Interreg North-West Europe

Co-funded by the European Union

CAMINO-2

Overview of the Shared Autonomous Vehicle landscape & legacy of CAMINO-1

D.1.1.1

A global and regional analysis of the current SAV landscape & summary of the CAMINO-1 project legacy.

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INTRODUCTION

Context and background

The transition towards sustainable, accessible, and efficient public transport in North-West Europe (NWE) relies heavily on the successful integration of Shared Automated Vehicles (SAVs). While the overarching vision for automated mobility has been established, the focus must now shift entirely toward practical, real-world deployment. Building directly upon the strategic groundwork laid by the CAMINO-1 project, CAMINO-2 aims to bridge the critical gap between strategic intent and operational reality for public transport actors across the NWE region.

Purpose of the report

The primary objective is to provide a comprehensive baseline of the current autonomous mobility ecosystem, evaluating market readiness, regulatory frameworks, and technological feasibility. By assessing the global and European landscape, this document identifies both the enablers and the persistent barriers to scaling SAV networks. Ultimately, the insights gathered here will directly inform the development of the SAV Blueprint Action Plan (SAV-BAP) and the subsequent SAV Implementation Toolkit (SAV-IT).

Document structure

To provide a clear pathway from past learnings to future deployment, this report is structured into three main sections:

- Part 1: global & regional landscape analysis examines the current state of the SAV market, comparing European progress with global benchmarks, and outlines the technological, regulatory, and governance realities of deployment.
- Part 2: CAMINO-1 provides a retrospective on the foundational strategies developed during the first phase of the project, highlighting crucial lessons learned regarding use case design, stakeholder ecosystems, and economic realities.
- Part 3: Conclusion synthesises these findings to pinpoint the remaining implementation gaps and outlines the strategic imperatives where European transport authorities and operators must act next.

PART 1: GLOBAL & REGIONAL LANDSCAPE ANALYSIS

1.1. SAV market and deployment landscape

The global deployment of Shared Autonomous Vehicles (SAVs) has passed the point of mere theoretical testing. Internationally, the transition to Level 4 automation is accelerating, but the maturity, scale, and underlying philosophy of these deployments vary dramatically by region. To understand where Europe stands, we must first look at the global landscape to see what is already active on the roads of the world's tech superpowers, and evaluate the foundational partnerships required to get them there.

1.1.1. Global benchmark: US/China/Europe

The global deployment of autonomous vehicles (AVs) shows a clear divide in regional maturity and strategic goals. The United States and China have commercialised ecosystems where Level 4 autonomous vehicles operate on public roads without human safety supervisors. However, the US and China focus primarily on the individualised ride-hailing market and lack integration with public transport networks. In contrast, Europe focuses on the public transport sector, viewing autonomous driving as a way to improve existing networks rather than expanding private car use. However, Europe is not yet where the US and China are; its market is dominated by a fragmented set of isolated solutions and individual small-scale pilot initiatives with little long-term viability and faces a complete lack of large-scale commercial deployment. Ultimately, this highlights two different mobility intentions: the commercial scaling of individual transport in the US and China versus Europe's focus on integrating shared autonomous mobility into public transit infrastructure.

A foundational barrier to scaling these initiatives lies in the nature and formation of project consortiums. Because launching an SAV service is an inherently cross-disciplinary effort that no single organization can execute in isolation, a formalized consortium is the essential legal and operational mechanism required to bind diverse sectors, including vehicle manufacturing, software development, public transit operations, and digital infrastructure, under a unified strategic framework. Without this structured collaboration, critical operational components remain siloed, blocking the technical integration, data sharing, and mutual risk-allocation required to safely operate automated fleets on public roads.

In the European context, however, the actual assembly of these vital partnerships presents a key challenge. Despite their absolute structural importance, consortiums are frequently created for reasons other than technical capabilities, such as meeting political goals or addressing public awareness concerns. This results in suboptimal team arrangements and decreases the likelihood of successful outcomes.

Furthermore, many projects are underdeveloped in their initial design phase. Planning horizons tend to be short-term, and finance mechanism frequently incentivise cautious approaches over ambitious, scalable solutions. As a result, smaller and less experienced actors receive disproportionate representation, reducing the ability to generate meaningful learnings.

Criteria	Europe	USA	China
Education / talent / know-how	+- Strong engineering base, but AI/software talent is less concentrated and often migrates to U.S. tech ecosystems.	++ Best AI / software and tech universities / companies are located there	++ Strong state-backed focus on AI, software, ICV and innovation hubs, supported by national industrial strategies
Government funding	- Federalism is reflected in projects. No overall picture is visible	+- Less dependent on central public funding due to strong private capital	++ Strong national and local government programs actively accelerate AV, AI and ICV development
Access to venture capital	-- VC investment is only in the low double-digit million range	++ Deep VC and growth-capital markets support rapid technology development and commercialization	+- Strong investment base remains available, though funding is more state-influenced and market conditions are more volatile
Regulation / safety	+ A comprehensive regulatory framework has been created, but it is perceived as deterrent and complex	+- State-level regulation creates flexibility, with leading states enabling AV testing and commercial deployment	+- Strong state steering enables speed, but transparency and data-sharing requirements can deter foreign providers
Market access / business model	+- Strong public transport structures support integration, but regulated markets make commercial entry and scaling slower	++ Established ride-hailing platforms make robotaxi integration and driver substitution commercially attractive	+ China pushes local innovation and technology
Model regions / commercialization	- Many barriers remain before commercialization, such as type approval and trial permits	++ Commercial robotaxi operations exist in selected states and cities, supported by lower deployment barriers	++ Local governments use pilot zones and coordinated programs to accelerate commercialization and scaling

The USA offers the strongest technology and capital environment, China offers the fastest state-driven scaling environment, while Europe provides regulatory legitimacy and PT integration, but lacks speed, capital depth and visible local SDS champions

The global competitive landscape for autonomous vehicles varies greatly between Europe, the United States, and China. Europe has a strong engineering base, but suffers from a relative scarcity of AI and software talent, much of which is migrating to US technological hubs. In contrast, the United States has top AI institutes and companies, while China is quickly developing capabilities through state-sponsored industrial initiatives.

Public financing schemes

Europe's federal system results in fragmented initiatives that lack a coherent strategic direction. The United States is more reliant on private capital, whereas China benefits from coordinated national and local government programs that actively promote growth.

Access to venture capital

The US has robust capital markets that enable quick growth and commercialisation. China maintains a strong, although more state-influenced, investment environment. Europe, by comparison, has limited venture capital, which limits growth.

Regulatory environments

Europe has created a comprehensive but complicated regulatory system, which may discourage innovation. The US enables flexibility through state-level regulation, while China uses centralised control to accelerate deployment, albeit with certain transparency limits.

Commercialisation

The US leads in active robotaxi deployments, while China is rapidly growing through specialised pilot zones. However, Europe continues to face challenges such as type approval and permits, which hinder the development of commercialisation.

1.1.1.1. Market insights US

The United States has one of the most mature autonomous driving ecosystems globally. Waymo, May Mobility, and Zoox have advanced beyond pure pilots and are now displaying technological maturity in real-work commercial operations. Publicly accessible autonomous services are available in selected cities, particularly in states with more favourable regulatory environments.

The US market benefits from a well-developed software and technology ecosystem, robust venture capital markets, and strong commercial ties to ride-hailing platforms like Uber and Lyft. Autonomous robotaxis are mostly marketed as an extension of existing ride-hailing services, with an emphasis on replacing drivers in commercially attractive urban mobility markets.

However, the US does not have a unified national AV framework. Regulation and approval processes differ greatly per state. Progressive states like California, Arizona, and Texas have permitted early deployment and commercialisation, whilst other states are more restricted or less active. The public's acceptance is similarly varied. Incidents, traffic disruptions, and safety concerns have influenced public opinion on robotaxi operations. Furthermore, integration with public transport is limited because the US mobility market is less focused on public transport systems than many European countries.

1.1.1.2. Market insights China

China has established a highly competitive autonomous vehicle ecosystem, with significant involvement from technology firms, OEMs, ride-hailing platforms, and local governments. Leading players like Baidu Apollo, Pony.ai, and WeRide have already shown Level 4 capabilities at meaningful scale.

