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D5.1 Report analysing the impact of CCAM on each use case

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Abbreviations

Abbreviation	**Definition**
ADAS	Advanced Driver Assistance Systems – In-vehicle systems that provide safety and convenience functions (e.g. lane-keeping, adaptive cruise control) to assist the driver.
ADS	Automated Driving System – The hardware and software that enable a vehicle to drive itself autonomously (often referring to the self-driving technology stack).
AGV	Automated Guided Vehicle – A portable robot or driverless vehicle used to move materials or perform tasks, commonly in industrial or logistics settings (e.g. autonomous cargo movers in ports).
AI	Artificial Intelligence – Computer systems or algorithms able to perform tasks that typically require human intelligence, such as perception, decision-making, and learning.
AR	Augmented Reality – Technology that overlays digital information (images, data, etc.) onto the real-world environment, often through devices like smart glasses or mobile screens.
AV	Autonomous Vehicle – A self-driving vehicle capable of operating without a human driver by using sensors, cameras, and AI to navigate. (In this report, often referring to vehicles with high automation, such as SAE Level 4 vehicles.)
CCAM	Connected, Cooperative, and Automated Mobility – An umbrella term for next-generation transport systems where vehicles are connected (able to communicate with each other and infrastructure), cooperate with traffic management, and have automated driving capabilities.
CCAM-ERAS	*CCAM – Employment Realization through the Acquisition of Skills* – The name of the European project under Horizon Europe focusing on the workforce and skills aspects of CCAM deployment (this project produces Deliverable D5.1).
DRT	Demand-Responsive Transport – Flexible transport services (often shared shuttles or minibuses) that adjust routes and schedules based on real-time demand rather than following a fixed line, used to improve coverage in low-demand areas.
EU	European Union – A political and economic union of 27 member states in Europe, which funds and regulates many transport and research initiatives relevant to this report.

Abbreviation	**Definition**
GDPR	General Data Protection Regulation – The EU's strict data privacy and protection law, which governs how personal data (including data from connected vehicles and sensors) must be handled and protected.
LiDAR	Light Detection and Ranging – A sensor technology that uses laser light to measure distances and create precise 3D maps of the environment; commonly used by autonomous vehicles for detecting obstacles and surroundings.
MaaS	Mobility as a Service – An integrated transport model where users can plan, book, and pay for multiple types of mobility services (public transit, ride-sharing, bike rental, etc.) through a single digital platform.
MODI	Name of an EU project demonstrating automated heavy-haul vehicles and trucking corridors. The MODI project focuses on real-world trials of autonomous freight transport (e.g. between Rotterdam and other hubs) to identify and address barriers to deployment.
ODD	Operational Design Domain – The specific conditions under which an automated driving system is designed to function. The ODD defines the environment and scenarios (such as types of roads, weather, speed range) where the vehicle can operate in autonomous mode.
PESTLE	Political, Economic, Social, Technological, Legal, and Environmental – An analytical framework used to examine the external factors affecting a project or industry. (In this context, a PESTLE analysis was conducted to understand the broader context for CCAM.)
SAE	Society of Automotive Engineers – Refers here to the **SAE International** standard J3016, which defines levels of driving automation from 0 (no automation) to 5 (full automation). For example, *SAE Level 4* indicates a high level of vehicle autonomy within set conditions.
TRL	Technology Readiness Level – A scale (from 1 to 9) used to assess the maturity of a technology, with 1 being early research and 9 being fully proven in real operational conditions. Higher TRL (e.g. 7–8) means the technology has been demonstrated in real-world pilots.
ULTIMO	Urban Logistics and Transport Innovation through Modular Operations – A Horizon Europe project aimed at deploying large-scale, on-demand autonomous public transport services (autonomous shuttles) in cities by 2025–2030.
V2I	Vehicle-to-Infrastructure – A form of connected vehicle communication where a vehicle exchanges data with road infrastructure (traffic lights, road sensors, etc.) to improve safety and coordination.

Abbreviation	Definition
V2V	Vehicle-to-Vehicle – Direct communication between vehicles, enabling them to share information like speed or alerts to prevent collisions and coordinate movement.
V2X	Vehicle-to-Everything – A broad term for vehicle communication with any relevant entity, including other vehicles (V2V), infrastructure (V2I), pedestrians or networks. V2X connectivity supports cooperative driving and informed decision-making by automated vehicles.
VR	Virtual Reality – An immersive technology that simulates a complete digital environment, often experienced through VR headsets. (Used in training or visualization, e.g. to simulate driving scenarios for operator training.)
WP	Work Package – A component of a research or innovation project that groups related tasks and deliverables. (For example, *WP5* in CCAM-ERAS refers to the project phase dealing with skills development and workforce adaptation.)

Executive summary

This deliverable, **D5.1: Report analysing the impact of CCAM on each use case**, presents a comprehensive assessment of the socio-economic impacts, skill mismatches, and workforce transformation challenges associated with the deployment of Connected, Cooperative, and Automated Mobility (CCAM) across multiple transport-related use cases. It forms part of the CCAM-ERAS project's aim of understanding how automation and connectivity will affect employment, skills, and operational models in the transport and mobility sector.

Scope of Use Cases: The analysis covers six representative use cases in mobility, each illustrating different aspects of CCAM deployment: (1) **Ground transportation for last-mile delivery**, (2) **Bus depots**, (3) **Ports and terminals**, (4) **Public shared transport**, (5) **Private shared transport**, and (6) **Shared transport targeting specific user groups**. For each scenario, the report examines the expected changes to business operations and logistics, the impacts on workforce structure and job roles, relevant policy and regulatory considerations, and broader societal implications. In addition, it identifies emerging job roles and skill requirements, highlighting where upskilling or reskilling will be necessary as traditional roles evolve.

Key Findings Across Use Cases: Despite the diversity of these six use cases, several common themes and conclusions emerge:

- **Workforce Transformation:** CCAM adoption is projected to **transform the workforce rather than simply reduce it**. In all scenarios, certain routine or physical tasks can be automated, but new roles are appearing in their place. A recurring finding is the **emergence of hybrid roles** that blend physical duties with digital oversight and remote supervision. For example, in last-mile delivery pilots, autonomous vans handle driving while human couriers focus on final hand-offs to customers, creating jobs like **remote fleet supervisors** instead of traditional drivers. In bus depots, staff may transition from driving buses to managing automated systems and ensuring vehicles connect to chargers or wash stations. Similarly, ports are seeing roles shift from manual cargo handling to overseeing fleets of autonomous trucks and managing digital logistics systems. Across all use cases, **front-line workers will need more technical skills** (such as managing vehicle software or data feeds) alongside their domain knowledge, signaling a move toward a more tech-savvy transport workforce.

- **Skill Gaps and Mismatches:** With these new hybrid and technical roles emerging, the report highlights a risk of **skills mismatches** if the current workforce is not prepared. Many existing workers may lack the IT, data analysis, or advanced technical skills that CCAM systems demand. For instance, professional drivers and equipment operators might need training in monitoring autonomous systems, interpreting sensor data, or handling exceptions when the automated system encounters something unexpected. Without intervention, this could lead to unfilled jobs on the one hand and displaced workers on the other. The **upskilling and reskilling needs** are significant in all use cases – from training depot mechanics to service new autonomous fleets, to teaching port logistics staff how to work with AI-driven decision support systems. Proactive measures

are needed to bridge the gap between **current workforce capabilities and future job requirements**.

- **Regulatory and Operational Challenges:** Deploying CCAM solutions at scale faces notable **regulatory hurdles and operational uncertainties**. Each use case reveals some regulatory challenge that must be addressed for smooth implementation. For example, **safety and liability regulations** are still evolving for autonomous delivery vehicles on public streets and for driverless shuttles in public transport. Bus depots and port automation projects often operate in confined environments or pilot programs, highlighting the need for clear standards and legal frameworks to move beyond experimental phases. Additionally, issues such as data privacy (e.g. **GDPR** compliance for vehicles collecting data), cybersecurity, and insurance for autonomous operations require coordinated policy responses. The report emphasizes that without updated regulations and harmonized standards, CCAM deployment could be uneven – with some regions forging ahead while others lag due to legal uncertainty. **Operational best practices** are also still being defined: stakeholders must establish protocols for integrating autonomous systems with existing traffic, emergency fallback procedures, and cross-compatibility between different vendors' technologies. These challenges underscore the role of policymakers and industry bodies in creating an enabling environment for CCAM.

- **Opportunities and Benefits:** Alongside the challenges, CCAM technologies offer significant **opportunities for improved efficiency, safety, and service quality**. In last-mile logistics, autonomous vehicles can operate longer hours (potentially 24/7) and reduce costs for deliveries, while also cutting emissions if they are electric. In public transport, automated shuttles and buses could extend mobility to underserved areas (such as rural communities or off-peak times) through demand-responsive services, improving inclusion and convenience. Ports and freight hubs can benefit from smoother, around-the-clock operations as autonomous trucks and equipment reduce bottlenecks. **Safety improvements** are expected as well – removing human driver fatigue and error from certain operations could lower accident rates. Each use case demonstrated some early **deployment success** – for instance, pilot projects have shown that autonomous shuttles can reliably supplement public transit, and automated yard vehicles can work in busy terminal environments. These successes point to opportunities to scale up CCAM deployment, bringing wider benefits in productivity and customer experience. The report's findings suggest that if managed well, automation can augment human work (handling repetitive or dangerous tasks) and allow workers to focus on higher-value or customer-facing activities, thereby enhancing overall service delivery.

- **Need for Proactive Planning:** A major conclusion of the report is that **proactive planning and support are vital to harness CCAM benefits while mitigating disruptions**. The transition to automated mobility will not happen smoothly on its own; it requires deliberate strategies by both public authorities and industry leaders. The report highlights the strategic importance of investing early in **training programs, education curricula, and certification frameworks** to prepare the workforce for new CCAM-related roles. For example, developing modular training courses on vehicle teleoperation or data analytics for transport can help upskill current employees. Engaging in **public-private partnerships** is recommended – such as collaborations between tech companies, transport operators, and vocational institutes – to design relevant training and apprenticeship opportunities. Moreover, **policy support** at the government level is critical: this includes updating transport regulations, providing funding or incentives for CCAM pilot projects and infrastructure (like V2X communication networks), and setting safety standards that all operators must follow. By planning ahead with a focus on **workforce transition strategies** (e.g. creating new career pathways for affected drivers or port workers) and **inclusive policies**, stakeholders can ensure that the adoption of automation is as smooth and equitable as possible.

In summary, Deliverable D5.1 finds that CCAM deployment will **profoundly reshape mobility jobs and services**, but with careful preparation it can be a positive transformation. The report calls for early and coordinated action so that Europe's transport workforce is not left behind. It stresses that **strategic foresight and investment now** – in skills development, regulatory clarity, and stakeholder coordination – will pay off in a **smoother transition** to automated mobility. By mapping out emerging roles and competencies needed, and by identifying the gaps and challenges across these six use cases, the report provides a foundation for targeted actions. Ultimately, this executive analysis underlines that **human capital and supportive policy** are as important as technology in realizing the full benefits of automated transport, ensuring a future where automation and the workforce advance together seamlessly.

Contents

1 Introduction

This report forms part of the CCAM-ERAS project's broader effort to assess the socio-economic implications of deploying CCAM technologies in real-world transport environments. Deliverable D5.1 specifically contributes to Work Package 5 by analysing the **impact of CCAM on employment, operations, and skill requirements** across six key mobility use cases:

- last-mile delivery,
- bus depots,
- ports and terminals,
- public shared transport,
- private shared transport, and
- shared transport for specific user groups.

The findings presented in this report build upon the earlier work carried out in **Work Package 3 (CCAM Scan and Innovation Radar)** and **Work Package 4 (Analysis of the Effects of CCAM)**. WP3 helped define the operational characteristics, automation levels, and deployment conditions of each use case, while WP4 provided a detailed understanding of the existing workforce profiles and emerging skill gaps.

The analysis draws on several key internal documents, including:

- Deliverable D3.1 *CCAM-Scan PESTLE analysis report*
- Deliverable D3.3 *Final selection of use cases*
- Deliverable D4.5 *Skills foresight report* (internal draft, to be completed January 2026)

Where relevant data or detail was unavailable in these sources, supplementary literature and policy reports were consulted to fill specific gaps. All external references used in the analysis are cited throughout this document and included in the reference list.

In addition, targeted **interviews with key stakeholders involved in pilot deployments** were conducted to enrich the analysis with real-world operational insights, practical barriers, and organisational strategies.

Each use case is analysed across two primary dimensions:

1. **Impact of CCAM** – Including business models, operational challenges, economic and regulatory drivers, and societal implications.
2. **Skills needs and mismatches** – Examining job transformations, skill gaps, upskilling/reskilling needs, institutional readiness, and labour market dynamics.

Additionally, to understand the labour market implications of CCAM deployment on the use cases, the 'skills needs and mismatches' dimension applies a brief SWOT analysis focused on emerging professional roles and skill requirements. The objective is to identify internal strengths and weaknesses within CCAM-enabled delivery systems, as well as external opportunities and threats that may influence workforce readiness and economic development. This approach aims to support policymakers in anticipating the types of training, support, and structural changes needed to align workforce capabilities with the evolving demands of automated logistics.

The primary objective of this deliverable is to analyse the impacts of CCAM across the selected use cases, specifically examining their implications for employment, skills requirements, and workforce transformation. It aims to provide clear, actionable guidance to policymakers, educational institutions, industry stakeholders, and employers to facilitate targeted reskilling and upskilling activities that align with emerging labour market demands.

This work contributes directly to Work Package 5 (WP5) of the CCAM-ERAS project, which focuses on developing concrete schemes and actions to anticipate and address evolving skill needs associated with CCAM deployment. By using a detailed use-case approach, this deliverable explores real-world scenarios that reflect the diverse challenges and opportunities presented by CCAM technologies. The analysis not only assesses the immediate and long-term implications of CCAM for the labour market but also identifies specific skills mismatches and gender gaps, providing foundational insights for subsequent educational and training initiatives.

Through combining desk research, stakeholder consultations, and real-world pilot insights, this report establishes a base to support the development of educational policies, training programmes, and employment strategies. Ultimately, it provides practical guidance for ensuring that the deployment of CCAM solutions across Europe effectively meets both current and future workforce requirements.

2 Ground transportation for last mile delivery

Ground Transportation for Middle- and Last-Mile Delivery focuses on the deployment of **autonomous utility vehicles** for the distribution of **parcels and groceries** in **urban and peri-urban** environments. This freight-focused application falls within the broader **CCAM theme of automated logistics** and is currently being demonstrated under the **LOXO project**,[1] in collaboration with the Swiss Association for Autonomous Mobility (**SAAM)**. The LOXO project demonstrates a novel approach to middle- and last-mile logistics by deploying autonomous delivery vehicles in real urban environments. One active pilot in Bern, Switzerland, exemplifies this approach: parcels arriving at a city depot by train are transferred to an autonomous vehicle, which navigates to 13 distribution points across city neighbourhoods. At each location, the vehicle meets with a human delivery driver—typically using a scooter and trailer—who collects and delivers the parcels. This cooperative model ensures that human resources focus on direct delivery tasks while the vehicle handles repetitive urban navigation and inter-neighbourhood transport.

LOXO vehicles are designed to operate autonomously at speeds of up to 60km p/h, under typical urban traffic conditions, adhering to standard rules such as speed limits, stop signs, traffic lights, pedestrian crossings, etc. Utilising advanced sensing technologies, including LIDAR; radar; ultrasonic sensors; and cameras, they maintain comprehensive, 360-degree situational awareness. The vehicles are currently classified as SAE Level 4,[2] which indicates full driving automation within specific, predefined operational design domains (ODDs). In this case, the vehicles are capable of navigating mapped urban environments without requiring human input under normal conditions. Human intervention is not expected during standard operation, although remote monitoring and fallback mechanisms are maintained to manage exceptions or unexpected events. At Technology Readiness Level (TRL) 7,[3] they have been successfully demonstrated in real-world environments, though remote supervision remains available for unblocking the vehicle in unpredictable scenarios.

The autonomous delivery vehicle will communicate with some traffic management infrastructures, enabling dynamic routing and enhanced traffic coordination. The vehicle is loaded manually and equipped with an electric winch mechanism capable of handling containers up to 200 kg. Supervision is handled remotely, with one remote supervisor overseeing the vehicle. In the end, the idea is to have this one remote supervisor overseeing up to ten vehicles and stepping in only when needed. For example, temporary road obstacles or else.

This deployment specifically targets dense urban zones, offering scalable, low-emission alternatives to traditional delivery systems. It also highlights important prerequisites for broader implementation, including reliable connectivity, regulatory clarity, standard operating procedures, and stakeholder alignment. Essential stakeholders, including vehicle manufacturers, logistics companies, municipalities, service providers, and regulatory bodies, play critical roles in coordinating efforts to ensure the safe and seamless integration of this technology into existing urban logistics ecosystems.

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[1] See: https://www.loxo.ch/en/

[2] For explanation of SAE levels, see: https://www.sae.org/blog/sae-j3016-update

[3] For explanation of TRL levels, see: https://euraxess.ec.europa.eu/career-development/researchers/manual-scientific-entrepreneurship/major-steps/trl

2.1 Impact of CCAM

2.1.1 Business model and operation concept

The business model of the first business case revolves around providing an **autonomous freight transport service as a last/middle-mile delivery solution** for the delivery of parcels and groceries. The use case is led by SAAM and is based on the experience of their partner LOXO who already provides the autonomous delivery service.

LOXO's business model centers on providing autonomous delivery as a service to commercial partners, either through its own vehicles (like the LOXO Alpha) or via its LOXO Digital Driver (LDD) software integrated into client fleets.[4] In practice, LOXO works B2B/B2B2C: retailers and logistics firms deploy LOXO's self-driving vehicles to carry goods to end customers. For example, in early 2023 **LOXO partnered with Swiss retailer Migros and elevator manufacturer Schindler to launch "Migronomous," delivering groceries from a Migros store to the Schindler campus for employees**.[5] In this pilot, Migros staff loaded orders into the LOXO Alpha, which then autonomously shuttled them ~500 m to Schindler's site, where employees retrieved their items from locked compartments using access codes. The LOXO Alpha vehicle can carry **up to 64 shopping bags** per trip and travels at safe low speeds (up to ~30 km/h) for urban operations.

LOXO's delivery format is versatile, handling groceries (as with Migros) and parcels in logistics networks. In late 2024, LOXO and Swiss logistics company Planzer launched the "Dynamic Micro-Hub" pilot in Bern, targeting parcel distribution.[6] This pilot repurposes a VW ID.Buzz van equipped with LOXO's autonomous tech to ferry parcels from a rail depot to 13 **exchange points around the city, where smaller electric carts take over final deliveries**.[7] Through such collaborations, **LOXO's operation concept emphasizes integration with existing supply chains**: its vehicle function as mobile hub or last-mile shuttle that complement traditional delivery teams rather than replacing them outright.[8]

In terms of offerings, LOXO's business model is delivered via a subscription or "autonomy-as-a-service" approach. Clients can **subscribe to the LOXO Digital Driver software platform or procure fully integrated autonomous vehicles (vehicle + LDD)**. This flexible model means a company might retrofit its own fleet with LOXO's self-driving system or opt to use LOXO's ready-built vehicles. Pricing details are not publicly disclosed, but the service model implies recurring fees (for software licensing or vehicle leasing) rather than one-off sales. Notably, **LOXO positions its solution as a way to automate deliveries cost-effectively** – for instance, one LDD license can potentially replace a human driver's labour on repetitive routes. While **per-delivery pricing is not explicitly advertised, pilot programs have been framed in terms of service partnerships** (e.g. Migros paying for a pilot service to its campus, Planzer co-developing a new logistics concept) rather than charging individual end-users. This B2B focus allows LOXO to refine its technology in controlled commercial use cases before broader deployment. **Overall, LOXO's operation concept is a cooperative model: working with retail and logistics partners (Migros,**

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[4] See: https://www.loxo.ch/en/

[5] See: https://retail-optimiser.de/en/migros-pilots-autonomous-delivery-with-loxo/

[6] See: https://www.saam.swiss/projects/dynamic-micro-hub-w-loxo/

[7] See: https://www.saam.swiss/projects/dynamic-micro-hub-w-loxo/

[8] See: https://www.parcelandpostaltechnologyinternational.com/features/feature-addressing-middle-mile-challenges-with-autonomous-delivery.html

Schindler, Planzer, etc.) to fill specific last-mile needs – such as grocery drop-offs or parcel shuttling – using autonomous electric vehicles on a subscription/service basis.[9] The showcase LOXO Alpha vehicle's design (compact size, modular compartments, customer code interface) further supports these use cases by enabling multi-stop, multi-customer rounds in urban areas.

2.1.2 Expected benefits and impact of CCAM technology on the use case

LOXO's autonomous delivery solution promises several concrete benefits, combining efficiency, safety, and sustainability in last-mile logistics. First, the electric LOXO Alpha vehicles produce zero tailpipe emissions, directly contributing to lower urban air pollution and CO_2 reductions. By replacing conventional diesel vans for local deliveries, a single LOXO vehicle can eliminate significant emissions over time; **LOXO's founders highlight that one Alpha can carry dozens of grocery orders (up to 64 bags) at once, which has "huge potential to reduce private traffic," as fewer customers need to drive to stores**.[10] The vehicles are also designed for **continuous 24/7 operation**, since they do not require driver shift changes or breaks. This round-the-clock capability means orders can be delivered during off-peak hours or overnight, improving delivery speed and asset utilisation. (For example, an autonomous van could do late-night grocery runs or multiple parcel trips per day, which a human-driven service might struggle to staff.) In the Planzer-LOXO pilot, the autonomous van runs **several trips daily across a 67 km urban route network**, demonstrating the potential for high-frequency, on-demand logistics.[11]

Another key expected benefit is **enhanced safety and reliability** in delivery operations. LOXO vehicles use an advanced sensor and software suite to mitigate accidents: **each autonomous vehicle is fitted with at least six cameras, four LiDAR units, one radar, and dozens of ultrasonic sensors to monitor its surroundings**. The sensor data feeds into a redundant AI "driver" system – **LOXO's software employs two parallel algorithms (the primary AI, called Loxo Fuser, and a secondary co-pilot called Loxo Guard) running simultaneously to detect and react to hazards**. This dual-layer autonomy, combined with a remote human supervisor as a final fallback, creates **triple redundancy for safety**.[12] In practice, the LOXO vehicle drives conservatively (limited to ~45 km/h) and can perform emergency stops if obstacles are detected, aiming to minimise risk to pedestrians and cyclists in mixed traffic. Early results have been promising – during the **Migronomous pilot, the LOXO Alpha operated on public roads without any safety incidents reported, gradually increasing its autonomous operation time** (initially with a chaperone, later fully driverless). This suggests that with its sensor-rich platform and cautious driving profile, LOXO's system can safely navigate real urban environments (including complex scenarios like busy crossings or cycling traffic in Bern).

Beyond safety and environmental gains, **LOXO's approach offers efficiency and economic benefits**. Autonomous vehicles can be deployed to match demand dynamically – for example, the system can be routed in real time to optimise deliveries, and vehicles can serve multiple neighbourhoods without downtime. In general, **by automating the transport leg of delivery, companies can address driver shortages and potentially reduce labour costs**, while redeploying human couriers to value-added tasks (like customer service on the doorstep). Moreover, LOXO's electric fleet contributes to noise reduction (the quiet electric motors are less

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[9] https://www.circuit.press/posts/loxo-launches-first-international-subsidiary-in-germany

[10] See: https://www.s-ge.com/en/article/news/20231-mobility-loxo-introduces-first-driverless-delivery-switzerland?ct

[11] See: https://www.loxo.ch/en/news/revolutionizing-urban-logistics-with-autonomous-micro-hubs

[12] See: https://www.parcelandpostaltechnologyinternational.com/features/feature-addressing-middle-mile-challenges-with-autonomous-delivery.html

disruptive in residential areas). Finally, the high-tech image of autonomous deliveries can have a positive marketing impact for partners like Migros or Planzer, signalling innovation and improved service quality (e.g. more flexible delivery times).

