and roads can gain control functions (road-based) to realize multi-level (key node layer, road section layer, traffic corridor layer, and global macro layer) and multi-group (individual vehicle, fleet, etc.) collaborative automated driving in complex environments.

C-V2X Industry and Technology Development Roadmap, CIC

In the 2020 Disciplinary Development Project of the China Association for Science and Technology, the China Institute of Communications (CIC) undertook the roadmap research project for the development of the C-V2X industry and technology. The final draft of the project was completed in April 2022. The roadmap analyzes the development status of the global C-V2X industry, focuses on the development status and trend of China's C-V2X industry and technology, and summarizes the typical application cases of the Internet of vehicles. The overall objectives by 2025 and 2030 are addressed while the C-V2X technology and product development roadmap is compiled. The proposal for the development of China's C-V2X industry and technology is made.

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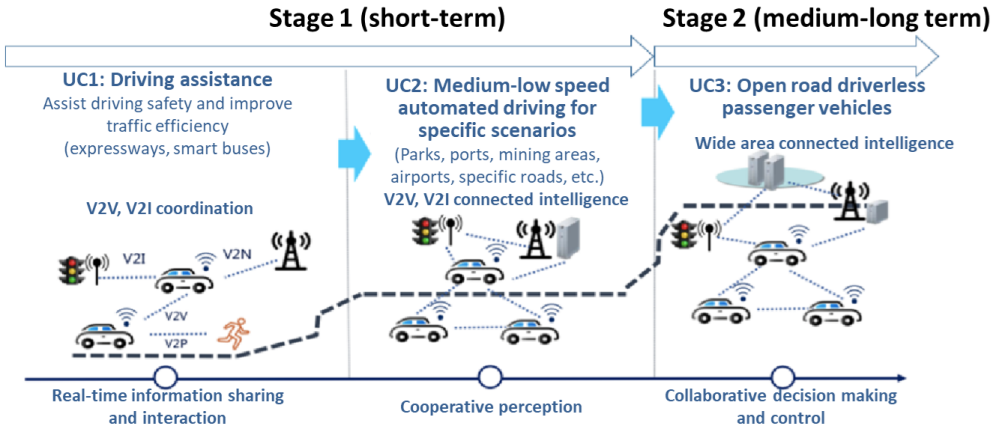
  This roadmap points out the two stages of China's C-V2X development in the ICV industry. In the short term, it focuses on assisted driving via LTE-V2X and 4G cellular network, as well as the cooperative perception of medium-low speed automated driving in specific areas and specific scenes via LTE-V2X and 5G eMBB. In the medium-long term, collaborative decision-making and control are expected to be supported via NR-V2X and 5G eMBB.



  To reach a high penetration rate of OBUs and RSUs toward 2030, the roadmap also sets phased targets for OBU penetration in vehicles and RSU coverage at the roadside.

- Objectives and Milestones

  By 2025: Pre-installed OBUs are performed on new vehicles. The RSU coverage rate of highways and urban intersections is close to 100%.

  By 2030: Pre-installed OBUs have a 90% penetration rate on new vehicles. RSUs are further deployed in more different scenarios.

  Correspondingly, more detailed milestones of C-V2X communications, network technologies, and supply chains are proposed. Taking C-V2X communications as an example, the milestones are as follows:

	Milestone in 2025	Milestone in 2030
C-V2X standardization	• Completion of LTE-V2X standardization • Completion of 3GPP NR-V2X technical standardizaiton • Domestic NR-V2X standard system initially formed	• Completion of domestic NR-V2X standard system • Completion of technical standard system of C-V2X. • The standard system based on C-V2X comm. evolution technology is researched.
C-V2X tech.	• The integrated sidelink (PC5) and cellular (Uu) comm. mechanism • Supporting distributed radio resource scheduling and heterogeneous multi-source synchronization	• Preliminary design of C-V2X comm. and perception integration technology. • Supporting Multi-dimensional distributed scheduling of comm., perception, computing and control. • Full-scenario-fusion synchronization mechanism is supported.
Sidelink positioning	• Supporting LTE-V2X positioning without reliable GNSS • High precision NR-V2X positioning	• Supporting full-scenario NR-V2X comm. sensing computing integrated positioning • Preliminarily supporting integrated positioning of C-V2X comm. evolution technology
Power saving	• Supporting LTE-V2X power saving mechanism • Supporting NR-V2X enhanced power savig mechanism	• Flexible power saving mechanism • Configurable processing capabilities for different terminals
Spectrum utilization efficiency	• Carrier aggregation below 6GHz • Multi-carrier retransmission • preliminarily supporting unlicensed spectrum applications.	• Efficient utilization of combinations of spectrum resources in various frequency • Supporting carrier aggregation and multi-carrier retransmission • Supporting mmWave spectrum and unlicensed spectrum applications
Integration of C-V2X and other tech.	• Preliminary integrated solution of C-V2X and ADAS • Preliminary integrated solutions of C-V2X comm., AI and machine learning	• Deeply integrated C-V2X and ADAS across domains • Deeply integrated C-V2X, AI, machine learning and other technologies. • Preliminary C-V2X space-ground integrated network based on the initial integration of air-based, space-based and ground-based networks. • Integrated sensing and comm. (ISAC)

Connected, Cooperative and Automated Mobility Roadmap, ERTRAC

Since the launch of the *Automated Driving Roadmap* in 2015, ERTRAC continuously revised and updated its roadmap in this field. Based on the 2019 version, *Connected Automated Driving Roadmap*, ERTRAC released the *Connected, Cooperative, and Automated Mobility Roadmap* in 2022, providing a joint stakeholder view on the long-term development of CCAM in Europe. This new roadmap outlines a long-term vision for 2050 and identifies the necessary short-term actions: agenda 2030 and outlook 2040. The key enablers that are necessary to meet the long-term challenges are presented as well. This series of roadmaps are authoritative in shaping the thinking around CCAM development.

