Enova sluttrapport

Pilotering av ny energi- og klimateknologi
På vegne av Ruter As

30.08.2025

Tilpasning av selvkjøringsteknologi for kollektivtransport i Norge

Pilotering av delte elektriske, selvkjørende, kjøretøy i bestillingstjeneste

Enova Final Report

Pilot Project for New Energy and Climate Technology
On behalf of Ruter As

30.08.2025

Adapting Autonomous Vehicle Technology for Public Transport in Norway

Piloting Shared, Electric, Autonomous Vehicles in On-Demand Service

Ruter#

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Acronyms

ADAS	Advanced driver-assistance systems
ADS	Autonomous Drive System
APT	Autonomous Public Transport
AV	Autonomous Vehicle
HD	High-Definition
IPCC	UN Intergovernmental Panel on Climate Change
KPI	Key Point Indicatior
Lidar	Light Detection and Ranging
MaaS	Mobility as a Service
NPRA	Norwegian Public Road Administration
NPS	Net Promoter Score
ODD	Operational Design Domain
PUDO	PickUp- and DropOff point
R&D	Research and Development
Radar	Radio Detection and Ranging
REM	Road Experience Management
SAE	Society of Automotive Engineers
SAV	Shared Autonomous Vehicle
SDS	Self-Driving System
TØI	Transportøknomisk Institutt / Institute of Transport Economics
UiO	Universitetet i Oslo / University of Oslo

Sammendrag (Norwegian)

Denne sluttrapporten oppsummerer Ruters pilotprosjekt med elektriske, delte og selvkjørende kjøretøy i Oslo-regionen, med støtte fra Enova. Målet har vært å teste og tilpasse avansert selvkjøringsteknologi til norske forhold – både teknisk, klimamessig og innenfor det regulatoriske rammeverket – som grunnlag for et fremtidig kollektivtilbud uten sjåfør.

Det ble anskaffet fem NIO ES8-kjøretøy, utstyrt med Mobileyes SAE nivå 4-teknologi. Disse ble satt i drift i et 20 km² stort område i Groruddalen. Kjøretøyene kjørte i blandet trafikk i hastigheter opptil 60 km/t og håndterte komplekse situasjoner som rundkjøringer, fotgjengerfelt og flerfeltsveier. I motsetning til tidligere piloter var kjøretøyene ikke begrenset til faste ruter, og de krevde kun menneskelig inngrep i tilfeller hvor det var nødvendig å bryte trafikkregler, som ved kryssing av doble sperrelinjer ved passering av feilparkerte biler. Det ble samlet inn ca. 9 000 kjøretimer med data for å trene teknologien opp til norske forhold.

Blant prosjektets milepæler:

- Kartlegging av området med høyoppløselige HD- og REM-kart
- Tilpasning til vinterforhold med is, brøytekanter og varierende sikt
- Etablering og simulering av 70 virtuelle hente-/leveringspunkter
- Brukertesting med en begrenset gruppe for å evaluere kundeopplevelsen
- Godkjenning fra Statens vegvesen i tråd med norsk regelverk for selvkjørende kjøretøy

Piloten viser at det er teknisk mulig å tilby trygge og effektive selvkjørende transporttjenester i Norge. Når teknologien skaleres, kan dette redusere behovet for privatbil, kutte utslipp og bedre tilgjengeligheten til kollektivtransport – særlig i områder med lav dekning.

Det som gjør denne tjenesten unik i europeisk sammenheng, er at den er designet for samkjøring og full integrasjon med kollektivsystemet. Dette står i kontrast til robotaxi-modeller som utvikles i USA og Kina, hvor tjenestene primært er individuelle og kommersielle. Pilotprosjektet representerer dermed ikke bare en teknologisk milepæl, men også et strategisk veivalg for hvordan Europa kan utvikle autonome mobilitetstjenester i tråd med offentlige mål og verdier.

Executive Summary (English)

This final report summarizes Ruter's pilot project with electric, shared, autonomous vehicles (AVs) in the Oslo region, supported by Enova. The project aimed to adapt high-performance autonomous driving technology to Norwegian conditions—including road infrastructure, weather, regulation, and traffic behavior—as a foundation for future driverless public transport services.

Five NIO ES8 vehicles equipped with Mobileye's SAE Level 4 technology were deployed in a 20 km² area of Groruddalen. The vehicles operated in mixed traffic at speeds up to 60 km/h, navigating complex environments such as roundabouts, multilane roads, and pedestrian crossings. Unlike previous AV pilots, these vehicles were not restricted to fixed routes and required human intervention only in rare cases (e.g., crossing double barrier lines while navigating around illegally parked cars). Over 9,000 driving hours were logged to train the system to local conditions.

Key milestones include:

- High-definition HD and REM mapping of the pilot area
- Adaptation to Nordic winter conditions, including snowbanks and limited visibility
- Definition and simulation of 70 virtual pickup and drop-off points (PUDOs)
- Limited user testing to evaluate passenger experience
- Regulatory approval from the Norwegian Public Roads Administration in line with national AV legislation

The pilot demonstrates that safe, efficient, and scalable autonomous transport services are technically feasible in Norway. When fully deployed, such services can reduce car dependency, lower emissions, and improve accessibility—especially in underserved areas.

What sets this project apart on the international stage is its core design: a **shared**, **on-demand**, **public** mobility service integrated into the broader transit system. This contrasts sharply with robotaxi models emerging in the US and China, which focus on individual, commercial rides. This pilot is not just a technical breakthrough—it is a strategic prototype for how Europe can develop autonomous mobility aligned with climate goals, social equity, and public ownership.

1. Introduction

Ruter's autonomous vehicle (AV) strategy is inspired by insights from the 2019 Oslo Study conducted by COWI[1], which explored **how large-scale deployment of shared AVs could influence transport systems and urban development.** The study used simulation models to examine a scenario in which private cars, taxis, and low-frequency buses were replaced by shared, electric AVs integrated into the public transport network. The results pointed to the possibility of reducing traffic volumes by 14% to 31%, and meeting mobility needs with only 9% of today's private car fleet.

Under the assumptions in the Oslo simulation, this level of impact would correspond to a fleet of approximately 20,000–30,000 shared, electric autonomous vehicles operating as an on-demand service—potentially replacing most private cars in the region. This gives a sense of the scale that might be needed to unlock the full benefits of autonomous, shared mobility.

Similar studies using the same modelling framework have been conducted in cities such as Lisbon, Gothenburg and Helsinki, showing comparable results. This suggests that the potential effects of shared AV systems are not unique to Oslo, but could be relevant across a wide range of urban environments.

A pilot project was necessary to adapt autonomous vehicle technology to Norwegian conditions and to public transport operations. The project required investment in five purpose-built vehicles capable of collecting video and sensor data, as well as access to high-performance computing infrastructure for storing, processing, and training Norwegian data models using large volumes of video and telemetry. In addition, the pilot included the production of high-definition maps for a selected area.

This became the first project in Europe to deploy automated vehicles not reliant on fixed routes—using so-called "Virtual Rail" technology—and capable of operating in mixed traffic at speeds of up to 90 km/h without a safety driver onboard. This represented a major technological shift from anything previously tested in Norway. The pilot was conducted in a densely populated urban area covering approximately 20 km², in partnership with one of the world's leading autonomous vehicle developers.

While the pilot itself did not directly reduce emissions, it laid critical groundwork. Once Ruter is able to introduce these services at scale—both in terms of fleet size and geographic coverage across the metropolitan region—it opens the **potential for annual savings of up to 270,000 tonnes of CO_2-equivalents, in addition to a one-off reduction of 5 million tonnes for the Oslo area alone**.

[1] COWI, «The Oslo Study - How Autonomous Cars May Change Transport in Cities» (Oslo, 24. april 2019), https://www.cowi.com/about/news-and-press/new-report-how-self-driving-transport-will-affect-the-oslo-region.

This would reduce the need for private car ownership, lower the number of vehicles on the road, and cut emissions from personal transport. It also supports several of the UN Sustainable Development Goals, particularly Goal 11: Sustainable Cities and Communities. Moreover, the knowledge and experience gained through the pilot can be leveraged to achieve similar environmental effects both nationally and internationally.

2. Partners and Technology Providers

Ruter As is responsible for public transport in Oslo and Akershus. Ruter's job is to provide an attractive offer for the residents of the region and contribute to a more sustainable social development.

The public transport itself is carried out by various companies that have contracts with Ruter. Ruter therefore does not own any buses, cars, trams, boats, metro trains or other means of transport. Sporveien T-banen AS and Sporveien Trikken AS are permanent contract partners, while bus and boat contracts are awarded after competitive tenders.

Ruter As is owned by Oslo Municipality (60%) and Akershus County Municipality (40%).