2.1.3 Challenges and barriers to use case deployment

LOXO's deployment faces significant challenges and barriers, especially regarding regulations, operational constraints, and technology limitations. A primary challenge is navigating the **regulatory approval process** in different countries. In Switzerland, LOXO's home base, there was no comprehensive legal framework for driverless vehicles on public roads until recently. This meant working closely with local authorities to get permission for each pilot zone. The lack of national regulation created uncertainty and uneven requirements (i.e. **local vs. national permission hurdles**, where a city might green-light a trial under strict oversight, but expansion to multiple regions awaited federal rules). Only in 2025 is Switzerland enacting a new ordinance (AFV) to allow broader automated driving, which should streamline future deployments.[13] **Until then, LOXO had to operate under temporary test licenses with mandated safety measures, limiting the speed and areas of operation**.

Aside from regulation, **technical and operational challenges persist**. One major hurdle is handling the **"last 100 meters" problem of delivery** – i.e. how the package gets from the autonomous vehicle into the customer's hands. LOXO's solution of using lockers/compartments with PIN codes works for controlled scenarios (like employees picking up at a campus or drivers meeting the van at a micro-hub), but **fully autonomous home delivery (leaving a parcel at someone's door) remains unsolved in LOXO's model**. The company has acknowledged that handing over goods directly to end-users is difficult to automate.[14] This dependency on either the recipient or a human proxy (e.g. a Planzer courier at the transfer hub) can limit the use cases and requires coordination.

Additionally, **ensuring the vehicles can handle all weather and traffic situations is a barrier** – Switzerland's climate includes heavy snow and ice, which can interfere with sensors or vehicle traction. LOXO's current operations might need to pause in extreme weather or have a remote operator take over, which is not a long-term scalable solution. Edge cases like construction zones, or unexpected road closures also pose technical challenges; **LOXO mitigates these with remote supervision on standby, but reliance on remote supervision indicates the AI isn't yet fully autonomous in all scenarios**.[15]

Finally, there are social barriers: public acceptance and trust. An incident (even a minor collision or a perceived close call) could set back trust in the technology. LOXO must ensure impeccable safety records and engage with communities to overcome scepticism.

2.1.4 Policy and regulatory factors

The policy landscape for autonomous delivery is pivotal for LOXO's rollout, with Switzerland's regime evolving and European standards still solidifying. In Switzerland, a new legal framework for automated vehicles is taking shape: **an Ordinance on Automated Driving**

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[13] See: https://www.autonomousvehicleinternational.com/news/last-mile-delivery/loxo-and-planzer-begin-commercial-autonomous-delivery-in-europe.html

[14] See: https://www.parcelandpostaltechnologyinternational.com/features/feature-addressing-middle-mile-challenges-with-autonomous-delivery.html

[15] See: https://www.saam.swiss/autonomous-delivery-loxo-ready-for-next-steps/

(German: *Verordnung über automatisiertes Fahren*, AFV) and amendments to the road traffic law will come into force in 2025, providing clear rules for Level 4 vehicles.[16] This marks a shift from the previous ad-hoc approval process – under the new regime, companies like LOXO can apply to operate driverless vehicles under defined conditions (initially on specific routes or areas, likely with permits from the federal roads office). **The Swiss approach has so far been relatively flexible, allowing pioneering projects under exemptions, which enabled LOXO to claim Europe's first Level-4 public road deployment**. Now, with formal regulations, Switzerland aims to maintain innovation momentum while ensuring safety through certification and oversight.

In the European Union, regulatory harmonisation is an important factor for LOXO's expansion. While Switzerland isn't in the EU, LOXO's move into Germany and potentially other EU markets means dealing with EU-wide vehicle regulations and data laws. The EU is gradually developing unified rules for automated vehicles – e.g., it has adopted UNECE Regulation 157 for ALKS (automated lane keeping systems) and is working on frameworks for higher automation. However, full **type-approval for Level 4 delivery vehicles is still emerging**, so interim national schemes apply.

Another regulatory dimension is **privacy and data protection**. LOXO's vehicles continuously capture video and sensor data in public spaces, which in the EU triggers GDPR (General Data Protection Regulation) considerations. **LOXO has proactively addressed this by implementing privacy-by-design measures: all its vehicles display prominent notices about video recording, with a QR code/link to a privacy policy, ensuring transparency to the public**.[17] The company states that it collects data solely for navigation safety and improving the autonomous system, under strict retention and anonymisation policies in line with GDPR. For example, LOXO classifies and anonymises objects (pedestrians, license plates, etc.) in real time and does not identify individuals in its processing. Any personal data inadvertently captured is protected by measures like short storage duration and use of legal bases such as "legitimate interest" for safety research.

UNECE regulations and EU laws also influence technical requirements. UNECE sets global vehicle safety standards – LOXO's vehicles, being electric and automated, must comply with basic vehicle safety regulations (brakes, lights, etc.) and likely any specific UNECE rules for autonomous systems (like failsafe braking, cybersecurity requirements, etc.). As a Swiss product aiming at EU markets, LOXO will need to meet the **UNECE WP.29 guidelines for automated driving**, which ensure a consistent safety level. Additionally, **municipal policies affect LOXO's operations**: city governments may have rules on whether autonomous delivery vehicles can use bike lanes, or how they must yield to pedestrians, or requirements for local data sharing (for instance, a city might require AV operators to provide traffic data to authorities). LOXO's pilots in Bern and others have involved city officials to coordinate such issues.

Lastly, liability and insurance policy is a factor – regulators are determining how liability is assigned if an autonomous vehicle causes an accident. LOXO must navigate these legal questions (product liability vs. operator liability) which are still being refined in policy.

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[16] See: https://www.saam.swiss/laws-and-guides-on-automated-driving/

[17] See: https://www.loxo.ch/en/news/loxo-on-public-roads

2.1.5 Geographic and Operational Context

LOXO's autonomous delivery pilots are currently grounded in **Swiss urban environments**, with careful consideration of local geography and conditions. The company's flagship operations have taken place in Bern, the capital of Switzerland, and its surroundings. Bern serves as an ideal testbed: it's a mid-sized city with a mix of dense old-town areas, modern districts, and substantial bicycle and pedestrian traffic – a challenging but manageable environment for an AV. In the "Dynamic Micro-Hub" pilot across Bern, the LOXO/Planzer autonomous van navigates a 67 km route network that spans from a logistics centre on the city's outskirts into various urban neighbourhoods.[18]

Importantly, the pilot route was designed to avoid the narrowest medieval streets in Bern's core while still reaching 13 strategic exchange points around the city. This reflects LOXO's operational strategy to work in urban-suburban interface zones – linking logistic hubs (like train cargo centres or malls) with local distribution points closer to residential areas. By focusing on these connector routes, LOXO vehicles operate on public roads that include busy multi-modal corridors (with cars, cyclists, trams, etc.), thereby proving they can handle real city traffic. Meanwhile, they avoid ultra-congested pedestrian precincts where an autonomous van would be impractical.

2.1.6 Economic and market factors

LOXO operates at the intersection of the logistics market's emerging needs and the push for automation, positioning itself as a first mover in Europe's autonomous delivery niche. The company's market positioning is that of a **technology enabler for logistics firms and retailers**. Rather than selling a consumer service directly, LOXO provides the autonomous driving capability (software + vehicle platform) to businesses that handle deliveries. This means LOXO's immediate customers are large retailers (like Migros) and transport companies (like Planzer) looking to innovate their distribution models. Economically, this B2B model makes sense: those partners have the delivery volume and budgets to invest in pilots, and they stand to gain efficiency and cost savings if autonomy reduces labour or extends service hours. LOXO's value proposition to them is increased productivity (one vehicle doing many trips with minimal human involvement) and potential cost reduction per delivery in the long run. In an industry facing driver shortages and rising wage costs, this is a compelling pitch.[19]

In terms of market context, **the last-mile delivery sector is booming due to e-commerce growth**. For perspective, the autonomous last-mile delivery market globally is projected to reach several billion dollars by the end of the decade.[20] Economically, **LOXO likely operates on a project-based revenue model in the pilot stage**. On the market side, **competition and collaboration are both factors**. There are other European efforts in autonomous delivery (for instance, France's Carrefour trialed a delivery robot van with Goggo network), and big tech companies are eyeing last-mile automation.

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[18] See: https://www.saam.swiss/projects/dynamic-micro-hub-w-loxo/

[19] See: https://www.parcelandpostaltechnologyinternational.com/features/feature-addressing-middle-mile-challenges-with-autonomous-delivery.html

[20] See: https://www.telecomreviewasia.com/news/technology-pick/12563-unlocking-24-7-autonomous-delivery-for-seamless-urban-logistics/

2.1.7 Social and environmental impact

LOXO's autonomous delivery vehicles promise positive social and environmental impacts, aligning with sustainability goals and potentially improving accessibility in urban communities. On the environmental front, the impact is direct and significant: **LOXO vehicles are 100% electric and produce zero local emissions**, replacing what might otherwise be delivery vans running on diesel or gasoline. Over time, widespread use of such vehicles could cut CO_2 emissions from last-mile logistics substantially. Additionally, if LOXO's concept reduces the number of individual customer car trips (as Migros suggested – people not needing to drive to the store), it further lowers traffic congestion and emissions. The electric vans are also quieter than combustion engines, so city noise pollution can be reduced, especially impactful by nighttime or early-morning deliveries where traditional trucks would be disruptive.

In the Migronomous pilot, while the recipients were employees (not necessarily low-mobility persons), the concept demonstrated that a vehicle can conveniently come to one's location. In the future, as the service expands, it could be extended to home deliveries for the general public, meaning people who cannot easily leave home would have equal access to timely deliveries of food, medicines, or packages. This addresses social equity by bridging mobility gaps with technology. Moreover, LOXO's customer interface (PIN-code access to compartments) is simple and does not require tech-savvy – even those unfamiliar with apps can retrieve their delivery with a basic code, potentially making it user-friendly for all demographics.

However, public acceptance is a crucial social factor that LOXO must continually foster. Introducing a driverless vehicle into neighbourhoods can trigger curiosity, enthusiasm, but also concerns (safety, privacy, or job displacement worries). **LOXO has taken steps to build public trust**: for instance, clearly labelling the vehicles with information about camera use and being transparent about data (as mentioned, a QR code to the privacy policy is on the vehicle) helps address privacy concerns. The company also ensures a human can be contacted – during deliveries, a remote operator is available to answer questions from the public via the vehicle's communication interface. This kind of measure can reassure people that the robot is under supervision and responsive.

Another social impact is the potential improvement in road safety – a bit paradoxical, since autonomous vehicles introduce new worries, but they also remove human error. LOXO's vehicles obey speed limits (currently max **45** km/h) and have 360° sensors active at all times, which could mean fewer accidents than a rushed human courier might cause. They also don't get tired or distracted. If the public observes the LOXO shuttles consistently stopping for pedestrians and navigating carefully, trust will increase and so will willingness to use the service. On the flip side, LOXO must manage the **workforce impact** socially – there is often concern that automation will displace delivery jobs. In LOXO's framing, the technology is meant to assist rather than completely replace couriers.[21] For example, Planzer emphasises that human drivers are still doing handovers, and autonomy just relieves them of the monotonous shuttle trips. Communicating this clearly is important to maintain social license to operate.

Lastly, **LOXO contributes to urban liveability** in ways beyond emissions: by potentially reducing the number of delivery vans on the road (through consolidation of loads and more efficient routing), it can free up road space and parking, which is a benefit to city dwellers. Fewer vehicles performing the same deliveries means less traffic and potentially faster travel for everyone. If

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[21] See: https://www.parcelandpostaltechnologyinternational.com/features/feature-addressing-middle-mile-challenges-with-autonomous-delivery.html

concepts like the dynamic micro-hub catch on, trains and autonomous shuttles could replace fleets of vans swarming city centres, which residents would likely welcome.

2.1.8 Dependencies and external influences

LOXO's autonomous delivery operations depend on several external factors and supporting systems to function smoothly. One major dependency is on **digital infrastructure**, particularly wireless connectivity. LOXO vehicles leverage live telecommunication links (4G/5G networks) to enable remote supervision and control. In edge-case scenarios or emergencies, a remote supervisor can take over driving or assist the vehicle, so a stable, low-latency connection is critical.[22] This means that deploying LOXO in a given area requires reliable mobile network coverage. In Swiss cities this is generally available, but if the vehicle's route goes through coverage dead zones or tunnels, LOXO must work with telecom providers or use buffered autonomy to bridge those gaps.

Municipal infrastructure and cooperation are also key external influences. LOXO's model requires working with cities for things like curb side access and parking at pick-up/drop-off points. In the Bern pilot, 13 micro-hub spots were approved throughout the city – the city helped identify these and have provided permits so the autonomous van can safely stop there to unload. If a city is not cooperative, securing such loading zones or special AV routes becomes difficult. The presence of supporting infrastructure (like dedicated AV lanes or smart traffic signals that communicate with the vehicle) could greatly enhance operation, but these depend on public investment.

Remote supervision and human oversight resources are another dependency. While one of the goals is to minimise human intervention, in current operations LOXO still relies on a remote operations team. The company is aiming for a **ratio where multiple vehicles are overseen by a single teleoperator** as efficiency improves. But to achieve that, they depend on advancing the software's reliability and also training skilled operators. External events like a surge in vehicles deployed would mean scaling the remote supervision center – hiring and training staff, which is an organisational dependency.

Supply chain and technology partners are influences too. LOXO doesn't manufacture all components; it sources sensors (LiDAR from suppliers like Aeva[23], cameras, etc.) and vehicle platforms (Volkswagen ID.Buzz for the R1, custom chassis for Alpha).

Finally, **public policy and societal factors are external influences** that can either enable or hinder LOXO. If a city has a pro-innovation stance and provides grants or lenient regulations, LOXO can flourish (as in Switzerland so far). If there's a change in local government or a public backlash (say an incident causing fear), regulations might tighten, or permission to operate might be revoked. LOXO is thus dependent on maintaining a positive public narrative and complying with evolving rules (as discussed in policy factors

2.1.9 Past experiences and lessons learned

LOXO's journey through pilot projects has yielded valuable experiences and lessons that inform its ongoing development. The first major trial, the **"Migronomous" pilot in 2023**, served as a proof of concept for driverless last-mile delivery in Switzerland. In this project, LOXO learned

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[22] See: https://www.saam.swiss/autonomous-delivery-loxo-ready-for-next-steps/

[23] See: https://www.aeva.com/press/loxo-selects-aeva-to-power-autonomous-delivery-vehicles/

how to integrate its service with a retailer's operations (Migros online ordering) and a corporate client (Schindler) in a real-world setting. One key lesson was the importance of phased deployment: Initially, the LOXO Alpha had a person walking next to it for the first fee weeks to visually supervise the vehicle during operations and it was operated once daily on a short route. This cautious start allowed the team to validate vehicle performance and safety procedures.

Another lesson from Migronomous was about stakeholder collaboration. The **triple partnership of a retailer, a tech startup, and an industrial company showcased that autonomous delivery isn't just about the vehicle, but about ecosystem cooperation**. P**ublic communication and transparency are crucial** Any concerns (like "will this take delivery jobs?") could be addressed by emphasising it as a complement to existing services.

Several other **pilot projects** and **real-world demonstrations** have tested autonomous last-mile delivery vehicles in **urban and suburban areas**, focusing on groceries and parcel logistics. These pilots have validated core aspects of the technology under controlled conditions, often within defined ODDs.

Many pilots are at **TRL 4–5**, having successfully demonstrated feasibility in test environments or limited real-world deployments. The goal across these pilots is to **advance to TRL 6**, achieving consistent performance in operational settings.

Key lessons learned include:

- The critical role of **remote supervision** in handling exceptions e.g., blocked sidewalks, unexpected pedestrian activity, or incorrect parking.
- The importance of **integration with existing logistics platforms**, to ensure smooth data exchange and coordination of delivery times and customer notifications.
- The need for **cooperation with local authorities** to facilitate deployment (e.g., use of public space, safety regulations, and drop-off zone design).
- Recognition that **social acceptance** and **user interaction design** (such as mobile interfaces or access to drop-off compartments) are essential for long-term adoption

2.2 Skills needs and mismatches

2.2.1 Labour market trends

Labour demand is shifting away from traditional driving and toward supervision, coordination, and system maintenance roles. Although some roles may decline (e.g., van drivers), last-mile CCAM implementations such as LOXO's are designed to supplement rising parcel demand, not eliminate jobs. LOXO anticipates a job shift rather than loss, human workers are needed in scooters for final handoffs, and new middle-skill jobs like Autonomous Vehicle (AV) supervision are being created. Urban delivery jobs are particularly likely to persist, as they involve tasks that remain difficult to automate, such as parcel loading, direct customer interaction, and theft prevention. As the demand for freight transport is projected to double worldwide by 2050,[24] cities will require increasingly sophisticated last-mile systems to handle growing parcel volumes. This trend is expected to drive continued demand for human labour in urban delivery, even as automation reduces costs and reshapes job profiles.

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[24] ITF (2023), "ITF Transport Outlook 2023: Summary", OECD Publishing, Paris.

2.2.2 Skills gaps and mismatches

The shift to CCAM-enabled last-mile delivery introduces a range of new skill requirements that are not yet reflected in traditional logistics training. As automation changes the nature of operational roles, gaps are emerging between the technical demands of AV interaction and the current capabilities of the workforce, especially among smaller operators. This section outlines key areas where existing competencies fall short, and highlights the evolving skillsets needed to support safe and efficient deployment.

- The interface between human operators and AVs (such as initiating, loading, and troubleshooting AVs) demands new technical proficiencies not covered in traditional logistics training.
- Preliminary research identifies a mismatch between technological skill requirements and the current workforce's educational and digital readiness, particularly in small-scale operators.
- Manual labour and route knowledge are less relevant. In contrast, situational awareness, data interpretation, and digital communication are becoming essential.
- LOXO reports that remote supervisors require dispatcher-like skills: map reading, predication, digital tools, which are currently rare among traditional delivery staff.

2.2.3 New job roles and competencies

As CCAM technologies are introduced into last-mile delivery, new job roles are emerging that require a mix of digital, operational, and technical skills. These roles go beyond traditional delivery work and reflect the increasing need for human oversight, system support, and infrastructure adaptation. This section outlines the key new positions and the core competencies they involve, including transitional roles expected to evolve as automation matures.

- **Remote Vehicle Supervisors**: Oversee vehicle operations, make safety calls, respond to anomalies via digital systems, monitor surroundings.
- **AV Fleet Coordinators**: Coordinate routes and logistics across partially automated networks.
- **Maintenance & Support Staff**: Basic engineering knowledge, AV-specific diagnostics, sensor calibration, vehicle preparation.
- **Public Infrastructure Trainers**: Train public authorities in AV interaction.
- **Safety Drivers (transitional role)**: During early CCAM deployment phases, safety drivers play a crucial role in ensuring operational continuity and risk mitigation. They require basic driving skills as well as awareness of automated systems' behaviour and are expected to transition out as remote supervision becomes standard.

2.2.4 Professions and skills mapping (SWOT analysis)

Strengths	Weaknesses
• CCAM-enabled last-mile delivery creates new roles such as remote supervisors, vehicle preparation workers and infrastructure educators, which broadens job diversity beyond traditional courier roles. • Emerging job profiles related to remote supervision, and maintenance suggest the sector is evolving rather than reducing headcount. • Automation relieves human workers from physically and cognitively intensive driving tasks, offering potential for better work-life balance.	• Many last-mile workers (e.g. delivery couriers) possess low levels of digital proficiency, making it difficult to transition into hybrid roles involving technology interaction. • A lack of standardisation in CCAM roles makes it difficult to build public training programmes, as job descriptions and requirements are still evolving.
Opportunities	**Threats**
• There is scope for developing public-private training collaborations, especially once operational roles stabilise, and training can move beyond pilot-phase internal programs. • Increased automation opens pathways to more attractive, lower-stress roles, such as scooter-based parcel delivery, replacing van driving in dense cities and potentially increasing job attractiveness. • New positions like remote supervisors, AC maintenance support, delivery system coordinators, and infrastructure trainers present reskilling and upskilling potential across different education levels. • The retrofitting of conventional vehicles and deployment of small fleets opens opportunities in vehicle modification, logistics coordination, and technical operations.	• Inadequate public training frameworks due to lack of recognised qualifications and standardisation hampers workforce preparation. • Skills mismatch risks are magnified in regions with low digital infrastructure or entrenched manual logistics processes. • Connectivity and legal inconsistencies across regions slow down deployment and role maturity, making it hard to scale skill programmes.

2.2.5 Reskilling and upskilling needs

The shift to autonomous last-mile delivery introduces a range of new competencies for workers traditionally engaged in manual logistics roles. Remote supervisors, for example, will require significant reskilling—moving from basic driving tasks to more complex roles that resemble digital dispatch or control room operations. This transition involves acquiring new proficiencies in navigation software, fleet coordination tools, and emergency intervention protocols.

At the same time, frontline workers such as loaders and delivery assistants will need access to tailored onboarding resources, especially those with lower digital literacy. Familiarity with app-based communication, safe vehicle interaction, and standardised loading procedures will be essential. As vehicles become increasingly reliant on software and sensor systems, there is also growing demand for technical upskilling in maintenance. This includes competencies in diagnostics, sensor calibration, and basic preparation for autonomous operation.

Currently, LOXO provides all training in-house, drawing on its internal expertise and operational knowledge. However, the long-term aim is to transition training delivery to public and private educational institutions, once industry-wide standards are established. This underscores the need for scalable training programmes that can be adopted more broadly across the logistics and mobility sectors.

2.2.6 Training and education gaps

Current training and education systems are not yet equipped to support the growing demands of CCAM-enabled last-mile delivery. Most training is still provided in-house by technology developers, which limits scalability. Below outlines key gaps in education, certification, and public awareness that need to be addressed to support wider deployment.

- Current vocational education frameworks may still not be equipped to support the skill demands emerging from autonomous logistics. Due to a lack of general training models, LOXO handles all training internally (including robotics systems, safety protocols, diagnostics and remote supervision).[25] This underlines the need for modernised, modular training programs that reflect the technical realities of last-mile automation.
- **Certification** and **accreditation** for emerging AV-related logistics roles are not yet available in most EU Member States, limiting institutional response.
- LOXO cited a **lack of institutional know-how** as a key barrier: even public authorities lack the technical knowledge needed to support the deployment of CCAM in last-mile delivery.
- **Public awareness training** is lacking - for example, education for emergency responders or the general public on AV behaviour and interaction.

2.2.7 Gender and inclusion considerations

Less physically demanding roles such as AV supervision could attract more women and older workers to the logistics workforce. However, without targeted inclusion policies and training tailored to diverse learner needs, these opportunities risk remaining inaccessible.

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[25] Interview with LOXO representative.

3 Bus depot

The bus depot automation use case explores the d**eployment of SAE Level 4 CCAM systems within the confined and highly structured environments of public transport depots**. These depots serve as operational hubs where buses undergo routine service processes, including refuelling, washing, inspection, and parking. The goal of this use case is to automate internal vehicle circulation to improve efficiency, reduce costs, and enable workforce reallocation.

Initiated by SAAM and led by the Public Transport Operator in Geneva (TPG Geneve), the AutoDepot prototype project[26] serves as the second use case. It pilots infrastructure-based automation: rather than relying on the onboard intelligence of vehicles, the system employs a centralised management architecture coordinated through infrastructure-mounted sensors (e.g., LiDAR, radar, cameras). Once a bus enters the depot, the driver activates automated mode and exits the vehicle. The AutoDepot system then takes over to guide the bus through the required service points. In the event of obstacles or unexpected scenarios, teleoperation is used to remotely control the vehicle.

Currently at TRL 4, the AutoDepot prototype aims to reach TRL 6 by validating operations in a real-world setting. This use case demonstrates a scalable model for CCAM implementation in transit operations, offering insights into vehicle-to-infrastructure (V2I) communication, operational coordination, and human-machine interaction in enclosed environments. The pilot represents a strategic step toward broader CCAM adoption into simplifying public transport operations.

3.1 Impact of CCAM

3.1.1 Business model and operational concept

The AutoDepot prototype introduces automated bus handling within depots, reducing reliance on drivers for internal movements. The operational concept enables public transport companies to optimise resource use by automating non-revenue-generating activities.