Compared to the United States, China takes a more city-integrated smart transportation strategy. Autonomous driving is frequently integrated into larger smart city goals, aided by AV zones, digital infrastructure, and coordinated local government programs. Wuhan, Beijing, Shanghai, Guangzhou, Shenzhen, and other major metropolitan innovation hubs are prime deployment locations.

China is progressively shifting away from robotaxi pilots and toward commercial scaling. Aside from robotaxis, autonomous buses, logistics vehicles, sanitation vehicles, and closed-area applications are becoming increasingly relevant. This development approach relies heavily on partnerships among AV software companies, OEMs, platform suppliers, and local government.

Regulation is widely supported nationwide, but it is heavily enforced at the local and provincial levels. Rollout speed is determined by safety certification, remote monitoring, local permissions, and regulatory confidence. Overall, China combines strong state control with a diverse industrial ecosystem, allowing for faster scaling than in Europe.

1.1.1.3. Market insights Europe

The European autonomous mobility market differs greatly from the American and Chinese sectors. In Western Europe, autonomous driving is generally considered as a means of strengthening public transport rather than replacing private car use or expanding ride-hailing. The overarching goal is to offer inexpensive, inclusive and sustainable transportation for everyone. This results in a different customer structure.

In Europe, the primary customers are cities, public transportation agencies, and fleet operators, rather than individual end users. The most promising use case is shared autonomous mobility, which includes ride sharing, autonomous shuttles, and feeder services for public transportation networks. Europe also has a less established competitive landscape for self-driving software and systems. While there are several pilot programs, there are presently no large-scale Level 4 commercial operations equivalent to those found in select US or Chinese cities. Existing pilots are often too small to create long-term added value or significant operational learnings.

At the same time, Europe has clear demand drivers. Driver shortages, the need to service uneconomic routes, climate targets, inclusiveness aims, and the overall transport change all drive demand for autonomous public transport options. Although EU-level laws and national legal frameworks serve as a solid basis, successful growth will necessitate larger fleets, more technological preparedness, and better integration with public transport operations.

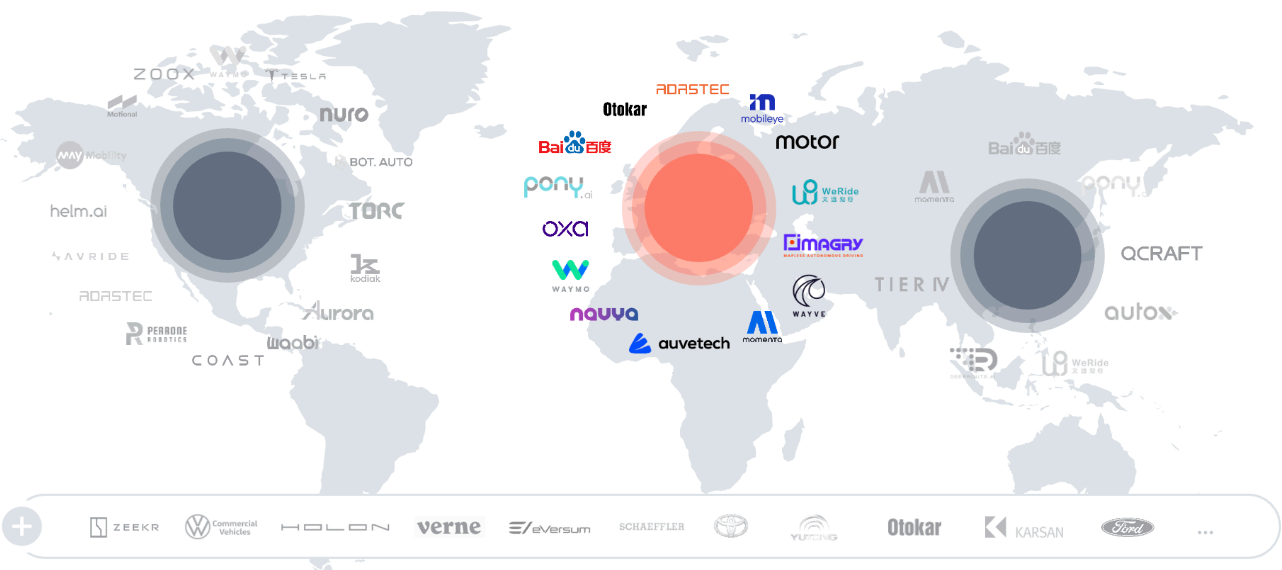
1.1.2. Main AV/SAV players relevant for Europe/NWE

Autonomous mobility-as-a-service can be designed for a variety of use cases and operational conditions. The relevant environments range from highways and dense metropolitan areas to suburban neighbourhoods, rural villages, and guarded areas like harbours, airports, depots, and industrial yards.

The robotaxi is the most prominent ride-hailing use case, especially in urban areas. The vehicle types that are relevant in ride-sharing and public transportation are more diversified. They consist of low-speed shuttles, roboshuttles, robotaxis, robomidibuses, and robobuses. Vehicle size and capacity vary based on the use. Smaller vehicles may be appropriate for low-density or flexible services, but bigger autonomous buses are better suited for high-demand corridors and public transit integration.

For Europe and Northwestern Europe, the most relevant opportunities are likely to be shared autonomous mobility, autonomous shuttles, and higher-capacity vehicles that can supplement current public transportation networks. The major strategic concern Is not only whether autonomous driving technology is available, but also which vehicle type and service model are suited to the given operating environment.

Overview of active AV companies in Europe



1.1.3. Current presence and maturity of suppliers in Europe

	Public transport focus	Existing projects (exemplary)	Technology maturity
	Is the provider generally focused on public transport (e.g., use-case focus, vehicle, ...)?	What current (pilot) projects does the company already have in Europe?	How mature and scalable is the L4 technology?
WAYMO	Focuses on autonomous robotaxis, with public transport relevance mainly as a feeder service.	European rollout is planned for London, while current scale is mainly in the U.S.	Very mature and scalable robotaxi technology
ADASTEC	Focuses on autonomous buses for scheduled public transport on fixed routes.	Active EU projects include Hannover's ALBUS with a Karsan Autonomous e-ATAK	Scalable L4 readiness to be proven. Vehicle platform not L4 ready yet (e.g., redundancy)
mobileye	Provides autonomous driving technology for multiple vehicle types, including shuttles	Used in Germany's KIRA project for L4 on-demand public transport trials.	Technically advanced and scalable, but dependent on vehicle & operator integration
motor	Focuses on autonomous driving software for public transport and shuttle applications.	Public references focus on German PT integration rather than many live deployments	Promising L4 software approach, but market proof appears less mature than leading players
imagry	Focuses on mapless autonomous driving software for buses and shuttle services.	Plans European roboshuttle deployment in Latvia with Carguru	Still needs broader operational validation in Europe
WAYVE	Focuses on AI-based autonomous driving for passenger cars and robotaxis	Uber plans a London robotaxi trial with Wayve in 2026	Highly scalable AI approach
navya	Focuses on low-speed shuttles for campuses, districts and short public transport routes.	Navya vehicles continue to appear in L4 shuttle demonstrations such as ULTIMO	Proven shuttle heritage, but low software maturity
oxa	No focus on passenger transport anymore	Oxa has demonstrated zero-occupancy autonomous operation in Oxford.	Technically credible L4 software, but public transport scaling remains limited
Otokar	Focuses on compact autonomous buses for urban public transport.	The autonomous e-Centro is being used in public transport in Mercamadrid, Spain.	L4 readiness (both SW and HW) still to be proven
WeRide	Focuses on autonomous mobility services, including robotaxis, robobuses and robovans.	European projects include Leuven, Zurich Airport and Renault public transport trials.	Mature L4 technology globally, with growing but still early European deployment
pony.ai	Primarily robotaxi-focused, with PT relevance mainly as an on-demand feeder service	European activity is emerging through Luxembourg & Croatia robotaxi partnerships	Mature L4 technology globally
momenta	Primarily focused on autonomous driving software and robotaxis	Planned European testing includes Uber robotaxi trials in Munich from 2026	Advanced L4-capable software, but European deployment is still at testing stage
Baidu 百度	Strong robotaxi focus, with possible feeder-service relevance but limited PT orientation	Pilot in Switzerland. Plans European robotaxi launches in Germany, the UK and London	Highly mature in China, but lacks behind Pony.ai and WeRide
auvetech	Clearly focused on compact autonomous shuttles for public transport and local mobility	European shuttle deployments include Tartu and other public-road shuttle applications	Mature for low-speed shuttle use, but less scalable for complex traffic scenarios

1.1.4. Market gaps: vehicle availability, service models, vendor lock-in, commercial readiness.

Europe has made progress in developing a legislative framework for autonomous vehicles, but the technology and commercial ecosystem are not yet equally mature. The primary concern is whether adequate technology exists for scalable European public transport use cases.