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Contact: Christian Willoch, Executive Advisor, Radical Innovation

The Institute of Transport Economics (TØI) is Norway's national transport research center and a non-profit research foundation. TØI conducts commissioned research for the Ministry of Transport, the Norwegian Public Roads Administration, local and regional authorities, the Research Council of Norway, and various EU bodies. TØI has been an active research partner in all of Ruter's autonomous mobility pilots, and has also conducted its own research related to autonomous vehicles.

Institute of Transport Economics / Norwegian Centre for Transport Research
Gaustadalleen 21, 0349 Oslo, Norway
Contact: Petr Pokorny, Senior Research Engineer

CICERO Center for International Climate Research is an independent research foundation affiliated with the University of Oslo. It is Norway's leading institute for climate research, with activities spanning both natural sciences and the social sciences. Several CICERO researchers contribute to the main assessment reports from the UN Intergovernmental Panel on Climate Change (IPCC).

CICERO Center for International Climate Research
Gaustadalléen 21, 0349 Oslo, Norway
Contact: Tom Erik Julsrud, Research Director

Holo is Ruter's R&D partner. In 2018, Ruter entered into a research and development agreement with Holo designed to ensure value creation within a framework where results remain publicly available. Holo is one of the leading operators of autonomous vehicles in Europe, with operations across the Nordic and Baltic regions, and more than 60 employees dedicated to accelerating AV deployment in Northern Europe.

Holo A/S
Banevingen 14A, 2200 København N, Denmark
Contact: Hans Friedberg, Manager Scandics

Mobileye provides the self-driving technology that is being adapted to Norwegian conditions. As an R&D partner, Holo—together with Ruter—has established itself as a globally attractive partner for testing and verifying autonomous technology for public transport.

Through this collaboration, along with Ruter's early and ongoing involvement in the AV field since 2018, the project has built a validated and realistic shortlist of the market's leading technology providers. The primary expected technology provider is **Mobileye**, a subsidiary of Intel Inc. Mobileye's "Drive AV" platform is a near turn-key autonomous driving system ready for large-scale commercial deployment in passenger cars, taxis, shuttle buses, and city buses.

Mobileye Global Inc.
Shlomo Momo ha-Levi St 1, Jerusalem 9777019, Israel
Contact: Shalom Mines, Senior Director, AV Everywhere

3. Documentation of Selected Solutions

The project procured five NIO ES8 vehicles retrofitted with Mobileye's autonomous driving technology, which utilizes advanced image processing systems, sophisticated processing algorithms, and mapping technology. The system relies on a comprehensive sensor suite including multiple cameras, lidars (Light Detection and Ranging), radars, and other sensors to gain an extensive understanding of the vehicle's surroundings and its own condition. The collected data is processed by onboard computers, enabling real-time object recognition, lane tracking, and traffic sign detection, among other functions.

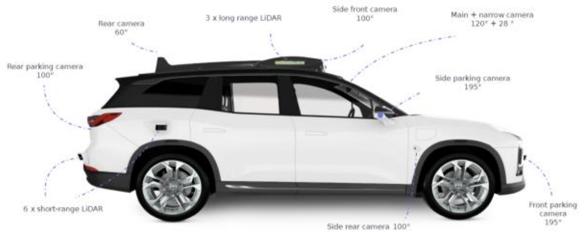

Figure 1: Technical spec on vehicle

Additionally, the system uses high-definition map data to provide precise localization and navigation. This combination of sensor input and map information allows the vehicle to perform autonomous driving operations across a variety of operational environments.

Mobileye's TrueRedundancy™ offers a unique approach to computer vision, where two independent subsystems serve as backups for each other.

The project's goal was to adapt the technology to Norwegian conditions and evaluate its potential to contribute to sustainable transport solutions within the Norwegian context.

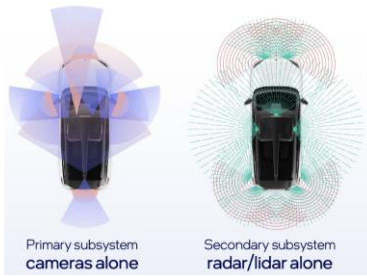

Figure 2: Camera vs Radar/Lidar

4. Activities

4.1. Procurement of Vehicles and Autonomous Driving Technology

Before the project began, Ruter had already received strong signals of interest from several leading technology providers in the market. The plan was to deploy up to five vehicles for this purpose—striking a balance between keeping initial investment costs manageable while still ensuring sufficient data collection within a reasonable timeframe.

The project's R&D partner, Holo, owned the vehicles and depreciated them over the course of the project, while Ruter leased the R&D service.

The technology provider selected was Mobileye, a company owned by Intel, specializing in advanced driver-assistance systems (ADAS) and autonomous driving platforms. Mobileye develops sensor technology, computing systems, and mapping solutions for both partially and fully autonomous vehicles. The self-driving technology was installed and validated on NIO ES8 vehicles.

4.2. Approvals

The Norwegian Legeslative Framework for Autonomous Pilot Projects[2]

In Norway a proposal on new legislation with regards to autonomous vehicles was made in June 2017. The law was reviewed throughout 2017 and in January 2018 the law took effect (Lovdata). Approval to conduct projects with autonomous vehicles was granted as one approval related to the route(s) and time period described in the application. The approval/permit was granted by the Norwegian Public Road Administration (NPRA. The vehicles were registered and specifically linked to the time and place of the permit and registration would run out when the permit runs out.

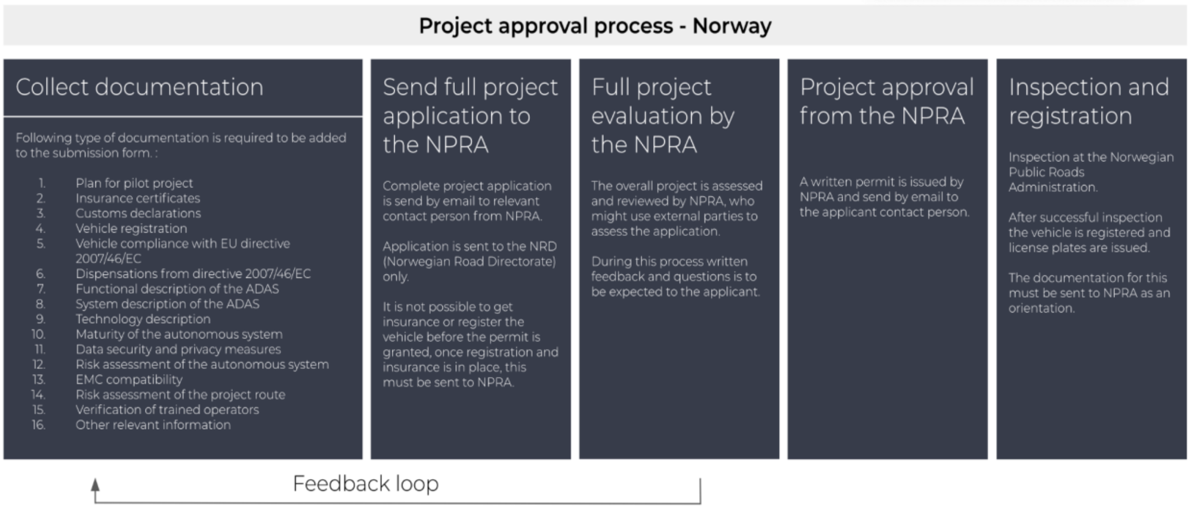

Figure 3: Project Approval Process

All documentation illustrated was sent to NPRA for review and approval. NPRA assessed all documentation and sent questions and requirements for further explanation, documentation or potentially third party validation of technical or autonomous functionality. This feedback loop was characterized with a high degree of dialogue between applicant and approver, meaning the NPRA makes key personnel available for questions, follow up and in some cases recommendations.

As part of the registration process, all vehicles went through inspection. The inspection ensured compliance with the technical requirements described in the project application and was conducted by the NPRA.

The application consisted of an overall application form with 16 attachments where the technology and project risks was described in depth.

These attachments contain detailed technical descriptions and risk assessments provided by the R&D partner as part of the approval process with the NPRA. These documents are subject to intellectual property (IP) rights and contain proprietary information. Due to confidentiality and

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[2] Felthaus, Fridberg, Green, Holo (12/2021). *APPROVALS OF AUTONOMOUS PILOT PROJECTS IN THE NORDICS*. AUTOPIA. https://www.arcgis.com/home/item.html?id=da30edb2648540d586592528bb3a4aed

contractual obligations, they cannot be shared publicly and are therefore not included in this report.

Approval Process

The application and approval process for the pilot project in Groruddalen & Lørenskog followed the Norwegian legislation. The project received approval for driving with safety operator on all roads in the service area with speed limits 60 km/h or less.

In September 2024, The Norwegian Public Roads Administration granted permission for further testing of the five autonomous motor vehicles in Groruddalen. The approval[3] defined the vehicles, testing area, safety requirements, speed limits, operator training, reporting, data security and supervision requirements. And most importantly: passengers were allowed.