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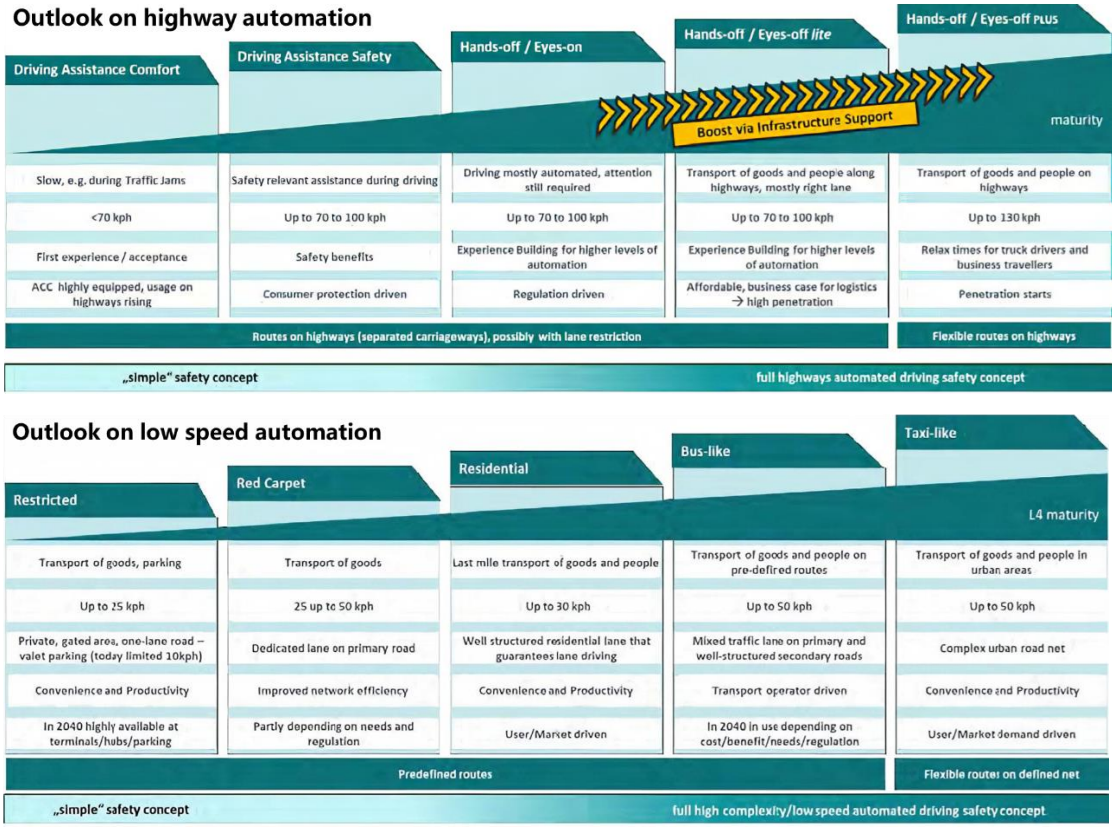
  In agenda 2030, 4 separate domains of CCAM products and services are described, including highways and corridors, confined areas, urban mixed traffic, and rural roads.

Each of the four domains is described in terms of its characteristics, motivation, expected societal benefits and demonstrations, use cases, and key enablers, as well as the need for standardization and regulation updates.

In outlook 2040, the roadmap represents the development route of autonomous driving in highway and low-speed scenarios. The fully industrialized roll-out of these two main approaches will be realized following the logical sequence of use cases below.



- Vision

  To support the expected positive impacts for society described in CCAM, including reducing road fatalities and vehicular accidents caused by human error, reducing transport emissions and congestion by optimizing capacity, etc.

- Objectives

  By 2030: Separate domains develop and offer a large variety of use cases. Large-scale demonstrations are implemented all over Europe.

  By 2040: Use cases widen and grow together, focusing on the industrialization of highways and low-speed automation. Corridors further enable use cases on highways to master speed challenges. Low-speed use cases further evolve and combine to master traffic complexity challenges.

  By 2050: Mature technology allows wide automation applications. Automation domains

are linked with each other. Vehicles have 100% real-time connectivity on the relevant road network.

ERTICO CCAM RoadMap 2020-2035, ERTICO

ERTICO's roadmap regarding the field of ICV, *ERTICO CCAM Roadmap 2020-2035*, sets out the path towards reaching its vision by 2035 of integrated, accepted, inclusive, and infrastructure-supported operational CCAM services supporting decarbonization. This roadmap focuses on the convergence of C-ITS, cellular connectivity, and automated vehicles along with the evolution of the road infrastructure. The current version has been developed based on previous ones and is aligned with current policy priorities and targets from the European Commission. Through its multiple innovation platforms and projects in CCAM, it also supports the EU in delivering its societal targets.

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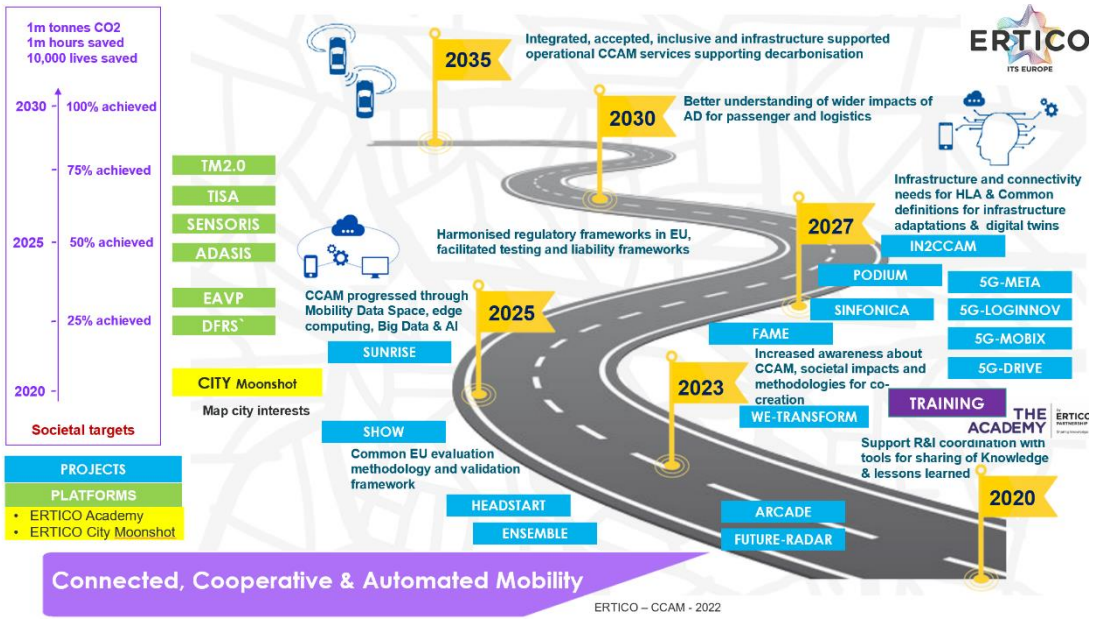
  ERTICO's Roadmap on CCAM sets out the path toward reaching ERTICO's vision by 2035 of integrated, accepted, inclusive, and infrastructure-supported operational CCAM services supporting decarbonization.

  Marked by essential milestones, this roadmap is a project-based roadmap accompanied each time by a relevant set of policy milestones.