Several market gaps remain:

1	**Legislative procedures are not yet harmonised throughout Europe**, increasing complexity and perhaps discouraging global market players. Although legislative frameworks exist in numerous EU nations, operational needs, approval procedures and country-specific interpretations may impede scaling.
2	**Technological and pre-commercial maturity have been more visible in the US and China than in Europe.** European timelines, maturity levels, and performance benchmarks are often ambiguous or non-transparent, reducing confidence and complicating procurement for public transport authorities.
3	**Scaling is difficult because autonomous systems must be tailored to various local conditions, road environments, and operational design domains**. Providers frequently do not provide adequate transparency through similar quality and performance indicators. As a result, public transport authorities may perceive procurement as uncertain and risky.

1.2. NWE pilot and use case landscape

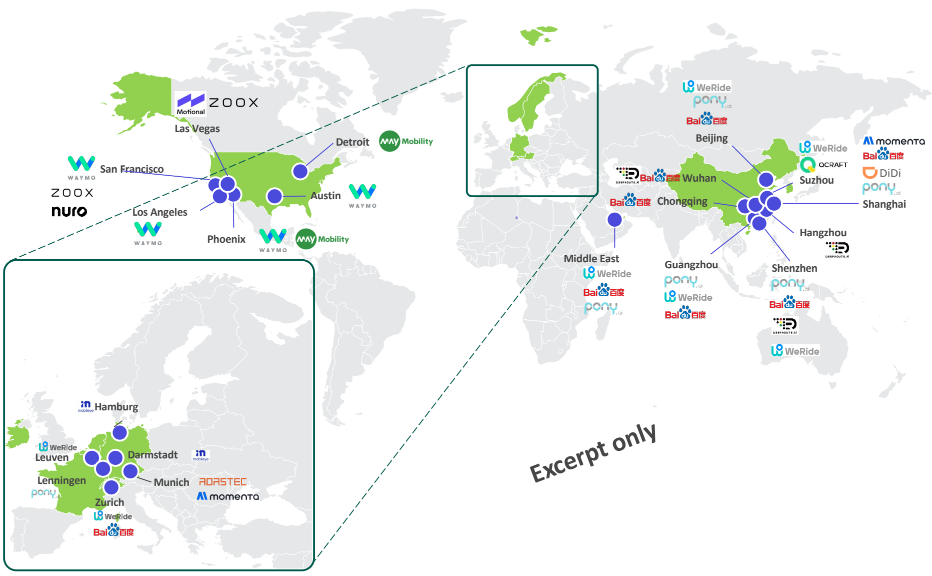
1.2.1. Major pilots in NWE and Europe

Across Europe, Noth America, China and the Middle East, the number of pilots for autonomous vehicles is increasing. Commercial services are becoming more evident, particularly in the United States, China and several Middel Eastern countries. Cities like San Francisco, Phoenix, Los Angeles, Austin, Las Vegas, Wuhan, Beijing, Shanghai, Guangzhou, and Shenzhen demonstrate that commercial deployment is no longer purely theoretical.

In Europe, however, smaller-scale pilots continue to dominate. Projects in Munich, Hamburg, Darmstadt, Leuven, Zurich, and other European cities are gaining traction, although most efforts continue to operate with small fleets and limited operating scope. The main European challenges are a lack of EU-ready autonomous buses and shuttles for public transport operations, some ADS providers' reluctance to enter public transport rather than ride-hailing, fragmented approval and homologation processes, and scaling beyond isolated pilot projects.

For Europe, the next phase is to transition from demonstration projects to financially viable, procurable, and operationally sustainable public transport services.

Pilot projects are on the rise



Status Quo & Challenges

Commercial services are on the rise, mainly in the US, China and Middle East

Europe determined by small scale pilots. Challenges are for instance:

- Lack of EU-ready autonomous buses/shuttles for public transport operations
- Willingness of ADS providers to enter public transport instead of hailing business
- Fragmented approval, liability, and homologation across European countries
- Scaling beyond isolated pilots into fundable, procurable public-transport services

1.2.1.1. Project snapshot: Hamburg

Europe is steadily transitioning from early, low-speed autonomous applications to more advanced driverless ride-pooling solutions. Previously, many programs concentrated on initial deployments in gated areas or simple public-road situations. The emphasis today and in the near future is on enhancing traditional public transport with more advanced autonomous vehicle technologies. The Hamburg project illustrates this transition. It aims to launch one of the first autonomous on-demand ride-sharing services with up to 20 vehicles beginning in 2026, with federal assistance. The project involves two vehicle suppliers, two vehicle types, and two fleet operators serving the same service area.

1.2.2. Comparison of use cases: first/last mile, DRT, peri-urban, rural, dense urban, depot automation

1.2.2.1. Three main service models

European cities are increasingly demanding higher-capacity autonomous vehicles to meet rising passenger demand and expand public transport networks. Three main service models are relevant: autonomous fixed-route services, autonomous on-demand services, and mixed models.

Autonomous fixed-route services

This model adheres to a predefined route and schedule. They are easier to plan and incorporate into existing networks, and they can boost frequency on high-traffic routes. However, they provide little flexibility and may be less appealing when demand is dispersed or unpredictable.

Autonomous on-demand services

This model is more flexible and user friendly. They can act as feeder services, cover underserved areas, and provide mobility to new demographics or time periods. However, they require more sophisticated operational controls, digital booking systems, fleet information, mapping, and user communication.

Mixed models

These models combine both approaches. Vehicles may run on set routes during peak hours and operate more flexibly in the evening or during low-demand periods. This model can increase vehicle utilisation by combining reliable base service with demand-responsive supplementation. However, it adds operational complexity, particularly when transitioning between service modes.

For public transport operators, the strategic focus is rapidly turning toward scalable solutions that combine service quality, vehicle availability, operational dependability, and economic feasibility.

SAV deployment should not be evaluated only by vehicle type or use case. The major challenge is whether the service can be integrated and scaled under real-world public transport conditions.

- Fixed-route SAVs are best suited to corridors with larger capacity and predictable demand.
- On-demand SAVs address first/last-mile, peri-urban, and rural mobility gaps.
- Mixed models can provide both fixed-route reliability and flexible off-peak coverage.
- Early assessments of ODD limitations, monitoring needs, safety driver requirements, and remote operation readiness must be assessed early for all models.

The most powerful SAV use case is one that solves a real PT gap and can be operated safely, reliably and affordably at scale.

1.2.2.2. Comparison of urban and rural areas regarding autonomous mobility

		Urban areas	Rural areas
Demand patterns		Potentially high demand, often concentrated in space and time (e.g., commuter flows, events)	Lower demand, varying significantly over time and space
Traffic density / complexity		Complex traffic scenarios, many road users	Often simpler traffic structures, lower dynamics
Infrastructure	Streets	Well developed, but often overloaded and congested	Weaker road networks, partly in poor condition
	Yards	Integration into existing depots is difficult due to different vehicle concepts and lack of space	Strategically favorable location choice for regional service, but high initial costs
	Charging	Partly available in a decentralized manner	High expansion needs, especially for fast charging and grid connection
	Digitization	Good 4G/5G coverage, some V2X-capable systems available	Significant deficits in mobile network coverage and real-time communication
Technical requirements		Very high requirements for system robustness	High requirements for system robustness
Traffic planning & Integration		Easy to integrate into existing multimodal concepts (public transport, cycling)	Often fragmented transport services, but great impact through new connectivity
User Acceptance		Mixed — higher awareness, but more skepticism regarding susceptibility to disruption and safety	Potentially greater openness, as alternative mobility options are lacking or insufficient
Social accessibility		Potential to relieve vulnerable groups (e.g., older people, children)	Major lever for social participation in regions without public transport access
Regulatory controllability		High political and public pressure, many actors involved	Often more direct municipal decision-making channels and willingness to cooperate
Viability		Potential through high utilization and short turnaround times	Questionable — operation economically viable only with subsidies or cooperation partners
Coordination effort		Complex: many stakeholders (transport operators, politics, technology, citizens)	Simpler, but often lack of resources and know-how at municipal level
Potential for scaling		High, especially for scheduled services and integration into MaaS platforms	Possible via regional networks or transport associations, but dependent on funding structures

Urban areas

Urban areas typically have higher and more concentrated demand, particularly around commuter routes, events, and dense corridors. This increases the possibility for high utilisation and quicker turnaround times. At the same time, urban settings are increasingly technically sophisticated. They involve dense traffic, many road users, congestion, limited deport space, and high requirements for system robustness. Integration into existing multimodal systems is simpler, but coordination is more difficult because many stakeholders are involved, including transport operators, municipal governments, technology suppliers, and citizens.