The **business model** of the bus depot centres around enabling public transport operators to reduce operational costs and improve depot efficiency through infrastructure-led automation. Rather than relying on fully autonomous vehicles, AutoDepot focuses on c**entralised depot intelligence and minimal vehicle modification** 27(i.e., drive-by-wire systems). This reduces investment risk and technological barriers for transport operators. By automating repetitive low-speed tasks such as parking, charging, and staging, it allows for the reallocation of human resources from depot logistics to customer-facing services. Based on findings from the AutoDepot project, the bus depot can result to cost savings—up to CHF 600,000 annually for a 100-bus fleet—through reduced driver labour, minimised incidents, and optimised use of depot space. The model is scalable across multiple cities and adaptable to both electric and

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[26] See: https://www.saam.swiss/projects/autodepot/

27 SAAM, 2024. Report on AutoDept- Autonomous Bus Depot.https://www.saam.swiss/wp-content/uploads/AutoDepot-report_vfin_eng.pdf

conventional fleets, making it an attractive proposition for public and private mobility providers seeking to modernise without full AV dependency.

Operationally, the bus depot is based on the AutoDepot project and is structured around **smart infrastructure, centralised control, and remote supervision**. Buses enter the depot under limited automated control, operating at speeds below 3 km/h while being guided by sensors embedded in the depot environment. A centralised control system manages routing, queuing, and docking while monitoring vehicle movements and safety. In case of anomalies (e.g., an obstacle or technical failure), alerts are routed to a remote operator who can intervene as needed. The low-speed and confined setting of the depot allows for high levels of predictability and system control, which reduces the need for complex AI or vehicle-side autonomy. The system is being prototyped at the En Chardon depot in Geneva by TPG, in collaboration with SAAM and industrial partners, and is designed to integrate seamlessly with existing depot workflows and electrification infrastructure.

3.1.2 Expected benefits and impact of CCAM technology on the use case

The introduction of CCAM technologies into bus depot operations offers clear benefits in terms of efficiency, safety, and cost-effectiveness. The AutoDepot project in which we have based this case study has pointed out which are the most important benefits and impacts by the deployment of the technology. The automation of services in the depot led into vehicle movements and optimising depot workflows, these systems can reduce manual labour, cut emissions and costs and improve overall depot safety.

- **Operational Efficiency:**
    - **Reduced Driver Hours:** By automating low-speed vehicle movements within depots (e.g., parking, repositioning, charging), operators can save an estimated **7,500–15,000 driver hours** annually per 100-bus fleet.
    - **Optimised Depot Throughput:** Precise vehicle routing and space utilisation enable tighter scheduling, more efficient shift changes, and higher depot capacity without physical expansion.
    - **Fewer Manual Errors:** Automation reduces minor collisions, incorrect parking, and missed charging sessions—common in dense, high-traffic depot environments.[28]
- **Sustainability:** Reduces unnecessary vehicle movements and idling, lowering emissions. (Optimised routing means buses spend less time circling or waiting, which curbs fuel or energy waste.)

  Accessibility & Safety: Improves depot traffic control and lowers the risk of accidents due the human fatigue or error. Notably, depots today can see anywhere from a few to dozens of minor collisions per year; an automated depot system aims to virtually eliminate these incidents by using precise sensor guidance and removing human error from low-speed manoeuvres.[28]
- **Operational Cost Reduction:**

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[28] SAAM, 2024. Report on AutoDept- Autonomous Bus Depot.https://www.saam.swiss/wp-content/uploads/AutoDepot-report_vfin_eng.pdf

  - **Direct Labor Cost Reductions:** Automation lowers the need for personnel to perform internal movements, with projected savings of up to **CHF 600,000 annually per depot**.
  - **Lower Incident Costs:** Fewer low-speed accidents mean reduced maintenance, repair, and insurance costs.
  - **Infrastructure Investment ROI:** The system leverages existing depots with infrastructure upgrades, avoiding the cost of full vehicle autonomy or entirely new facilities.

3.1.3 Challenges and barriers for use case deployment

While CCAM technologies hold strong potential for bus depot operations, their deployment is not without obstacles. Technical integration, regulatory uncertainty, and significant upfront investment remain key barriers. In addition, user acceptance—particularly from depot staff and unions—will be critical to successful implementation. The deployment of the bus depot concept can face the following obstacles:

- **Technical:** Integration of sensor infrastructure with central systems; teleoperation readiness; maintaining performance in various weather and lighting conditions. Moreover, all vehicles must be equipped (or retrofitted) with drive-by-wire capability and communication interfaces to interact with the AutoDepot system, which is a significant technical and logistical undertaking for legacy bus fleets.
- **Infrastructure constraints:** Older or space-constrained depots may not be easily adaptable to AutoDepot's routing and sensor requirements
- **Regulatory:** Legal frameworks for automated movements in semi-public/private settings are still evolving. For example, the AutoDepot initiative in Switzerland has required close consultation with federal and cantonal authorities; pilot deployments are proceeding under special permits, aided by the relatively low risk profile of closed depot sites with no passengers on board.[29]
- **Financial:** High initial infrastructure investment; long ROI horizon. The AutoDepot pre-study indicated that developing the first automated depot prototype would entail several million CHF in engineering, sensor, and system costs, a front-loaded expense that demands careful long-term planning and scaling to multiple depots to be justified.
- **User acceptance:** Requires buy-in from depot workers and transport unions; trust in remote operation and system reliability is essential. The project stakeholders are engaging employees early—emphasising transparent safety protocols and offering retraining opportunities—to build confidence that automation will augment jobs (e.g. new roles in remote supervision or system maintenance) rather than simply eliminate them.

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[29] See: SAAM, 2024. Report on AutoDept- Autonomous Bus Depot.https://www.saam.swiss/wp-content/uploads/AutoDepot-report_vfin_eng.pdf

3.1.4 Policy and regulatory factors

The deployment of CCAM technologies in bus depots intersects with multiple layers of policy and regulation. Currently, there is no EU-wide legal framework specifically addressing infrastructure-led vehicle automation in closed environments. Nevertheless, several policy initiatives and regulatory instruments are relevant.

The AutoDepot project leverages recent legislative changes that permit Level 4 vehicles under remote supervision in the Swiss law. Specifically, the **Swiss Ordinance on Automated Driving (VAF/OCA)**, effective **March 1, 2025**, establishes the legal basis for driverless (Level 4) vehicles on predefined routes—with mandated **remote supervision** by operators within Switzerland's borders[30].

In addition **Directive 2010/40/EU on Intelligent Transport Systems (ITS) lays** the groundwork for digital infrastructure and vehicle-to-infrastructure (V2I) services, while **UNECE WP.29** regulations provide a basis for autonomous driving systems, albeit mainly focused on vehicle-based automation.

National traffic and labour laws across Member States will govern how automation can be implemented within depots, including employment conditions and safety standards. Data protection and cybersecurity rules such as GDPR will be especially critical when handling real-time teleoperation data and sensor-based control.

3.1.5 Geographic and operational context

The AutoDepot system is being developed and piloted in Switzerland, with initial trials conducted at representative high-capacity depots such as Givisiez (Fribourg). These depots handling 100 buses and serve as centralised hubs for urban transit networks. The system is designed for depot environments with clearly defined driving lanes, predictable routes, and low-speed conditions. The Swiss environment—with varied seasons and strong public sector cooperation—provides a controlled yet realistic context for technical validation.[31]

The project is currently assessed at TRL 4–5, with feasibility demonstrated in lab conditions and pre-operational pilot environments. The next development phase (2025–2026) will involve pilot deployment in a functioning depot under real operating conditions, with close supervision and stepwise expansion of automated functions. Medium-term goals (by 2030) include scaling to other Swiss depots and supporting broader adoption across Europe, provided regulatory harmonisation and operational lessons are addressed.

3.1.6 Economic and market factors

The economic case for AutoDepot rests on reducing costs related to internal depot movements, increasing throughput efficiency, and improving space utilisation. The business model is capital-intensive upfront, requiring installation of infrastructure (LiDAR, radar, cameras, and control

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[30] https://www.loc.gov/item/global-legal-monitor/2024-12-19/switzerland-automated-driving-to-be-allowed-starting-in-2025/?utm_source=chatgpt.com

[31] SAAM, 2024. Report on AutoDept- Autonomous Bus Depot.https://www.saam.swiss/wp-content/uploads/AutoDepot-report_vfin_eng.pdf

systems) and retrofitting buses with digital interfaces. However, operating costs are expected to drop due to reduced staffing needs and better scheduling.

As European public transport systems contend with ageing workforces and skills shortages, depot automation represents a strategic investment. Early adopters may benefit from innovation funding and may position themselves as leaders in sustainable mobility, further justifying the cost of adoption. Vendors such as AMoTech, as well as public-private research initiatives like SAAM, help lower innovation risks for operators. The ROI comes after 10 years for a 100-bus depot but the main advantage that the public transport operators can gain is to anticipate and to deal with driver shortage.

3.1.7 Operational and logistical considerations

The automation of bus depot operations through the AutoDepot system introduces substantial improvements in operational logistics:

- **Fleet management:** The centralised control of up to 100 buses per hour enables fine-tuned coordination of internal movements, including parking, dispatch to maintenance bays, and preparation for daily service. Drivers no longer need to handle in-depot repositioning, freeing up resources for service routes. In addition it can help handle drivers shortages.
- **Service delivery:** Internal depot efficiency directly supports more reliable scheduling and availability of buses for passenger services. It eliminates inconsistencies caused by human factors in vehicle staging and increases the readiness of buses during peak hours.
- **Efficiency:** Time spent on non-productive driving tasks within the depot is significantly reduced. The system eliminates idle time and repetitive repositioning movements through dynamic routing and infrastructure control. The report[32] notes that depot operations are optimised for low traffic conditions, controlled rules (e.g., no overtaking), and standardised speeds (3 km/h), which further reduces risk and boosts throughput.

The system is currently at **TRL 4** and aims for **TRL 6**, meaning pilot environments are already producing measurable insights into these operational gains. In the long run, widespread CCAM deployment in depots could drive systemic efficiency improvements across urban transport fleets.

3.1.8 Social and environmental impact

Automating bus depot operations has broader implications beyond internal efficiency gains. By improving safety, reducing emissions, and freeing up human drivers for frontline service, CCAM technologies can support more accessible and sustainable public transport. However, workforce transitions and social acceptance—particularly among depot staff—remain important considerations.

The automation of internal depot movements releases human drivers for public-facing routes, indirectly increasing availability and reliability of public transport services. This can support better **transport access for underserved or time-constrained populations** by enabling more efficient service delivery schedules.

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[32] SAAM, 2024. Report on AutoDept- Autonomous Bus Depot.https://www.saam.swiss/wp-content/uploads/AutoDepot-report_vfin_eng.pdf

Environmentally, reduced idling and optimised routes within depots lower CO_2 emissions and noise pollution. Socially, it helps address driver shortages and allows for retraining and reassignment of staff to higher-value roles. However, stakeholder engagement is vital to ensure staff acceptance and avoid resistance.

PostBus and SwissMoves are taking a **proactive approach to communication and workforce transition**, with planned awareness campaigns, staff consultations, and reskilling programmes. The broader community benefits from improved service reliability and a reduction in operational incidents within depots.

3.1.9 Dependencies and external influences

The successful deployment of CCAM technologies in bus depots depends on several external factors, including infrastructure readiness, environmental conditions, and institutional support. For example the availability of 5G is also crucial for the AutoDepot case.

While the AutoDepot system operates within depot boundaries, its efficiency influences the reliability and punctuality of the broader public transport network. Smoother depot operations mean buses are better prepared for their scheduled routes, improving **overall network performance**. Hence, AutoDepot must integrate with broader CCAM, ITS, and fleet management frameworks to maximise impact.

3.1.10 Past experiences and lessons learned

The AutoDepot prototype serves as the core implementation experience for this use case. It represents a real-world proof-of-concept of infrastructure-led automation within a bus depot, where vehicle tasks are dictated by sensor systems and a centralised depot management system, not by onboard intelligence. As of the report, the prototype is at TRL 4, with the ambition to scale to TRL 6 during the project lifetime. The AutoDepot has been developed incrementally building upon the experience gained from other projects such as Project “Line X” that tested a simple AV and project “Avenue” with 3 AVs.

A key lesson from the AutoDepot development is the critical need for teleoperation backup. In any situation where the vehicle encounters an unknown or unsafe condition (e.g., blocked paths or sensor failure), it switches to a stop mode and notifies a human operator at the control centre, who can then intervene remotely.

Other significant takeaways include the importance of:

- **Depot-specific traffic regulations**, such as strict speed limits (3 km/h) and a no-overtaking policy, support safe and predictable automated operations.
- **Scalability and standardisation** are key, as the system is intended to be adapted across various EU depots with differing layouts and operational characteristics.

Complementing these operational lessons, several external studies provide valuable benchmarks and guidance:

- *Haslinger, Gaar, and Parragh (2025)* present a mathematical model for **multi-depot electric vehicle scheduling**, optimising fleet size, charging frequency, and energy use.

Their findings offer practical strategies for transit agencies managing zero-emission transitions.[33]

- *Fernández et al. (2025)* document the **operator experiences and cost considerations** of autonomous depot management at EMT Madrid under the Horizon 2020 SHOW project, highlighting the technical feasibility of automating routine depot tasks such as cleaning, charging, and parking.[34]
- **Siemens – Hamburg, Germany** provides another case of depot modernisation, where Siemens has equipped Europe's largest electric bus depot with **intelligent charging infrastructure**, supporting high-efficiency operations and energy optimisation.[35]

These examples reinforce that depot automation is not a theoretical concept, but an evolving operational reality with replicable models, proven components, and growing institutional knowledge. The challenge moving forward lies in aligning these technical innovations with workforce planning, funding, and standardised regulatory frameworks across the EU.

3.2 Skills needs and mismatches

The integration of CCAM technologies into bus depot operations is not only a technical challenge, but it also demands a significant transformation of the workforce. While depot environments are structured and closed, making them ideal for early-stage automation, they also rely on a well-established labour model involving drivers, cleaners, and maintenance technicians. As the AutoDepot concept shifts tasks from manual to automated and digital systems, existing job roles will be reshaped or replaced, requiring proactive skills development. The following subsections outline the main workforce implications, based on a SWOT analysis, labour market trends, and policy observations from earlier project findings, pilot studies and operator feedback.

3.2.1 Labour market trends

Labour market trends across the public transport sector are undergoing a significant shift, driven by demographic pressures and the growing influence of automation technologies. The AutoDepot project reports serious concerns about driver shortages, fuelled by upcoming waves of retirements and ongoing difficulties in attracting new entrants to the profession. Economic projections included in the project estimate the hourly cost of a driver at 80 CHF (80 EUR[36]), underscoring the financial burden of continuing with labour-intensive manual operations. In response, operators are implementing a range of measures to mitigate workforce gaps, including internal training programs, increased advertising efforts, collaboration with employment offices, and expanded opportunities for part-time work.

Meanwhile, automation is advancing across the industry. Technologies from freight and ride-sharing are now entering public transit, with manufacturers like Volvo and BYD producing buses

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[33] Xenia Haslinger, Elisabeth Gaar, Sophie N. Parragh (2025) *An Exact Approach for the Multi-Depot Electric Vehicle Scheduling Problem* https://www.researchgate.net/publication/390892897_An_exact_approach_for_the_multi-depot_electric_vehicle_scheduling_problem

[34] Fernández, C.O.C., Balaguer, S.F., de la Iglesia, L.I., Espinar, B.G. (2025). *Autonomous Bus Depot Management: Operator's Lessons Learned and Cost Analysis Perspective* https://link.springer.com/chapter/10.1007/978-3-031-71793-2_6

[35] Electrive (2020) Siemens to equip Europe's largest e-bus depot with charging https://www.electrive.com/2020/12/15/siemens-to-equip-europes-largest-e-bus-depot-with-charging/

[36] Conversion as of 26-6-2025

equipped with Advanced Driver Assistance Systems (ADAS). This signals a shift in labour demand toward more technical and supervisory roles.

At the Stuttgart-Gaisburg depot, automation of internal bus movements could save over €100,000 annually in staff costs. More importantly, it enables staff to shift into higher-value roles such as diagnostics and servicing. The transition is expected to be gradual, moving from assistive technologies to full automation, reflecting a broader trend toward fewer manual tasks and greater demand for oversight and system interaction skills.

3.2.2 Skills gaps and mismatches

The deployment of CCAM technologies highlights several specific skill deficits in the current depot workforce:

- Limited exposure to automation software and control systems.
- Lack of proficiency in sensor-based system diagnostics and maintenance.
- Insufficient training in teleoperation procedures and remote vehicle supervision.
- Low familiarity with cybersecurity protocols related to vehicle data.

These gaps illustrate the need for tailored training programs that bridge the divide between conventional depot work and CCAM-enabled operations.

3.2.3 New job roles and competencies

Automation in bus depots is reshaping, rather than replacing, the workforce. As vehicle movements become increasingly managed by infrastructure-based systems, many existing roles are evolving, and new ones are emerging to support the transition.

Existing roles:

- Bus drivers, for example, are being retrained to work as **remote teleoperators**, supervising automated vehicle movements and taking control when necessary. These operators must understand how to manage handovers between autonomous and manual control, often using advanced teleoperation stations equipped with steering wheels and multiple screens that simulate the driver’s cabin. While legal requirements for such roles may be limited in private depots, the AutoDepot project emphasises that these operators carry responsibilities equivalent to licensed drivers.
- Depot maintenance personnel are also seeing their responsibilities expand. In addition to mechanical repairs, they are increasingly expected to engage in **sensor alignment, diagnostics, and software updates**. This includes understanding how key systems, such as LiDARs, radars, thermal cameras, and GPS, contribute to automated navigation, and how to identify faults in real-time. [37]

New roles:

- **Teleoperators** supervise autonomous buses from control centres and intervene in unplanned scenarios. Beyond driving skills, they require familiarity with sensor behaviour, remote vehicle control systems, and quick decision-making under edge-case conditions.

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[37] Autodepot, Autonomous bus depot (2024) available: https://www.saam.swiss/wp-content/uploads/AutoDepot-report_vfin_eng.pdf; Stakeholder Interview (TPG).

- **Automation technicians** focus on the calibration and upkeep of depot infrastructure sensors and communication systems. They ensure reliable V2I data exchange and maintain critical perception infrastructure.
- **AV systems coordinators** oversee the integration of automation into depot routines. They monitor AV task scheduling, teleoperation status, and ensure consistency between system logic and daily operations.
- **Depot operations centre staff** are evolving to include responsibilities such as real-time AV supervision, system health monitoring, and coordination with teleoperators.

3.2.4 Reskilling and upskilling needs

To manage the workforce transition, training efforts should prioritise both technical and operational competencies. Each new position comes with specific upskilling needs which include

- **Teleoperator:** Remote control protocols and emergency handling, human-machine interaction principles, use of teleoperation stations and handover logic.
- **Automation technicians:** Sensor alignment and calibration, infrastructure troubleshooting (LiDAR, radar, cameras), familiarity with depot V2I systems.
- **AV systems coordinators**: Integration of CCAM systems into depot schedules, oversight of AV tasks and teleoperation flows, system-level fault handling and communication
- **Depot analysts:** Real-time fleet monitoring tools, dashboard interpretation and data-based performance tracking, digital workflow management.

In general, competency shifts across the workforce mean that staff must develop:

- A working knowledge of sensor functions, fields of view, and limitations.
- Skills in using supervision platforms, including dashboards and cloud-based coordination systems.
- Familiarity with manual override protocols, safety zones, and automated decision-making logic.

3.2.5 Training and education gaps

Training is typically provided initially by AV technology suppliers, such as WeRide in Geneva, before being cascaded internally through peer training models).[38] As automation scales up, the capacity to blend hands-on operational understanding with digital system fluency will be essential across roles.

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[38] Stakeholder interview (TPG)

3.2.6 Professions and skills mapping (SWOT analysis)

Strengths	**Weaknesses**
• The current depot workforce includes bus drivers, depot supervisors, dispatchers, workshop technicians, and maintenance staff. These professionals are skilled in manual vehicle handling, mechanical diagnostics, fuelling/charging procedures, and using digital tools like Depot Management Systems, SAP, and GMAO. Their operational knowledge and familiarity with depot workflows provide a solid foundation for adapting to partial automation. • The project enjoys institutional and regulatory support: the Swiss Federal Office of Transport (FOT) and SAAM have both demonstrated interest and commitment through financial investment and in-kind contributions to the AutoDepot initiative. • Bus depot operations currently rely on drivers to reposition vehicles between various service stations, with additional specialised personnel performing tasks such as maintenance, inspection, and cleaning. The enclosed and controlled environment of depots eliminates many of the external variables present in public traffic, such as pedestrians, bicycles, cars, animals and other vehicles. This predictable setting allows engineers to map fixed routes for buses, enabling autonomous movement without driver supervision.	• Most staff lack experience with automated vehicle systems, sensor diagnostics, or teleoperation. • The workforce is aging, and a significant proportion is nearing retirement. • There is also limited exposure to software-based monitoring, predictive maintenance tools, or human-machine interface protocols, which are essential for future operations. • Most buses currently in service are not equipped with "drive-by-wire" technology, which is an essential prerequisite for depot – level automation. While braking systems and autonomous shuttles use some related technologies, the core steering and propulsion systems in standard bus fleets remain incompatible. The "drive-by-wire" technology is not currently available on the market, and the reasons for acquiring or not having vehicles incorporating this technology are not specified. The potential obstacles to a "drive-by-wire" system include reliability, costs, availability, regulations, safety, and approvals.
Opportunities	Threats
• Automation introduces new roles such as: o Depot teleoperator (remote vehicle control and incident management) o Automation technician (sensor and systems maintenance) o Fleet operations analyst (data monitoring and diagnostics) o Digital mobility coordinator (overseeing vehicle flow and HMI systems) These roles open pathways for upskilling existing workers and attracting new talent with digital and technical backgrounds.	• Automation of vehicle circulation within depots could displace traditional driver roles, especially those focused solely on manoeuvring buses into parking or maintenance positions. While new roles may emerge, not all affected workers may transition easily due to skill mismatches or lack of training.

• The advancement of teleoperation technology allows operators to remotely oversee multiple buses from centralised control centres. This development not only optimises resource allocation but also facilitates the digital transformation of the workforce, creating new career paths in the digital sector.	

3.2.7 Other relevant considerations

3.2.7.1 Sectoral and regional variations

The readiness of transport operators to adopt depot automation varies widely by region. Urban areas with centralised, high-capacity depots are more likely to benefit from economies of scale and attract skilled workers. In contrast, smaller or rural operators may struggle with funding, recruitment, and access to technology partners, potentially widening regional disparities unless supported through policy measures

3.2.7.2 Gender and inclusion considerations

Depot automation has the potential to reduce physical demands in roles such as bus manoeuvring and heavy maintenance, making these positions more accessible to a broader range of workers, including women and older adults. However, the digital nature of emerging roles introduces a risk of digital exclusion. Promoting gender equity and accessibility should be a core component of workforce transition strategies.

4 Port/terminal

The **Port/Terminal** use case examines the deployment of **automated, battery-electric trucks** for logistics operations within **confined port and terminal environments**, forming a critical part of the broader **MODI project**,[39] with contributions from **ITSN, DAF, VOLVO, and EINRIDE**. These vehicles are intended to carry out core logistics functions, such as **access control, charging, loading/unloading**, and **modal transfer**, as well as route planning and coordination between port gates and nearby logistics hubs. Operating at **SAE Levels 2 to 4**, the trucks will perform dynamic driving tasks including **intersection navigation, roundabouts, mixed-traffic operation, and manual/automated handovers**. Although full deployment is scheduled for **Q2/Q3 2025**, certain components, such as **automated charging, pallet handling**, and **terminal booking systems**, are already reaching **TRL 7–8**. Within the CCAM-ERAS scope, the focus remains on activities inside the terminal perimeter, rather than the broader hub-to-hub or highway operations also covered by MODI. Connectivity is supported through **V2X infrastructure**, while remote supervision is planned for specific vehicles (e.g., EINRIDE) and a **safety driver** will be present during early phases for DAF and VOLVO fleets. Legal and operational frameworks are still under development, with **site-specific guidelines and safety protocols** determining speed limits and route permissions. The use case illustrates how high-automation freight vehicles can streamline **port logistics**, enhance **sustainability**, and lay the groundwork for **fully autonomous supply chain nodes**.