NPRA found it likely that traffic safety would be adequately maintained in the trial, provided that the testing was conducted under the conditions and framework described.

4.3. Adaptation of the Technology to Norwegian Conditions and Initiation of Training for Norwegian Data Models

Background

As part of the pilot project aimed at advancing autonomous driving capabilities in Norway, an essential part of the implementation includes the adaptation and deployment of the Automated Driving Systems (ADS) to fit the Norwegian road- and driving conditions. This adaptation represents a critical step towards the realization of commercially viable and economically sustainable public transportation services in Norway, with a focus on providing mobility services in real urban environments.

Adapting one's driving to a specific country or area is crucial for ensuring safety and compliance with both the written and unwritten rules of traffic. This applies equally to human drivers and automated driving systems (ADS). Each location has unique road conditions, traffic patterns, and cultural norms that influence how drivers are expected to behave. Written laws dictate speed limits, right-of-way, and other fundamental aspects, but unwritten rules—such as local driving etiquette, the typical behavior of other road users, and common reactions to road conditions—are equally important. Understanding and adapting to these nuances is a necessity to prevent accidents, and uninterrupted traffic flow, as well as ensuring harmonious interaction with other traffic users.

Compared to other countries worldwide, Norway's driving style is characterized by a strong emphasis on caution and respect for road safety. Drivers will typically adhere closely to speed

[3] Letter from The Norweigan Public Roads Administration, 24.09.2024, ref 23/104534-28. "Utvidelse av tillatelse til utprøving av selvkjørende motorvogn – Groruddalen".

limits and are highly considerate of pedestrians, cyclists, and changing weather conditions. Additionally, the presence of right of way to right hand traffic also when driving on bigger roads, is unique to the traffic landscape.

Moreover, Norway's unique and challenging weather conditions, characterized by harsh winters, fluctuating temperatures, and changing traffic scenarios, presents significant obstacles that must be specifically addressed to enable safe reliable operation of autonomous vehicles.

The successful deployment of ADS in such conditions is not only essential for the specific goals of this pilot project but also for the broader advancement of autonomous driving technology in similar environments worldwide.

HD Mapping and REM Mapping

REM (Road Experience Management) is a technology developed by Mobileye. It is a crowdsourced mapping system used to generate and continuously update high-definition (HD) maps in real time, based on data collected from regular vehicles equipped with Mobileye cameras.

Mapping of the operational area began in June 2023 and provided the foundational data for the HD maps to be used by the autonomous vehicles. The goal of the project was to deploy five NIO ES8 vehicles equipped with Mobileye's Autonomous Drive System (ADS) on the roads of Groruddalen. In the initial phase, these vehicles would operate with safety drivers onboard, while the ADS underwent final validation within the specific Operational Design Domain (ODD[4]) defined for Groruddalen. A successful validation would pave the way for scaling the fleet to 15 vehicles—expanding the reach and impact of autonomous transport in the region.

In parallel, a comprehensive risk assessment of the area was conducted, based on a methodology outlined in a separate report from Holo[5].

Groruddalen presents a demanding environment, with complex road systems, varied traffic conditions, and seasonal weather challenges—including icy roads, heavy snowfall, and low winter sun. These factors made it an ideal testing ground for further development of the ADS technology. The pilot aimed to validate that autonomous vehicles could operate safely and efficiently at speeds up to 90 km/h, navigate multilane highways, roundabouts, pedestrian crossings, and handle real-world challenges such as illegally parked vehicles.

The area itself is diverse, comprising large residential neighborhoods, business parks, and industrial zones. Groruddalen covers approximately 22 km², with about 560 km of roads and a population of around 140,000. Although three major motorways connect the valley to central Oslo, the majority of the road network consists of smaller residential streets not suitable for traditional city buses.

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[4] Operational Design Domain (ODD) defines the specific conditions under which an autonomous vehicle is designed to operate. This includes factors such as geographical area, road types, traffic conditions, weather and lighting conditions, and speed limits.

[5] Sophie Green, Hans Fridberg, og Mikkel Haugaard, «Methodology for route risk assessment» (Copenhagen / oslo: Holo, september 2024), https://www.arcgis.com/home/item.html?id=3f025ec180044fe4a1c71845fe58c653#.

Adherence to Speed Limits and Safe Distances

In Norway, there is generally a strict respect and adherence to speed limits and maintaining safe following distances. An ADS hence required to be adjusted to ensure it complies with these driving cultural norms. To refrain from causing unnecessary insecurity to other road users, safety is to be prioritized over assertiveness, which might be more common in other driving cultures.

It is also legally required to yield to buses indicating their intention to leave a stop using turn signals, which is widely respected and typically enforced.

Road infrastructure and Signage in Norway

Norwegian roads are generally well maintained, with clear signage, standardized road markings, and a consistent layout for pedestrian crossings, roundabouts, and bus stops. These features support predictable driving behavior but also place high expectations on vehicle compliance with marked infrastructure. For example, bus bays and pull-outs are typically well-defined, and vehicles are expected to yield to buses re-entering traffic. Additionally, signage indicating right-of-way — or the lack thereof — is critical, as Norwegian drivers rely heavily on these cues. The ADS must be calibrated to recognize and interpret these elements precisely, as even subtle signage differences can affect legal yielding behavior.

Navigating Roundabouts

Roundabouts are a prominent feature of Norwegian roads, requiring smooth and predictable navigation. The ADS must be adapted to handle these roundabouts with precision, ensuring it yields appropriately and merges seamlessly with traffic. Moreover, the considerate use of turn signals and lane positioning is a strong norm in Norway — one that can be challenging to replicate in ADS behavior.

Yielding To Right Hand Traffic in Intersections

One of the fundamental differences in driving culture in Norway is the rule of yielding to the right at intersections. In Norway, drivers must yield to vehicles approaching from the right at unmarked intersections unless otherwise indicated by signs or road markings. These intersections are particularly present in residential areas with many smaller and medium roads. An ADS deployed in Norway must be specifically programmed to recognize these scenarios and consistently yield to vehicles approaching from the right, adapting its behavior to align with local traffic expectations and legal requirements.

Pedestrian Awareness and Courtesy

One fundamental cultural characterization of Norwegian, and in general Scandinavian driving culture, is a strong emphasis on soft road user's rights. Drivers almost certainly yield at crossings and the law does dictate so. Hence the ADS needs to be recalibrated to recognize and respond to pedestrian crossings proactively, aligning with local expectations of courtesy and safety.

Impact of Winter Weather on Autonomous Driving

As part of the pilot project, autonomous vehicles equipped with Mobileye's ADS technology were tested under real-world winter conditions in Oslo. The project has offered valuable insight into both the limitations and potential of autonomous driving in a Nordic climate, where seasonal weather poses significant operational challenges.

After operating through two winter seasons (2023/2024 and 2024/2025), it has become evident that autonomous driving was affected by harsh weather conditions, particularly during the winter months. Weather events such as heavy snowfall, snow banks, and ice made it — similar to human drivers — more challenging for the vehicle to maintain a high level of autonomous performance.

During the 2024/2025 winter season, data on the number of kilometers driven in manual and autonomous mode was compared to weather conditions recorded during the same period. The results are presented in Figure 4.

When analyzing the percentage of autonomous driving against snow depth and precipitation levels, the data shows that the percentage of autonomous driving consistently remained lower — though still above 60% — when snow depth increased. On days with strong precipitation, the percentage of autonomous driving dropped significantly.

However, it is important to highlight that during the heaviest snowstorms, the AV service was the only public transport operation that remained in service.