Rural areas

Rural areas face opposite challenge. Demand is lower and more dispersed, road networks may be degraded, and mobile network coverage may be inadequate. Charging infrastructure and digital connection may necessitate large investments. However, traffic conditions are often easier, and autonomous mobility can have a significant social impact by providing access for persons who lack reliable public transportation options. Because alternative modes of transportation are often few in rural regions, user acceptability may be much greater. The key difficulty is economic feasibility, which will most likely rely on subsidies, regional collaborations, or incorporation into larger public service models.

Urban and rural SAV deployment require distinct implementation strategies.

- Urban areas have increased demand and better infrastructure, but they also have more traffic complexity, political pressure, and coordinating effort.
- Rural areas have greater mobility gaps and potential for higher social value, but they also have inferior infrastructure, lower demand density, and more fragile business cases.

SAV adoption should be evaluated case-by-case, taking into account demand, infrastructure preparedness, digital coverage, governance capacity and long-term viability.

1.2.3. Demand patterns and service suitability

The suitability of autonomous public transport use cases is heavily influenced by the geographic operating environment. ***In urban areas***, the biggest opportunity is to improve the efficiency of current transportation structures. Autonomoys fixed-route services may be suited for heavily trafficked corridors with high and predictable demand. On-demand services can supplement traditional networks during off-peak hours or in peripheral urban districts. Mixed models might also be appealing in urban settings, because peak traffic times are predictable. Vehicles, for example, might run fixed-route services during peak demand and then transition to flexible on-demand operations during low-demand periods. The key constraint is the availability of sufficient vehicle platforms capable of supporting both use cases successfully.

Fixed-route autonomous services are often inefficient ***in rural areas*** because the demand is too low and dispersed. In contrast, autonomous demand-responsive transport is highly relevant because it can address common rural mobility issues such as large distances, low demand density, and gaps in public transportation coverage. Mixed models may also be effective in rural regions, but only when demand patterns are simple and predictable. Excessive switching logic or highly dynamic operations may overload consumers and operators. Overall, metropolitan regions profit the most from efficiency improvements, whereas rural areas benefit from the establishment, of reliable basic transportation services.

Service suitability is determined by both location and demand logic.

- Fixed route SAVs perform well if demand is predictable and regular.
- On-demand SAVs are most useful where traditional PT fails to offer consistent service, particularly in rural and peri-urban areas.
- Mixed models can connect both logics, but they need simple operational principles and clear user communication.

The optimal SAV model is one that reflects local demand patterns while staying operationally simple, dependable, and scalable.

1.2.4. Barriers to scaling from pilots to regular PT operation

No clear scalable business case: Pilots are grant-funded. Regular service needs predictable operating costs, procurement models, and fare/subsidy logic

Lack of suitable production vehicles: Many autonomous shuttles remain low-speed, small-capacity, pilot-oriented, or not ready for full public-transport duty cycles

Fragmented approval and liability regimes: Operating permits, safety cases, insurance, remote supervision, and liability still vary across cities and countries

Public-transport integration gap: AV services must integrate with timetables, ticketing, dispatching, depots, passenger information, and operator workflows

Unclear operational responsibility model: Cities, PTOs, OEMs, tech providers, remote operators, and safety stewards need defined roles and accountability

High supervision and fallback costs: If each vehicle still needs onboard staff or intensive remote monitoring, the cost advantage disappears

Limited standardization of requirements: European operators often specify vehicles, safety processes, data, KPIs, and quality control differently, limiting scale

Weak demand aggregation across cities: Single-city pilots do not create enough volume for suppliers. European initiatives are now trying to build "critical mass" of demand across transport organizers

1.3. Technology readiness and feasibility

1.3.1. ODD limitations, supervision, safety driver needs, and remote operation

Autonomous transportation use cases cannot be evaluated only by geography and demand. Their true deployment potential is dependent on whether the service can run safely and reliably under its existing technological and regulatory constraints.

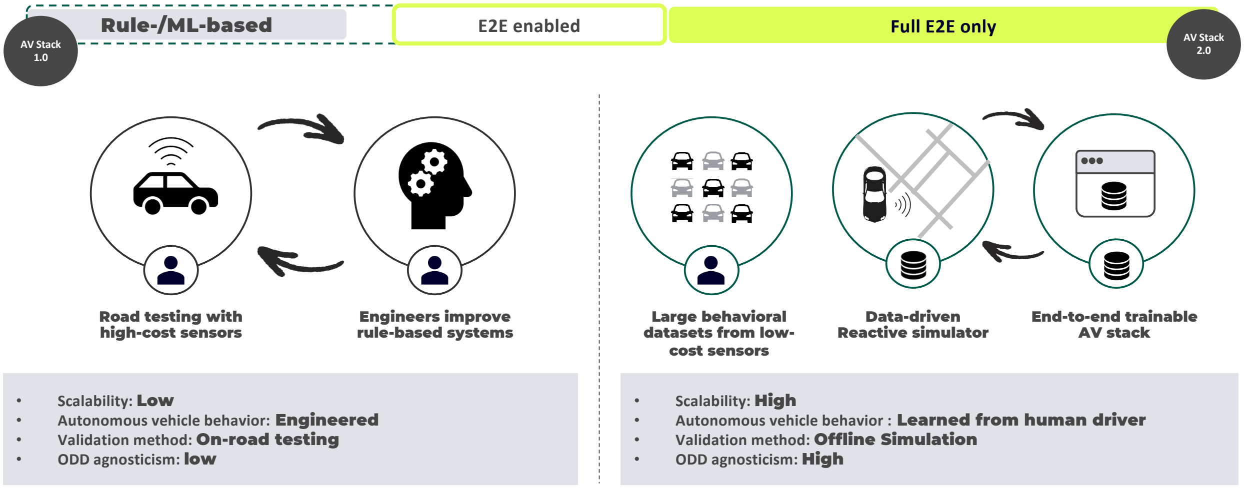
Key elements to evaluate:

- Operational Design Domain (ODD): where and under what conditions does the vehicle operate?
- Supervision model: How much human supervision is necessary during operation?
- Safety driver requirements: Is an onboard safety driver still necessary, and for how long?
- Remote operation readiness: Can vehicles be monitored, assisted, or intervened remotely?
- Scalability impact: Does the supervisory model still provide cost savings and operational efficiency at a higher scale?
- Regulatory suitability: Are remote supervision and autonomous operation authorised in the local/national context?

The ability to minimise onboard monitoring, handle ODD restrictions, and establish a secure remote operating model is more important for the transition from pilot to scaled SAV service than the vehicle itself.

1.3.2. AI/E2E trends, digital twins, V2X, fleet management

Adaption of generative AI ("End2End") could serve as catalyst for the industry to accelerate progress to "driver-out".



The use of generative AI and end-to-end techniques has the potential to catalyse the autonomous car sector. Traditional AV development has depended primarily on rule-based systems, costly sensor configurations, on-road testing, and engineering-driven enhancements. This strategy can provide safety and interpretability, but it is hard to scale and often highly dependent on specific operational design domains.

The emerging AV 2.0 logic is more data-driven. Instead of manually designing every behaviour, systems learn from large behavioural datasets, which are often acquired using low-cost sensors. Validation is shifting from road testing to offline simulation and reactive simulation settings. This enables more scalability. Vehicle behaviour is now learnt from human driving patterns and enormous amounts of data, rather than being manufactured.