  The main targets to be progressively achieved between now and 2035 include supporting R&I coordination in Europe with methods and tools for knowledge sharing and the development of common evaluation and safety assessment methodologies for CCAM; contributing to increased awareness about CCAM among authorities, decision-makers and citizens; progressing CCAM through innovative technologies such as AI, edge computing, Big Data and contributing to the development of the Mobility Data Space; better understanding the wider impacts of Automated Mobility in particular related to sustainability for both passengers and goods; understanding the needs and requirements for High-Level Automation and common definitions for digital twins; finally

facilitating harmonized regulatory frameworks in Europe.



A Visionary Roadmap for Advanced Driving Use Cases Connectivity Technologies and Radio Spectrum Needs, 5GAA

The 5GAA roadmap sets out a consolidated view of the evolution of communication technologies and their application to automotive connectivity. It defines basic safety and advanced use cases which are expected to be enabled by LTE-V2X or 5G-V2X up to 2030 and considers their spectrum needs as well as the required technology evolution and readiness. There is a growing deployment of connected safety services targeting traffic efficiency and safety since the publication of the initial 5GAA roadmap in 2020. The latest roadmap, which synthesizes its further vision and develops the forward-looking C-V2X roadmap, has been recently released.

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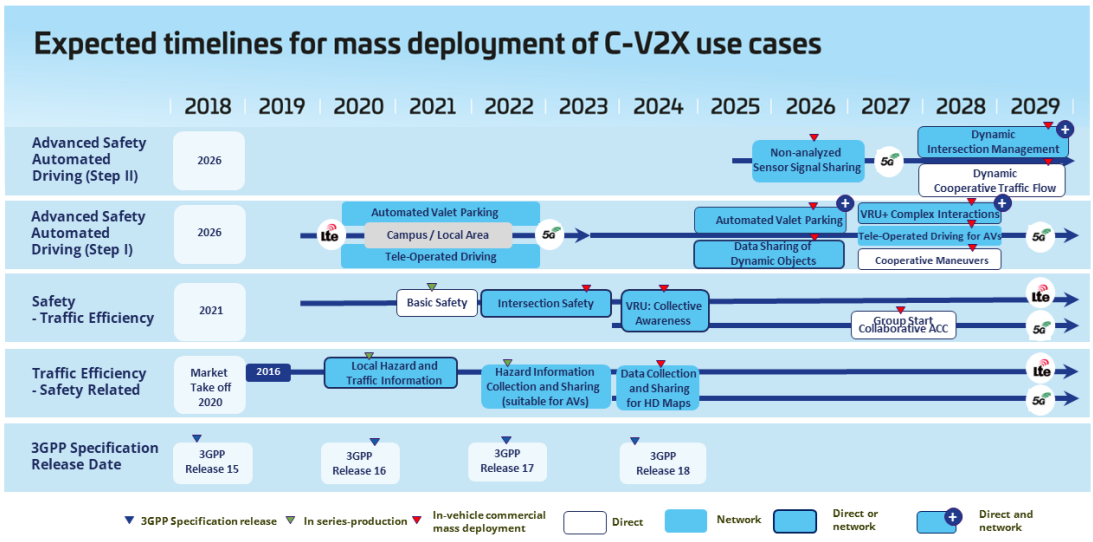
  Distinct from national or regional roadmaps, the 5GAA's roadmap is a deployment roadmap with a particular focus on the mass deployment of connectivity technologies,

aiming to prepare the supply chain for the entire global V2X industry ecosystem and make sure chipsets, modules, radios, security, and software stack are getting ready in advance.

As a large number of day-1 basic safety and intersection use cases have been analyzed and are being implemented, this updated roadmap, therefore, focuses on advanced driving use cases which pave the way to automated driving, teleoperation, automated valet parking, and sensor sharing. The expected timelines for mass deployment of selected advanced C-V2X use cases are established from 2024 to 2030 as follows.



This updated roadmap also provides an overview of some of the most relevant standards-setting and development, including the radio layer covered by 3GPP, upper layer standardization occurring in regional standards development organizations, as well as the foresight of spectrum considerations and needs.

- Overall vision

  To enhance road safety, improve traffic efficiency, make a greener environmental impact, and achieve more comfortable driving.

- Use cases and timelines

  Sensor Sharing use cases:

  Starting in 2024, 'Data Collection and Sharing for HD Maps' will help providers build higher definition maps that are dynamically updated and more accurate to reflect the near real-time environment/conditions with more precise and accurate object positioning.

  Starting in 2026, 'Data Sharing of Dynamic Objects' supported by 5G-V2X will begin to enable cooperative perception. 'Non-analyzed Sensor Signal Sharing' enabled by 5G-

V2X will support the development of further automated driving capabilities in the future.

Tele-operated Driving services:

A progressive deployment for ToD services is envisaged starting with campus and confined areas, followed by dedicated or limited public areas, and general open public roads later on.

As one variant of ToD service focuses on limited geographic areas such as parking facilities, factories, and others, the mass deployment of AVP is foreseen in 2026.

Future of Transportation Society Utilizing Digital Technology 2022, Japan's Cabinet Office

To realize the mass deployment of autonomous driving, the overall strategy of Japan, the *Public-Private ITS Initiative/Roadmaps*, has been jointly formulated through cooperation between the public and private sectors. To ensure its practical advancement, it has been revised every year according to the latest situational changes since it was compiled and released in 2014.

In 2022, based on the Government and the Public ITS Roadmap, Japan released the *Future of transportation society utilizing digital technology 2022*. From the perspective of constructing the development of digital-driven social transportation, it further explores the development path of necessary technology development and transportation infrastructure, laws, and regulations.

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  The research comprehensively considers the construction of a brand-new social transportation system. Based on its previous versions, it also proposes the countermeasures that should be taken from the perspective of both the demand and supply sides simultaneously.