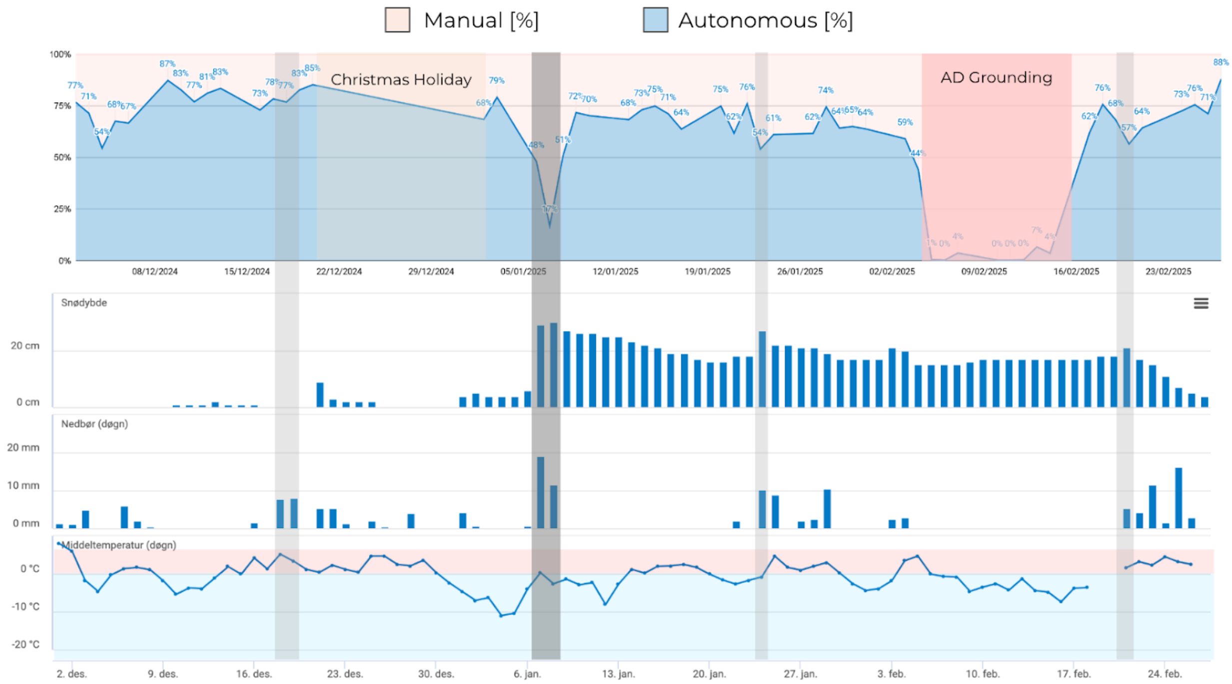

Figure 4: Autonomous Driving Based on Weather Conditions

Winter and Snow Challenges to Hardware

One of the most significant hurdles in adapting the Mobileye ADS to Norwegian road conditions, particularly during winter, is the impact of snow and ice on the vehicle's sensors. The fluctuating temperatures in the area, where snow can frequently melt and refreeze, pose a risk of sensors being covered in ice or wet snow. This can lead to impaired functionality of crucial sensors like LIDARs, cameras, and radars, which are essential for the vehicle's ability to perceive and navigate its environment. To mitigate this, sensors may require protective coatings or periodic manual cleaning by the safety driver to maintain consistent functionality.

Figure 5: Impact of snow on vehicles

Winter and Snow Challenges Sensing and Software

In addition to the hardware challenges, the local environment presents significant difficulties for the ADS's sensing and decision-making software. Heavy, wet snow, which is common in this area, can be particularly challenging for LIDAR systems, as it is not easily filtered out compared to lighter, powdery snow. This necessitates specific calibration of the sensors to better handle such conditions, ensuring reliable operation in all types of snowfall.

Moreover, the ADS must be capable of accurately detecting and categorizing snow banks and snow piles, which are prevalent during Norwegian winters. The decision-making engine of the Mobileye ADS must be sophisticated enough to interpret these formations and adjust the vehicle's behavior accordingly. For example, snowbanks may temporarily narrow roads, requiring the vehicle to deviate from its preset drivable path—a critical capability for navigating the smaller residential streets in the area.

Winter Impact on Road Infrastructure and Perception

During the winter months, key elements of road infrastructure — such as lane markings, curbs, and signage — may become partially or fully obscured by snow. This challenges ADS localization, lane-keeping, and legal compliance, especially in areas with minimal roadside barriers or frequent snowbanks. Norwegian municipalities do not uniformly clear all residential roads to bare pavement, making it essential that the ADS can operate even when visual cues are missing. Furthermore, snow piles can physically narrow roads, especially near intersections or parking zones, requiring the system to dynamically recalculate safe paths beyond its pre-defined HD maps.

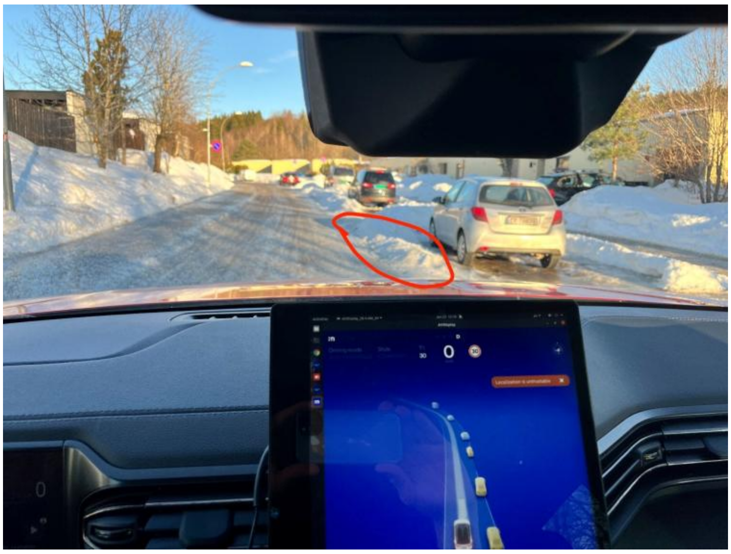

Figure 6: Undetected snowpile

Human Intervention Thresholds and Lessons From Safety Driver Behavior

Throughout the two winter seasons of operation, the role of the onboard safety driver has provided valuable insights into the limitations of the current ADS system under Norwegian conditions. Interventions typically occurred in situations involving low visibility due to snowfall, unexpected snowbanks encroaching on the drivable path, or unclear lane markings following heavy snow.

These situations revealed that while the ADS could technically continue operation in degraded conditions, the threshold for human intervention was often driven by uncertainty rather than direct system failure. In many cases, safety drivers intervened preemptively to avoid ambiguous scenarios or where the ADS exhibited overly cautious or hesitant behavior that could be misinterpreted by other road users.

Determining the reason behind human intervention, allows safety operators to identify patterns and develop frameworks based on the scenarios that are most likely to trigger disengagements. Such a framework can help map out the limitations of the technology or the vehicle, providing a strong indicator for future development needs. Incorporating safety driver feedback into system training and policy refinement will be essential to improving resilience in unpredictable winter conditions, especially in low-traffic, partially cleared residential streets where human judgment still outperforms automation.

The Need for Dynamic AD Policies

The driving policy of the Mobileye ADS will need to be highly adaptive to account for the varying road conditions in Grorud Valley, particularly the transition between icy surfaces, snow-covered roads, and normal dry conditions. Currently, ADS technology faces challenges in dynamically adjusting to these changing conditions, underscoring the need for a system that can modify its parameters in real-time to maintain safety and efficiency.

Additionally, the ADS must be capable of dynamically adjusting to changes in traction caused by different weather conditions, including not only snow and ice but also rain. This includes modifying speed, braking distances, and steering inputs in response to the decreased coefficient of friction that these conditions introduce. Such adaptability is essential for the safe and effective operation of the ADS within the complex and diverse traffic scenarios found in the area.

Figure 7: Icy conditions

Additional Winter Testing by Mobileye

The challenging winter conditions in our Operational Design Domain (ODD) represents a valuable testing ground, not only for the Grorud pilot but also for other autonomous driving projects. In February 2025, Mobileye conducted separate winter tests using vehicles other than those deployed in our pilot. The purpose was to assess system performance under Nordic winter conditions, focusing on two main areas for improvement in winter driving mode: detection and driving behaviour.

The tests confirmed that achieving reliable performance in these conditions requires a substantial amount of data collected in the specific environment in which the vehicles operate. This is necessary both to refine perception models so that winter-specific objects are correctly detected, and to ensure that those detections are used to adapt driving behaviour appropriately. It is an ongoing, iterative process: data is collected, models are refined, driving behaviour is adjusted, and new data is gathered — creating a constant feedback loop with countless small adjustments and continuous learnings, each improving the quality of the next system iteration.

Key areas of work included:

Detection

- Identifying falling snow as a transient object to be filtered out using camera perception.
- Improving recognition of large snow piles and snowbanks, from parked vehicles and preventing misclassification as moving objects.
- Maintaining correct road path alignment despite altered road boundaries caused by snow accumulation.

Driving Behaviour

- Adjusting speed reductions, to speed limits (higher reductions in high speed areas)
- Refining acceleration and deceleration patterns to account for reduced traction.
- Improving lane-change behaviour under winter road conditions, when road lines are covered by snow.
- Optimising angle-of-approach for turns and manoeuvres on icy or snow-covered surfaces and altered road edges.

Other Observations

- Addressing occasional loss of localisation in snowy conditions.
- Detecting changes in friction and traction to enable dynamic driving style adjustments.

These findings complement insights from the Grorud pilot and demonstrate the ODD's value as a robust environment for identifying limitations, refining perception, and continuously improving winter driving performance in autonomous vehicles.

Defining and Mapping Potential Pick-Up- and Drop-Off-Points (PUDOs)

Identifying and mapping suitable pick-up and drop-off locations—commonly referred to as PUDOs—poses a range of challenges related to infrastructure, physical layout, regulatory constraints, user experience, and, not least, the vehicle's ability to stop accurately at the designated location.