4.1 Impact of CCAM

4.1.1 Business model and operational concept

The use case centres on fully automating routine truck moves inside a container terminal using battery-electric trucks. Autonomous vehicles handle trailer moves, container transfers between quay and yard, charging and loading/unloading under fixed routes and geo-fenced areas controlled by the terminal's management system. Vehicles rely on high-definition maps and V2X communications (DSRC/5G) to navigate inside the gate, while a cloud-based fleet management platform assigns jobs in real time. For example, in the **MODI project DAF's localisation system** was tested at the Broekman Logistics terminal in Rotterdam and Volvo trucks are equipped with ITS-G5 V2X units, illustrating how OEMs are integrating CCAM tech in live port pilots.[40] Remote supervision is built in: an operator hub (e.g. for Einride's vehicles) can tele-operate trucks if needed, and safety drivers accompany other trucks during early trials. This hybrid concept aims for 24/7 precision operations – trucks can work continuously without breaks, extending throughput – and minimises human labour in hazardous areas. In practice, pilots show that autonomous terminal tractors can operate around the clock with reduced labour, leading to higher productivity in yard management. Several ports and terminals worldwide are already trailing and implementing autonomous vehicle technology, underscoring that this use case aligns with broader industry trends.

4.1.2 Expected benefits and impact of CCAM technology on the use case

Automation in port and terminal environments offers measurable gains in:

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[39] See: https://modiproject.eu/.

[40] See: https://modiproject.eu/milestone-achieved-vehicle-providers-make-strides-in-modi-project-implementation-and-testing/

- **Efficiency:** Automation enables continuous, 24/7 operations without fatigue or shift changes, significantly increasing terminal throughput and container movement speed. Autonomous vehicles can be coordinated in real time to reduce idle time and improve yard management efficiency.
- **Sustainability:** CCAM-supported port operations use electric or hybrid autonomous transport vehicles, which reduce emissions and noise pollution in port zones. Energy use is optimised by avoiding unnecessary vehicle movements and optimising routing.
- **Accessibility:** While accessibility in the conventional sense is limited due to the restricted, non-public nature of terminals, automation improves system reliability, benefiting shipping lines, logistics providers, and customers by reducing port congestion and delays.
- **Safety improvements**: Removing human drivers from high-traffic areas in ports significantly reduces the risk of accidents involving people and heavy machinery. Long-term health issues related to the handling of equipment such as back pain are eliminated. Autonomous vehicles operate at controlled speeds with predictable, rules-based behaviour, improving occupational safety for remaining on-site personnel.
- **Economic impact:** CCAM reduces operational costs by lowering reliance on manual labour for repetitive container transport tasks. Over time, this supports better margins for terminal operators and increased competitiveness, particularly for ports under pressure to meet higher container volumes with constrained space and labour availability

4.1.3 Challenges and barriers

Deploying CCAM in terminals faces technical and socio-legal hurdles. From a technical perspective, GPS signals are often unreliable beneath container stacks and crane gantries, making precise localisation difficult. Autonomous trucks must fuse camera, lidar and other sensor data to navigate in these cluttered environments. Interactions with other systems (automated cranes, gantry rails, legacy equipment) add complexity. Systems must also scale: a high-volume terminal could require dozens of coordinated vehicles, so the fleet management back-end must handle heavy data and control loads reliably. Teleoperation is planned as a fallback, but integrating that live override capability is itself a technical challenge. Currently on the MODI project the testing phase is from Level 2 automation and aims to test Level 4 features by the end of the project. [41]

One of the biggest barriers is the lack of areas that can cover the testing needs. High volume of testing facilities and long-term validation is required for the necessary safety validations. Infrastructure needs in deports for charging, sensors and 5G for seamless data interactions need to be in place for the optimal implementation.

Finally the regulatory fragmentation and restriction is an important barrier. There is no harmonised EU standard yet for highly automated trucks in private ports. Liability in the event of a crash or system failure remains unclear for autonomous or tele-operated vehicles. Customs and security rules traditionally expect human truckers and inspections; adapting these protocols (e.g. for auto-gates or automated cargo logging) is still a work in progress. Because terminals cross national jurisdictions, inconsistent rules (for example, differing teleoperation certifications) complicate cross-border deployments.

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[41] Interview with Mr Tim Johannes, MODI project, May 2025.

Automation also requires high upfront investment in vehicles, digital platforms, charging stations and facility upgrades. This is a major barrier for smaller terminals without deep pockets. Workers may resist losing driver positions; unions will demand retraining and guarantees. CCAM projects must therefore include workforce transition plans.

4.1.4 Policy and regulatory factors

Port environments are governed by a mix of local, national, and EU-level regulations.

Specifically it should follow the EU law when operating within **predefined zones** and adhering to ADS type-approval rules under Regulation 2022/1426[42]. These must be complemented with cybersecurity (R155), software update protocols (R156), and communication/infrastructure standards set by UNECE (UNECE WP29 Framework). National adaptation should ensure operator protocols, liability coverage, and terminal-specific safety cases align with this harmonised regulatory framework. For example in Germany where one of the MODI use cases takes place implementations is challenged by a complex regulatory landscape that involves multiple approval layers at both federal and city levels. This fragmented framework often leads to delays and increased administrative burdens, particularly when compared to more streamlined approaches in Nordic countries. While German regulations are considered "tough but necessary" to ensure safety, risk management, and orderly scaling, there is a growing consensus that **EU-wide regulatory alignment** is essential to facilitate cross-border innovation and accelerate deployment. In this context, clear and harmonised testing protocols would also support faster experimentation and replication across different jurisdictions.

Regarding the freight transport and port security regulations and customs protocols (e.g., EU Customs Code) may impose constraints on full automation, especially for cargo subject to checks or manual documentation. Occupational safety regulations also influence how automated systems must interact with human workers in mixed environments.

4.1.5 Geographic and operational context

This scenario is intended for large, high-throughput container terminals (e.g. Rotterdam, Antwerp, Hamburg, Valencia). In such ports thousands of containers move daily, often managed by advanced yard cranes already. The use case exploits these controlled-access environments: public roadways are not involved, which simplifies some legal issues. For example, MODI's port trial is studying autonomous trucks in the busy Port of Rotterdam, where vehicles must navigate mixed traffic among cranes and Automated Guided Vehicles (AGVs). It should be noted here that Port of Rotterdam already has the experience of implementing AGVs which are controlled from a remote-operations control room. It has existing an digital infrastructure (like TOS and yard management systems, V2X connectivity and 5G) and is an ideal candidate. For future implementation, both new "greenfield" terminals and retrofitted existing yards could apply the solution so long as container flows are consistent and centralised control is possible.

Technologically, current systems are around TRL 4–5 – that is, basic prototypes have been tested in restricted settings. MODI aims to pilot full autonomous yard segments by 2025. In fact, some subsystems are already at TRL 7–8: for instance, a recent Rotterdam demo had a self-driving electric truck autonomously connect to a robotic charging station. In the short term (2025–2027) these pilots will expand to cover entire yard blocks and integrate with quay crane and gate

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[42] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A32022R1426&utm_source=chatgpt.com

operations. By the late 2020s (2028–2030) full-scale deployment is expected at major EU hubs. Longer-term, the vision is a fully automated terminal: fleets of electric AGVs, automated stacking cranes and dock cranes, all coordinated via a digital twin of yard operations. As one CCAM expert notes, automation in the immediate future is expected first in "short distances and in controlled, confined environments, such as terminals and ports".

4.1.6 Economic and market factors

The integration of CCAM technologies in ports accelerates the shift toward digitised, automated logistics ecosystems. Terminal operators that implement automation early may gain a competitive advantage by offering faster turnaround times, lower labour costs, and higher reliability, especially attractive to global shipping lines. This could lead to market consolidation, where technologically advanced terminals attract more business and volume.

The automation of container handling intensifies competitive pressure on smaller or less digitised terminals. Terminals with the infrastructure to support automation may see greater investment and freight traffic, while others may struggle to maintain competitiveness. This may widen the gap between top-tier EU ports and smaller regional facilities. Implementing CCAM in terminal environments demands high capital investment in:

- Autonomous transport vehicles (AGVs, terminal tractors)
- Digital fleet and yard management systems
- Infrastructure upgrades (e.g., V2X, connectivity, mapping)
- Support systems like teleoperation platforms

The return on investment is expected to materialise through labour savings, operational efficiency, and improved service offerings to shipping partners.

4.1.7 Operational and logistical considerations

In port and terminal environments, CCAM technologies offer **significant potential to streamline operations and improve service delivery**. Fleet movements can be orchestrated through a management platform that integrates sensor data, routing algorithms, and vehicle coordination to optimise flow between quay cranes and storage yards. Vehicles can be reassigned dynamically, reducing idle time and improving equipment utilisation.

However important operational consideration should be made:

- Ports are often governed by port authorities and terminal operators, requiring multi-stakeholder coordination for technology deployment.
- Standardisation is a key issue: terminals use a mix of equipment brands, systems, and operational models, so CCAM deployment must be interoperable or modular.
- Digital infrastructure maturity (e.g., V2X capability, 5G availability, yard management systems) varies between terminals, affecting readiness for full automation
- Stable, well-maintained road surfaces and predictable traffic patterns, as autonomous vehicles are sensitive to environmental inconsistencies.
- Integration with existing equipment and IT systems (e.g., Terminal Operating Systems, or TOS), requiring significant interoperability efforts

4.1.8 Social and environmental impact

Even though port terminals are not public spaces, CCAM significantly affects surrounding communities and workers. By automating container transport, **human presence in the most**

hazardous zones is reduced. This shift improves safety: vehicles follow strict rules and advanced sensor systems prevent collisions, so remaining workers face a safer environment. Furthermore, because these trucks are electric, noise and air pollution inside and around the port drop dramatically. A UNDP analysis[43] highlights that electrifying port operations and dedicated charging infrastructure will "drastically cut emissions in high-traffic, pollution-heavy areas," directly protecting public health. In practice, local communities near busy ports should experience lower diesel fumes and quieter operation as fewer human-driven diesel trucks enter.

Digitally coordinated CCAM operations also improve the supply chain. Reduced delays at the terminal gate mean less traffic queuing on local roads. The overall standardisation of transport processes makes arrival times more reliable for inland hauliers and rail, improving accessibility indirectly. In combination with other green measures at the port (such as shore power for ships or LNG bunkering), automated electric freight vehicles align well with EU climate goals.

4.1.9 Dependencies and external influences

The effectiveness of CCAM deployment in ports is shaped by a range of external dependencies: Automated port/terminal operations must **integrate seamlessly with trucking services, rail terminals, and shipping lines**. Efficient handover between autonomous internal transport and external logistics systems is crucial. Disruptions or delays in one mode (e.g., trucking bottlenecks) can affect overall terminal efficiency.

In addition, successful CCAM deployment in port/terminal facilities heavily depends on robust physical and digital infrastructure, such as described in Section 4.1.7. **Climate conditions** are also a key factor in port/terminal environments. Harsh weather can affect sensor performance and vehicle navigation reliability. Autonomous vehicles must have fallback strategies like slowing down, stopping safely, or switching to teleoperation when conditions deteriorate.

Additionally, automation projects at ports and in freight transport in general typically require collaboration and consensus from various stakeholders such as the backing of port authorities, municipal governments, and national regulators. Long-term investment stability, supportive public policy, and cross-border cooperation (especially for EU inland terminals) are important to sustain CCAM deployment momentum in these scenarios.

4.1.10 Past experiences and lessons learned

Several ports worldwide have already piloted or partially deployed automated container transport systems, particularly using AGVs or automated terminal tractors. Examples include: Port of Rotterdam, Port of Hamburg, and Port of Antwerp, where terminals have implemented semi-automated or fully automated container yard operations[44].

The technology is currently at TRL 4–5, meaning it has been demonstrated successfully in structured operational environments but still faces scaling challenges. Key lessons learned include:

- Robust communication infrastructure (e.g., 5G, V2I) is crucial for real-time fleet management and safe coordination.

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[43] https://www.undp.org/sites/g/files/zskgke326/files/2024-12/main_report_to_drvn_en_29.11.2024.pdf?utm_source=chatgpt.com

[44] See: https://modiproject.eu/.

- Teleoperation backup systems are necessary to intervene when automated vehicles encounter unexpected conditions.
- Surface and route maintenance must be consistently high to prevent vehicle guidance errors.
- Human-machine coexistence strategies (mixed operations with human-driven vehicles) require clear operational rules and careful safety planning.
- Early engagement with port authorities, labour unions, and logistics partners is critical for successful deployment and acceptance.

These pilots have also emphasised that phased deployment (starting with small sections of the terminal) and incremental scaling are practical approaches for minimising risk during the transition to full automation.

Recent studies underscore the importance of technological innovation and stakeholder coordination in optimising port and terminal operations. Montwiłł (2019) highlights best practices in managing inland ports across Europe, emphasising their strategic role in multimodal transport systems and regional development.[45] Key success factors include integrating ports into broader logistics chains, adopting advanced technologies, and fostering collaboration among public and private actors to improve efficiency and competitiveness. Complementing this perspective, Nadi et al. (2023) present a data-driven, multi-agent decision support system developed for the Port of Rotterdam. The system is designed to optimise truck arrival times at container terminals, reducing congestion and enhancing coordination. By leveraging big data and simulation modelling, it demonstrates how digital tools can support smarter, more adaptive port logistics.[46]

4.2 Skills needs and mismatches

4.2.1 Labour market trends

The port logistics sector is under pressure from rising freight volumes, aging workforces, and labour shortages in physically demanding roles. Automation is increasingly seen as a response to these challenges, with major terminals investing in autonomous trucks, AGVs, and crane coordination systems. As digitalisation expands, demand is shifting toward technical roles in system monitoring, diagnostics, and data-driven logistics.

4.2.2 Skills gaps and mismatches

The current workforce faces challenges adapting to CCAM-related roles, as many workers lack the technical skills required to work with emerging technologies. Training in the port industry must adapt to an evolving landscape influenced by technological, operational, and organisational changes. Key areas include redefining essential skills for modern port jobs, familiarising workers with emerging technologies and tools, encouraging continuous self-development, and preparing personnel for flexible, multi-skilled roles.[47]

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[45] Andrzej Montwiłł (2019*) Best practices in managing inland ports in Europe*

[46] Ali Nadi, Maaike Snelder, J.W.C. van Lint, Lóránt Tavasszy (2023) *A Data-driven and multi-agent decision support system for time slot management at container terminals: A case study for the Port of Rotterdam*

[47] Giannossa, L. C., Mangone, A., Lagioia, G., Palazzo, G., & Gentile, L. (2023). From byssus threads to Pinna nobilis sea-silk: a fiber characterization. Academia Materials Science, 1(1). https://doi.org/10.20935/AcadMatSci6123.

A key development is the **remote operation of quay cranes**, requiring workers to interact with human-machine interfaces from secure control rooms. This shift reduces physical risks but introduces new technical responsibilities that many current staff are unprepared for.

AR and VR at port gate checkpoints require new competencies in system operation and monitoring, which most existing staff have not been trained in.

The **fragmentation of certification standards** across terminals and countries has led to inconsistencies in training quality and skill recognition, complicating the transition to a more standardised, automated workforce.

4.2.3 New job roles and competencies

The MODI pilot illustrates how CCAM deployment in ports is generating new technical demands while also reshaping existing logistics roles.

Existing roles:

- Port operations and logistics personnel are not being replaced but are increasingly expected to understand and work alongside automated systems.
- Traditional roles such as terminal supervisors, fleet managers, and logistics coordinators will need to engage with AV platforms, understand system behaviours, and make decisions based on real-time data feeds from connected infrastructure.
- Operators will also interface with new mapping tools, vehicle status dashboards, and scenario-based AI systems for planning and control.[48]

New roles:

- **CCAM project managers** coordinate deployment of automation pilots, working across OEMs, infrastructure providers, logistics companies, and public authorities to align technologies, processes, and evaluation frameworks.
- **Control room operators** are envisioned to monitor and supervise automated freight movements, potentially taking over remotely during critical incidents or unexpected scenarios. The role remains under development but is expected to play a central part in scaled-up operations.
- **Sensor and infrastructure technicians** configure, calibrate, and maintain roadside sensor systems (e.g. LiDAR, radar), modify traffic signals, and support V2X communication infrastructure.
- **Mapping and data specialists** manage detailed operational maps or alternative approaches like scenario-based AI navigation, crucial for ensuring reliable AV performance in dynamic port conditions.
- **Logistics ecosystem integrators** oversee the interplay between automated vehicles, charging stations, aftermarket services, and depot scheduling, enabling a systems-level view of terminal automation.

4.2.4 Reskilling and upskilling needs

As the MODI pilot shows, full automation in complex environments such as ports and terminals introduces a combination of entirely new roles and transformed existing ones. All of these roles demand a shift in competencies. Technical proficiency in AV systems, sensor logic, and AI-

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[48] Stakeholder interview (MODI)

enabled decision tools must be paired with practical knowledge of freight flows, safety protocols, and port operations. Specific skills include:

- **CCAM project managers:** Multistakeholder coordination, technical literacy in AV systems and interfaces, risk and system deployment planning.
- **Control room operators**: Remote monitoring of AVs and traffic flows, intervention protocols for exception handling, familiarity with AV dashboards and system alerts.
- **Sensor and infrastructure technicians**: Installation and calibration of LiDAR, radar, and camera systems; understanding sensor coverage, blind spots, and failure diagnostics; V2X communication support.
- **Mapping and data specialists**: Scenario-based mapping and localisation; integration of map data with AV navigation logic; AI-based route prediction and validation tools.
- **Logistics ecosystem integrators:** coordination across AVs, chargers, service infrastructure; system-level thinking around scheduling, prioritisation, and vehicle flow; basic systems analysis.

4.2.5 Training and education gaps

The MODI pilot highlights that learning currently happens through hands-on involvement in pilot testing, with OEMs like Volvo playing a key role in early knowledge transfer. However, there is also a notable absence of structured training pathways, short-format expert training, and a need for formal certification programmes as the technology scales, and especially as responsibilities shift toward port authorities, operators, and third-party logistics firms.[49]

4.2.6 Professions and skills mapping (SWOT analysis)

Strengths	Weaknesses
• Clear identification of emerging roles across technical, operational, and supervisory domains (e.g. teleoperators, automation technicians, ecosystem integrators). • Existing workforce can be adapted rather than replaced—many traditional roles (e.g. drivers, maintenance staff, logistics coordinators) can transition with targeted upskilling. • Strong alignment between job tasks and new competencies, allowing for modular, role-specific training design. • Growing demand for hybrid skill sets (e.g. mechanical + digital; operational + data-driven), creating opportunities for career progression and professional development. • Hands-on pilot projects provide real-world learning environments, enabling staff to acquire new skills through experience ("learning by doing").	• Rural areas are particularly disadvantaged due to limited access to high-quality training and digital infrastructure, creating a geographic skills divide. • Workers in roles most at risk of displacement, such as logistics staff and equipment operators, are likely to have the most significant changes. • Another weakness is the lack of harmonised certification standards across countries and ports. Each port authority and terminal operator develops its own requirements, leading to fragmentation, inefficiency, and restricted workforce mobility within the EU. • Lack of formal training frameworks or certifications for most new roles (e.g. teleoperators, AV systems coordinators), leading to ad hoc or inconsistent skill development. • Heavy reliance on OEMs for early knowledge transfer, which limits internal

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[49] Stakeholder interview (MODI).

• Industry engagement (OEMs, operators, infrastructure providers) offers practical input into role requirements and competency design.	capacity building and makes public operators dependent on vendors.
Opportunities	**Threats**
• Positions such as control room operators, robotics and automation technicians, and warehouse IT specialists are becoming increasingly important. These roles demand a mix of technical skills and adaptability, particularly in managing and maintaining automated systems. • The integration of AR and VR at port checkpoints, the oversight of AGVs, and cybersecurity tasks related to protecting digital infrastructure are creating entirely new career paths. As digital systems become part of port operations, workers will have to possess both soft skills and technical expertise. • Opportunity to integrate skills mapping into early training and certification frameworks, setting the foundation for future standards. • Develop standardised training and certification frameworks for new roles (e.g. teleoperators, automation technicians), supporting cross-sector and cross-border workforce mobility.	• By 2040, up to 90% of tasks performed by port workers could be automated, potentially leading to an 8.2% reduction in port employment and a 25% decrease in jobs across the broader maritime sector, particularly in countries like the Netherlands. • Regulatory uncertainty, particularly the absence of a standardised certification framework, continues to hinder the formation of a unified port labour market. This lack of uniformisation makes it difficult to develop consistent training and employment methods, especially across the EU. • Delayed development of formal training and certification pathways could leave workers underprepared and lead to slow CCAM deployment. • Dependency on OEMs for skill development may limit the autonomy of operators and public authorities in building internal expertise.

4.2.7 Other considerations

4.2.7.1 Sectoral and regional variations

Automation is already advancing in container terminals. Fully automated facilities such as the Container Terminal Altenwerder in Hamburg use technologies like automated guided vehicles and automated stacking cranes, which significantly minimise the need of human labour. The role of workers has evolved from manual tasks to overseeing and controlling digital systems remotely.[50] Another example of autonomation in port logistics is the project launched in Gothenburg, Sweden, where electric and autonomous trucks are integrated with a cloud-based control tower system. In this initiative, autonomous vehicles transport containers from a DFDS logistics centre to the APM Terminals container terminal within the Port of Gothenburg.[51]

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[50] Victor Oyaro Gekara and Vi-Xuan Thanh Nguyen, ‘New technologies and the transformation of work and skills: a study of computerisation and automation of Australian container terminals’, available at: https://www.researchgate.net/publication/341211931_Challenges_of_Implementing_Container_Terminal_Operating_System_The_Case_of_the_Port_of_Mombasa_from_the_Belt_and_Road_Initiative_BRI_Perspective.

[51] Volvo, ‘More than autonomous trucks- Building the ecosystem for autonomous transport solutions in ports and logistics centers.’ , available at: https://www.volvoautonomoussolutions.com/en-en/news-and-

In contrast, the automation of the Ro-Ro (roll-on/roll-off) system used for car carriers remains largely unexplored. Unlike container terminals, Ro-Ro terminals rely on human labour, particularly stevedores, to manage the loading and unloading of vehicles. Each gang of stevedores typically includes a supervisor (foreman), hatch boss, signalman, key car, drivers, van driver, and lasher. Multiple driver teams are responsible for moving and parking vehicles onboard, while lashers secure them on deck. These tasks are difficult to automate, making the Ro-Ro system reliant on manual labour.[52] However, in 2023, EasyMile and Terberg Special Vehicles have successfully deployed an autonomous terminal tractor at the DFDS Ro-Ro terminal in Rotterdam, marking a major step in port automation. The vehicle completed complex tasks such as driverless trailer transfers, shunting, and most importantly, autonomously driving on and off a ship for the first time.[53]

Historically, Northern European ports have a dominant position due to historical factors such as strong reputations, efficient inland connections, and coordinated rail networks. In contrast, Southern European ports, particularly in Italy, have faced challenges in the past, including limited rail integration and weaker connectivity. However, this dynamic had shifted.[54] Ports in the Mediterranean, especially in the Ligurian region, are improving their infrastructure and adapting to larger vessel calls, while rail services in the south had also become more developed.[55]

Moreover, European ports show a clear divide between high-tech and low-tech development, particularly when comparing core seaports with small and medium-sized ports (SMSPs). In the Adriatic, Ionian, and Ligurian Sea regions, SMSPs dominate the maritime landscape. Specifically, 58 of 67 ports in the Adriatic, 31 of 34 in the Ionian, and 4 of 6 in the Ligurian region are SMSPs.[56]Unlike their counterparts in the Baltic Sea Region, these southern ports face significant challenges in spatial connectivity, particularly between critical energy and transport infrastructures needed for clean fuel integration.

Geographic barriers such as mountain ranges further hinder effective connections to inland areas. Many SMSPs are physically and economically isolated, limiting their integration with international markets and complicating cooperation on shared environmental strategies. Large international ports like Rotterdam benefit from dedicated CCAM programs, while smaller terminals may lag without targeted policy and funding support to advance their technological capabilities. As a result, these ports are often left out of technological developmental planning.[57]

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insights/press-releases/2022/feb/more-than-autonomous-trucks-building-the-ecosystem-for-autonomous-transport-solutions-in-ports-and-logistics-centers.html.