End-to-end trainable AV stack offers improved ODD agnosticism, faster adaptation to new environments, and reduced manual tuning. However, this transformation presents additional obstacles. The industry must demonstrate that data-driven, end-to-end systems can be evaluated, monitored, and trusted at safety-critical levels. The transition from AV Stack 1.0 to AV Stack 2.0 represents not just a technology development, but also a shift in validation philosophy.

1.3.2.1. Modular architectures (AV 1.0) to end-to-end (E2E) AI-powered systems (AV 2.0)

Modular approach (AV1.0)

- Separate modules (perception, localisation, planning, and control).
- High system complexity and integration effort.
- Significant reliance on HD maps and sensor redundancy.
- Limited scalability and significant engineering effort

End-to-End Approach (AV 2.0)

- A unified AI model manages the vehicle.
- Scales more easily across regions and use scenarios.
- Reduced costs owing to reduced sensor and mapping needs.
- Faster iteration cycles.

Key trade-off

- Modular systems are more interpretable and validated, but slower to scale. E2E systems are extremely scalable and efficient, but less visible ("black box") and challenging to validate.
- The industry is now in transition, with both models coexisting. Selection is based on risk tolerance and strategic positioning.

1.3.2.2. Digital twins

Digital twins can be a key facilitator in transitioning SAV deployment from isolated pilots to scalable operations. They enable PTAs/PTOs to simulate routes, demand scenarios, ODD limits, and operational hazards before real-world implementation.

Key added value:

- Simulate SAV services before expensive road tests.
- Compare the fixed-route, on-demand, and mixed operating modes.
- Test the ODD limits in various traffic, weather, and infrastructure situations.
- Support safety validation and risk assessment.
- Improve fleet size, charging, monitoring, and depot operations.
- Generate proof for procurement, business models, and KPI definitions.

Digital twins cannot replace real-world pilots, but they can decrease deployment risk, expedite learning, and enable more evidence-based SAV planning.

1.4. Regulation, governance, PPP and procurement

Successfully scaling Shared Autonomous Vehicles (SAVs) depends less on technical capability and more on institutional readiness. This section outlines the regulatory, governance, and procurement frameworks required to safely integrate automated fleets into public transit networks. By defining clear operational roles, liabilities, and partnership models, it provides public authorities with a strategic roadmap to transition from isolated pilots to permanent, scalable mobility solutions.

1.4.1. European regulatory framework

Europe has one of the most sophisticated regulatory regimes for autonomous driving, namely for Level 4 systems.

Key aspects:

- A strong focus on safety, security, and compliance.
- Comprehensive type approval requirements under EU legislation (e.g., EU 2022/1426).
- Integration of national legislation and additional frameworks (e.g., Germany's AFGBV)

The regulatory system operates across multiple levels.

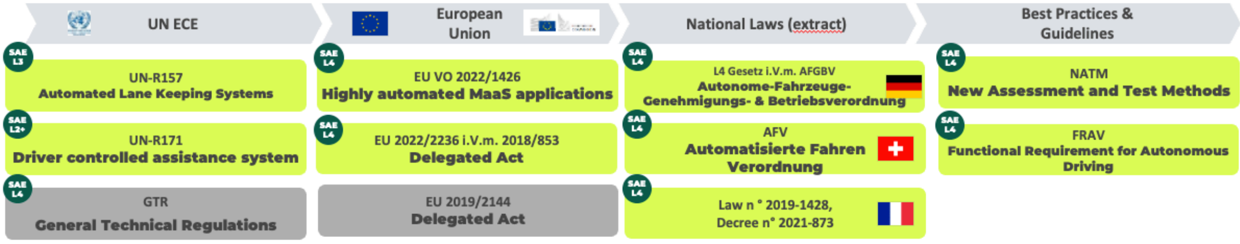
- UN ECE (International Standards) European Union regulations
- National legislation and operational permissions.
- Non-binding best practices and standards (ISO and SAE)

Integrating operational issues into system development is an absolute must. This includes:

- Safety management systems (SMS, CSMS, and SUMS)
- Real-time monitoring and incident management.
- Compliance with behavioural and traffic legislation
- Approval of Operating Areas and Service Concept
- While the framework ensures safety and robustness, its complexity presents impediments to quick implementation and scalability.

1.4.2. Country-level differences in NWE

Legal relationship and hierarchies in the field of AV legislation



1.4.2.1. From legal framework to deployment governance

AV regulation is more than just a type-approval problem. The main problem for public transportation deployment is connecting vehicle approval to operational authorisation, supervisory models, liability allocation, and local service governance.

Key implications

- Clearly distinguish between vehicle type approval and authorisation to operate in a specified location.
- Define the operational design domain prior to service planning and procurement.
- Clarify the responsibilities of PTA, PTO, vehicle supplier, operator, and remote supervisor.
- Include safety management, incident handling, and fallback procedures from the start.
- Ensure that procurement contracts incorporate supervisory requirements, data sharing, liability, and regulatory uncertainties.
- Treat national differences as a scaling obstacle to be managed by shared guidance and cross-country learning.

Scalable SAV implementation need a governance approach that integrates legislation, operations, safety, and procurement, rather than merely technical compliance.

1.4.3. Governance models for PTA/PTO/city cooperation

Successful SAV deployment requires clear collaboration among the public transportation authority, the operator, and the city/municipality. Governance should specify who establishes mobility goals, who executes the service, who controls public space and infrastructure, and who bears safety and liability risks.

Key components of a governance model:

- Clearly defined roles for PTA, PTO, city, vehicle supplier, and technology provider.
- Jointly define service objectives, target users, ODD, and integration with the PT network.
- Early agreement on permits, road infrastructure, stops, charging stations, depots, and digital connection.
- Shared safety governance, comprising a supervisory model, incident management, and fallback procedures
- The procurement approach is aligned with operational roles, data sharing, and liability allocation.
- Structured cooperation throughout planning, testing, operation, and assessment.

SAV implementation is more than just a technology project. It requires a collaborative governance model that links mobility planning, operations, legislation, infrastructure, and public acceptance.

1.4.4. PPP, concession, turnkey and procurement models

SAV deployment requires procurement models that include both innovation risk and long-term public service needs. PTAs/PTOs should avoid only purchasing vehicles; the actual issue is how responsibility for technology, operation, monitoring, maintenance, data, safety, and service performance is distributed.

Key model options:

- *PPP model:* Useful when public authorities wish to share investment, innovation risk, and operational learning with private partners.
- *Concession model*: Relevant when a PTO/operator can take responsibility for service delivery within set performance and safety requirements.
- *Turnkey model*: Attractive for early deployment since vehicle, software, supervision, and maintenance may all be combined by one vendor.
- *Framework procurement*: Suitable for expanding beyond pilots and minimising recurring procurement efforts across areas or operators.
- *Service-oriented procurement*: Focuses on availability, reliability, safety, user experience, and integration rather than vehicle ownership.

The procurement model should correspond to the maturity of the technology, the local governance structure, and the intended path from pilot to scalable SAV service.

1.4.5. Key barriers and enablers for public authorities

Public authorities are central to scaling SAVs, but many are still transitioning from strategic interest to practical implementation. The primary difficulty is to provide the right conditions for deployment, including clear governance, regulatory confidence, feasible procurement models, infrastructural preparedness, and public acceptance.

Key barriers:

- Limited organisational capacity and technological expertise.
- Fragmented approval and regulatory procedures
- Uncertain allocation of roles, risks, and liabilities
- Weak business cases after pilot funding
- Infrastructure gaps include charging, depots, connectivity, and road readiness.
- Low public trust if citizens are not involved in the early stages.

Key enablers:

- Clear SAV action plans, with specified targets and KPIs
- Early PTA/PTO/city collaboration and stakeholder involvement.
- Procurement models that clearly assign risk and duties
- Evidence from Living Labs, digital twins, and operational data.
- Cross-border learning can help prevent isolated pilot approaches.
- Training and capacity building for public authorities

For public authorities, the key is to shift from "testing technology" to building the governance, procurement, and operational capacity required for scaling SAV services.