We aimed to gain deeper insight into:

- The different types of PUDOs required, and the operational demands associated with them
- Areas where stopping is not possible, and how this information can be digitally mapped
- How to combine fixed and dynamic stops
- What is required of PUDO infrastructure when transitioning from SAE Level 2 to Level 4 autonomy

- Whether there are special considerations for stops near schools or public transport hubs
- What is needed for implementing virtual stops

We began by identifying approximately 50 pick-up and drop-off points within the pilot area. These PUDOs were selected based on a combination of factors:

- Proximity to users
- Connection to existing public transport and key destinations
- Accessibility for autonomous vehicles (e.g., avoiding the need to reverse)
- Traffic safety (lighting, perceived safety, safe waiting areas, visibility, speed limits, and school-related considerations)
- Traffic flow (available space, traffic volume, speed limits)
- Comfort level (low priority in the pilot phase)
- No-stopping zones (as defined by Norwegian traffic regulations)

Initial simulations with 59 stops revealed the need for a significantly larger number of PUDOs to ensure accessibility for most residents in the area. We therefore increased the number of PUDOs to 135. A second simulation showed that this provided coverage for 92% of the area's residents and 71% of its employees, assuming a maximum walking distance of 400 meters.

We believe that 135 PUDOs are sufficient for the pilot phase. However, for future scaling, our goal is to reduce the walking distance to around 200 meters—and eventually enable true "anywhere" stops within the service area.

5. Operation Without a Safety Driver

5.1. Challenges in Integrating Vehicle Platform and Autonomous Technology

As we are entering a new mobility phase that revolves around autonomous vehicles, it has become clear that optimizing only certain aspects of an autonomous vehicle like sensors or compute power is not sufficient. The challenge is multidisciplinary and includes many aspects like hardware, software, safety critical technology, regulation as well as operation. Developers face the task of validating these complex systems through testing – both in the virtual and in the real world – while ensuring cybersecurity, redundancy, and compliance with evolving global standards like ISO 26262 and SAE Level 4 certifications. The goal is to orchestrate all individual aspects like precision sensor placement, high-performance compute, steering and braking systems and more to reach reliable and safer-than-human driving.

The current development environment in semi-autonomous mode with a safety driver also poses the challenge of intuitive user interfaces that manage the transition from human to machine. Combined with development costs and scalability challenges, the journey to autonomy demands deep engineering expertise, rigorous validation, and smart platform strategies. Autonomous driving isn't just a software upgrade – it's a complete system transformation.

As autonomous vehicles will be deployed as part of public transportation services, additional operational integration becomes critical. This includes ensuring compatibility with scheduling systems, fleet management platforms, accessibility standards, and real-time passenger information systems. Public transport operators must be able to seamlessly monitor, dispatch, and maintain autonomous vehicles as part of a mixed fleet, while aligning with regulatory, safety, and service-level expectations. True autonomy at scale requires not only vehicle intelligence but also system-wide interoperability

5.2. Developing the Role of Safety Operator

The safety operator had a very important role in preparing, validating, and "training" the digital driver Ruter's operational area. Ensuring safety was the highest priority. Equally important was the operator's role in observing, recording, testing, and providing feedback to the technology provider to enable continuous development and improvement of the software and map updates.
The safety operator thus had many roles. The requirements were high. It required a high ability to handle the vehicle with the level of attention that was necessary. Additionally, the operator must have sufficient technical competence in their role as an observer in a validation and testing regime. One might think that such a role is temporary. However, this role will be needed for the foreseeable future. As operations scale up, there will be a need for the validation of new operational areas, and software updates will need to be tested.

In order to conduct safe operation in the project, the operator and the SDS-provider ensured that Safety Operators are trained properly and with a clear understanding of their safety responsibilities. Only trainers who had completed the trainer's course would be allowed to afterwards conduct training of Safety Operators.

When we searched for a safety operator, we were looking for candidates with specific broad competence and experience, combined with a personality suited to the role, with a focus on responsibility and ambassadorship. They were responsible for a variety of tasks related to operating the fleet, such as

- Ensuring the service of autonomous vehicles in a large suburban area
- Provide detailed feedback on driving experience, safety performance, security, passenger impressions and other topics of interest to internal departments
- Collect and upload data and log files
- Light user maintenance of vehicles
- Be part of a team of safety operators in a time-sensitive and demanding environment
- Handling of any incident as defined in relevant training
- Hosting passengers and explaining about Ruter and related technologies

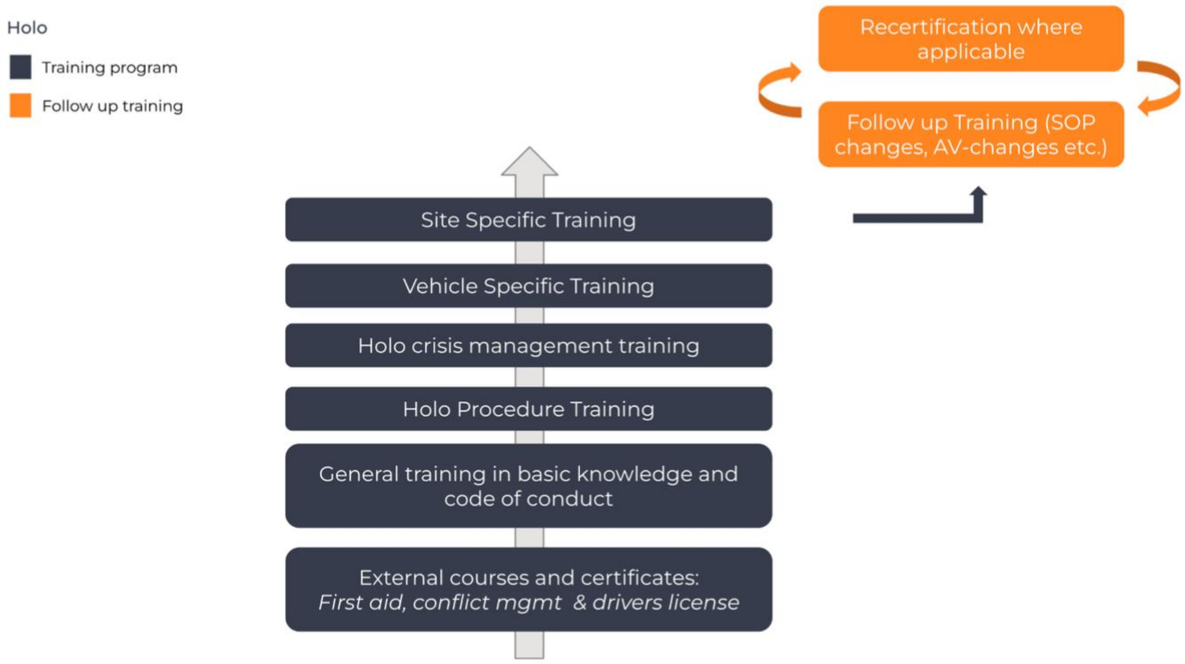

Figure 8: Overview of Safety Driver training programme

The purpose of the program was to provide Safety Operators with the knowledge, skills, and competences needed to manage both manual and autonomous driving in any conceivable traffic situation. Additionally, Safety Drivers should be able to apply relevant procedures and incident management processes both in daily operations and in the case of an incident.

6. Statistics and KPIs

A semi-automated approach was developed to monitor performance in relation to selected KPIs during the pilot. These KPIs reflected both system performance and user experience, with the intention of tracking readiness across four dimensions: technical readiness, service readiness, passenger readiness, and scalability readiness. The indicators were chosen to provide early signs of progress toward a scalable Level 4 autonomous service that also meets passenger expectations.

6.1. Technical Readiness

Autonomous Driving Rate & Uptime Hours

This metric measured the percentage of time that vehicles operated in autonomous mode when technically possible. Periods of known downtime were excluded to focus solely on performance when autonomous driving was feasible. This was the primary indicator of progress toward Level 4 autonomy.

System availability was measured through uptime, specifically during periods when autonomous operation was possible. Like autonomous driving rate, irrelevant periods were filtered out.

Together, these two indicators offered a clear view of how close the system was to delivering continuous Level 4 availability.