[52] Sanghyung Park, Jeho Hwang, Hangjin Yang and Sihyun Kim, ‘Simulation Modelling for Automated Guided Vehicle Introduction to the Loading Process of Ro-Ro Ships’, available at: https://www.mdpi.com/2077-1312/9/4/441

[53] EasyMile, ‘Autonomous Terminal Tractor in First Roll-on/Roll-off (RoRo) Port Operations’ available at: https://easymile.com/news/autonomous-terminal-tractor-first-roll-onroll-roro-port-operations

[54] Vincent Wee, ‘Northern, southern Europe ports can benefit from being complementary’, available at: https://www.seatrade-maritime.com/ports-logistics/northern-southern-europe-ports-can-benefit-from-being-complementary.

[55] Ibid.

[56] Laima Gerlitz and Christopher Meyer, ‘Small and Medium-Sized Ports in the TEN-T Network and Nexus of Europe’s Twin Transition: The Way towards Sustainable and Digital Port Service Ecosystems’, available at:https://www.mdpi.com/2071-1050/13/8/4386.

[57] Ibid.

4.2.7.2 Gender and inclusion considerations

The **maritime industry remains male-dominated**, with women underrepresented, particularly in technical and operational roles. Despite some progress in countries like **the Netherlands and Nordic states**, women are still concentrated in lower-paid or administrative positions. Fields like maintenance, shipyards, and dock work remain overwhelmingly male.

The **Port of Rotterdam** promotes **diversity and inclusion** as part of its CSR strategy, though gender is not explicitly prioritised. Initiatives such as work-life balance policies and support networks help address structural barriers. Recruitment reforms and outreach programs are needed to ensure women and underrepresented groups can access emerging technical roles in CCAM.

5 Public (shared) transportation

The public shared transport use case focuses on deploying **large-scale, SAE Level 4 autonomous minibuses and shuttles in peri-urban and rural settings** to provide flexible, demand-responsive mobility. Developed under the EU-funded **ULTIMO** project,[58] this use case explores how self-driving shuttles can fill mobility gaps where conventional transport is limited, such as low-density areas, off-peak hours, or underserved neighbourhoods, while ensuring safe, inclusive, and sustainable service delivery.

The ULTIMO project is coordinated by UITP and brings together a **broad consortium of public transport operators, technology providers, municipalities, and research organisations** across Europe. The pilot services aim to operate **without an onboard safety driver**, using advanced V2X connectivity and sensor integration to support complex real-world driving tasks. Remote assistance is enabled through teleoperation centres, allowing trained staff to intervene in edge cases or unexpected scenarios. Vehicles are designed to comply with existing traffic rules and perform minimum risk manoeuvres when necessary, enhancing safety and interoperability across national contexts. With vehicles currently at Technology Readiness Level 6+, the ULTIMO use case represents a major step toward the operational deployment of shared autonomous mobility in Europe.

5.1 Impact of CCAM

5.1.1 Business model and operation concept

The ULTIMO project on which we will build upon the use case is based on a **public-private partnership** (PPP) framework, where **municipal authorities** procure services, and **mobility operators** manage fleets of automated shuttles or buses. These service run on fixed routes or within geo-fenced service areas, coordinated via digital platforms. Operators may offer fully automated services (Level 4) or use **remote supervision** and **teleoperation** to support system safety and user interaction. Pricing models vary from fare-free pilots (subsidised by city councils) to **fare structures** for demand-responsive services. Integration with multimodal journey planners and Mobility-as-a-Service (MaaS) platforms is a key part of the operational vision.

Most prior automated vehicle pilots in public transport remained experiments due to missing scalable business models. ULTIMO addresses this gap by developing a novel shared-mobility model that combines passenger transport (MaaS) and urban logistics (LaaS) in one fleet. Its goal is to deploy large fleets of multi-vendor Level 4 shuttles (15+ vehicles per site) operating on-demand, door-to-door without onboard safety drivers.[59] Through a user-centric, cross-sector approach, ULTIMO has tested innovative revenue schemes and service designs that optimise vehicle utilisation (for example by switching between passenger and freight service in off-peak hours). The project reports that these “cross-sector business models…ensure economic sustainability” of CCAM services. By proving a viable cost structure for shared automated services, ULTIMO aims to demonstrate that AV transit can be commercially feasible in low-density areas.

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[58] See: https://ultimo-he.eu/.

[59] See: https://cordis.europa.eu/project/id/101077587

5.1.2 Expected benefits and impact of CCAM technology on the use case

CCAM technologies have the potential to significantly enhance the efficiency, accessibility, and sustainability of public transport services. By enabling smaller, electric, and automated vehicles to serve low-demand or underserved areas, they can complement existing networks while reducing operating costs and environmental impact. The following benefits are expected:

- **Efficiency:** Enables cost-effective transit in low-density or underserved areas, reducing the need for large buses or underused fixed lines.
- **Sustainability:** Primarily electric fleets help reduce urban emissions and noise pollution.
- **Accessibility**: Improves mobility for elderly, disabled, or rural populations, supporting inclusive transport.
- **Safety improvements:** Reduces human error-related accidents; vehicles follow predictable, cautious driving patterns.
- **Economic impact:** Cuts operating costs by reducing driver-related expenses; opens up new service models and technology markets. Helps deal with the shortage of drivers; Enables 24/7 operation and autonomous vehicle repositioning, allowing for more demand-driven, customer-centric service offerings and improved availability across time and locatio.

5.1.3 Challenges and barriers

Deploying CCAM technologies in public transport presents a unique set of challenges. These include ensuring safe operation in complex urban environments, navigating fragmented regulatory frameworks, and securing funding for high upfront costs. Public acceptance remains a critical hurdle, especially where safety concerns persist. This section outlines the technical, legal, financial, and social barriers to implementation, while also linking them to broader policy goals around sustainability and inclusive mobility.

Technical:

- Safe operation in mixed traffic and unpredictable pedestrian environments.
- Teleoperation, mapping accuracy, and real-time fleet monitoring are essential.
- Adapting to weather, lighting, and dynamic street conditions.
- Ensuring the safe boarding and unboarding of passengers with special needs (elderly, people with disabilities)
- Persistent connectivity and low-latency communication required for teleoperation and autonomous repositioning.
- Cybersecurity and data sovereignty challenges when working with non-European software and infrastructure.

Regulatory:

- Lack of harmonised EU-wide frameworks for automated public transport.
- Legal issues regarding passenger safety, insurance, and liability.
- Licensing rules and alignment with public transport regulations vary locally.
- Lack of operational know-how and clear procedures for deployment permits beyond vehicle type approval – on both authority and operator side
- Risk of a fragmented approach across regions and stakeholders, limiting scalability and cross-border learning.

Financial:

- High initial investment in vehicles, digital platforms, and operations centres.
- Public transport agencies may face budget constraints for new tech adoption.
- Risk of fragmented funding across small, disconnected pilots instead of coordinated investment in long-term deployment strategies (many pilots receive public funding, but lack structured knowledge transfer to support scalable commercialisation)

User Acceptance:

- Public may lack trust in driverless buses, especially with safety concerns.
- Success depends on demonstrations, public outreach, and reliable performance.

5.1.4 Policy and regulatory factors

The legal framework for automated public transport remains under development. In the previous sections (2.14 and 3.1.4) we have discussed in detail the regulations and policies affecting the use case. However national relevant regulation may influence the operation of the AVs and such a service. In addition, the service must align with existing public transport laws and contracts.

5.1.5 Geographic and operational context

ULTIMO's services are explicitly designed to augment, not replace, conventional public transport. In each demonstration site the AV fleet is integrated into the existing network to enhance connectivity. For instance, in Oslo's Grorud Valley the automated shuttles operate as on-demand feeders to nearby metro and bus lines: travellers can book rides that "plug the gaps" for first/last-mile trips, with AVs covering routes during low-demand periods in lieu of empty-running buses.[60] Similarly, in Herford (North Rhine-Westphalia) autonomous minibuses bridge city and rural zones by connecting residential areas and smaller towns to the central transport hub. In all cases ULTIMO vehicles share the road with other traffic and are deployed flexibly (often free-floating over large areas) to serve passenger needs. By embedding AVs within the multimodal system, ULTIMO helps improve network coverage and service frequency in underserved peri-urban corridors.

In terms of **scale,** the use case is highly applicable in city districts, suburbs, or total fringes with low to moderate demand. In terms of **geographical scope,** it is applicable across EU Member States, particularly where public transport gaps exist.

In terms of **timeframe,** currently, CCAM technologies in public shared transportation are at TRL 4–5, with various demonstrators and pilot projects underway across Europe. In the **short term (2025–2027**), these initiatives are expected to expand into more structured pilot deployments, primarily in controlled environments such as dedicated lanes or geo-fenced urban districts. By the **medium term (2028–2030)**, broader deployment is anticipated, with expanded ODDs and the potential integration of autonomous public transport into city-wide MaaS platforms, supporting more flexible and interconnected urban mobility systems.

5.1.6 Economic and market factors

The integration of CCAM technologies into public transport introduces new market dynamics and investment requirements. Automated, demand-responsive services can fill gaps in low-density areas, offering an alternative to underused fixed routes. However, this shift also brings

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[60] See: https://www.connectedautomateddriving.eu/blog/ultimo-autonomous-vehicles-in-oslo-ready-for-action/

competition with existing modes like minibuses and taxis, and requires substantial investment in vehicles, digital infrastructure, and operational systems.

- **Market dynamics:** CCAM opens new service niches in public mobility. Demand-responsive automated services could reduce reliance on traditional buses in low-demand areas.
- **Competition:** Competes with conventional minibuses, taxis, and paratransit. May complement or substitute underused fixed-route services.
- **Investment:** Requires upfront spending on vehicles, control centres, mapping, and IT systems.
  Infrastructure needs: Curb side stop points, charging stations, digital platforms, and V2I infrastructure.

5.1.7 Operational and logistical considerations

Autonomous public transport can significantly improve the operational flexibility of public transport systems. By enabling real-time fleet coordination and demand-responsive routing, it can offer more efficient coverage, especially in low-ridership or hard-to-serve areas. The most important operational and logistical considerations are:

- **Fleet management:** Real-time coordination of autonomous shuttles to ensure service reliability and coverage.
- **Service delivery:** Flexible routing, dynamic scheduling, and better response to demand fluctuations.
- **MaaS integration:** The service can be integrated in MaaS services.
- **Remote areas inclusion:** Automates low-ridership areas with fewer resources; reduces deadheading and driver-related scheduling gaps.
- **Interaction with other modes:** Designed to connect to buses, trams, rail stations (multimodal integration).
- **Infrastructure dependency:** Needs 5G/V2X networks, well-maintained roads, and curb management policies.
- **Climate impact**: Sensor performance may be affected by fog, snow, or rain, requiring robust fallback procedures and dynamic ODD management. AV software must be calibrated to local weather conditions and supported by ongoing risk assessments to ensure safe operations year-round.
  Political Support: Public transport operators and usually public authorities or municipality level play critical role in funding these services, investing in them and enabling their possible rollouts.

5.1.8 Social and environmental impact

Autonomous public transport has the potential to deliver meaningful social and environmental benefits. By improving accessibility, particularly in underserved or car-dependent areas, and supporting emission reductions through electric fleets, these systems contribute to broader sustainability and equity goals.

- **Accessibility:** Enhances mobility for those without cars or in underserved areas. Ensures the access to transportation to all and reduces transport poverty.
- **Safety:** Avoids driver fatigue and distraction; safer for vulnerable road users.
- **Emissions:** Typically electric; supports climate goals and cleaner cities.

- **Urban planning:** Reduces car dependency; encourages compact urban development.

The effectiveness of CCAM-enabled public transport depends on a range of external factors, from infrastructure readiness to political support. Seamless integration with existing modes like buses and rail is essential for multimodal connectivity, while reliable digital networks and weather-resilient systems are key to maintaining service quality.

5.1.9 Past experiences and lessons learned

Pilots across Europe (e.g., in France, Finland, Germany) have tested autonomous shuttles on campuses, business parks, and urban loops. These pilots have reached TRL 4–5, showing feasibility for short trips under controlled conditions.

Examples of past experiences can be found below:

1. ULTIMO (Urban Logistics and Transport Innovation through Modular Operations)[61] is a Horizon Europe project aiming to deploy large-scale, on-demand autonomous public transport services in urban environments by 2025–2030. It has pilot deployments in Geneva (Switzerland), Oslo (Norway), and Herford (Germany). It builds on previous projects like AVENUE[62] and SHOW[63], and includes partners like TPG Genève, UITP, EasyMile, Navya, and SAAM.
2. Navya & Keolis – Lyon Confluence Autonomous Shuttle in France. Operated from 2016 to 2021 in Lyon's Confluence district using Navya shuttles on a predefined route. It is one of Europe's earliest long-term pilot programs in mixed-traffic conditions.
3. Brabant & Rivium ParkShuttle [64]– Capelle aan den IJssel in the Netherlands. Operated since 1999, the Rivium ParkShuttle near Rotterdam is one of the world's oldest autonomous shuttle systems, initially using fixed-guideways. As of 2023, plans are underway to transition to Level 4 autonomous vehicles on public roads. Its partners are 2getthere, Connexxion, City of Capelle.
4. Linköping, Sweden, autonomous electric minibuses were trialed along a 2 km route connecting neighborhoods with a transport hub. The operators are Transdev, RISE, and the city of Linköping.
5. As part of the **SHOW project**[65], the Basque city tested autonomous minibuses within a university campus and surrounding roads
6. An initiative by Hochbahn and IAV to test a **5-meter autonomous electric shuttle** on a dedicated 2.2 km track in Hamburg's HafenCity.[66] From 2019–2021, gradually removed the safety driver and added more complexity. Helped define regulatory and safety requirements for future urban AV deployment.

The key lessons learn from these applications are:

- High public interest but cautious trust.
- Importance of teleoperation and clear ODD limitations.
- Need for engagement with local transit operators and communities.

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[61] www.ultimo-he.eu

[62] https://h2020-avenue.eu/

[63] https://show-project.eu/objectives/

[64] https://www.2getthere.eu/projects/rivium/rivium-3-0/

[65] https://show-project.eu/objectives/

[66] https://innovationinpolitics.eu/showroom/project/heat-hamburg-electric-autonomous-transportation/

- Scaling from pilots to real-world services requires strong institutional alignment and regulatory certainty.

5.2 Skills needs and mismatches

5.2.1 Labour market trends

The public (shared) transportation is predicted to encounter three labour market trends. To begin with, the sector will experience a decline in traditional jobs. It is predicted that passenger jobs will decline by 2.2% to 12.5% by 2050, resulting in the reduction from 2,122,000 jobs in 2020 to between 1,857,000 and 2,076,000 in 2050. Bus drivers are predicted to suffer loss of jobs due to automation, as it is predicted that 160,000 conventional bus driver jobs will be lost.[67]

Second, automation will bring about job transformation and new roles in the public (shared) transportation sector. Displaced workers in this sector may shift into customer service, logistics, app development, or fleet operations. The bus sector is also predicted to undergo evolution, as “bus ambassadors” and attendants will be needed to assist passengers, especially in inclusive mobility contexts (see also use case 6).[68]

The final labour market trend in characterised by Rise of Ride-Sharing and Ride-Hailing Services. The ride-sharing sector is predicted to produce 600,000 jobs by 2050, while the automated taxi sector is predicted to create 5,000 jobs.[69] The ride-sharing sector is predicted to compete with the taxi and bus sector, eventually displacing them (see use case 5).

5.2.2 Skills gaps and mismatches

Manual skills are becoming obsolete. Physical and routine tasks like manual driving, control precision, and near vision are increasingly being automated.[70] The public (shared) transportation sector encounters skill gaps in three categories. The first and biggest category is related to technical skills. Drivers will require skills to work with automated systems, monitor vehicle sensors, and recognise system malfunctions.[71] For workers operating with semi-automated systems, basic knowledge of AV systems and the ability to switch between automated and manual control will be required.[72] Former bus drivers switching to new roles will require strong V2I and vehicle-to-vehicle (V2V) communication proficiency and a good understanding of

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[67] Study on exploring the possible employment implications of connected and automated driving (2020) https://www.ecorys.com/app/uploads/files/2021-03/CAD_Employment_Impacts_Annexes.pdf

[68] Pakusch, Christina & Boden, Alexander & Stein, Martin & Stevens, Gunnar. (2021). The Automation of the Taxi Industry – Taxi Drivers’ Expectations and Attitudes Towards the Future of their Work. Computer Supported Cooperative Work (CSCW). 30. 10.1007/s10606-021-09408-1.

[69] Yankelevich, A., Rikard, R. V., Kadylak, T., Hall, M. J., Mack, E. A., Verboncoeur, J. P., & Cotten, S. R. (2018). *Preparing the workforce for automated vehicles*. https://comartsci.msu.edu/sites/default/files/documents/MSU-TTI-Preparing-Workforce-for-AVs-and-Truck-Platooning-Reports%20.pdf

[70] ITF (2023), “Adapting (to) automation: Transport workforce in transition”, *International Transport Forum Policy Papers*, No. 122, OECD Publishing, Paris, https://doi.org/10.1787/905fdc2c-en.

[71] Orfanou, F., Vlahogianni, E., Yannis, G. (2021). A Taxonomy of Skills and Knowledge for Efficient Autonomous Vehicle Operation. In: Nathanail, E.G., Adamos, G., Karakikes, I. (eds) Advances in Mobility-as-a-Service Systems. CSUM 2020. Advances in Intelligent Systems and Computing, vol 1278. Springer, Cham. https://doi.org/10.1007/978-3-030-61075-3_30.

[72] Pakusch, Christina & Boden, Alexander & Stein, Martin & Stevens, Gunnar. (2021). The Automation of the Taxi Industry – Taxi Drivers’ Expectations and Attitudes Towards the Future of their Work. Computer Supported Cooperative Work (CSCW). 30. 10.1007/s10606-021-09408-1.

wireless communication systems. The shift to new jobs will require workers to adapt to the use of new digital platforms such as MaaS platforms integrating multiple transport modes. In the absence of a human driver, staff must also be trained to uphold operational safety standards through remote supervision, fault detection, and emergency response procedures. This includes adhering to safety-critical protocols such as the four-eyes principle, which requires qualified human oversight during remote operations.

In addition to technical skills, automation will bring a rise in customer service skills. Traditional driving skills are becoming less relevant, while customer service abilities like communication and empathy are growing in importance. Finally, jobs in AV fleet management will require business management skills, such as marketing, billing, and fleet organisation.

5.2.3 New job roles and competencies

While full automation in public transportation reduces the need for on-board driving, it does not eliminate human involvement. Instead, it redirects it into roles focused on oversight, support, coordination, and inclusivity. Roles traditionally centred around manual driving or on-site supervision are shifting toward new functions:

- Taxi and Bus Drivers may transition into:
    - **Tele-assistants or remote supervisors**, providing oversight of automated vehicle fleets and supporting them during exceptions.
    - **Field support agents** (FSAs), assisting vehicles and passengers on-site when needed — a critical role during early deployment phases.
    - **Stewards or bus ambassadors**, offering in-vehicle or stop-based support for elderly, disabled, or anxious passengers, helping build public trust and ensure inclusive access.
- **Customer service staff** are expanding into: digital platform support roles, handling app-based rider requests, real-time updates, and escalations across mobility services.
- **Operations Coordinators** in transport control centres are taking on more advanced system supervision roles, often involving dashboards, incident response tools, and mobility analytics.[73]

Additionally, CCAM also introduces job profiles that have no direct precedent in conventional public transport:

- **Remote operations specialist**: Monitors and intervenes in AV operations from a centralised control centre. Requires situational awareness and confidence in AV logic and limitations.
- **AV maintenance technician**: Combines hands-on vehicle servicing with the ability to manage sensor systems, software updates, and diagnostics.
- **Mobility data analyst**: Interprets rider behaviour, vehicle performance, and system-level patterns to optimise fleet operations and service design.
- **Socio-technical mobility planner**: Integrates CCAM systems into broader urban mobility strategies, addressing accessibility, equity, and user experience across communities.

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[73] Stakeholder interview (Oscar Nissin).

- **Engagement and outreach coordinator**: Bridges the gap between technology developers, operators, public authorities, and communities, helping build trust in automated services.[74]

Despite the emergence of these new job profiles, many public transport operators and local authorities currently lack internal training structures, operational frameworks, or dedicated units to systematically build and retain such CCAM-related competencies. Without structured workforce development and role clarity across stakeholders, scaling autonomous mobility services beyond pilot phases will remain difficult

5.2.4 Reskilling and upskilling needs

Each aforementioned emerging or evolving role comes with specific upskilling needs:

- **Tele-assistants / remote supervisors**: Real-time AV fleet monitoring; remote intervention protocols; interface fluency with teleoperation tools; incident escalation procedures.
- **Field support agents**: Passenger assistance and reassurance; basic AV troubleshooting (e.g., restarts, door jams); communication and accessibility skills.
- **Stewards / bus ambassadors**: Assisting vulnerable passengers during boarding or navigation; conflict mediation; promoting trust in AV services through human presence.
- **Customer service staff**: Support via digital platforms (apps, kiosks); handling rider questions and issues across automated services; escalation to technical teams; training in inclusive and accessible communication.
- **Operations coordinators**: System-level fleet monitoring; coordination with remote operators and FSAs; familiarity with service KPIs and anomaly reporting; basic understanding of AV operation boundaries.
- **Remote operations specialists**: Situational awareness and AV system logic; high-stakes decision-making during system override; multi-vehicle supervision interfaces; coordination with field agents and system engineers.
- **AV maintenance technicians**: Sensor diagnostics and calibration (LiDAR, radar, cameras); updating and testing vehicle control systems; preventative maintenance for connected fleets.
- **Mobility data analysts**: Real-time data visualisation tools; passenger demand forecasting; AV performance monitoring and reporting.
- **Socio-technical mobility planner**: Integration of AV into urban systems and mobility policy; scenario planning and accessibility strategy; stakeholder alignment and governance.
- **Engagement & outreach coordinators**: Stakeholder communication (residents, policymakers, media); CCAM literacy for non-technical audiences; use of participatory tools to build trust.

5.2.5 Training and education gaps

Workers must be prepared for the shift towards automation, and they should be prepared at the education stage. The curricula of schools, universities and vocational training institutions should be updated to reflect the future requirements of the workforce. Such updates should reflect the integration of AI, robotics, and data analytics, so that workers are fit in light of technological

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[74] Stakeholder interview (Magdalena Szymańska).

advancements. In order to meet the broad demand of the CCAM sector, problem-solving activities and capabilities should be included in school curricula.[75] Upskilling and reskilling the current workforce are advisable to close the skills gap. This can be achieved through introducing lifelong learning programs, to ease the transition of employees into new roles. Additionally, employees at risk of losing their jobs should be prioritised. Therefore, it is critical to design upskilling or reskilling programs for those individuals.[76]

Current training programs are lacklustre in several key areas. Soft skills such as communication, teamwork, and emotional intelligence are growing in importance. There is also a mismatch between the training material and the specific skills required particularly in fields such as cybersecurity where qualified trainers are lacking. Additionally, the emergence of new job roles demands the upgrading of higher education curricula. It is crucial to develop lifelong learning, especially through flexible, accessible, and on-the-job training methods. Interviewees stressed that learning-by-doing is currently the default model, but this will not scale without structured frameworks. Additionally, they highlighted the urgent need for formalised training pathways and cross-sector education strategies that match the speed of CCAM deployment and reflect its human impact. Funding must be drawn to initiatives for upskilling and reskilling workers. Governments, as well as employers, partnerships between employers, and educational institutions should meet the cost of reskilling the workforce to face automation and digitalisation in the transport sector.[77]

5.2.6 Professions and skills mapping (SWOT analysis)

Strengths	Weaknesses
• The sector includes experienced staff (e.g. drivers, dispatchers, fleet supervisors) who possess deep operational knowledge and strong customer-facing skills. • Workers in public transport are already familiar with routine-based workflows, safety protocols, and service quality standards — useful foundations for CCAM operations. • Some workers are open to adapting, especially when training is linked to job security and progression. • Vocational retraining schemes already exist in many EU countries, and EU-level	• The current workforce lacks exposure to CCAM-specific technologies such as teleoperation platforms, V2X communication systems, and AV diagnostics. • Education and training pathways are not aligned with the emerging roles (e.g. remote operator, AV maintenance technician, socio-technical planner). • There is no recognised certification or standardised curriculum for new hybrid roles that blend logistics, tech, and customer care.