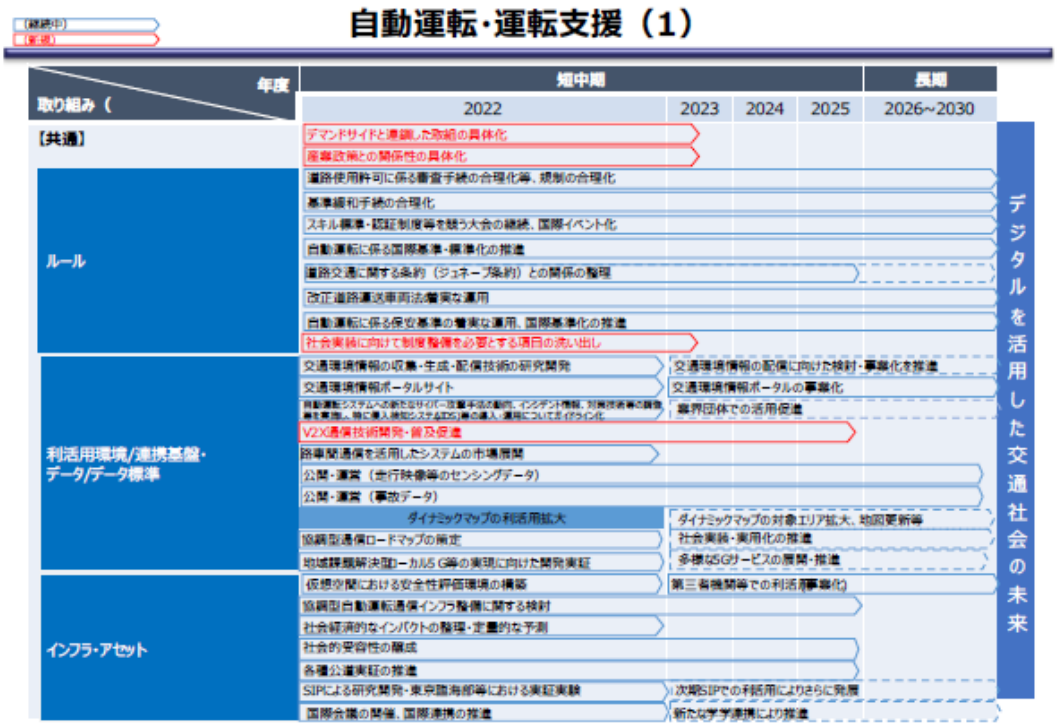
  This report focuses on the analysis of successful cases of social traffic optimization and puts forward 11 service strategy design concepts. The countermeasure design ideas from

the technical perspective include autonomous driving technology, road, UAV, flying car, and collaborative modes in different fields.

- Objectives

  A series of goals have been formulated for the short and medium term (2022-2025), as well as the long term (2026-2030), covering a roadmap for the advancement of autonomous driving (mobility services, transportation, private cars), road space, drones, flying cars, and the synergy of transportation roles.

  The corresponding goals of autonomous driving industrialization are also proposed, such as the driverless mobility service in 40 regions in 2025, the L4 truck operation on highways in 2025, and the high popularity of L3 private cars in 2030.



- Features

  This roadmap comprehensively considers the construction mode and promotion strategy of the entire transportation system from a broader perspective, and also indicates a comprehensive approach and countermeasures for autonomous driving, mobility service, logistics service, private cars, etc.

Roadmap for the Realization and Spread of Unmanned AD Services, Japan's Cabinet Office

In Japan, based on the successive 1.0-3.0 versions of the *Action Policy for Automated Driving*, the *Action Report and Policy for Automated Driving 4.0* was released in May 2020, and the *Roadmap for the Realization and Spread of Unmanned AD Services* was established. This roadmap is a common automated driving indicator for all relevant parties of governmental and non-governmental organizations.

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  In the roadmap, the driving environment is divided into five categories: closed space, specific space, vehicle-only space, space with an improved traffic environment, and mixed space.

  It proposes the gradual development goals for small passenger vehicles, urban area taxis, bus rapid transit (BRT) services, and specific regional and trunk logistics transportation services in the short-term (2020-2022), mid-term (2023-2025), and long-term (2026 onward) phases, respectively. Additionally, it applies this as the foundation for conducting test and pilot activities.
- Vision

  To utilize AD mobility services to create new added value, including labor and time saving, reduced personnel requirements, easier access to human resources, and improved operational efficiency.
- Objectives

  In enclosed spaces (factories, airports, and ports), more than 10 factories will be equipped with autonomous driving services with remote monitoring only by 2025.

  In confined spaces (e.g., BRT-only bus routes), autonomous driving services with only remote monitoring or attendants will be available in more than 10 areas by 2025.

  In dedicated roads (e.g., expressways), trunk transport services will be commercialized after 2025.

In arterial roads, the autonomous driving service (Robotaxi and robobus) with only remote monitoring or attendants will be popularized in more than ten areas by 2025.

In mixed spaces (roads in living areas), AD services (shuttle buses and robotaxis) with only remote monitoring or attendants will be introduced after 2026.

Drive Sweden's Outlook for the Transport System, Drive Sweden

Drive Sweden brings together relative mobility stakeholders and constantly updates *Drive Sweden's Outlook for the Transport System*, which is a consensus view clarifying the vision and milestones in 2020-2030 for Sweden's sustainable transport system. Focusing on safe, accessible, and sustainable mobile systems for people and goods, and helping to guide related project investments, this roadmap comprehensively considers the implementation of service development, new business models, digital infrastructure, social development, policy changes, citizen participation, and vehicle and transport system research.

- Issued in

  2022
- Issued by

  Drive Sweden
- Major Objectives

  By 2024: A proposal for a Swedish legal framework fully compatible with autonomous vehicles is reached.

  By 2025: Robotaxi pilot in a complex urban environment.

  By 2026: Smart geofencing zones in operation (to support ICVs).

  By 2027: The first- and last-mile solutions for combined goods and people transport are in the pilot phase. Self-driving trucks (SAE 4) are on highways.

UK Connected and Automated Mobility Roadmap to 2030, Zenzic

In 2019, the *UK Connected and Automated Mobility Roadmap to 2030* was launched by Zenzic in collaboration with the UK Connected and Automated Mobility (CAM) ecosystem. The updated version was launched in September 2020. This roadmap set out the vision for the at-scale deployment of highly automated CAM on UK roads, involving four aspects: society and people, vehicles, infrastructure, and services. It identifies six "Golden Themes", indicating areas that rely on multi-industry collaboration and parallel development, to achieve the objective of providing driverless services to the public by 2030.