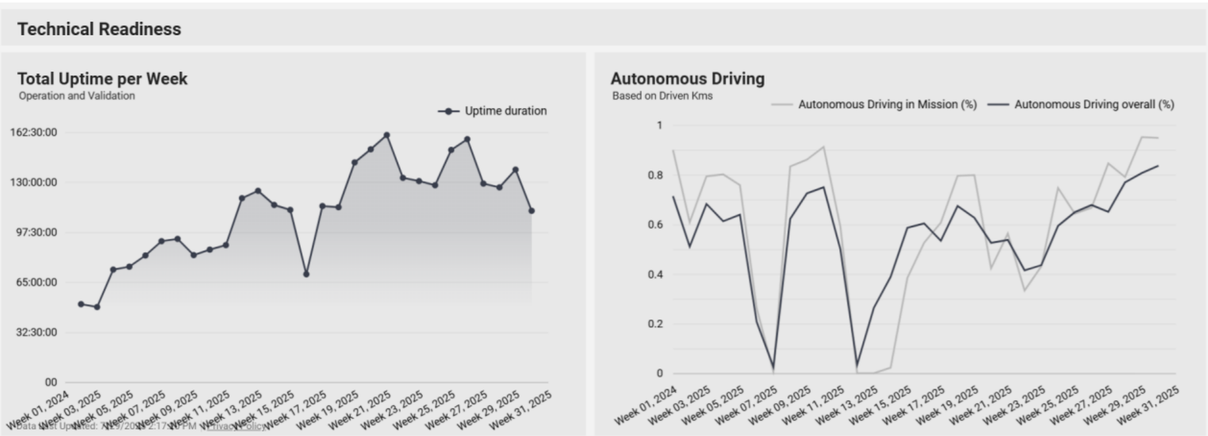

Figure 9: Autonomous driving rate & Uptime hours

6.2. Service Readiness

Coverage Rate and Wait Time

PUDO Coverage was assessed by measuring the ability to serve trips within the Operational Design Domain (ODD) based on walking distance from pickup and drop-off points, specifically within 200, 400, and 600 meters. This helped to identify blind spots in routing or vehicle distribution. 69 PUDO points have been implemented in the Groruddalen service area. This results in a coverage rate of 17.3% within 200 meters, 48.2% within 400 meters, and 73.6% within 600 meters walking distance.

Wait time was tracked from the moment a ride was requested to the actual pickup. Median, minimum, and maximum wait times were recorded. This was a critical factor in evaluating trust and satisfaction with the on-demand model.

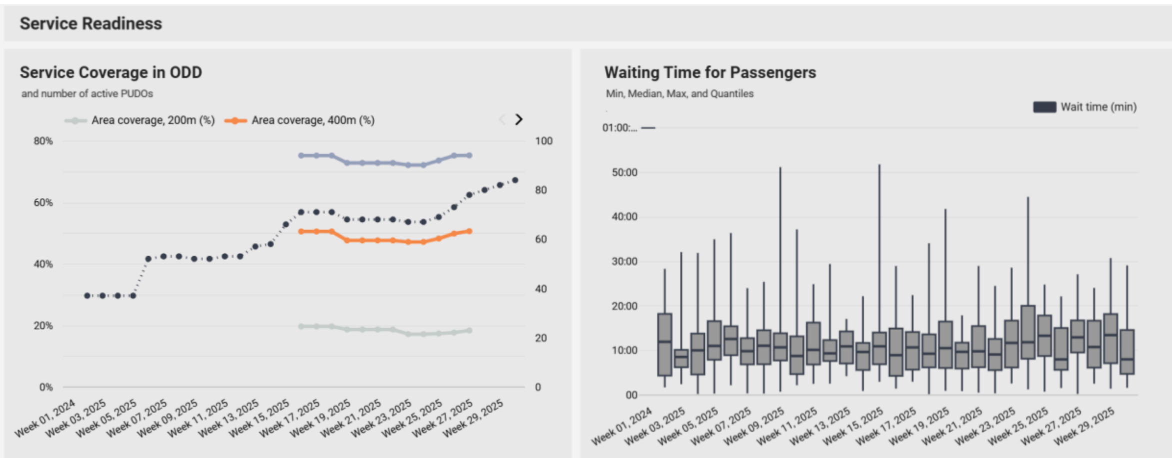

Figure 10: Service Coverage Rate & Wait time

6.3. Passenger Readiness

Unique Number of Passengers and Cancellation Rate

The number of distinct users provided insight into adoption patterns. This metric was used to assess growth and test relevance to different user segments. Early in the pilot, the data showed a strong presence of returning users, with fewer new passengers.

This metric reflected service reliability from the user's point of view. High cancellation rates often indicate issues in planning, routing, or vehicle availability.

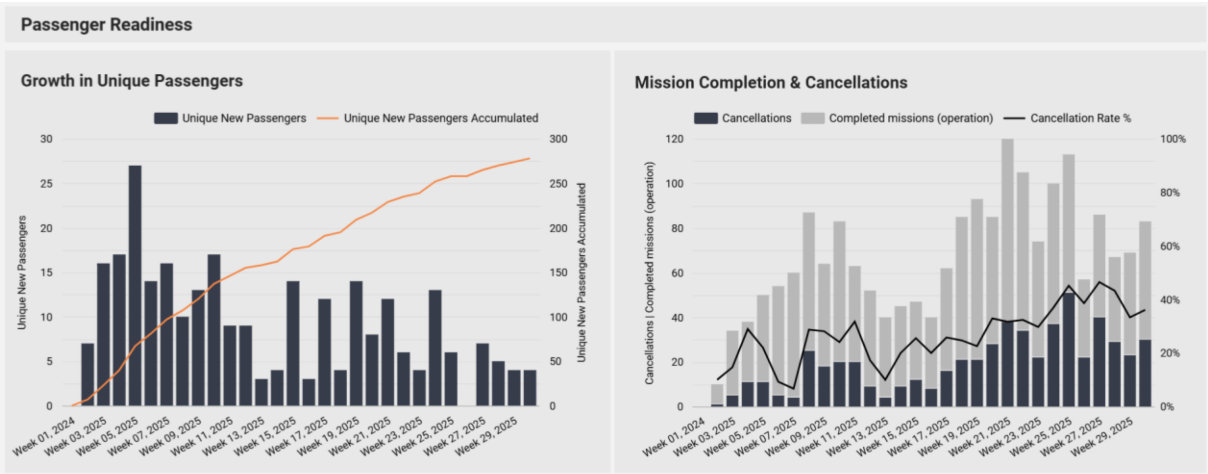

Figure 11: Unique Number of Passengers & Cancellation rate

6.4. Scalability Readiness

Net Promoter Score (NPS)

Passenger satisfaction was evaluated using the Net Promoter Score, collected over four-week periods through an in-app survey. NPS offered a direct measure of user experience and readiness for scaling. Even if technical indicators were strong, a low score suggested the service did not meet expectations.

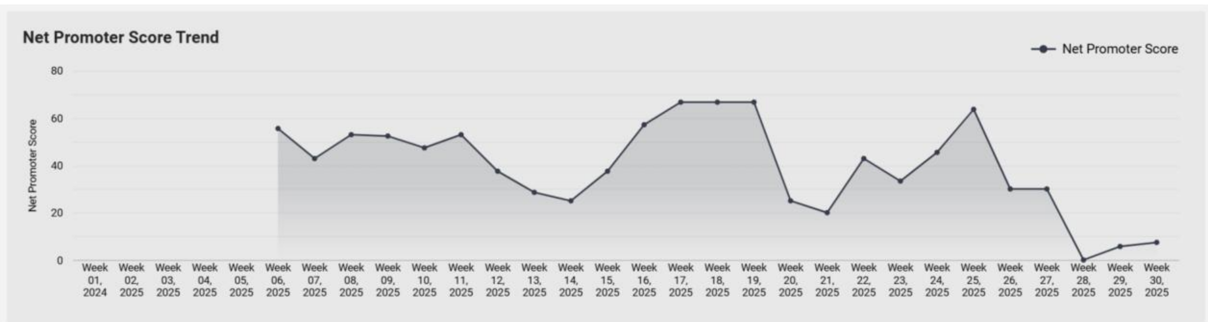

Figure 12: Net Promoter Score (NPS)

Each KPI was selected to reflect either progress toward Level 4 autonomy or trust in the service from the user's perspective. Given the volume of available data, a focused approach was required to filter out irrelevant periods and highlight meaningful trends. The KPIs were designed to measure real progress, providing a clearer view of what it would take to move from pilot to scalable deployment.

Operational Dashboard and Improvement Process

Operational dashboard was widely used during the project to determine progress towards the goals. A weekly operational meeting was part of a continuous improvement process. Key challenges and improvement suggestions were identified during the meeting, where each project partner was responsible for implementing changes and track impact between the meetings.