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[75] Chanda, Thelma & Sain, Zohaib & Mpolomoka, Daniel & Akpan, Wisdom & Davy, Mainde. (2024). Curriculum Design for the Digital Age: Strategies for Effective Technology Integration in Higher Education. International Journal of Research. 11. 185-201. 10.5281/ZENODO.13123899.

[76] Alonso Raposo M., Grosso, M., Després, J., Fernández Macías, E., Galassi, C., Krasenbrink, A., Krause, J., Levati, L., Mourtzouchou, A., Saveyn, B., Thiel, C. and Ciuffo, B., An analysis of possible socio-economic effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe - Effects of automated driving on the economy, employment and skills, EUR 29226 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-85857-4, doi:10.2760/777, JRC111477.

[77] Ioannis Karakikes, Helen Thanopoulou, Amalia Polydoropoulou, Cristina Pronello, Automation and digitalisation on the transport workforce: How can the shock be prevented?, Transportation Research Procedia, Volume 82, 2025, Pages 2984-3006,ISSN 2352-1465,https://doi.org/10.1016/j.trpro.2024.12.232.(https://www.sciencedirect.com/science/article/pii/S2352146524005313)

programs (e.g., France's PIC, Germany's RRP) show institutional readiness for supporting transitions. • The importance of human roles in AV supervision, field support, and inclusive service delivery is acknowledged by system designers and policy actors.	• Digital skill levels vary widely, especially among older or rural workers, making access and adaptation uneven. • Pilot project experiences are not yet systematised into replicable training modules across cities or countries.
Opportunities	**Threats**
• New CCAM roles are taking shape: teleassistants, remote operations specialist, bus ambassadors, socio-technical planners etc. • Increased funding for CCAM can drive demand for modular, simulation-based, and lifelong learning options tailored to operational staff. • Transitioning staff from legacy roles (e.g. drivers) into support and ambassador positions can preserve institutional knowledge and promote inclusive employment. • The sector can attract younger, tech-oriented workers through roles in app-based customer interaction, data analytics, and mobility coordination. • There is an opportunity to pilot peer-led, practical training formats (learning-by-doing) that align with current workplace cultures.	• Risk of social exclusion or job loss among workers who cannot (or do not want to) retrain for new roles, particularly older drivers. • Delays in developing formal training, recognition systems, and career paths could slow workforce readiness and limit deployment. • Regulatory and policy gaps may hinder clear definition and ownership of roles like AV supervision and remote control. • Absence of EU-wide skill standards or mobility frameworks could fragment training efforts and restrict workforce flexibility. • Without strong public communication and transition support, negative perceptions around automation and displacement may affect recruitment and trust.

5.2.7 Other relevant considerations

5.2.7.1 Sectoral and regional variations

Rural areas may be disproportionately disadvantaged in the transition to automation due to underdevelopment in key enabling factors such as education, digital infrastructure, and access to technology-driven employment. Limited training opportunities, lack of access to new technologies and lack of jobs in the tech sector, increase the risk that these regions will beo negatively affected by technological advancements.[78] The combination of these factors doesn't only pose risks to the workforce, but can impede innovation and technological growth in these areas altogether.[79]

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[78] European Training Foundation *Financial incentives for companies' engagement in VET* (2018) https://www.etf.europa.eu/sites/default/files/2020-02/policy_guidance_note_financial_incentives_rev.pdf

[79] International Labour Organisation (2019) *Skills and jobs mismatches in low- and middle-income countries* https://www.ilo.org/sites/default/files/wcmsp5/groups/public/@ed_emp/documents/publication/wcms_726816.pdf

5.2.7.2 Gender and inclusion considerations

Automation presents opportunities to make public transport operations more inclusive by:

- Reducing physical demands of driving and vehicle handling.
- Opening up remote work opportunities (e.g., teleoperation or system monitoring), which may appeal to groups underrepresented in the sector, such as women and people with mobility limitations.

However, women remain underrepresented in transport technology and operations roles. Without targeted outreach and inclusive training initiatives, the benefits of automation may reinforce existing inequalities.

6 Private (shared) transportation

The **Private (shared) transportation** use case centres on the deployment of SAE Level 4-capable automated vehicles for shared, on-demand mobility services in suburban and mixed-use environments. Developed under the Selvkjørende project, with operational leadership by Holo[80] and involvement from SAAM, the service offers robotaxi-style transport within a 22 km^2 area northeast of Oslo, integrating residential, industrial, and commercial zones.

The service is publicly commissioned and part of a broader strategy to improve mobility in underserved suburban areas. While operated by a private company on behalf of Ruter, Oslo's public transport authority, the service is public-facing and integrated into the wider mobility offering. Users book rides via a dedicated app, are directed to nearby pickup and drop-off points (PUDOs), and may share rides with others heading in a similar direction. Initially offered free of charge during the pilot phase, the service is publicly subsidised. In the long term, it is intended to be fully embedded in the public transport fare system – allowing payment via regular single tickets or day passes valid in the region.

The vehicles are retrofitted passenger cars, equipped with an automated driving system (ADS) designed to handle the full dynamic driving task (DDT) within an operational design domain (ODD) covering urban roads, suburban streets, and highways up to 90 km/h. The sensor suite includes a 360° setup of cameras (primary), radar, and LiDAR (secondary), with connectivity via 4G and GPS (non-safety critical). While the ADS is technically Level 4, it is currently under validation and supervised by an onboard safety operator, who remains responsible for risk mitigation.

6.1 Impact of CCAM

6.1.1 Business model and operation concept

The **Holo** use case is implemented as a platform-based, on-demand ride service in Oslo's Grorud Valley. Passengers book trips via a mobile app and are picked up by autonomous electric shuttles. **Holo's "Selvkjørende" project** partners with the Oslo transit authority Ruter and Mobileye; it uses NIO electric SUVs outfitted with Mobileye self-driving software to operate as a shared on-demand service.[81] [82]Key features of this business model include:

- **On-demand ride-hailing via a mobile app:** The Selvkjørende service is accessed through a custom app. **Passengers choose pick-up and drop-off points** in real-time, and the system dispatches a nearby AV to fulfil the request.
- **Dynamic routing and pooling:** Holo's system groups multiple riders with similar routes when possible, to improve efficiency. Vehicles follow dynamically optimised routes, picking up and dropping off passengers along the way.
- **Autonomous operation with remote supervision:** The vehicles currently operate with a safety operator on board to support ongoing validation of Level 4 autonomy. Once the required proof point for fully driverless operation is achieved, the safety operator will no longer be needed. From that point on, Holo's remote operations team will assume full responsibility for supervising the vehicles. While active remote driving is not part of

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[80] See: https://www.letsholo.com/

[81] See: https://www.letsholo.com/grorud-valley

[82] See: https://ruter.no/en/plan-a-journey/selvkjorende-shared-autonomous-transport-on-demand

normal operations, fallback teleoperation is possible in exceptional cases – for example, to assist the vehicle in safely navigating around unexpected obstacles. Human oversight and certified fail-safe systems remain essential components of the deployment.

- **Integration with existing transit:** The service is explicitly designed to **complement Oslo's high-capacity public transport**. It fills first-mile/last-mile gaps around Grorud Valley, working alongside buses and metro lines[83]. Passengers can use the app to connect seamlessly to main transit hubs.

6.1.2 Expected benefits and impact of CCAM technology on the use case

Holo's autonomous shared vehicles promise to enhance efficiency, safety, and accessibility in Oslo's suburban context. Because the fleet is all-electric (battery-powered NIO SUVs), the service is **"eco-friendly"** and emissions-free at the tailpipe.[84] This aligns with Oslo's goals: authorities aim for 0% emissions in public transport, and the Holo project is explicitly testing how driverless EVs can help achieve that target.[85] On a per-kilometer basis, shared AV rides will emit far less CO_2 than private cars or diesel buses, especially as renewable electricity powers the fleet.

Shared autonomous vehicles also improve resource utilisation. **Holo's shuttles operate continuously** (subject only to charging needs), unlike human drivers with shift limits, which increases vehicle utilisation. The system can automatically route each vehicle to new requests immediately after drop-off, minimising idle time. Dynamic ride pooling further reduces "deadhead" travel by combining passenger trips. In dense urban corridors, this can significantly cut congestion: for example, the Grorud Valley service is aimed at **complementing existing transit** rather than replacing it, thereby potentially drawing riders out of private cars and into shared EVs. These services can also be deployed 24/7, enabling demand-responsive operation outside traditional service hours and thereby improving off-peak connectivity for shift workers or people in underserved areas

Accessibility is a major benefit. By design, the future Selvkjørende shuttle will have space for wheelchairs and bicycles, and the flexible service area covers multiple residential districts. Early trials by Holo in Oslo demonstrated that autonomous shuttles can dramatically **expand mobility for non-drivers**. For instance, on the Ormøya island route trial, the service makes the area more accessible for people without cars, and some expected *'regular customers'* are children being driven to and from school every day. In Grorud Valley, the app allows elderly, disabled, or low-income residents to book rides to anywhere in the service zone, effectively providing an on-demand link where bus service may be limited. The flexible repositioning of vehicles based on real-time demand also allows the service to adapt to dynamic patterns such as school times, shopping hours, or late-night activities, making it more attuned to local mobility needs.

6.1.3 Challenges and barriers

Implementing Holo's autonomous ride-sharing faces multiple hurdles:

- **Technical:** Safely navigating Oslo's mixed-traffic environment is hard. Holo vehicles must detect cars, buses, bicycles and pedestrians, often in tight urban streets. Nordic weather (snow, ice) adds complexity; indeed, developers note that Norwegian conditions are a

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[83] letsholo.comcomputerweekly.com

[84] See: https://ruter.no/en/plan-a-journey/selvkjorende-shared-autonomous-transport-on-demand

[85] See: https://www.letsholo.com/oslo

rigorous testbed for AV tech.[86] To address this, Holo uses a high-quality sensor suite (Mobileye's suite on NIO SUVs) and conducts extensive mapping campaigns. For example, Holo ran a "REM" mapping phase with manually driven vehicles to collect detailed road data.[87] Teleoperation remains necessary; **Holo's remote supervision team** continuously monitors vehicles and can support a safety driver during unusual situations. Ensuring cybersecurity of the AV control and data links is also a vital concern. AV software must be continuously adapted to local climate and road conditions to ensure reliable operation throughout the year, including fallback routines in case of sensor obstruction or degraded performance. Stable, high-bandwidth connectivity is critical to enable safe teleoperation and real-time fleet monitoring; network latency or outages could compromise safety

- **Regulatory:** Norway does not yet have complete legislation for fully driverless ride services. Holo must work within pilot exemptions and obtain special permits. In 2023 Holo submitted an application to the Norwegian Public Roads Administration for a Level 2/3 automated driving permit (a step toward Level 4). The pilot operates under a research framework: it is coordinated by Ruter (the transit agency) and is considered a limited experimental service. Liability rules are still evolving; for the trial period, responsibility and insurance for accidents involving the self-driving vehicles must be handled case by case.

- **Financial:** The upfront costs are high. Holo must retrofit vehicles with autonomy hardware (sensors, computers) and invest in IT systems (ride-hailing app, fleet management). Charging infrastructure is needed for the EV fleet. Early on, these costs are subsidised by public funds or partnerships (Ruter, Mobileye). Balancing affordability and sustainability is tough when demand is uncertain. **Holo's CFO notes** that consumers want pay-per-trip models, but building a fleet of EV shuttles and support facilities still requires significant capital from investors or municipalities.

- **User acceptance:** People must trust driverless cars. To build confidence, Holo and Ruter are running the system with full transparency: they have held public demo events (for example, in Oct. 2023 new AVs were shown to local residents) and are offering free trial rides. Still, some riders may be wary about safety or reliability. Clear communication via the app (e.g. showing wait times and vehicle locations) is essential. There may also be pushback from existing taxi or bus drivers who fear competition. Holo has engaged stakeholders early to explain how the service complements, rather than replaces, traditional transit.

6.1.4 Policy and regulatory factors

In the private shared mobility sector, **current regulations are still catching up**. In Norway, autonomous on-demand services like Holo's are new terrain: there are no dedicated ride-hailing rules for driverless shuttles. The Selvkjørende project therefore runs under a special research exemption and pilot permissions. For example, Holo has been **responsible for securing all necessary approvals** (working with authorities) for the trial. Insurance and liability frameworks also need adaptation: traditionally, a human driver's insurer would be at fault, but for an AV,

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[86] See: https://www.computerweekly.com/news/252495657/Nordic-region-provides-autonomous-vehicle-test-bed

[87] See: https://www.letsholo.com/grorud-valley

responsibility may lie with the operator or manufacturer. These issues are being addressed on a case-by-case basis in the pilot.

At the local level, municipal planning matters too. Oslo and its agencies (like Ruter) are generally supportive of innovation, which helps Holo gain necessary support. However, cities elsewhere may hesitate to allow large AV fleets due to concerns about congestion, labour markets, or equitable service provision. In practice, authorities require not only vehicle type approval, but also a local permit for operational deployment. a process that is often unclear or not yet formalised. Currently Holo's shared mobility service operates in a geo-fenced zone (Grorud Valley) where rules have been agreed. Broad deployment will likely require new licensing categories for "automated ride services" and perhaps separate regulation from both public transit and taxi industries. The Selvkjørende trial itself is essentially a pilot project (comparable to other city pilots) and will inform how rules should evolve. The involvement of Ruter and Oslo's commitment to sustainable transport provide a favourable political context, but harmonised policies across municipalities will be needed if Holo's model is to scale across Norway or the EU. A further challenge though is that many local authorities and transport operators lack the technical expertise to assess AV systems or define their own operational requirements (also Cyber Security, data sovereignty), despite being responsible for shared safety oversight

In EU and international level regulations have been analysed in sections 2.1.4 and 3.1.4.

6.1.5 Geographic and operational context

Holo's Grorud Valley pilot serves a **suburban area of Oslo** (population ~140,000; about 20% of the city's residents) spread over roughly 21.8 km^2 with about 290 km of road. This mixed residential-industrial district provides a representative urban context with dense apartment blocks and commercial zones. Oslo (and Norway at large) is a supportive environment for such projects: Norway has high EV adoption, strong digital infrastructure, and active smart city programs, making it a prime testbed. Other European cities with similar profiles (dense neighbourhoods, emission targets, open regulators) would be natural next steps. Holo's ultimate goal is to expand the service throughout Oslo's metro area and potentially into neighbouring regions.

In terms of timeline, Holo's project is currently at a technology demonstration stage (roughly TRL 4–5). The first phase (2023–2025) involves only a few vehicles (initially two) operating in Grorud Valley to prove the concept and gather data. Looking ahead, Holo envisions scaling: internal projections show that by the mid-2020s this could expand to tens or hundreds of vehicles covering larger urban districts. Their published roadmap indicates a **business-viability phase (2023–2025) with about 20–250 AVs over ~480 km^2** of service area, and by 2030 potentially thousands of vehicles and thousands of square kilometres served. In the short term (2025–2027) we expect only limited ODDs and fleet sizes (pilot phase), while medium term (2028–2030) could see growth to a city-wide network. Long term (post-2030), the ambition is full commercial deployment as part of Oslo's regular transit mix, as autonomous shuttles become mainstream.

6.1.6 Economic and market factors

As automated ride-sharing platforms emerge, they will compete with traditional transport providers and micromobility options, potentially consolidating around major players. CCAM in shared transportation creates **new service markets around automated ride-sharing and mobility platforms**. It accelerates the shift away from private vehicle ownership toward on-demand, flexible mobility solutions. Companies that deploy early will shape consumer expectations and standards for automated mobility services.

CCAM-enabled services will directly **compete with traditional taxi and ride-hailing companies**, as well as with emerging micromobility solutions (e-scooters, bikes). The market could quickly become consolidated around major mobility operators, platform providers, and shared autonomous vehicle manufacturers.

Significant **upfront investment** is required for:
- Autonomous vehicle fleet acquisition.
- Development of ride-booking and fleet management software platforms.
- Teleoperation centres for supervision and exception handling.
- Charging infrastructure and depot facilities for fleet operations. Investors may need to support longer payback periods, particularly during early adoption phases.

Infrastructure needs include urban digital infrastructure for real-time fleet monitoring and routing (5G networks, V2I systems), designated pick-up/drop-off zones for safe and efficient passenger handling and data-sharing agreements between operators and cities to integrate CCAM services into urban mobility ecosystems

6.1.7 Operational and logistical considerations

CCAM enables centralised, dynamic control of shared vehicle fleets. Operators can monitor vehicle availability, optimise pick-up and drop-off locations, and balance supply across service areas in real time. Predictive algorithms manage vehicle repositioning to meet fluctuating passenger demand.

Automated fleets also support **on-demand ride services without driver availability constraints**. The system allows for dynamic ride pooling, where passengers with similar routes are matched automatically, improving vehicle utilisation and lowering service costs per user.

Shared autonomous vehicles reduce dead mileage (traveling without passengers) through optimised routing and ride pooling strategies. Fleet operators can maximise occupancy rates and ensure consistent service levels, even during peak traffic times or in underserved neighbourhoods.

Additionally, the absence of driver scheduling constraints supports 24/7 service availability, improving mobility access around the clock.

Holo manages a centralised AV fleet for Grorud Valley. The operator monitors all vehicles in real-time via its control center, **dispatching rides and rebalancing vehicles across the service area**. Predictive algorithms forecast demand; for example, if a cluster of trip requests appears near a metro station, the system can pre-position shuttles there. This kind of demand-responsive repositioning reduces wait times and improves coverage. Because there are no drivers, vehicles can in principle run 24/7 (maintenance and charging allowing), offering flexibility beyond fixed-schedule services.

Currently, vehicles are sent to each passenger one at a time (the app indicates exactly when and where to board). In the future, Holo plans to add **dynamic ride pooling**, automatically matching multiple riders with similar routes to share a shuttle. This will further increase average occupancy and lower cost per user. Logistics also include managing "dead mileage" – Holo's routing software minimises unnecessary empty trips when, for example, sending a vehicle to a distant passenger.

Overall, Holo's operations rely on advanced software: a fleet management platform (its "AV Suite") integrates live GPS data, route planning, and even health monitoring of each vehicle. Vehicles report their status (battery, location, etc.) continuously. The operator can remotely update software, adjust schedules, and intervene if a vehicle is stuck. The Grorud pilot is relatively small-scale, but the same framework would support expansion. In essence, Holo runs a high-tech bus service where each "bus" is a software-driven robot that can be re-dispatched and maintained centrally. As one industry summary puts it, the long-term vision is a network of "connected, electric and autonomous" vehicles enabling a new mobility ecosystem.

6.1.8 Social and environmental impact

Shared autonomous transport services offer meaningful social and environmental benefits, particularly in terms of accessibility, safety, and sustainability. CCAM-enabled shared transportation **enhances mobility for elderly, disabled, and non-driving populations** by offering affordable, flexible rides without needing a driver. It expands first-mile/last-mile connectivity in areas underserved by traditional public transport. Autonomous vehicles **reduce crash risks related to human error** (e.g., distraction, fatigue, impairment). Their consistent, rules-based behaviour improves safety outcomes, especially in urban environments with high pedestrian and cyclist interaction.

Full scale deployment depends on policy alignment and regulatory readiness at the local and national levels. Political will is essential to:

- Authorise pilot zones.
- Adapt transport and safety regulations.
- Ensure public infrastructure investments.
- Political instability or inconsistent governance can delay scaling or erode investor confidence.

Holo's shared autonomous shuttles offer substantial societal and environmental benefits if widely deployed in Oslo. The service expands mobility for those without cars – elderly, disabled, or low-income residents – by giving them on-demand rides. Early autonomous shuttle trials in Oslo already demonstrated this: for example, island communities gained daily transit links, aiding children's commutes and elderly residents' errands. In Grorud, the same effect is expected: residents in distant parts of the valley can now reach stores, offices or transit hubs on demand. The app-based model (with low or no fares during testing) lowers economic barriers to travel, helping include poorer populations.

By using battery-electric vehicles exclusively, Holo's service cuts greenhouse gases and local pollutants compared to fossil-fueled transport. Every rider carried on a full shuttle produces far fewer emissions (per km) than if they drove separately. If Holo's model succeeds and replaces many private-car trips, it could significantly improve Oslo's air quality and help meet climate goals. This aligns with Oslo's ambition of a zero-emission public transport system.

Fewer private cars on the road means less need for parking. In principle, widespread AV-sharing could free up curb space in Grorud and other dense areas for bike lanes, parks or new pedestrian zones. Early pilots haven't yet transformed city design, but planners note that shifting to shared AV fleets would eventually reduce parking lots. Holo also coordinates with city planners to locate pickup/dropoff zones in safe, efficient locations, a positive change from ad-hoc street stops.

Public trust is critical. So far, the pilot service is provided free during tests, which encourages people to try it and build word-of-mouth.[88] Holo and Ruter share clear information via the app and outreach events. Nonetheless, some resistance is inevitable: taxi drivers and unions worry about lost jobs, and some residents may feel uneasy about sharing rides with strangers or riding in driverless vehicles. Holo addresses these concerns by keeping an operator in the loop (at least remotely) and by highlighting service reliability – for example, guaranteeing that customer support is one tap away in the app. City officials believe acceptance grows with transparency and experience: showing residents exactly how the tech works (as with Holo's public demo days) and giving them early access helps build legitimacy. Over time, Holo expects that riders who start using the free service will become advocates for the technology.

6.1.9 Past experiences and lessons learned

For the implementation of private shared transport Holo and its partners have already accrued practical lessons from pilot projects in Norway and the Nordic region:

- **Incremental deployment:** Previous Oslo pilots (2019–2020) operated a small fleet of 4 Navya shuttles on fixed short routes. These trials, run in partnership with Oslo and Ruter, showed the value of starting in controlled environments (e.g. a route between a cruise port and city square) before scaling up.
- **Human supervision (teleoperation):** All early trials confirmed the importance of backup systems. In Oslo, each shuttle had a trained operator on board and a remote control center. Holo learned to invest in a capable remote supervision team to support vehicles via live monitoringhttps://www.letsholo.com/grorud-valley. This reduces safety risks and ensures rapid response to unexpected events (e.g. a roadblock or sensor fault). Future operations will continue to use teleoperators during the transition to fully driverless service.
- **High-quality mapping and infrastructure**: Precise digital maps are critical. For Grorud, Holo ran a Road Experience Management (REM) campaign: five crewed vehicles systematically drove all streets to collect 3D data.89 Creating these HD maps and defining detailed navigation rules proved essential for reliable autonomy. Holo's experience highlights that cities aiming to host AV services may need to invest in mapping, dedicated pick-up/drop-off zones, and possibly V2X installations (as tested by Holo on Kongens Gate in Oslo). Consistent street infrastructure (signage, road markings) also makes a difference.

6.2 Skills needs and mismatches

6.2.1 Labour market trends

The deployment of CCAM is reshaping job roles and employment levels across the passenger transport sector. EU-level projections indicate a decline of between 2.2% and 12.5% in transport employment by 2050, depending on the pace of Connected and Autonomous Vehicle (CAV) adaptation. In taxi services, automation at SAE Levels 4 and 5 and the competition of ridesharing services such as Uber are contributing to job losses. However, the ridesharing sector is projected

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[88] See: https://ruter.no/en/plan-a-journey/selvkjorende-shared-autonomous-transport-on-demand

[89] See: https://www.letsholo.com/grorud-valley

to grow, reaching approximately 660,000 jobs by 2050, while automated taxi services may only create around 5,500 jobs.