- Issued in

  2020

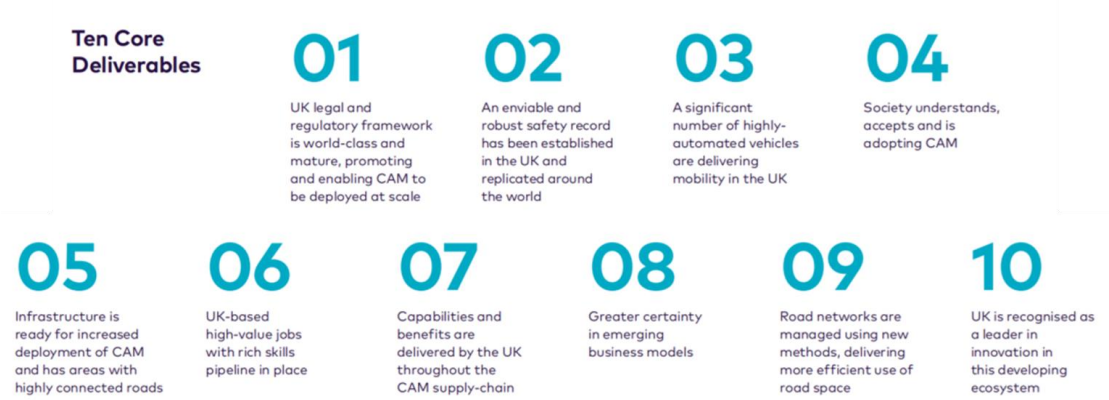
- Issued by

  Zenzic

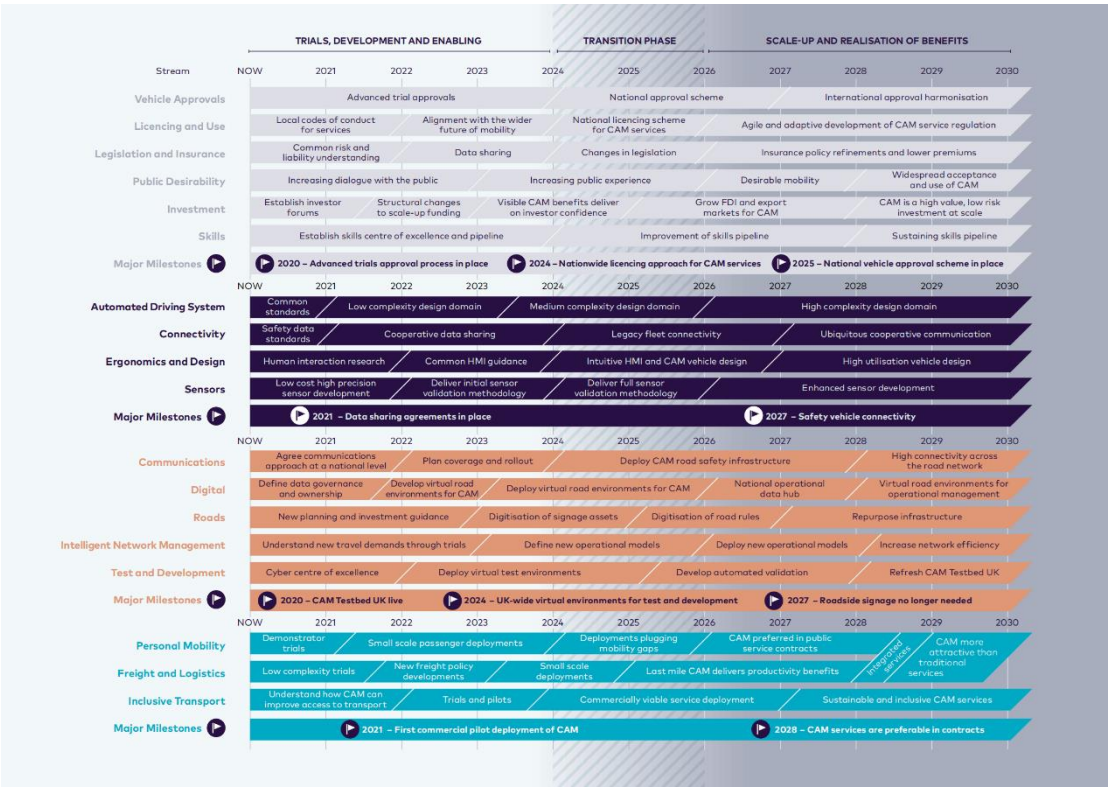
- Contents

  The roadmap sets out an aspiration of where the industrial ecosystem aims to be and the benefits to be realized by 2030, which is to benefit from proven connected and automated mobility, with an increasingly safe and secure road network, improved productivity, and greater access to transport for all.

  A set of 10 core deliverables to achieve by 2030 are also identified, including a mature legal and regulatory framework promoting and enabling CAM to be deployed at scale, a well-established and robust safety record, etc.



  Subtopics and milestones are further proposed under each of the four themes: society and people, vehicles, infrastructure, and services.



- Major milestones

  Society and people:

  Nationwide licensing approach for CAM services by 2024. National vehicle approval scheme in place by 2025.

  Vehicles:

  Safety vehicle connectivity is assured by 2027.

  Infrastructure:

  UK-wide virtual environments for testing and development are established by 2024. Roadside signage is no longer needed by 2027.

  Services:

  CAM services are preferable in contracts by 2028.

2. Expected Consensuses and Respective Characteristics of the ICV Roadmaps

Expected Consensuses

Overall visions

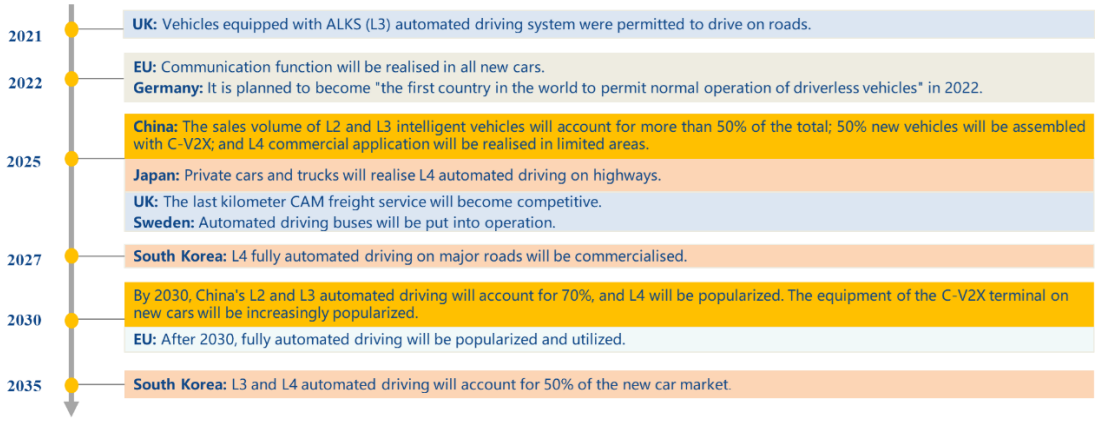
ICV has become the mother ecology for the next generation of the technology revolution, which will have a profound impact on the strategic upgrading of the global automotive industry and the intelligent transformation of the whole society. Different roadmaps draw similar visions as followed:

- Enhancing road safety
- Improving traffic efficiency
- Decreasing energy consumption and emissions
- Reducing driver workload and increasing convenience

The shared vision above lays the foundation for further cooperation between the roadmaps built along projects, technology evolutions, regulatory and policy evolutions, etc. toward the global integration development of the ICV industry.

Timeframe

The timeframe for at-scale L3 & L4 development and deployment is largely consistent across different roadmaps and industrial strategies around the world. 2025 is widely considered as a milestone of large-scale application of L3 automated driving and L4 commercial application in limited areas. And L4 autonomous vehicles are expected to be deployed on a large scale after 2030.



Meanwhile, the launch schedules of major OEMs' valid AD systems are synchronized with the timeframe above. Many automobile brands are continuously evolving the L2 functions which support hands-off driving and promoting the deployment of L3 & L4 systems including AVP, TJP, HWA, and other functions. Guided by UNECE's framework as well as different exemption procedures, L3 automated systems such as ALKS and L4 in specific use cases are obtaining type approval and are about to enter the commercialization stage.