Examples of data and dashboard used during the meetings are shown below:

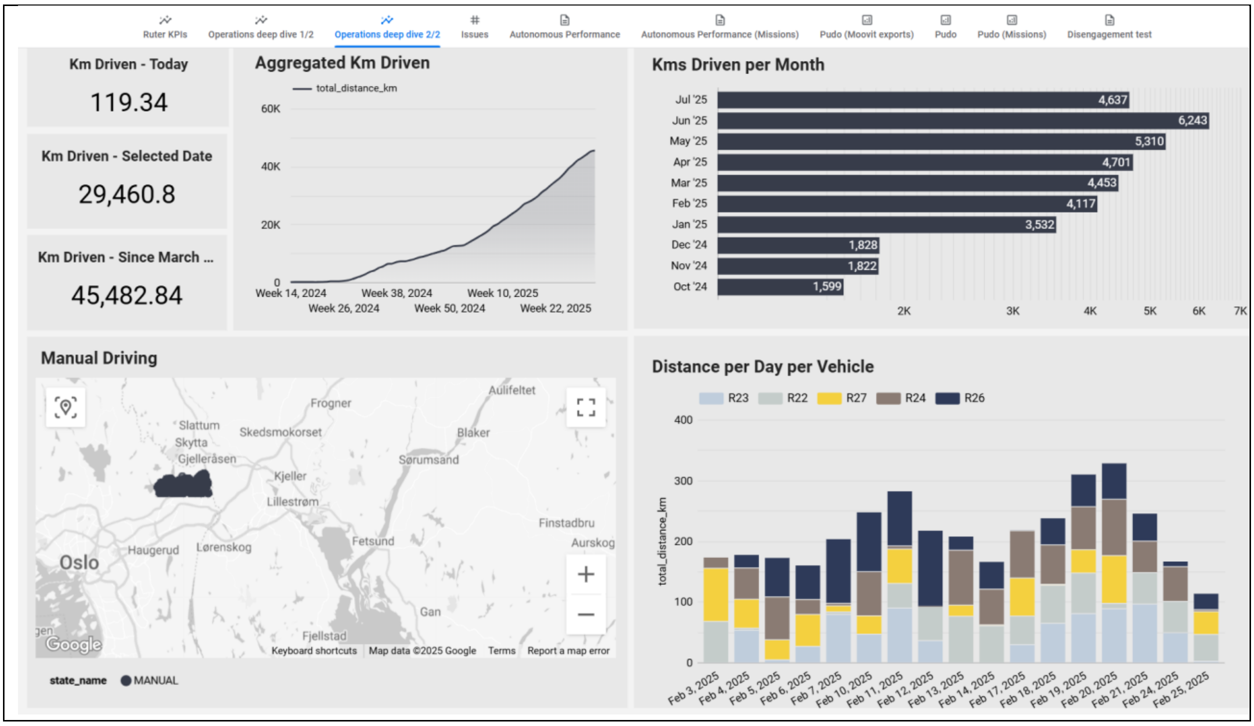

Figure 13: Key statistics from dashboards

Key Statistics from MaaS App

Another part of the integral process of preparing the service for public transport is the improvement process for customer adoption. The white label MaaS app from Moovit came with a full analytics solution and dashboard.

Figure 14: Key statistics from MaaS app

7. Interactions with Residents and Users

7.1. Research Conducted by CICERO[6]

Using qualitative research methods, CICERO aimed to gain insight into the user journey and how the service could be developed from today's private car–oriented model into a truly attractive public transport offering. A focus was therefore on understanding more about the social mechanisms that can lead Autonomous Public Transport (APT) replacing private car ownership.

The user group included travellers of all ages, including individuals with disabilities. The approach was iterative, with continuous feedback between the research findings and the technological adaptation. Results from the user research were actively integrated into the project to ensure that the autonomous vehicle technology was sufficiently tailored to user needs and local conditions.

Some main findings include:

- The need to expand user groups beyond the largely male "first movers" on new technology.
- For couples or families, it is important to keep in mind that both people need to switch to APT to replace a private car.
- Several first movers noted that their partner would likely still use or keep their car, even if they substituted a private car for APT for themselves.
- Finding the right price level for APT will be a challenge, in order to outcompete private cars but simultaneously avoid replacing other public transport use or walking and biking.
- Mainstreaming ridesharing in the APT will be a crucial factor for reducing transport emissions and reducing traffic. This will require establishing new norms for interaction when sharing a car with strangers.
- Related barriers are that some interviewees were sceptical to the idea and/or would rather pay more to ride alone. There were also some safety concerns for sharing with strangers, particularly for women (amongst both genders).
- Further technological development is needed for better access for people with disabilities. An ambulatory wheelchair user could only use the service for trips that involved minimal walking because wheelchairs were not possible to bring in the car, yet they also experienced being dropped off more than 600 meters away from the indicated point, which was a much larger issue for them than most others.
- The impression of the current status of the pilot also varied widely, from the technology being very much a work-in-progress to wishing they could use the service all over Oslo today, even without a safety driver.

All results will be collected in a publicly available CICERO report with more findings and more context for each finding.

[6] CICERO: Center for International Climate Research
Lead researcher: Mikkel Vindegg, Senior Researcher (https://cicero.oslo.no/en/employees/mikkel-vindegg)

7.2. Research Conducted by TØI[7]

Video Observations

TØI combined observatory analyses of video data with AVs' operational data, such as their status – manual/autonomous, speed and position. The aim was to gather knowledge regarding AVs' interactions with other road users at selected sites in Groruddalen under various environmental conditions, with focus on safety. Applying various criteria (such as accident hotspots; challenging locations for AVs and cyclists according to TØI's previous research; pick-up/drop off points in sensitive areas), TØI identified 27 sites - candidates for observations.

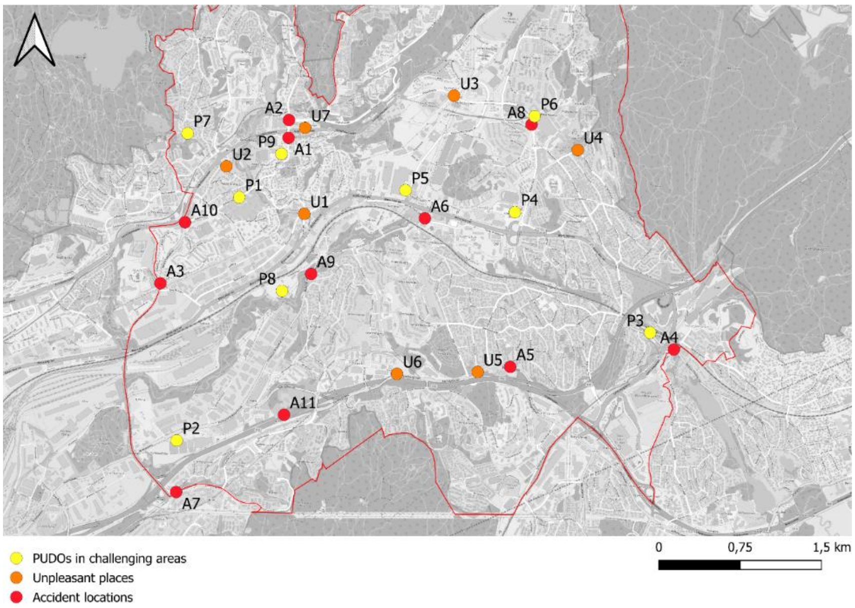

Figure 15: [Locations of candidates for video observations]()

For external video recording, seven Miovision Scout portable video units have been continuously installed at selected sites. These cameras enable long-term recording with 720x480 resolution, from 6 m height with 120-degree wide angle. The recording started in January 2024 and was finished in February 2025. The selection of sites for recording from the list of candidates was based on the actual AVs' routes and schedule – updates on that were provided regularly by HOLO. The total amount of recorded video data was 3103 hours collected at 13 sites. Due to limited availability of operational data from AVs earlier in the project and specifications of the testing phase (especially with AVs performance being in flux because of continuous updates), the observational analyses utilised the data collected in final stage of the project, in December 2024 and January 2025. Two topics were the focus of interest:

1. **Right-of-way interactions on T-intersection regulated by right-hand rule, under winter conditions**. The manuscript that presents findings from behavioural analyses of 154 interactions between AVs and other road users was submitted into the special issue of Transportation Research Part F - Traffic Psychology and Behaviour in June 2025. The manuscript t is currently under review (*Right-of-way interactions between automated*

[7] Lead researcher: Petr Pokorny, Forsker II (https://www.toi.no/ansatte/pokorny-petr)

vehicles and other road users in winter conditions – insights from Oslo, Norway; Pokorny, P., Berge, S., de Jong T., George, C., Bjørnskau, T.).

2. **AVs performance in traffic interactions, while considering local traffic rulers, norms and culture.** Using semi-structured group interviews with 11 practice supervisors at the traffic instructor training, TØI together with NORD University Business School in Stjørdal, Norway assessed AVs driving behaviour (as captured on camera at two locations in Groruddalen) in light of the main objectives of the curriculum for the driver's license class B. Currently, the manuscript is being finalised under a working title *Traffic Norms and Culture: Challenges in AV Interactions* and will be submitted to an international academic journal later in 2025.

Furthermore, in addition to regular status meetings within the project, the other dissemination activities conducted were:

- *Interactions between automated cars and other traffic participants in mixed urban traffic – insights from video-observation study in Oslo (Norway)*. Pokorny, P., de Jong, T., Weyde, K.J., Aasvik O., Berge, S.H. Pitch and Interactive poster session at International Cooperation on Theories and Concepts in Traffic Safety conference (ICTST), Hague, The Netherland, 10/2024.
- *People and Shared AVs – Behavioural Observations in Mixed Traffic*. Pokorny, P., de Jong, T. Presentation and working session at ULTIMO meeting. Oslo, 04/2024.
- Organising a lunch seminar at TØI on the topic of shared AVs and future mobility, with presentations by Fournier, G (*How to shape mobility of the future which serves general interest*) and by Pokorny, P. and de Jong T. (*Grorud valley: Interactions between automated cars and other traffic participants in mixed urban traffic*). Oslo, 10/2024
- *Autonomous shared vehicles and their interactions with other road users*. Pokorny, P. Presentation at National Road Conference. Brno, The Czech Republic, 09/2025.