1.5. Stakeholders, flagship initiatives and ecosystem outlook

1.5.1. Leading organisations, consortia, projects and networks

Layer	Leading organisations / networks	Role in L4 public transport
Policy and R&I coordination	CCAM partnership / CCAM Association, European Commission DG MOVE / DG RTD / DG CNECT / CINEA / ERTRAC	Align EU research, pilots, impact assessment, safety, harmonisation, and deployment pathways. CCAM's stated goals include harmonising European R&I and exploiting safety, environmental and inclusiveness benefits of CCAM.
Knowledge and ITS networks	ERTICO – ITS Europe, ConnectedAutomatedDriving.eu, POLIS, Eurocities, UITP	Convene cities, operators, industry and researchers; disseminate pilots; shape urban deployment practice. ERTICO works across connected/automated mobility, urban mobility, clean mobility and logistics, and City Moonshot interviews cities on smart-mobility needs.
Public transport associations	UITP, VDV in Germany; national transit associations	Define operator needs, labour/social dialogue, service integration, funding and safety expectations. VDV's position is that autonomous scheduled services and self-driving shuttles can expand public transport and local distribution.
Transit operators / MaaS operators	HOCHBAHN, MOIA, Keolis, DB Regio Bus, PostBus, beti, BVG, MVG/SWMn local PTAs	Operate pilots and integrate autonomous fleets into booking, dispatch, depots, fares and public-service networks. ALIKE in Hamburg is operated by HOCHBAHN and MOIA as an autonomous-on-demand complement to bus and rail.
Research institutions	KIT, universities in Horizon projects, German Aerospace Center-type institutions, transport research labs	Safety validation, user acceptance, business models regulation, remote operations, infrastructure readiness. KIT is a partner in Hamburg's ALIKE autonomous ridepooling project.
Insurance / risk / certification	Macif, national approval bodies such as Germany's KBA, technical inspection/certification bodies	Enable permits, risk allocation, liability models and operating approval. The French Renault-WeRide-beti deployment includes Macif as insurer, while Germany's KBA has granted Level 4 testing approvals for specific public-transport vehicles.

1.5.2. Role of the SAV Innovation Alliance

The SAV Innovation Alliance serves as CAMINO-2's external co-creation and validation community. It brings together PTAs, PTOs, cities, operators, technology players, and expert organisations to guarantee that the SAV-BAP and SAV-IT are practical, transferable, and relevant across different NWE contexts.

Key roles:

- Provide real-world feedback on local and regional SAV deployment needs.
- Validate SAV-BAP from the standpoint of future users.
- Share knowledge in governance, procurement, regulation, and operations.
- Review Living Lab learnings and assess their transferability
- Support cross-border exchange and reduce fragmented pilot-by-pilot learning.
- Help prepare for greater adoption through the Ambassador Program.

The Alliance assures that CAMINO-2 outputs are not developed in isolation, but rather moulded by the wider ecosystem that will eventually use, adapt, and scale them.

1.5.3. Links with CCAM, UITP, NEXT-RIDE, etc.

CAMINO-2 should not stand alone but should connect actively with key European initiatives and networks focused on autonomous mobility and public transport innovation. These links help to ensure that project outcomes are in line with current policy discussions, sector needs, and emerging deployment techniques.

Key Links:

- CCAM Partnership / CCAM Ambassador: Connect CAMINO-2 outputs to the larger European CCAM deployment ecosystem.
- UITP Automated Mobility Working Group: validate findings with important public transport authorities and operators.
- NEXT-RIDE: establish a feedback loop between Living Lab outcomes and regional policy development.
- CAMINO-1 network: ensure continuity from strategic planning to operational execution.
- SAV Innovation Alliance: engage external PTAs/PTOs, cities, and experts in co-creation and validation.
- National and regional initiatives: facilitate transferability across various regulatory and operational environments.

These connections assist establish CAMINO-2 as a realistic link between European strategy, public transport policy, and real-world SAV deployment.

1.5.4. Outlook toward scalable SAV networks over the next decade

The European SAV market is transitioning from technological demonstrations to controlled operational deployment. The fundamental question is no longer whether autonomous shuttles can drive, but whether they can be incorporated into public transport systems using a sustainable operating model.

Key observations:

- The strongest near-term use cases include first and last-mile services, business parks, campuses, suburbs, and peri-urban regions.
- Integration with existing PT applications, DRT platforms, and MaaS systems will be essential.
- Remote supervision will only scale once ODDs, safety cases, incident procedures, and regulations have matured.
- Higher-capacity vehicles suggest a transition from niche pilots to larger transport-relevant services.
- The main bottlenecks are now operational: cost, procurement, safety assurance, staffing, charging, data, insurance, and public acceptance.

The next phase of SAV deployment will be won by players that successfully integrate technology, operations, governance, and business models to provide a reliable public transport service.

1.6. Implications for the SAV-BAP

The Shared Autonomous Vehicle Action Plan (SAV-BAP) serves as a dynamic decision-support framework designed to assist Public Transport Authorities (PTAs) and Public Transport Operators (PTOs) in moving from high-level ambition to structured deployment decisions. Rather than acting as a static strategy paper, the SAV-BAP functions as an adaptable, in-house planning tool that translates regional mobility landscapes into concrete, localized action plans.

As public transit actors look to integrate autonomous fleets, the SAV-BAP ensures that operational use cases, risk management, regulatory compliance, and procurement models are structurally aligned from the very beginning. This section outlines how the broader autonomous vehicle landscape shapes effective action planning, defines the core modules of the SAV-BAP framework, and establishes the priority questions that Living Labs must address to provide a robust, scalable evidence base.

1.6.1. What the landscape means for action planning

Public transport actors should begin with the use case, operational model, and scaling pathway rather than the supplier.

- Define the SAV use case before selecting technology.
- Avoid early single-vendor dependencies.
- Begin with controlled and scalable deployment environments.
- Build procurement and evaluation capacity early.
- Use pilots to generate operational proof rather than merely visibility.
- Plan vehicles, infrastructure, supervision, and operations together.
- Cooperate among authorities, operators, regulators, and providers.

The landscape points toward structured capability development: clear use cases, transparent assessment criteria, and a steady transition from pilots to operational SAV services.

1.6.2. Recommended BAP modules: goals, KPIs, roadmaps, risks, governance, procurement, stakeholder engagement

Module	What it is	Why we need that
Goals	A clear definition of the strategic objectives of deployments, such as closing mobility gaps, reducing driver dependency, improving service coverage or testing new operating models	To ensure pilots are not technology showcases, but directly linked to public transport priorities and political objectives
KPIs	A measurable performance framework covering safety, reliability, availability, passenger acceptance, cost, operational effort and scalability	To compare providers transparently, track progress objectively and decide whether a pilot is ready to scale
Roadmaps	A phased implementation plan from use-case selection and site preparation to pilot launch, evaluation, expansion and potential regular operation	To create realistic timelines, align dependencies and make scaling manageable across technology, operations, regulation and infrastructure
Risks	A structured assessment of technical, regulatory, operational, financial, reputational and acceptance-related risks	To identify critical barriers early and define mitigation measures before they delay or derail deployment
Governance	A clear decision-making and coordination model across the transport operator, city, regulator, technology provider, vehicle OEM and infrastructure partners	To avoid fragmented responsibilities and ensure fast, accountable decisions during planning, pilot operation and scaling
Procurement	A structured approach and framework to sourcing vehicles, SDS providers, operators, charging infrastructure, control-center solutions and integration services	To move beyond vendor claims, enable comparability and reduce lock-in through transparent requirements and performance-based selection
Stakeholder engagement	A plan for involving passengers, drivers, municipalities, regulators, unions, emergency services, accessibility groups and the public	To build acceptance, address concerns early and ensure the service fits real user needs and local operating conditions.

The SAV-BAP should translate the landscape analysis into a useful planning tool for PTAs and PTOs. Its modules are intended to assist public authorities in transitioning from ambition to structured deployment decisions. The BAP should be a decision-support framework rather than merely a strategy paper.

1.6.3. Priority questions for Living Lab partners

Living Labs should not only test vehicles, but generate comparable evidence for SAV-BAP and SAV-IT.

Priority Questions:

- What specific PT problem does the Living Lab address?
- What SAV use case is being tested: fixed-route, on-demand, mixed model, or depot automation?
- What are the ODD limitations, supervision needs, and safety driver requirements?
- Which governance model is used by the PTA, PTO, city, supplier, and regulator?
- Which procurement or PPP model is being tested?
- Which KPIs will demonstrate if the service is secure, useful, reliable, and scalable?
- What infrastructure is required, including charging stations, depots, connectivity, and a control centre?