6.2.2 Skills gaps and mismatches

In the private shared transportation use case the transition toward digital, connected, and autonomous services is exposing critical skills gaps in the workforce. One such gap arises in digital and technical competencies. There is a concern that many current drivers and support staff may lack sufficient digital literacy and data-handling skills to effectively use advanced platforms and analytics. Safety drivers, responsible for operational safety and quick-response, are also required for providing detailed feedback to engineering teams. These roles necessitate rapid IT adaptation, basic software literacy, and the ability to anticipate autonomous vehicle behaviour effectively. The existing workforce, particularly older bus drivers, often struggles with this adaptation, limiting effective retraining and highlighting an essential mismatch between existing skillsets and evolving technological requirements.[90]

Remote operational supervisors similarly face elevated skill requirements, including robust data literacy, crisis management abilities, and interpreting complex operational data streams encompassing vehicle performance, environmental conditions, and regulatory compliance. Supervisors with higher educational backgrounds in logistics or engineering typically adapt more quickly, yet the existing talent pool remains limited, complicating rapid scalability and operational expansion. In maintenance and technical support roles, traditional mechanical tasks increasingly overlap with advanced technological responsibilities. Technicians must now gain proficiency in sensor calibration, software diagnostics, cybersecurity fundamentals, and passenger interface management. This blended skill requirement represents a significant transition from conventional mechanical competencies, necessitating targeted retraining and upskilling initiatives. This evolution also challenges existing vocational training structures, as traditional automotive curricula rarely cover the hybridisation of mechanical and digital domains required for AV maintenance.

Regulatory knowledge presents another notable skills gap. The regulatory landscape for shared mobility is evolving rapidly, from local licensing rules to EU-wide data protection and safety standards, yet frontline operators and authorities often have limited expertise in navigating these complexities. The patchwork of rules and unharmonised certifications illustrate a need for better regulatory literacy, without which, compliance and safety could be compromised, and services face deployment delays.

6.2.3 New job roles and competencies

As autonomous, on-demand mobility services like Selvkjørende expand, workforce roles in the private transport sector are shifting from traditional driving to remote support and system coordination. While full automation reduces the need for in-vehicle operators, it increases demand for blended skillsets that combine, among other things, digital fluency, and logistical awareness.

Existing roles:

- Taxi drivers may transition into:

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[90] Interview with HOLO.

    - Field support agents (FSAs) – respond to real-world incidents such as vehicle malfunctions, navigation issues, or user support needs. This role maintains physical presence and safety assurance in a driverless service context.
    - Tele-Assistants – remotely monitor vehicle activity and respond to user inquiries during rides, including providing reassurance, safety instructions, or basic troubleshooting.
- Dispatchers and route planners may become:
    - Fleet and operations coordinators – manage the dispatch, optimisation, and scheduling of AV fleets to ensure high utilisation, coverage, and responsiveness in a dynamic service area.
- Customer service staff evolve into:
    - Mobility experience managers – oversee service quality, interface design, and accessibility, ensuring a smooth passenger journey across app booking, vehicle boarding, and in-ride experience.[91]
- Safety drivers: Although the long-term aim of services like Selvkjørende is a fully driverless operation, the current phase still relies on onboard safety drivers.

Emerging occupations in CCAM-based private transportation include:

- **Remote operations specialists:** monitor AV fleets in real time from control centres, ready to intervene in edge cases or escalate to field agents. This role requires decision-making under uncertainty and understanding of AV system boundaries.
- **AV systems technicians:** maintain and calibrate sensor suites (camera, radar, LiDAR), onboard computing systems, and connectivity links. These workers blend mechanical knowledge with digital diagnostics.
- **Customer service managers** will focus on improving and overseeing the passenger experience within autonomous vehicle services. Their work ensures that service delivery meets user expectations.
- **App interface developers & analysts:** will support CCAM-based mobility services by designing or managing the mobile platforms used to book and coordinate rides. These apps are central to accessing AV services.
- **Urban integration planners:** will draw from their background in passenger transport to help design urban systems that integrate autonomous vehicles.
- **Regulatory and compliance officers:** ensure that operations comply with evolving local, national, and EU-level CCAM regulations. This includes data protection, liability structures, and permitting processes, often in close collaboration with public authorities.

6.2.4 Reskilling and upskilling needs

Each aforementioned emerging or evolving role comes with specific upskilling needs:

- **Field support agent (FSA)**: on-the-ground incident response (e.g. flat tires, stalled AVs); safety protocol adherence; communication and passenger assistance skills.
- **Tele-Assistant**: Live monitoring of ride experience; Remote interaction with passengers; Incident triage and escalation procedures; Service empathy and clarity.

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[91] Stakeholder interviews (Holo) and (Ruter).

- **Remote operations specialist**: Real-time AV fleet supervision; edge case assessment and decision-making; deep understanding of AV limitations and behaviour; coordination with FSAs.
- **Fleet and operations coordinator**: Scheduling and dispatch optimisation; system-level oversight of vehicle routing; platform interface fluency (e.g., fleet dashboards, demand prediction).
- **Mobility experience manager**: Customer feedback monitoring; integration of accessibility features; managing service design elements in AV user experience.
- **AV systems technician**: Sensor diagnostics (camera, radar, LiDAR); software/hardware interfacing; OTA (over-the-air) update execution; system calibration under TRL-level constraints.
- **App interface developer / analyst**: Mobile UX/UI design for on-demand AV services; user data monitoring and A/B testing; integration with MaaS platforms and real-time APIs.
- **Urban integration planner**: Infrastructure adaptation for PUDO design; multimodal planning with AV fleet integration; safety signage and road system analysis.
- **Safety Driver (in-transition role)**: Advanced situational awareness under AV supervision; understanding of ADS behaviour and limits; manual intervention readiness during degraded mode; communication and reporting of system anomalies; serving as a bridge between engineering teams and operational realities.

6.2.5 Training and education gaps

There are several critical gaps in the current training and education landscape for CCAM-related roles, particularly in services like Selvkjørende. Firstly, there is a lack of formal training frameworks for key transitional roles such as safety drivers and remote supervisors. As noted by Holo, current safety drivers receive internal training, but no nationally or EU-recognised certification exists for this type of work. This gap creates a challenge for standardising competencies and scaling workforce preparation as deployment expands.

Secondly, most skill development currently relies on ad hoc, on-the-job learning. Staff acquire expertise through internal mentorship or experiential exposure, rather than through structured or accredited programmes. While this may suffice for early-stage pilots, it is not a scalable or sustainable approach as AV services grow in complexity and geographic reach.

Interviewees also pointed to unclear job definitions. Emerging roles such as "remote operator" or "field support agent" are not yet formally defined in labour systems or occupational classifications. This ambiguity delays the development of training curricula, recruitment standards, and job descriptions, making it harder to attract or prepare workers for these positions. A further gap lies in the mismatch between traditional transport competencies and the digital skillsets required in CCAM. Many professionals in the public and private mobility sectors have limited experience with digital interfaces, data systems, or AV-specific software platforms — all of which are now becoming core elements of operational roles.

Lastly, there is a noticeable absence of multidisciplinary, socio-technical integration in existing training programs. Current education frameworks tend to focus on either technical mechanics or service operations, but not both. Interviewees stressed the need for roles that bridge engineering knowledge with human-centred service delivery—skills that are increasingly critical in public-facing CCAM deployments.

6.2.6 Professions and skills mapping (SWOT analysis)

Strengths	**Weaknesses**
• Passenger transport professionals, especially those with backgrounds in taxi driving or fleet operation, bring valuable expertise in situational awareness, navigation, and service delivery. These skills are transferable to transitional roles such as safety operators, tele-assistants, or field support agents, particularly in the early stages of Level 4 deployment. • The service-oriented experience of existing staff—especially in customer interaction, problem-solving, and public safety—remains relevant and irreplaceable in many human-in-the-loop roles that support CCAM. • There is growing awareness among private operators of the need to integrate human roles into automated mobility systems, as reflected in service models like Selvkjørende, which currently blend AV technology with human oversight and customer support. • Some companies are already implementing internal training practices, laying the groundwork for experience-based upskilling models that can be scaled in the future.	• The current workforce often lacks formal training in software systems, digital interfaces, and teleoperation, making it difficult to prepare quickly for CCAM-specific operational roles. • Safety drivers and remote supervisors are essential in early deployments, but no standardised certification or vocational training exists for these positions, creating inconsistency in preparation and performance. • Education systems and labour classifications have not yet adapted to reflect new job profiles such as remote operations specialists, fleet coordinators, or accessibility stewards. • The transition from driver to supervisor/support roles can involve a significant cultural and skills shift, particularly for workers with limited prior exposure to digital tools or automation concepts.
Opportunities	**Threats**
• New job roles are emerging alongside the automation of private shared transport, including remote operators, mobility experience managers, AV technicians, app developers, and urban planners specialising in AV integration. • Services like Selvkjørende showcase the potential for hybrid mobility models where public transport subsidies support private AV operators, creating new organisational and service delivery roles. • Mobility-as-a-Service (MaaS) ecosystems will rely on professionals for human-centred design, cross-modal coordination, user support, and fleet-level optimisation—offering a diverse set of employment opportunities beyond driving. • The current emphasis on public trust and accessibility in AV rollouts provides a	• Without proactive investment in targeted reskilling programmes, workers may be left behind due to gaps in digital readiness, technical adaptability, or familiarity with AV service models. • A lack of role recognition, training infrastructure, and policy coordination may slow the development of a skilled CCAM workforce and delay deployment timelines. • Labour market mismatches, especially in suburban or rural areas, could lead to critical skill shortages in roles essential for safe, user-friendly, and scalable AV operation.

platform to promote inclusive employment, such as roles supporting elderly or disabled passengers.	

6.2.7 Other relevant considerations

6.2.7.1 Sectoral and regional variations

The deployment robotaxis and private hire vehicles is expected to impact European regions unevenly due to the economic, educational, and infrastructural differences. Western and Northern European countries, such as Germany, the Netherlands, France, and Scandinavia, typically enjoy stronger technical infrastructures and better access to workforce development resources. These conditions support smoother upskilling and reskilling processes, placing these regions in a more favourable position to adopt automated mobility solutions at scale.

On the other hand, Southern and Eastern European countries may face significant delays in CCAM adoption. These regions often experience pronounced skills mismatches, driven by more limited access to higher education and digital training programs. This gap hinders the local workforce from engaging in emerging mobility sectors and deepens the urban–rural divide. In economically weaker areas, automation risks reinforcing existing inequalities if tailored policies and funding mechanisms are not introduced.

Moreover, **spatial disparities in skills availability** compound the problem. Urban regions typically concentrate more research institutions, training centres, and innovation clusters, which allows them to meet CCAM-related skill demands more effectively. However, rural areas often struggle with a lack of broadband internet, low exposure to technological advances, and reduced mobility options. These factors limit the workforce's ability to engage with new job roles in the robotaxi sector.

6.2.7.2 Gender and inclusion considerations

The taxi workforce remains overwhelmingly male. In a sample of 19 driver interviews, only one participant was a woman.[92] While not the study's focus, this suggests a significant gender imbalance in the sector. Without targeted interventions, women are at risk of continued underrepresentation in emerging roles within CCAM-enabled shared mobility. Roles such as tele-assistants, passenger stewards, and mobility experience managers emphasise communication, empathy, and service design—areas where female representation tends to be stronger. Creating these roles opens pathways into the mobility sector that are less physically demanding and more focused on user-centric service delivery. Additionally, private, on-demand transport services staffed by remote operators, app developers, and AV technicians can offer shift-based, flexible working arrangements. This supports better work-life balance - a key factor in reducing career interruptions often experienced by women.[93]

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[92] Pakusch, C., Boden, A., Stein, M., & Stevens, G. (2021). The Automation of the Taxi Industry – Taxi Drivers' Expectations and Attitudes Towards the Future of their Work. Page 548. Available at: The Automation of the Taxi Industry – Taxi Drivers' Expectations and Attitudes Towards the Future of their Work | Computer Supported Cooperative Work (CSCW).

[93] ITF (2021), "Transport Innovation for Sustainable Development: A Gender Perspective", OECD Publishing, Paris.

7 Shared transportation targeting specific groups

The **Shared Transportation Targeting Specific Groups** use case explores the deployment of SAE Level 4 autonomous shuttles designed to improve mobility for population groups with specific needs—such as people with disabilities, the elderly, and residents of rural or low-accessibility areas. A prominent example is the BLEES electric autonomous shuttle,[94] developed for inclusive, demand-responsive transport in environments like clean city zones, suburban developments, and mobility-deprived regions.

Vehicles operate along predefined routes at speeds of up to 50 km/h and autonomously navigate around stationary or slow-moving obstacles without overtaking. Unlike systems that rely on road-sign reading, these shuttles follow pre-programmed behaviour integrated with route mapping and local infrastructure, including traffic signal controllers that grant intersection priority. The system includes robust two-way connectivity to enable remote monitoring, real-time communication with passengers, and operator intervention when required.

Passengers request trips via a mobile app or call centre, are guided to designated pickup and drop-off points (PUDOs), and receive real-time journey updates through an enhanced human-machine interface (HMI). This HMI also communicates externally, for instance, by alerting pedestrians that they've been detected, supporting both safety and trust. While passengers cannot directly initiate or terminate automated driving, remote or on-site operators manage these transitions.

Though the solution's TRL is not formally stated, it anticipates scalable supervision models, where a single operator may oversee multiple vehicles. Local support staff can be deployed in sensitive areas to assist passengers with specific needs, such as those requiring boarding assistance or social reassurance.

7.1 Impact of CCAM

7.1.1 Business model and operation concept

CCAM-based on-demand transport is typically funded and organised through local authorities. In Blees's approach, **the service is offered directly to cities, municipalities and institutions**, reflecting a public-sector deployment model.[95] The company provides a cloud-based service management platform that automates routing and scheduling for flexible, demand-driven transit. Users can book rides via a smartphone app or phone call, with an operator entering any phone-booked trips into the system. Vehicles may run with or without onboard staff depending on context. **Blees's shuttle is designed for SAE Level 4 autonomy (no onboard driver)**, monitored by remote operators.[96] A single remote operator can supervise multiple vehicles, handling takeovers if needed. The design emphasises inclusion: for example, the BB-1 includes **wheelchair spaces with seatbelts and sensors** and AI that detects wheelchairs and strollers. In practice, Blees aims to **eliminate service inaccessibility for people with limited mobility**, integrating with health and social care objectives in underserved communities.

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[94] See: https://blees.co/en/.

[95] See: https://blees.co/en/solution/

[96] See: https://blees.co/en/safety/

7.1.2 Expected benefits and impact of CCAM technology on the use case

CCAM technologies offer substantial benefits when applied to transport services designed for specific user groups, such as the elderly, people with disabilities, or individuals in low-demand areas. These services can be delivered more efficiently and sustainably using electric autonomous vehicles, while also improving safety and accessibility for vulnerable populations.

The Blees shuttle uses advanced sensors (lidar, cameras, radar) to continuously scan its surroundings and detect pedestrians and obstacles. This enables **predictable, cautious behaviour** that enhances safety. Nearly 80% of test passengers (especially those aged 60+) reported a high sense of security during rides, indicating strong trust in the autonomous service.

- **Efficiency:** Reduces operating costs for niche transport needs. Blees's on-demand platform automates scheduling and optimies routes, improving efficiency on low-demand routes.
- **Sustainability:** Uses an all-electric vehicle. The BB-1 shuttle is fully electric with zero tailpipe emissions, supporting green mobility goals. Electric power and automated routing together lower the environmental footprint.
- **Accessibility:** Greatly improves mobility for elderly, disabled, or isolated users. Blees explicitly targets accessibility (e.g. eliminating mobility barriers), with features like wheelchair detection and dedicated boarding spaces. This can extend transit access to citizens who currently cannot easily use buses or trains.
- **Safety:** Offers cautious, reliable operation. The shuttle's sensors and high-definition maps allow it to avoid collisions smoothly. The system also includes passenger-counting cameras and two-way communication, so incidents can be detected in real time. Removing human error is expected to reduce accidents (studies show ~90% of crashes are human-caused).
- **Economic impact:** Enables cost-effective services without a full-time driver. Remote supervision (one operator for multiple shuttles) cuts labour costs. Blees's case studies have shown reduced operating expenses and environmental impact, suggesting fewer subsidies or less reliance on expensive paratransit vehicles.

7.1.3 Challenges and barriers

Deploying inclusive autonomous shuttles faces multiple challenges.

- **Technical:** Meeting accessibility needs and UX design is complex. Blees must ensure its vehicle and apps are user-friendly for people with diverse impairments. For example, it includes **wheelchair detection and dedicated seating**, but developing intuitive interfaces (large fonts, clear announcements) for elderly or sensory-impaired users remains difficult. Robust teleoperation is needed for unexpected situations.
- **Regulatory:** Automated DRT services for vulnerable users lack harmonised rules. Blees's shuttles must comply with existing disabled-transport regulations (e.g. secure wheelchair transport, sensor-based safety) even though those rules were not written for driverless vehicles. Navigating insurance and safety standards for Level 4 shuttles adds uncertainty.
- **Financial:** Public funding is critical. Niche services like Blees's are rarely self-sustaining on fares. Blees's pilots (e.g., a municipal school shuttle) rely on city budgets or grants. Long-term viability depends on subsidies or integrating costs into public welfare transport.

- **User acceptance:** Riders may worry about the lack of onboard staff. Addressing this is essential. Blees's trials show that information and support build trust – nearly **80% of riders rated the Blees shuttle highly on security** – but some users still prefer human assistance. Training, demonstrations, or attendants may be needed initially.
- **Policy objectives:** The Blees case aligns with goals for inclusive mobility. Its focus on accessibility and rural service supports policies like the **EU Disability Strategy 2021–2030** and Sustainable Urban Mobility Plans. By co-designing with communities and emphasising universal design, Blees aims to meet equity objectives in transport.

7.1.4 Policy and regulatory factors

Shared transportation services targeting specific user groups typically operate under local or regional public transport regulations, which require compliance with accessibility laws, data protection standards, and public service obligations. However, there is currently no consistent regulatory framework across the EU that specifically addresses automated DRT services designed for vulnerable populations. To enable safe and inclusive deployment, regulations will need to evolve, supporting new vehicle types, flexible service models, and remote supervision mechanisms tailored to the needs of these user groups.

Blees's autonomous shuttle must operate within public-transport regulations and emerging AV rules. As a passenger service, it must adhere to accessibility laws: e.g., providing wheelchair ramps, announcements, and securement as required by EU and national disability regulations. Data privacy (GDPR) is also relevant, since the Blees app and monitoring system handle personal journey information. Currently there is no specific EU framework for automated DRT for vulnerable groups, so Blees's deployments (in Poland and elsewhere) rely on experimental permits and close coordination with authorities. Future regulations will need to acknowledge services like Blees's by allowing flexible operation models and remote supervision.

Relevant policies include the **EU Disability Strategy 2021–2030** and national accessibility laws, which emphasise inclusive transport; Blees explicitly targets "transport for people with disabilities". Sustainable Urban Mobility Plans encourage services for the elderly and disabled. The CCAM Partnership's emphasis on user-centred inclusive design also supports Blees's goals. Blees must also consider sector-specific rules: e.g., if serving schools or medical appointments, it must follow regulations for those services. Overall, ensuring legal compliance will involve adapting emerging automated-vehicle guidelines and data protection standards to Blees's context.

7.1.5 Geographic and operational context

In terms of **scale**, the Shared Transportation Targeting Specific Groups use case is intended for small-scale, localised deployments, such as villages, campuses, care homes, or community centres. These services are designed to serve a limited number of users with specific mobility needs, emphasising door-to-door accessibility, personal assistance, and flexible scheduling. Initial deployments are expected to focus on niche environments with well-defined populations, before potentially expanding into broader regional service models that integrate with health and welfare mobility systems.

In terms of **geographical scope**, this use case is particularly valuable in rural, suburban, and low-service-density areas across the EU, where conventional public transport is limited or unavailable. These regions often face significant transport exclusion, especially among elderly and disabled populations. By addressing gaps in existing services, CCAM solutions for targeted groups aim to improve transport equity and support social inclusion. Implementation is likely to be driven by local authorities and supported through public funding or social care programs.

In terms of **timescale**, the deployment of CCAM technologies in this context is currently at TRL 4–5, with systems in early demonstration or testing phases. In the **short term (2025–2027),** localised pilot services, often publicly funded, are expected to emerge in select municipalities or regions. By the **medium term (2028–2030**), these services may be more widely integrated into welfare mobility systems and rural transport strategies, especially where aligned with broader social policy and accessibility goals.

Blees's shuttles have been deployed at small scale in specific local areas. For example, a pilot in Gliwice (Poland) involved **10 autonomous minibuses serving 120 schoolchildren**.[97] Another project in Sosnowiec used Blees's on-demand night service across 53 pickup/dropoff points. These pilots illustrate operations in well-defined communities (schools, night-time commuters) rather than broad networks. In practice, Blees's shuttle runs on predefined urban routes (up to ~50 km/h in safe zones) and is suited to environments like **clean-air city zones, suburban developments, and rural areas with few transit options**.

In low-density or mobility-deprived regions, these services bridge gaps left by sparse buses. Blees plans to integrate its shuttles with existing welfare mobility systems, focusing initially on limited-target groups (schoolchildren, disabled residents) before wider rollout. As of 2024, the technology is in demonstration (roughly TRL 6–7): pilot runs were conducted in late 2023 in Gliwice. In the short term (2025–2027), more local pilots (publicly supported) are expected in European towns. By the medium term (2028–2030), Blees's services could be more widely embedded into regional mobility plans and social transport networks, in line with broader accessibility strategies.

7.1.6 Economic and market factors

The market for CCAM services targeting specific groups is niche, with few commercial players. Blees competes mainly against traditional paratransit and taxi services in this segment. Its main customers are municipalities and institutions rather than profit-driven companies. This niche focus means business cases often rely on public funding or grants. Blees's implementations have demonstrated operational savings (lower vehicle-hours and emissions), but scaling up will likely need continued subsidies or funding through social services budgets.

- **Market dynamics:** Blees creates a new niche for accessible mobility platforms, addressing gaps that conventional transit doesn't fill (e.g., low-demand school or disabled transport).
- **Competition:** Few direct competitors offer fully autonomous, inclusive shuttles. Blees's focus on elderly and disabled users is rare, so it often acts as first mover in its markets.
- **Investment:** Expansion requires sustained public-sector investment. Commercial investors are cautious until proven models exist; Blees may pursue EU or national grants.
- **Infrastructure needs:** Deployments need accessible boarding points and EV charging. For instance, the BB-1's specs include a **58 kWh battery** (200 km range) and 100 kW fast-charge capability, necessitating suitable chargers at depots or stops. Its **6 m turning radius** allows use of narrow streets, but curb design must accommodate ramps and easy

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[97] See: https://blees.co/en/realizacje/

boarding. Blees's service also relies on user-support infrastructure (call centers, teleassistance), which is already part of its platform to handle non-digital bookings.

7.1.7 Operational and logistical considerations

Operating CCAM services for specific user groups involves unique logistical requirements. These services typically rely on small, purpose-driven fleets that offer highly personalised, door-to-door transport. Service delivery must prioritise reliability, comfort, and coordination with caregivers or support staff, rather than high passenger throughput.

Operating Blees's service involves small, dedicated fleets with personalised routing. Passenger trips are scheduled centrally: riders request a pickup time/place via the app (or phone), and the platform computes an optimised route. The operator's app notifies vehicles where and whom to pick up. Blees's system can even **manually input phone-booked trips**, ensuring inclusion of users without smartphones.[98]

Service prioritises reliability and comfort over high throughput. Vehicles strictly stop at pre-designated PUDOs (pickup/drop-off points) on request, enabling door-to-door convenience. Real-time journey updates are provided through the app and in-vehicle displays, and voice announcements inform riders of upcoming stops. The BB-1 shuttle continuously smooths its acceleration and steering for a comfortable ride. Where needed, local support staff or companions can assist passengers boarding (e.g., deploying wheelchair ramps). Fleet supervision is centralised: a control centre monitors all shuttles, with remote operators able to intervene if necessary. This setup allows one operator to manage multiple vehicles simultaneously.

7.1.8 Social and environmental impact

CCAM services tailored to specific user groups can deliver strong social and environmental benefits. By enhancing mobility for individuals with limited independence, these solutions promote social inclusion and personal autonomy. Automated vehicles also offer safer, more predictable travel for vulnerable passengers and contribute to climate goals through electrification. When integrated into urban planning, such services support more accessible, people-centered environments. These services are often highly welcomed, though trust-building measures and person-cantered design are essential.

Blees's pilots show strong social acceptance, particularly among elderly riders. In trials, passengers aged 60+ rated their sense of security on the autonomous shuttle very highly (9/10 on average), higher than younger age groups.[99] Nearly 80% of respondents overall gave high security ratings, indicating trust in the technology. By providing independent travel options for the elderly and disabled, the service promotes social inclusion and autonomy. For example, enabling seniors to run errands or visit family without a driver greatly improves quality of life.