Attention from vehicles to domains

As for the deployment of ICV, the roadmaps are used to focus on different vehicle types, and swift to pay more attention to domains later. Specifically, in the early years, *Technology Roadmap for Intelligent & Connected Vehicles 2.0* from China, the *Connected Automated Driving Roadmap* from Europe, and *Public-Private ITS Initiative/Roadmaps* from Japan all set milestones for passenger vehicles, freight vehicles, and mobility services separately. As the typical use cases, common standards, and approaches for testing and development evolve, application scenarios get more attention around the world. The subsequent *Innovative Application Roadmap* and *Connected, Cooperative, and Automated Mobility Roadmap* are both domain-oriented.

This shift also indicates that the test and pilot programs, as well as related research activities, are being driven by the industry as well as applied research based on real market prospects. The end goal should always be to create a viable commercial market with ready-to-market products and a supply chain once the technology itself is validated. Furthermore, long series of pilot programs aiming at the same objectives in different cities/regions/countries are

expected for integration and synergy to improve efficiency.

Convergence of automation and connectivity

Roadmaps around the world share the agreement that automation and connectivity will jointly promote the development of autonomous vehicles. In 2020, the roadmap further strengthens the concept of intelligent and networked cooperation to promote the realization of high-level autonomous driving

In China, the classification of connectivity level was first proposed in *Technology Roadmap for Intelligent & Connected Vehicles* in 2016. And the concept of integration between automation and connectivity to enable high-level autonomous driving was further strengthened in its 2.0 version in 2020. Higher levels of automation and connectivity are expected to get upgraded with more powerful abilities for environmental perception and edge computing, which enable the cooperation between vehicles to perform coordinated perception, decision-making, and control, and coordinately support the realization of autonomous driving.

Accordingly, in ERTRAC's CCAM roadmap, the ISAD (Infrastructure Support levels for Automated Driving) classification has been proposed, to give automated vehicles information about the infrastructure support that can be expected. Furthermore, higher ISAD levels are expected to be extended to include more functionality, e.g., related to improved traffic management and cooperative maneuvers. ERTICO's roadmap also mentions the need to gather the requirements for connectivity and infrastructure. In the US, the classification of Cooperative Driving Automation is also put forward in J3216 released by SAE international. In Japan, reference architectures in mobility are proposed in the *Public-Private ITS Initiative/Roadmaps*, in which connectivity is also an important part.

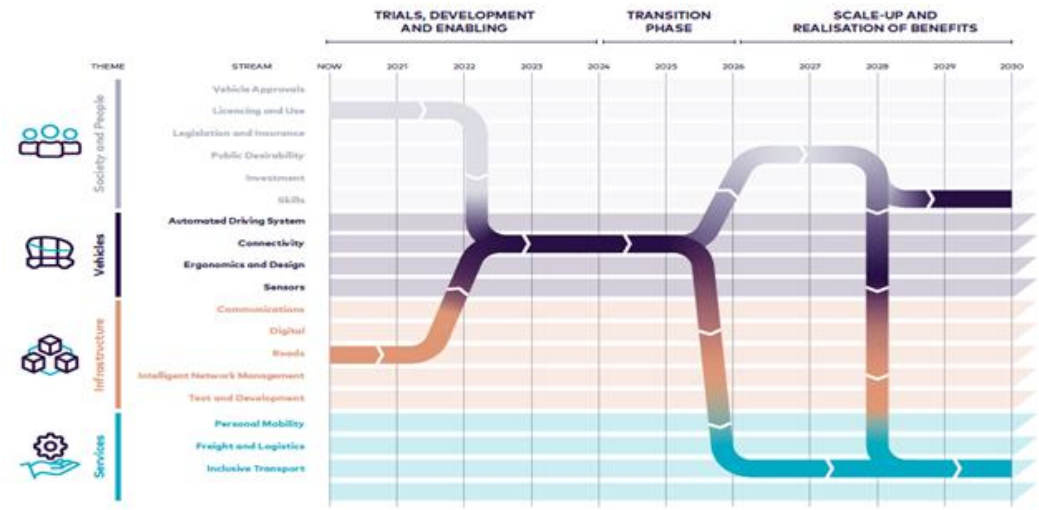
It is generally recognized that the integration of automation and connectivity is of great significance to enable the vehicle, reduce its BoM cost, and promote the free flow of data. At the same time, the broader V2X implementation will hardly be promoted by any of the OEMs themselves, but require the involvement of all stakeholders as well as regulation impetus. In addition, the synergy of roadmaps in this field is widely expected to be completed.

Respective Characteristics

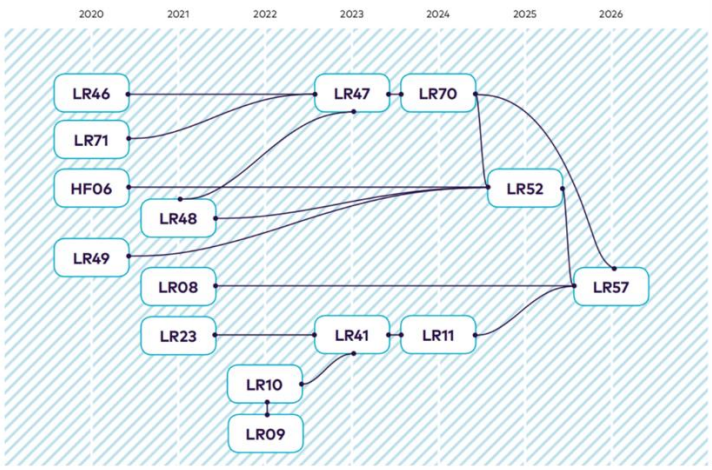
Comprehensive topic setting with cross connections

Not limited to any single topic, Zenzic's roadmap is a comprehensive strategic roadmap covering the full spectrum of an industrial ecosystem in the UK, specifically incorporating social and people, vehicles, infrastructure, and services. It systematically indicates that all the key enablers, including infrastructure, regulation, societal readiness, technology, etc. require ongoing collaboration to bring together the integrated solutions. The need for new solutions in critical areas such as cyber resilience, simulation environments, sign-off approval for production, and in-use compliance are also highlighted within this framework.

In a field as complex and emergent as ICV, one single roadmap structure for its strategy setting is inevitably not enough. This roadmap, therefore, addresses this through 'Golden Threads' which show the interdependencies between milestones and allow cross-topic narratives. These threads are grouped around specific topics to give a detailed view across the roadmap, which is not restricted by these 4 themes.



For example, in the first golden thread, legislation and regulation, the establishment of a harmonized and holistic approval scheme for self-driving vehicles is considered a vital major deliverable. All the milestones with timetables in this strand are shown below.