- How do passengers, drivers, and local stakeholders participate?
- What evidence can be shared with other NWE regions?

Each Living Lab should produce practical lessons on what works, what hinders deployment, and what must be in place before scaling.

PART 2: PROJECT LEGACY OF THE CAMINO-1 PROJECT

2.1. Project overview and strategic objectives

What was CAMINO-1?

CAMINO, or CAMINO-1as we refer it to, stands for "Blueprinting Automated Mobility on-Demand Deployment for Sustainable Public Transport". The project was an initiative co-funded by the Interreg North-West Europe (NWE) programme and was spearheaded by a collaborative consortium led by the Municipality of Almere, which acted as the lead partner and Public Transport Authority (PTA) in the Netherlands. They were joined by De Lijn, a Public Transport Operator (PTO) based in Belgium, and the ROSAS research centre from Switzerland. To create practical, long-term deployment strategies for automated transport, the project actively leveraged the expertise of a network comprising 11 industry-leading associated organisations.

The problem statement

Public Transport Authorities and Public Transport Operators faced a growing obligation to provide sustainable, affordable, and accessible transport to meet the European Union's ambitious mandate of achieving a 90 per cent reduction in emissions by the year 2050. However, these organisations were confronted with severe, ongoing challenges, including shrinking budgets, rising fuel costs, demographic disparities, and persistent staff and driver shortages. Consequently, the overall provision of public transport was deteriorating, which in turn drove up private car ownership and led to higher greenhouse gas emissions across North-West Europe. While Automated Mobility on Demand (AMoD) offered a highly viable solution by reducing operational costs and providing a sustainable alternative that could lead to a modal shift of up to 42 per cent, transport authorities and operators lacked the necessary know-how to plan for the sustainable implementation of these concepts within their existing networks.

The goals

The primary goal of the CAMINO-1 project was to facilitate the widespread adoption of Automated Mobility on Demand to drastically improve public transport while simultaneously reducing car dependency and greenhouse gas emissions. To achieve this, the project focused on the following objectives:

- The project aimed to help PTAs and PTOs precisely define why, where, when, and how they should deploy connected, cooperative, and automated mobility concepts to enhance the long-term sustainability of their transport networks.

- A core objective was the joint development of two distinct, long-term implementation strategies, one tailored specifically for PTAs and another for PTOs, to serve as comprehensive blueprints for integration in North-West Europe.
- By establishing collaborative frameworks, assessing market expectations, simulating uptake scenarios, and evaluating readiness levels across technical, market, regulatory, user, and organisational domains, CAMINO-1 sought to ensure that future AMoD deployments would be effective, scalable, and replicable.

2.2. The stakeholder ecosystem

The CAMINO-1 consortium was structured around three core entities, each fulfilling a distinct role to ensure a comprehensive approach to Automated Mobility on Demand (AMoD). The Municipality of Almere in the Netherlands acted as the Lead Partner and Public Transport Authority (PTA), bringing expertise in urban transport planning. De Lijn, the Belgian Public Transport Operator (PTO), focused on the practical integration of automated technologies to improve service quality and operational efficiency. Meanwhile, the Swiss research centre ROSAS provided essential academic expertise in data analytics, security, and operational research. This core group was further supported by 11 Associated Organisations, which acted as advisory and knowledge-sharing bodies. To effectively deploy AMoD, both Almere and De Lijn relied on uniquely mapped collaboration frameworks involving various decision-makers, advisory bodies, and operational partners.

Almere

For Almere, internal key decision-makers included the Council of Almere, the Alderman, and the Public Transport Team, whilst external decisions involved regional bodies like the Metropoolregio Amsterdam and the Province of Flevoland. They were advised internally by departments such as Legal, City Planning, and Urban Development, and externally by organisations like CROW and ROVER. Operational implementation was facilitated by external transport operators, including DOVA, Keolis, Qbuzz, RET, and Transdev.

De Lijn

Conversely, De Lijn's key decision-making was driven internally by the De Lijn Board, alongside their Strategy, Market & Mobility, and Automated Driving departments. They received advisory support from internal divisions, such as Finance, ICT, and Insurance, as well as external Independent Safety Assessors and local city authorities. Their operational facilitation relied heavily on direct collaboration with Belgian technology suppliers.

Furthermore, the successful deployment of AMoD heavily depended on national authorities governing road safety and vehicle approvals:

- In the Netherlands (Almere): The primary national authorities were the RDW (National Vehicle Authority) and the Ministry of Infrastructure and Water Management (IenW). These authorities were responsible for overseeing the approval and safety compliance of automated vehicles, ensuring they met national and EU regulations, and issuing controlled pilot permits.
- In Belgium (De Lijn): The primary federal authority was the Federal Public Service (FPS) for Mobility and Transport. This authority played a crucial role in granting permits for operations on public roads, establishing national standards for vehicle safety, and determining certification and insurance requirements.

2.3. Implementation methodology and activities

The CAMINO-1 project employed a comprehensive methodology designed to help transport authorities and operators precisely define why, where, when, and how to deploy Automated Mobility on Demand (AMoD). The approach was grounded in evaluating high-impact use cases, establishing structured milestones through a Readiness Matrix, and building strong collaborative frameworks.

The Almere case study

A prime example of this methodology was the Almere case study. The municipality utilised a 'Virtual Pilot' approach to investigate potential scenarios for future market development. The specific activities carried out for this case study included:

- Conducting interactive workshops to brainstorm and define potential futures.
- Executing demand forecasting and network analysis to optimise the proposed routes and service models.
- Gathering citizen feedback through a quantitative survey in late 2022 to gauge public reception and expectations.
- Reviewing the findings with urban planners and mobility experts in early 2023 to finalise three distinct deployment scenarios. These ranged from an evolutionary adaptation of the current system to a revolutionary overhaul featuring a dynamic network of automated buses.
- Ultimately, the case study focused on the Almere Hout district, exploring how small automated shuttles could provide crucial first- and last-mile connectivity to the main Bus Rapid Transit (BRT) network in a low-density, underserved area.

Key activities and reports

Throughout the project, the consortium carried out various activities and produced several key reports to support the final deployment strategies:

- **AMoD Use Case Design Methodology (D.1.1.2):** A guide created to assist organisations in defining, designing, and evaluating potential AMoD use cases by aligning service models and deployment areas with local mobility needs.
- **AMoD Use Case Readiness Matrix Report (D.1.2.1):** A strategic tool that assessed implementation milestones across five domains (technical, market, regulatory, user, and organisational readiness), using a 9-point Innovation Readiness Level scale.
- **Collaboration frameworks (D.1.3.1):** Detailed stakeholder mapping documents for both authorities and operators that clarified the roles of internal decision-makers, external advisory bodies, and facilitating partners.

- **Budget and resources guides (D.1.3.2 & D.1.3.3):** Comprehensive overviews outlining the necessary capital expenditure (CAPEX), operational expenditure (OPEX), digital infrastructure, and human resources required for successful deployment.
- **Terminal project summary paper (D.1.1.3):** An analysis of best practices and lessons learned from the prior Interreg Greater Region TERMINAL project, which focused on the legal and technical hurdles of cross-border automated vehicle pilots.
- **Knowledge sharing and engagement:** The project actively engaged its network of Associated Organisations through structured online seminars, roadmapping workshops, and conference presentations, such as the Urbanism Next Europe 2024 conference in Amsterdam.
- **Final implementation strategies (Outputs 1.1 & 1.2):** The culmination of the project resulted in jointly developed, long-term implementation strategies tailored specifically for Public Transport Authorities and Public Transport Operators across North-West Europe.

2.4. Outcomes and lessons learned

Outcomes

Utilising the aforementioned tools, the project successfully produced two distinct, long-term implementation strategies, highlighting the different roles required for successful AMoD integration.