Environmental benefits are also significant. The BB-1's electric propulsion means zero tailpipe emissions, helping reduce urban air pollution and meet climate targets. Passengers perceived the shuttle as environmentally friendly and necessary for sustainable transport. Moreover,

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[98] See: https://blees.co/en/solution/

[99] See: https://blees.co/en/passengers-feel-safe-in-autonomous-minibus/

automation is expected to enhance safety: without human driving errors, accident rates should drop.

7.1.9 Dependencies and external influences

The success of CCAM services for specific user groups depends heavily on supportive infrastructure, multimodal integration, and strong institutional backing. These services often act as connectors to broader public transport networks, healthcare, or educational facilities, requiring seamless coordination. Reliable digital connectivity, barrier-free access, and weather-resilient design are essential for consistent operation. To deploy these services, there needs to be strong **political support**, which involves strong dependence on municipal or regional governments, welfare budgets, and EU funding mechanisms.

Blees's deployment depends on robust infrastructure and institutional support. Technically, the system requires reliable high-definition maps for each route and constant vehicle connectivity. The shuttle streams sensor and video data to control centers, so stable 4G/5G (or better) internet is essential. City infrastructure must include accessible PUDOs with ramps or curb cuts for wheelchairs. Although the BB-1 uses radar to handle rain, severe weather or poor road conditions can still disrupt service.

Integration with other modes is beneficial: ideally, Blees's shuttle connects with bus or train networks to extend multimodal mobility. The service has been implemented in close cooperation with city governments (e.g. the Gliwice pilot was run by local authorities), showing the need for strong political backing. Funding for operations typically comes from municipal or regional budgets, sometimes supplemented by EU social mobility programs. Without continued institutional support – from transportation departments, health or education agencies, etc. – scaling the service beyond pilots will be difficult.

7.1.10 Past experiences and lessons learned

Pilot applications carried out by Blees reinforce key lessons:

- *Teleassistance:* Blees's shuttles include **two-way communication** with a control centre and a remote operator who can take control, ensuring immediate support in emergencies.
- *Customised design:* The BB-1 features wheelchair-accessible seating, safety belts and sensors, plus clear in-vehicle displays and announcements. These customisations align with the need for vehicles and interfaces tailored to vulnerable riders.
- *User engagement:* In its Gliwice trials, Blees surveyed passengers (with help from the University of Silesia) to gauge security and comfort. This co-creative approach (engaging target users from the start) mirrors best practices identified in projects like SMALL and INCLUSION.
    1. **SMALL Project – Interreg North Sea Region[100]:** A European initiative that co-created inclusive mobility solutions for children, elderly, and people with impairments. *Key learnings:* Co-creation with users ensures the solutions meet real needs; engaging policymakers promotes inclusive transport strategies.

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[100] https://www.interregnorthsea.eu/small

2. **INCLUSION Project – Horizon 2020[101]:** Focused on innovating transit accessibility for vulnerable groups in areas with equity challenges. *Key learnings:* Tailored, context-specific solutions are most effective; involving local stakeholders is crucial; sharing best practices accelerates uptake of inclusive measures.

7.2 Skills needs and mismatches

7.2.1 Labour market trends

Meeting mobility needs by ensuring that services are present, easy to reach, and appropriate for people with disabilities, the elderly, and those in rural or underserved areas is likely to create new labour market opportunities related to human-centred service delivery during and after the deployment of CCAM technologies.102

7.2.2 Skills gaps and mismatches

Rural areas face structural disadvantages due to being less developed and economically weaker. They experience limited access to advanced education and training, restricted exposure to new technologies, and a scarcity of employment opportunities in high-tech or automated mobility sectors. As a result, people in these regions often migrate to cities in search of better jobs, which increases the skills gap between rural and urban areas and making it increasingly difficult for rural regions to keep pace with CCAM developments.

7.2.3 New job roles and competencies

The transition to autonomous shared transport services targeting specific groups, such as people with disabilities, the elderly, and rural residents, requires a shift in workforce priorities. While driving tasks are reduced or eliminated, human presence remains critical to ensure safety, accessibility, and passenger confidence. As such, both existing roles are being redefined, and new ones are emerging to address these unique mobility needs.

Existing roles:

- Transport service agents / bus drivers can become:
    - **Passenger support agents**: In many pilot projects, former drivers are being redeployed in non-driving support roles, helping passengers with boarding, wayfinding, or using automated services. Their familiarity with passenger needs and transport protocols positions them well for this transition.
- Booking centre or dispatcher staff can become:
    - **Digital support facilitators**: Staff who previously handled fixed-route bookings are now being asked to assist with app-based services and help users navigate digital systems or voice-based bookings.

Emerging new roles:

- **Community mobility coordinators:** These roles act as local liaisons in rural areas, adapting services to local schedules, engaging residents, and gathering user feedback.

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[101] https://www.mpact.be/en/project-event/inclusion/

[102] SINFONICA Project, D1.1 Mobility Needs and Requirements of European Citizens https://sinfonica.eu/wp-content/uploads/2023/07/D1.1-Mobility-needs-and-requirements-of-European-citizens.pdf.

They may work for municipalities or transport operators, helping tailor CCAM services to local conditions.

- **Remote operations monitors (accessibility-aware):** These monitors oversee fleets and respond when vulnerable users encounter issues. They must be trained not just in system diagnostics, but also in interpreting human behaviour indicators (e.g. delayed boarding, emergency button activation).[103]
- **Inclusive mobility planners / designers:** These professionals support long-term integration of accessible CCAM into urban and rural mobility systems. They ensure that services are physically accessible, clearly signposted, and socially inclusive.[104]

7.2.4 Reskilling and upskilling needs

To ensure that CCAM technologies deliver equitable and inclusive mobility, particularly for people with disabilities, older adults, and residents of low-accessibility areas, targeted investment in human capital is essential. This section identifies priority reskilling and upskilling areas for key roles that will be critical to the successful, human-centred deployment and long-term sustainability of CCAM services.

- **Passenger support agents:** Disability awareness and inclusive communication; manual handling (e.g. wheelchair support) and safe boarding practices; first aid and incident response; understanding of vehicle interfaces and HMI alerts.
- **Digital support facilitators:** App navigation and platform use; basic digital troubleshooting and remote assistance; communication skills tailored to low-digital-literacy users; data privacy awareness and secure account handling.
- **Community mobility coordinators:** Local transport system knowledge; community engagement and outreach; coordination with municipalities and user groups; feedback collection and service adaptation tools.
- **Remote operations monitors**: Real-time supervision of AV systems; scenario-based incident response; user interaction through remote interfaces; recognition of accessibility-related alerts or emergency flags.
- **Inclusive mobility planners:** Universal design principles and accessibility standards; policy literacy (e.g. procurement and regulation); multimodal coordination and spatial planning tools; stakeholder collaboration (including disability advocacy groups).

7.2.5 Training and education gaps

Rural areas lack structured and accessible programs for education and training focused on CCAM-related occupations. The absence of local, high-quality training programs often compels residents to leave their communities to access new opportunities. Furthermore, education systems in these regions frequently lag behind in integrating digital, technical, and automation-related content, which are becoming essential for new roles in automated mobility services. This shows the need to expand educational infrastructure.

To ensure accessibility and uptake, training formats should prioritise modular delivery, on-the-job learning, and simulated user interaction scenarios. Co-creation with underrepresented

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[103] Blees safety architecture – https://blees.co/en/safety/ (mentions remote operator intervention in critical cases

[104] Stakeholder interviews (Oscar Nissan, Anita Pollak, Eetu Pilu Sihvola)

groups, including people with disabilities and older adults, will also be essential in developing training content that reflects real-world needs.

7.2.6 Professions and skills mapping (SWOT analysis)

Strengths	Weaknesses
• Human-centred roles remain critical: Roles like passenger support agents and digital mobility facilitators provide essential interpersonal functions that automation cannot replace, ensuring stable, socially valuable employment in inclusive mobility contexts. • Institutional alignment with social equity goals: Projects such as BLEES and broader EU initiatives like SINFONICA integrate inclusion from the outset, supporting gender, age, and disability-sensitive mobility design and workforce planning. • Rural participation through decentralised roles: Remote monitoring, call-centre-based digital support, and locally embedded coordination jobs make it feasible for rural residents to enter the CCAM workforce without relocation. • New hybrid professions are emerging: Interview evidence confirms growing demand for a range of non-engineering CCAM roles—such as stewards, community mobility coordinators, and user experience facilitators—which broaden the employment base beyond traditional transport and ICT.	• Lack of formal training pathways for new roles: Emerging occupations (e.g., accessibility stewards, remote user support) lack certification or vocational recognition, leaving workers and employers without standardised training guidance. • Peripheral regions face digital skills and infrastructure gaps: Low digital literacy and poor training provision in rural areas limit both workforce participation and the effectiveness of support roles designed to serve excluded populations. • Overreliance on informal training: Pilot operators and municipalities currently bear the burden of training staff informally, as there are no standard curricula for roles critical to inclusive CCAM deployment. • Underdeveloped job mobility frameworks: Workers in these new roles lack clear pathways for progression, and cross-sectoral mobility (e.g., from social care or public service) is not yet structured or supported.

Opportunities	Threats
• High employment potential in support roles: The demand for non-technical, service-oriented jobs (e.g., stewards, digital assistants, community liaisons) offers an entry point for individuals from diverse backgrounds, including those not traditionally employed in transport. • Revitalising regional labour markets: CCAM pilots in small towns and rural areas could create	• Unequal access to reskilling: Without dedicated investment, rural and economically disadvantaged populations may miss out on job creation due to lack of training opportunities and digital barriers. • Design neglect may limit usability—and jobs: If CCAM systems aren't co-designed with excluded groups, services may fail to meet accessibility needs, reducing both user uptake and the need for support staff.

local employment while improving mobility access—especially if modular, regionally delivered training is developed. • Inclusive training can diversify the workforce: Targeted upskilling and job design could attract more women, older workers, and people from caregiving or community sectors, especially in user-facing support functions. • Integration with municipal services: New CCAM roles can be aligned with local health, social care, and public engagement frameworks, creating blended positions that improve service coordination and employment quality.	• Automation could reduce human interaction prematurely: Overemphasis on full autonomy without embedding human-facing roles may erode social trust, especially for vulnerable users who require live assistance. • Underrepresentation of marginalised groups in CCAM workforce planning: Interviews confirm that disability and gender perspectives are often not systematically included in training design or pilot planning, risking a repeat of exclusion patterns in both service access and job access.

7.2.7 Other relevant condition

7.2.7.1 Sectoral and regional variations

The rollout of CCAM services designed to meet the needs of specific user groups reveals significant regional and sectoral disparities in preparedness across Europe. Unlike high-tech CCAM applications focused on urban robotaxis or freight logistics, this use case is highly dependent on human support roles, social infrastructure, and accessibility-sensitive planning.

Northern and Western European countries (e.g. Sweden, Finland, France, Germany) generally benefit from stronger institutional support for inclusion, better digital infrastructure, and established welfare systems. These factors help integrate CCAM pilots with public health, social care, and municipal services. For example, as noted in Finland's approach, mobility policies are increasingly linked to broader inclusion strategies, allowing for cross-sectoral planning of support staff roles like community mobility coordinators and accessibility stewards.[105]

In contrast, Southern and Eastern European regions often face constraints that delay both CCAM deployment and workforce transformation. These include limited digital training infrastructure, lower public investment in accessibility, and fragmented coordination between mobility and social services. Interview feedback also noted that many of these regions rely on informal, localised transport services and may lack the institutional capacity to integrate CCAM inclusively. Without targeted reskilling initiatives or inclusive public procurement frameworks, there is a risk of excluding rural and marginalised populations from both service use and job creation.

Rural areas across all regions face persistent barriers. These include lower digital literacy, weak broadband coverage, and reduced access to training institutions, all of which constrain the recruitment and upskilling of new roles such as digital mobility facilitators or remote operations monitors. As highlighted in the BLEES project, operators are often expected to fill multiple roles

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[105] Stakeholder interview (Eetu Pilli-Sihvola).

(e.g. managing teleoperation, supporting passengers, and handling troubleshooting), particularly in regions with limited staffing pools.

7.2.7.2 Gender and inclusion considerations

The deployment of inclusive CCAM services presents a significant opportunity to improve gender equity in the transport workforce by introducing roles that are both accessible and socially meaningful. Emerging occupations such as passenger support agents, digital mobility facilitators, and community coordinators rely on communication, empathy, and organisational skills, areas where women are traditionally well-represented but underutilised in the transport sector. These roles, often flexible or locally embedded, also support better work–life balance, making them attractive to women with caregiving responsibilities. However, gendered barriers such as low digital literacy and underrepresentation in technical roles may still persist. Addressing these gaps with gender equality initiatives can help ensure that CCAM job creation is both equitable and reflective of the diversity of the communities it serves.

8 Best practices and funding opportunities

8.1 Best practices

Across diverse CCAM pilots, from depot automation to inclusive shared mobility, several common best practices for skills development have emerged. These offer valuable lessons for ensuring the workforce transitions effectively alongside advancing vehicle automation.

- **Phased and role-based upskilling aligned with technological maturity**
  Gradual introduction of CCAM functions (e.g. from manual to remote operation) enables workers, especially safety drivers, technicians, and field support agents, to adapt incrementally. Examples like LOXO and Selvkjørende show how staged transitions reduce disruption and build confidence.
- **Integration of training into existing workflows**
  Embedding learning within operational environments, such as depots or pilot sites, supports real-time skill acquisition. Co-designing training with logistics firms, public transport operators, or municipalities may help ensure relevance and uptake.
- **Modular, simulation-based and accessible training formats**
  Simulation labs, remote learning modules, and short-cycle programmes can be effective for preparing workers for high-stakes roles such as remote operations specialists and safety-critical support staff. These flexible formats may also help widen participation, especially for women, older adults, and rural residents.
- **Blended skill profiles across technical and service roles**
  Many roles now demand both technical awareness and interpersonal skills (e.g., FSAs must troubleshoot while also supporting passengers). Training must reflect this convergence, avoiding separation between IT, mobility, and customer service domains.
- **Co-creation and user-informed training design**
  For inclusive transport services, training content should be informed by the lived experiences of target groups (e.g. people with disabilities, the elderly). This ensures that workforce competencies are grounded in real user needs, not assumptions.
- **Creation of new transitional roles with internal pathways**
  Safety operators/drivers, tele-assistants, and stewards are emerging as essential bridge roles between manual systems and full automation. Many pilots have developed in-

house training to fill gaps where no national standards exist, supporting faster role uptake and workforce continuity.

- **Certification, standardisation and competency frameworks**
  As new CCAM roles mature, public and private stakeholders must develop shared qualification systems, especially for inclusive mobility occupations. These frameworks will ensure portability of skills across regions and projects.
- **Promotion of inclusive recruitment and gender-aware job design**
  Flexible, less physically intensive, and remote-enabled CCAM roles offer new opportunities to underrepresented groups. Efforts to widen recruitment, paired with mentoring, accessible onboarding, and role visibility, may help foster greater diversity and equity across the mobility sector.
- **Cross-sectoral collaboration for scalable workforce development**
  Successful pilots consistently show the value of aligning employers, training providers, local authorities, and regulators in developing and delivering workforce strategies. Coordinated governance helps bridge policy, operations, and education.

8.2 Funding opportunities

The successful deployment of CCAM technologies depends not only on technical innovation but also on sustained, coordinated investment in workforce development. However, current funding structures across the EU often lag behind the pace of automation, with many public frameworks still focused on conventional logistics or transport tasks. As a result, emerging roles lack standardised qualifications and institutional backing, which in turn limits the availability of targeted training and funding.

Public and private actors are increasingly turning to EU-level programmes such as Horizon Europe, Erasmus+, the Digital Europe Programme, and the European Regional Development Fund (ERDF) to bridge this gap. These initiatives provide financial resources for reskilling, curriculum development, and digital literacy improvements, particularly for underserved groups. Projects like SINFONICA and AI4CCAM, both funded through Horizon Europe, exemplify the EU's commitment to inclusive and responsible automation, with a focus on accessibility, safety, and user trust.

At the national level, countries such as France, Germany, the Netherlands, and Poland are beginning to implement CCAM-relevant workforce initiatives. These include France's Plan d'Investissement dans les Compétences (PIC), Germany's Recovery and Resilience Plan (€7.5 billion allocated to digital upskilling), and Poland's career guidance and employer partnership frameworks. Lifelong learning schemes in the Netherlands offer flexible, employment-compatible training that could be adapted to CCAM sector needs.

To encourage industry participation, governments can offer co-funding, tax incentives, or direct grants for in-house training, pilot programme integration, and support for displaced workers. The European Globalisation Adjustment Fund for Displaced Workers (€210 million budget for 2021–2027) is also available to support workers affected by structural economic shifts, including automation in transport.

Ultimately, coordinated policymaker–industry partnerships are essential to align funding with technological timelines and evolving job profiles. Without institutional support and inclusive funding strategies, CCAM risks reinforcing transport inequality and excluding low-income, rural, or digitally disconnected populations from both mobility and employment opportunities. As reinforced by initiatives like the Lecco Declaration, mobility must be seen as a right tied to access to education, employment, and social inclusion.

9 Conclusions and strategic recommendations

This report has examined the impacts of CCAM across six diverse use cases, with a particular focus on employment, skill mismatches, and the institutional readiness required to support a successful transition. While each use case presents unique operational and regulatory conditions, a number of **cross-cutting patterns and strategic challenges** have emerged that are relevant to a wide range of stakeholders across Europe's mobility and employment ecosystem.

9.1 Summary of key findings

Across all six use cases, the deployment of CCAM technologies is expected to **transform rather than eliminate** jobs. The most prominent trends identified include:

- The emergence of **hybrid roles** that blend physical, logistical, and digital responsibilities (e.g., remote supervisors, vehicle preparation staff, and AV monitoring coordinators).
- Persistent **skills mismatches**, particularly in digital literacy, real-time decision-making, and system supervision.
- The importance of **safety-critical transitional roles** (e.g. safety drivers) in early-stage deployment phases.
- The uneven pace of institutional and regulatory readiness across regions and sectors, creating fragmentation in training provision and operational scaling.
- The need for **coordinated, sector-specific training strategies** aligned with actual pilot experiences and future deployment models.

9.2 Strategic recommendations

The introduction of CCAM technologies is not merely a technical or logistical innovation; it represents a **labour market shift** that touches on education policy, infrastructure planning, inclusion, and industry transformation. Without proactive planning, the resulting **disparities in skills, awareness, and institutional capacity** could exacerbate existing inequalities and delay widespread adoption.

At the same time, CCAM offers the opportunity to **modernise the workforce**, improve job quality, and reduce physical strain, particularly in urban logistics, public transport, and maintenance roles. To capitalise on these opportunities and mitigate risks, the following strategic actions are recommended:

For policymakers:

- Develop targeted **funding mechanisms** to support modular, short-cycle training programmes for emerging CCAM roles.
- Promote the **standardisation of role definitions** and qualifications to support curriculum development, cross-border labour mobility, and institutional coordination.
- Establish **legal and regulatory clarity** for transitional roles (e.g., safety drivers, remote operators) to accelerate safe deployment.

For education and training providers:

- Co-develop **hybrid training pathways** with technology developers and employers, focusing on both technical and soft skills.
- Integrate **real-world deployment insights** (e.g., from pilot projects) into vocational education and lifelong learning systems.
- Build flexibility into certification systems to keep pace with evolving CCAM technologies.

For employers and industry:

- Support **in-house upskilling programmes** and enable cross-functional training to facilitate workforce transition.
- Participate in multi-stakeholder partnerships to co-create training content and identify future job profiles.
- Leverage early-stage deployments to **test and refine workforce integration models**.

For EU institutions and coordinating bodies:

- Align CCAM workforce initiatives with broader frameworks such as the **Pact for Skills**, **Digital Europe**, and **Erasmus+** to ensure coherence and funding synergies.
- Encourage knowledge sharing between national and regional bodies to avoid fragmented deployment and duplication of training efforts.

9.2.1 Recommendations per use case

9.2.1.1 Ground transportation for last-mile delivery

Key skills takeaways:

- New roles emerging include remote vehicle supervisors, urban delivery technicians, and automated logistics coordinators.
- Workers require hybrid competencies in robotic operations, vehicle monitoring, and last-mile logistics, especially in dynamic urban environments.
- Emphasis on teleoperation, incident intervention, and safe loading/unloading procedures in partially automated zones.
- As vehicles become more autonomous, soft skills (customer communication, manual fallback handling) remain relevant for transitional phases.

Recommendations:

- Establish cross-training schemes for warehouse workers and couriers to step into automation-aware logistics support roles.
- Develop micro-credential programs in teleoperation, last-mile safety, and digital dispatch coordination.
- Create city-level training partnerships involving municipalities, logistics firms, and training providers to ensure urban workers can access reskilling pathways in CCAM delivery ecosystems.
- Support women and younger workers into emerging logistics jobs by aligning training with inclusive mobility and digital transition frameworks.

9.2.1.2 Bus depot

Key skills takeaways:

- Strong demand for hybrid technical roles that combine vehicle systems knowledge with digital fluency (e.g., automation technicians, fleet analysts).
- Emerging roles like teleoperators and maintenance integrators require upskilling in both software diagnostics and sensor calibration.
- Training needs to integrate in-situ learning within depots, and simulation-based modules for emergency response and remote intervention.

Recommendations:

- Develop modular, depot-integrated training programs for current maintenance staff.
- Establish certification pathways for automation-related roles with input from OEMs and transport operators.
- Promote cross-skilling for mechanics and IT technicians to bridge traditional and digital vehicle systems.

9.2.1.3 Ports and terminals

Key skills takeaways:

- Critical skills include remote operations, sensor system integration, and V2X communication management.
- Roles such as autonomous fleet coordinators and terminal operations specialists are emerging.
- Digital literacy and predictive analytics skills will be needed for managing logistics and infrastructure interoperability.

Recommendations:

- Launch joint industry–training centre programs for port workers to upskill into automation control and system monitoring.
- Embed digital systems thinking and basic AI literacy into logistics and transport vocational curricula.
- Promote training for port managers in CCAM strategy, cybersecurity, and platform coordination.

9.2.1.4 Public (shared) transportation

Key skills takeaways:

- Transition from driver roles to tele-assistants, field service agents, and fleet monitors.
- Skills gap around customer interaction in tech-enabled environments and digital service delivery.
- Demand for personnel who can manage multi-vehicle remote support and dynamic dispatch.

Recommendations:

- Fund retraining pathways for bus and taxi drivers into support roles (e.g., through teleoperation simulation labs).
- Introduce “human-in-the-loop” modules into public transport vocational programmes.

- Create incentives for employers to retain drivers by offering blended tech-support roles.

9.2.1.5 Private (shared) transportation

Key skills takeaways:

- High potential for former drivers to transition into fleet operators, remote support staff, or safety operators.
- Additional skills required in customer communication, app-based service facilitation, and autonomous system oversight.
- Teleoperation, risk response, and customer service convergence is key.

Recommendations:

- Create upskilling schemes that target former taxi drivers for digital coordination and risk intervention roles.
- Pilot national registries and qualification systems for teleoperators and remote supervisors.
- Develop public–private digital bootcamps in partnership with mobility providers and platforms.

9.2.1.6 Shared transportation for specific groups

Key skills takeaways:

- Demand for passenger support agents, community mobility coordinators, and digital inclusion facilitators.
- Skills should blend disability awareness, safety, communication, and basic tech fluency.
- Local embedding of roles in rural or low-accessibility areas is critical.

Recommendations:

- Develop EU-recognised training pathways for inclusive transport roles (e.g., accessibility stewards).
- Integrate co-designed training with users from the disability and elderly communities.
- Offer local, modular training delivery in community centres or public service hubs.

9.3 Final reflection

The transition to CCAM technologies is not simply about upgrading vehicles, it is about **preparing the systems and people** that support them. Successful deployment will depend not only on technical readiness but on the **capability of Europe's workforce, institutions, and policies** to evolve in step. With coordinated action, CCAM can become a driver of inclusive growth, improved job quality, and smarter, safer mobility systems.

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