KEY

ID	Milestone	Date
HF06	Human factors special interest group established	2020
LR08	Defined ODD catalogue for type approvals	2021
LR09	Law Commission review into automated vehicles	2022
LR10	Law Commission final report	2022
LR11	Process in place which speeds up new type approval from UNECE	2024
LR23	UNECE cyber security regulations development	2021
LR41	Policies and legal frameworks in place to allow passenger transport trials	2023
LR46	Consistent framework for approval and licencing of self-driving vehicles	2020
LR47	Small scale national type approval process begins	2023
LR48	Vehicle approval framework for self-driving vehicles in place	2021
LR49	Simulation used as part of regulation and certification	2026
LR52	Certification methodology in place for CAM	2028
LR57	Harmonised vehicle approval scheme established	2030
LR70	National vehicle approval scheme	2027
LR71	Digitisation of rules of the road (The Highway Code)	2020

Promoting worldwide deployment of the V2X ecosystem

Distinct from national or regional roadmaps, application and deployment roadmaps in a specific technical field focus more on its related regulations, technical reserve, standards, supply chain, ecology, market readiness, etc., and aim at guiding its mass deployment step-by-step.

The 5GAA's C-V2X roadmap is a deployment roadmap to prepare the supply chain for the entire global V2X industry ecosystem specifically. The common networking technologies and use cases, alignment of industry standards, supply chain preparation, and product mass production planning towards 2030 are all taken into consideration.

This white paper defines basic safety and advanced use cases and provides a detailed assessment of the relevant standards, technologies, spectrum availability, and timelines for market readiness. It also includes industry recommendations to regulators to ensure that the corresponding spectrum is made available in time for the market introduction of these new use cases, leveraging technology evolution on the road to automotive automation

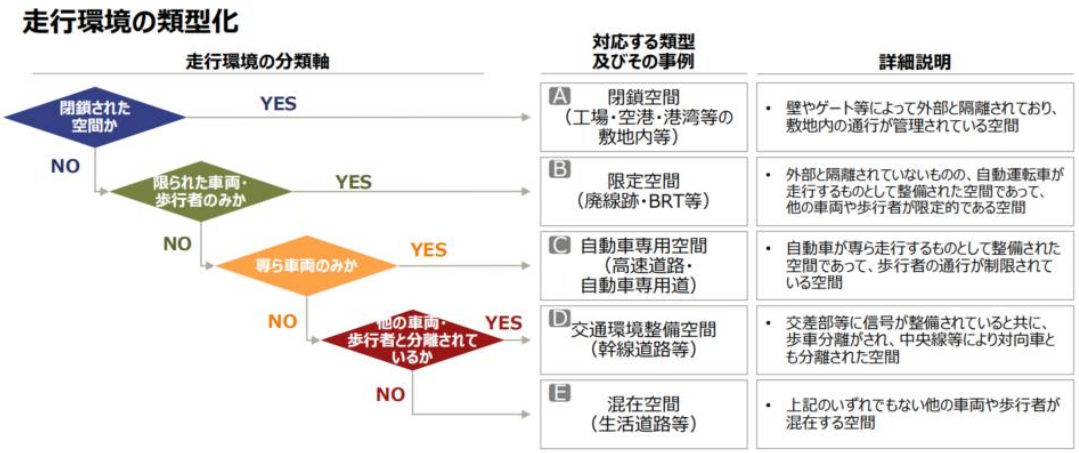
Given the differences in the expectations of the global connectivity approach and the

corresponding supply chain, 5GAA therefore also actively continues its collaboration with standards organizations, regulators, road operators, and other stakeholders to advance the field of cooperative driving in new road and automotive settings, aligning with the roadmap itself.

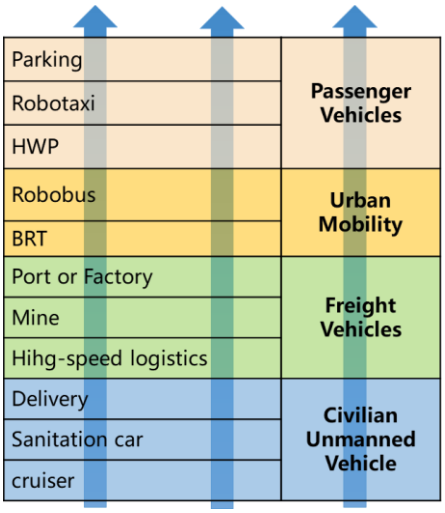
Scenario-oriented research and classification method for mass deployment

To better carry out a large-scale deployment of ICVs, some roadmaps began to focus on the applications of different domains, Japan's *Roadmap for the Realization and Spread of Unmanned AD Services* and China's *Innovative Application Roadmap of ICV* are both good examples of this.

Japan's *Roadmap for the Realization and Spread of Unmanned AD Services* innovatively puts forward an effective classification method based on the driving environment, duties of occupants, and driving speed. 5 different driving spaces (enclosed space, confined space, dedicated road, arterial road, mixed space) are therefore identified, under which 9 types of service scenarios are further studied, each with milestones setting.



Inspired by the roadmap above, the research on scenarios is further conducted in *the Innovative Application Roadmap of ICV* in China. Given the Chinese characteristic driving environment and driving speed, 11 key application scenarios are identified in this application roadmap, and the status quo, deployment challenges, milestone setting, implementation path, and other aspects of each application scenario are further analyzed.


Parking
Robotaxi
HWP
Passenger Vehicles
Robobus
BRT
Urban Mobility
Port or Factory
Mine
Hihg-speed logistics
Freight Vehicles
Delivery
Sanitation car
cruiser
Civilian Unmanned Vehicle

3. Best Practices of Roadmap Research and Application

Extensive Discussion by Collaborative Stakeholders

Although the roadmaps have their different focuses, they all involve a broad diversity of cross-stakeholder contributions and reflect the vision, needs, and priorities of different sectors.

In the context of electrified, autonomous, and connected mobility, ICV is not the automation of the vehicle itself. By integrating with emerging technologies including electronics, telecommunication, AI, big data, as well as cloud computing, and combining with transportation systems, energy systems, city operations, and social life, it's bringing a brand-new industrial ecology as a new species.