The blueprint for Public Transport Authorities (PTAs)

The PTA strategy focused heavily on their shift from mere service regulators to mobility innovators. Their primary goal in deploying AMoD was to secure the sustainability and accessibility of their networks, particularly to maintain coverage in low-density, underserved neighbourhoods without proportionally increasing costs. The implementation plan was divided into four phases:

- Phase 1: PTAs defined the exact role of AMoD (e.g., improving first/last-mile connectivity) and conducted feasibility studies examining local demand, technology readiness, and regulatory gaps.
- Phase 2: Authorities brought together stakeholders to align goals, and then prepared tenders to find service and technology partners, clearly outlining service standards and integration requirements.
- Phase 3: PTAs identified where upgraded infrastructure was needed, such as AMoD-compatible streets, pick-up/drop-off zones, and charging stations, and ensured integration with Mobility-as-a-Service (MaaS) platforms and unified payment systems.
- Phase 4: Results from initial pilots were analysed using key performance indicators (like modal shift and emissions reduction) to refine the service design, adjust regulations, and plan a gradual scale-up.

While PTAs did not typically purchase the vehicles, they were responsible for infrastructure development, digital integration, structuring public-private partnerships, and providing fixed-per-kilometre subsidies to operators for running the automated vehicles.

The blueprint for Public Transport Operators (PTOs)

The PTO strategy was highly focused on operational execution, safety, and fleet management. For operators, investing in AMoD was a strategic necessity to reduce reliance on fixed routes and mitigate persistent driver shortages, considering labour accounted for approximately 70 per cent of their operational costs. Their implementation plan spanned five phases:

- Phase 1: Operators conducted needs assessments to identify high-demand areas, performed cost-benefit analyses comparing AMoD to traditional transport, and selected technology partners.
- Phase 2: Operators conducted needs assessments to identify high-demand areas, performed cost-benefit analyses comparing AMoD to traditional transport, and selected technology partners.
- Phase 3: The AMoD service was tested in a controlled, limited geographic area where the PTO monitored safety metrics, collected user feedback, and evaluated operational costs.
- Phase 4: Service coverage was expanded to more routes, scaling infrastructure and working with stakeholders to foster public acceptance.
- Phase 5: Operators tracked key metrics continuously, adjusted pricing models for financial health, and explored green energy usage to ensure sustainability.

Operators bore the heavy initial Capital Expenditure (CAPEX) for vehicle acquisition, depot upgrades, and technology setups. To manage this, their strategy involved developing multi-year investment frameworks, securing co-financing from European innovation funds, and creating "resilience funds" to buffer against early-stage deployment risks like technical failures or regulatory delays.

Lessons learned

Through the analysis of previous cross-border trials (like the INTERREG TERMINAL project) and practical case studies like the Almere 'Virtual Pilot', the consortium uncovered several harsh realities regarding autonomous transport.

Regulatory and legal bottlenecks

Securing legal approval for automated vehicles remained a complex and time-consuming process. In cross-border contexts, there was a complete lack of mutual recognition for vehicle approvals between neighbouring countries, highlighting the desperate need for unified European regulatory frameworks.

Technological immaturity vs. economic reality

The market was not as mature as anticipated for higher-speed, longer-distance Level 4 automated driving. Economically, the project deduced a critical reality: AMoD cannot be financially viable as long as a human safety driver must remain inside the vehicle. Profitability strictly depended on achieving Level 4 autonomy, where a single remote supervisor could oversee a fleet of vehicles simultaneously.

Nuances in user acceptance

Passengers' feelings of safety were not negatively impacted by higher driving speeds; in fact, speed positively affected their willingness to use the service for longer rides. Vehicle comfort played a more significant role in user satisfaction than the novelty of the automation. However, poor spatial and temporal flexibility (e.g., infrequent schedules) acted as a massive barrier to adoption.

The value of virtual piloting

The Almere case study demonstrated that authorities did not need to wait for perfect technology to begin planning. By utilising a "Virtual Pilot" accompanied by quantitative modelling and citizen surveys, the municipality successfully kick-started essential discussions with urban planners, proving that evaluating future scenarios early on was crucial for future-proofing infrastructure.

2.5. CAMINO-1 to CAMINO-2

Relevance of CAMINO-1 for CAMINO-2

The primary relevance of CAMINO-1 is that it successfully established the structural groundwork required for deployment. By producing long-term implementation strategies, identifying specific operational and capital costs, and mapping out the necessary stakeholder ecosystems, Phase 1 provided the exact tools needed to overcome the outdated partnerships and fragmented regulations that currently block Shared Automated Vehicle (SAV) adoption.

Consequently, CAMINO-2 can bypass preliminary planning and focus entirely on bridging the gap between strategic intent and real-world deployment for the 45 North-West Europe (NWE) public transport actors it targets.

Strategic integration

To ensure seamless continuity, the outputs from CAMINO-1 should act as the direct starting points for the three main tasks of CAMINO-2:

Developing the SAV Blueprint Action Plan (SAV-BAP)

- **Integration:** The flexible planning template (SAV-BAP) being co-created for transport authorities should be fundamentally built upon the CAMINO-1 Use Case Design Methodology.
- **Application:** When setting goals and defining key performance indicators for local action plans, authorities should utilise the CAMINO-1 Readiness Matrix to baseline their starting points across technical, market, regulatory, user, and organisational domains.

Validating in living labs & creating the SAV-IT

- **Integration:** The four real-world Living Labs across Belgium, Germany, France, and the Netherlands can directly utilise the CAMINO-1 Collaboration Frameworks to structure the new Public-Private Partnership (PPP) models they intend to test.
- **Application:** As these pilots navigate diverse settings (from automated bus depots to on-demand suburban services), they should rely on the CAMINO-1 Budget and Resources Guides to forecast and manage procurement, operational expenditures, and capital investments. The practical findings from these pilots will then naturally evolve Phase 1's theoretical strategies into the highly practical SAV Implementation Toolkit (SAV-IT).

Scaling through the Ambassador Programme

- **Integration:** The 21 participants selected for the Ambassador Programme must be thoroughly trained using the original PTA and PTO long-term implementation strategies developed in CAMINO-1.
- **Application:** Providing these regional multipliers with the Phase 1 strategic blueprints, alongside the newly developed SAV-BAP and SAV-IT, will ensure they possess both the historical context and the practical tools required to confidently lead the replication and long-term deployment of SAV solutions across the wider NWE territory.

PART 3: CONCLUSION

The foundation built by CAMINO-1

The CAMINO-1 project successfully established the structural groundwork required for Shared Automated Vehicle (SAV) deployment across North-West Europe. By moving beyond theoretical visions, the project delivered distinct, long-term implementation strategies tailored for both Public Transport Authorities (PTAs) and Public Transport Operators (PTOs). Key outcomes included the realisation that Automated Mobility on Demand (AMoD) cannot achieve financial viability as long as a human safety driver is required, making the pursuit of Level 4 autonomy a strict economic necessity. Furthermore, CAMINO-1 demonstrated the critical value of "Virtual Piloting", proving that authorities can and should begin future-proofing infrastructure and planning network integrations long before the technology reaches perfect maturity.

Remaining implementation gaps

Despite the strategic blueprints provided by CAMINO-1, the transition from isolated pilot schemes to large-scale, operational SAV networks is currently being held back by a number of issues. In order to bridge the gap between strategic intent and real-world deployment, the following limitations must be addressed:

- Limited organisational capacity within PTAs/PTOs to plan and manage SAV deployment.
- Fragmented regulatory and approval procedures across NWE countries.
- Unclear procurement pathways for SAV technology, service operation, and turnkey models.
- Weak evidence on viable business models and cost-sharing between public and private actors.
- Insufficient real-world data on safety, user acceptance, service quality, and operational performance.
- Need for better integration of SAVs into existing public transport networks, ticketing, DRT platforms, and depots.
- Lack of common tools to compare pilots and translate lessons into scalable implementation plans.

Where Europe must act

If Europe is to remain competitive with the rapidly maturing autonomous ecosystems in the United States and China, it must fundamentally shift its approach. The current European landscape is characterised by a fragmented set of isolated solutions and small-scale pilot initiatives that lack long-term viability and consolidation of learnings.

To move forward, European action must focus on harmonising legislative frameworks to eliminate the cross-border complexities that currently discourage global market players and impede scaling. Furthermore, public financing and procurement mechanisms need to evolve from subsidising cautious, short-term demonstration projects to incentivising ambitious, scalable public transport solutions. Ultimately, the primary question for Europe is no longer whether autonomous shuttles can drive, but whether the ecosystem can build the collaborative governance, regulatory mutual recognition, and sustainable business models required to integrate them reliably into daily public transport.