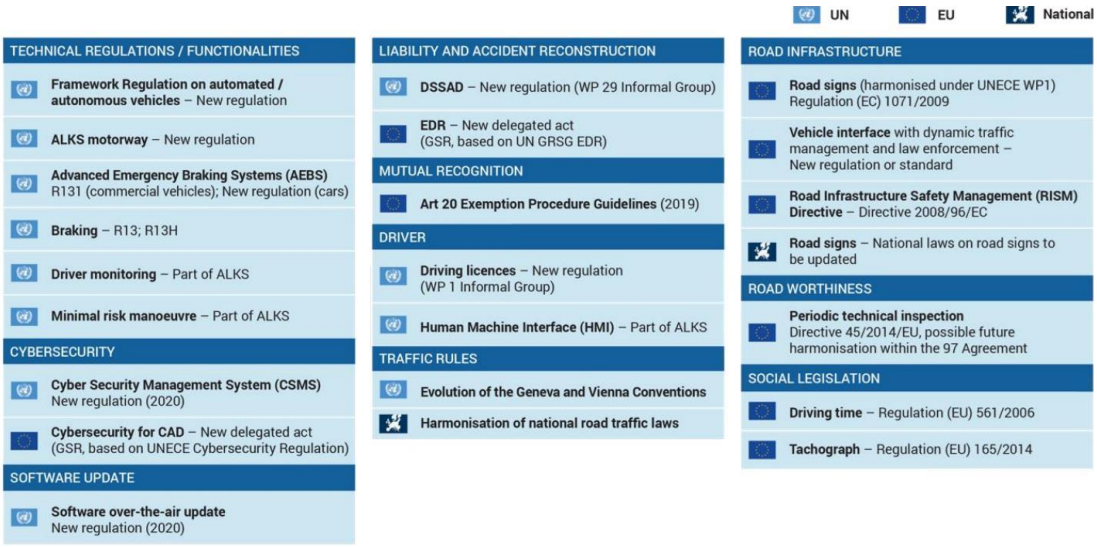
The ICV roadmaps have become an important measure to forge consensus among all of the sectors. The process of creating a roadmap is as important as the actual use of it. It's not only about determining development goals and formulating the realization path in advance. Extensive and long-term cross-industry communication during this period, as well as the process of presenting demands, showing interests and responsibilities, and building consensus among different stakeholders, is widely anticipated of much significance.

Involvements and References by Public Authorities

Most ICV roadmaps around the world are led by industry organizations, multi-stakeholder associations as well as governments, playing a crucial role in the technology route selection and public-private collaboration. These roadmaps provide valuable insights into the formulation of national or regional industrial strategies directly or indirectly, and the development and coordination of activities related to the roadmaps are complementary to the national policies, priorities, and programs as well.

For example, the *Technology Roadmap for Intelligent & Connected Vehicles 2.0* provides an important reference for the Chinese government to formulate its ICV industry strategy, including the *New Energy Automobile Industry Development Plan (2021-2035)* by the General Office of the State Council and *Intelligent Vehicle Innovation & Development Strategy* by NDRC. In Europe, aligning with the relevant roadmap activities, CCAM lays foundations for future regulation updates on cybersecurity, software update, liability and accident

reconstruction, etc. at the UN, EU, and national level as follows.



Supporting R&D and Investment Decisions

The EU continues to promote the development of ICVs through its R&D programs and roadmap updates. Horizon 2020 has funded a large number of innovative projects to effectively promote the development of connected autonomous driving. For example, following VRA and CARTRE, ARCADE promotes the deployment and application of CAD by coordinating the interests of all parties, gathering industry consensus, forming a complete knowledge base, and, therefore, support for ERTRAC roadmap research. The project INFRAMIX focuses the road infrastructure issues in mixed traffic conditions, and ISAD is later proposed and included in the ERTRAC roadmap as well.

In 2021, the EU launched Horizon Europe to succeed Horizon 2020, with an estimated total investment scale of 95.5 billion euros. CCAM Partnership was established as well, and more innovative projects are being carried out in the areas of large-scale demonstration, effectiveness assessment, road transport, enabling technologies, social acceptance, etc. to support the development of CCAM activities and the related roadmaps. As an example, the new project FAME, which builds on previous EU-funded coordination and support actions above, aims to develop and validate common methodologies and tools for CCAM solutions and also has a task dedicated to the analysis of roadmaps in Europe and globally.

Guiding and Supporting the Test and Pilot Projects

Testing and pilot initiatives are essential to raise awareness and better understand the wider impacts of industry ecology toward its large-scale deployment. Most roadmaps support collaborative project-based testing and pilot activities to achieve major milestones.

A very good example is the CCAM Partnership in Europe, composed of 7 Clusters structuring the activities. The objective of one cluster is to continuously implement the results of all other clusters into large-scale demonstrations in pilots, FOTs, and living labs supporting deployment readiness and a final impact assessment. As a member of the Executive Group of the CCAM Partnership, ERTICO's roadmap also strongly supports the need for carrying out further large-scale demonstrations, which is the main focus of the CCAM Partnership Strategic Research & Innovation Agenda (SRIA). It's a project-based roadmap accompanied each time by a relevant set of policy milestones.

Alignment with Regional & International Agendas

During the process of updating and evolving the roadmaps, most organizations have been actively involved in the development of the other roadmaps with reciprocal impact. Relevant information-sharing mechanisms within regional and international WG and congresses also regularly ensure mutual alignment.

In China, a unified technology development roadmap for vehicle-road collaborative autonomous driving (vehicle-road-cloud integration system) is being formulated to optimize the role and function division of vehicle, road, cloud, and network, based on the long-term partnership between the CAD roadmap by CHTS, ICV roadmap by CSAE, and C-V2X roadmap by CIC. Similarly in Europe, roadmaps for CCAM R&I are developed by the European Commission and several stakeholder associations. For example, the ERTRAC and ERTICO CCAM roadmaps are strongly aligned with commonalities and a shared vision, including the aspects related to the identification of physical and digital infrastructure needs, ODD, and ISAD.

Furthermore, the global alignment between different roadmaps is also the reason why this committee was initiated: to achieve in-depth discussion and cooperation on common concerns, to promote more similarity in the development of roadmaps, to enhance mutual

understanding of the differences, as well as to promote the synergistic development.

Thanks to all the contributors:

Amelie Gong, CSAE/CAICV

Andreas Schaller, 5GAA/Bosch

Armin Graeter, ERTRAC/CCAM Association

Chen Shanzhi, CICT

Deng Tingting, CICT

Duan Cong, CSAE/CAICV

Francis McKinney, Zenzic

Fuquan(Frank) Zhao, Tsinghua University

Georg Schmitt, 5GAA/BMW

Hu Jinling, CICT

Jan Ellsberger, Huawei

Jan Hellåker, Drive Sweden

Ji Yunjia, CSAE/CAICV

Jiang Hao, CSAE/CAICV

Joost Vantomme, ERTICO-ITS Europe

Li Keqiang, Tsinghua University

Li Linheng, Southeast University

Li Xiaolong, CSAE/CAICV

Maxime Flament, 5GAA

Ran Bin, CHTS

Seok-Cheol Kee, KSAE

Stephane Dreher, ERTICO-ITS Europe

Tristan Bacon, Zenzic

Zhang Zezhong, CSAE/CAICV

* In alphabetical order