Conclusion

While the research conducted is shaped by the limitations and specific conditions of the validation phase, the findings offer a timely snapshot of ongoing AV testing, and the interaction challenges observed in a Norwegian urban setting. Compared with the studies TØI conducted in 2020 to 2022 in Oslo region, the AVs in this pilot demonstrated notable improvements in their ability to operate in complex traffic environments. At the same time, the observational analyses from Groruddalen identified challenging situations involving negotiation, the assessment of other road users' intentions particularly in cases of ambiguous behaviour, as well as informal norms and mobility practices and some of these required a disengagement. It remains to be seen whether such situations can be effectively managed by AVs, which is precisely what ongoing pilot studies aim to explore. It is also worth noting that the research was conducted during the validation phase, when disengagements often reflect testing protocols or precautionary measures by the on-board operator rather than technical limitations. As such, the findings should not be interpreted as indicative of how AVs would perform in routine operations without an on-board human operator. Nevertheless, they suggest continued progress and provide relevant insights into how AVs are adapting to real-world urban settings. Complete findings are going to be published in the above described manuscripts.

7.3. Other Research Activities

In the spring of 2025, two students from Oslo University (UiO) wrote master's theses based on our self-driving pilot project.

Kristine Opsal: *"No Driver, No Stress – A Study of User Safety Perceptions in Autonomous Public Transport"*

Anne Lise Holst: *"Women's Perception of Safety in Shared Autonomous Transport – User Perspectives and Unconventional Design Alternatives"*

Both theses offer interesting perspectives that are worth considering as we continue to explore this field.

Some key takeaways:

- The absence of a driver creates uncertainty for users, especially in situations that require more than just technical precision.
- Digital solutions that provide real-time information about the vehicle's actions can give users a sense of control and help increase their feeling of safety.
- Trust in the technology develops over time – through users' own experiences and through positive feedback from others.
- Universal design and transparent user interfaces are important for creating a good user experience.
- Women tend to have greater concerns than men about sharing autonomous vehicles with strangers, particularly when no driver is present.
- To create a sense of safety, the solution should offer features such as control over who you share the ride with, emergency buttons, video surveillance, and an inclusive, calming interior design.
- Design principles like *defensible space* and *restorative environments* can help reduce stress and enhance the feeling of security.

7.4. Visits and Presentations

The pilot in Groruddalen and Lørenskog is not only about developing and preparing the technology for our region and Norwegian conditions. Equally important, it serves as a learning arena for national and international stakeholders who must prepare for the future of public transport. With "wheels on the ground" and a live pilot in operation with real passengers, we are in a unique position to shape the public discourse, test solutions for different user groups, and explore what works—and just as importantly, what doesn't. This is done not as a theoretical desk exercise, but as practical fieldwork, in close collaboration with a broad range of stakeholders.

The pilot has attracted considerable attention. Throughout the project period, we have delivered presentations, hosted numerous visits, and participated in a wide array of conferences. The aim has not been to showcase a final solution, but to create dialogue, share insights, and contribute to broader development. This way, the funding from Enova generates ripple effects well beyond our region.

Below are the most prominent examples of actors we have engaged with during the project:

Public authorities and policymakers:

- Norwegian Public Roads Administration
- Norwegian Directorate of Public Roads
- French transport authorities
- Agency for Urban Environment, City of Oslo
- Oslo's Standing Committee on Environment and Transport
- The Conservative Party (Høyre)
- Viken County Municipality
- Akershus County Municipality
- Norwegian Mapping Authority
- Norwegian Police University College

International public agencies:

- Civil Engineering Office, City of Zurich
- City of Helmond, Netherlands

Industry organisations and interest groups:

- Nordic Electric Bus
- ITS Norway
- UITP
- Norwegian Public Transport Association
- ITS Finland
- ITxPT
- Mobility Fornebu
- Norwegian Taxi Committee
- Danish Council for Green Transition
- The California Foundation on the Environment and the Economy (CFEE)
- ITS Nationals
- EIT Urban Mobility
- Norwegian Association of the Blind
- Mobility Innovation Alliance, Japan

Media coverage:

- NRK (multiple reports)
- TV2
- Aftenposten
- Dagbladet
- Jyllandsposten
- VG
- Groruddalen Newspaper

National transport operators:

- Hertz
- AtB
- UniBuss

Schools and academic institutions:

- Groruddalen School
- Kuben Upper Secondary School
- Oslo Metropolitan University (OsloMet)
- University of Washington
- Granstangen School

International operators and suppliers:

- PostAuto (Switzerland)
- Mitsubishi (Japan)
- Nio Norway
- Arriva
- Volkswagen
- Helsinki Regional Transport (HSL)
- Movia (Denmark)
- MAN Truck & Bus
- Stockholm Public Transport (SL)

Conferences and public events:

- Public Transport Day, Luleå, Sweden
- National Cycling Conference, Oslo
- PAVE Europe
- MODI Conference
- Mobility 2023
- Norwegian Public Transport Conference
- Urban Development Conference, Bergen
- Arendalsuka
- Smart Roads (Smarte Veger)

8. Climate Goals

This project has established the critical groundwork for implementing shared, demand-responsive, self-driving technology in Norway, creating the technological, regulatory, and operational frameworks necessary for unprecedented environmental transformation. While current environmental benefits are being realized through our preparatory work, we have positioned the region for extraordinary future impact. If the preferred scenario from the Oslo study (ref. Introduction) becomes reality, approximately 660,000 of today's private cars in Ruter's area of responsibility will be replaced with a fleet of just 20,000-30,000 shared, electric, self-driving vehicles - representing a 96% reduction in vehicle numbers while maintaining full mobility services.

This transformation, made possible by the foundations we have built, will deliver massive reductions in manufacturing emissions, complete elimination of direct transportation emissions through 100% electric operation, dramatically reduced urban space requirements, and optimized vehicle utilization that operates 8-10 times more efficiently than private car ownership.

Environmental benefits

Reduction in total vehicle mileage. Carpooling will contribute to a direct reduction in the number of vehicle kilometres. The Oslo study estimates a reduction of between 14% and 31%. This will have a major impact on global greenhouse gas emissions and the local urban environment.

Reduced emissions in the production of vehicles. The Oslo study estimates that one will manage with 30,000 private cars in the morning rush hour in Oslo/Akershus. Given that this is the peak in demand, it will be possible to reduce from the current 660,000 passenger cars to 30,000 in the Oslo area (a reduction of 95%).

Reduced congestion during rush hour. According to the TomTom congestion index[8] , an Oslo motorist who drives half an hour in rush hour traffic 230 days a year will stand in queues for 92 hours during the same year. A societal consequence of reducing the number of kilometres driven by 13 – 31% would be formidable.

Freeing up parking and driveway areas for other purposes. The area in the Oslo region that is currently used for parking spaces or driveways for cars will be reduced by approx. 30% according to calculations from MIT[9]. In the future, this can be used for other purposes such as parks, plantings or other recreational areas.

Figure 16: Environmental benefits

9. Next Steps and Future Outlook

9.1. Expected Cost Development

Introducing a large-scale autonomous, demand-responsive transport (DRT) service is expected to require a substantial investment. Based on our internal economic analysis, the total investment needed to scale up from today's pilot to a full-scale deployment of 500 autonomous vehicles is estimated to be between **NOK 2 and 2.8 billion**. This includes the cost of vehicles, self-driving technology, services centres, digital infrastructure, and other related facilities. Annual operating costs for a 500-vehicle fleet are estimated at **NOK 460–790 million**, excluding one-time adaptation costs in the range of **NOK 170–330 million**.

These figures reflect significant uncertainties, given that the service does not yet exist at scale, and the supplier market is still emerging. The high cost level is largely driven by the complexity of the technology, the need for skilled technical personnel, and the requirement to establish service centres with infrastructure for charging, cleaning, and maintenance. Even though the vehicles operate without drivers, the total personnel cost remains high due to the need for fleet monitoring, remote support, and technical servicing.

[8] https://www.tomtom.com/en_gb/traffic-index/oslo-traffic/
[9] Massachusetts Institute of Technology

Looking forward, it is expected that total costs will gradually decrease as the technology matures and automation levels increase. Economies of scale, reduced vehicle prices due to mass production, and lower personnel costs will contribute to this decline. Furthermore, cost savings could be significant if investments in physical infrastructure, such as service centres, can be minimised through smart integration with existing facilities or future automation of servicing operations.

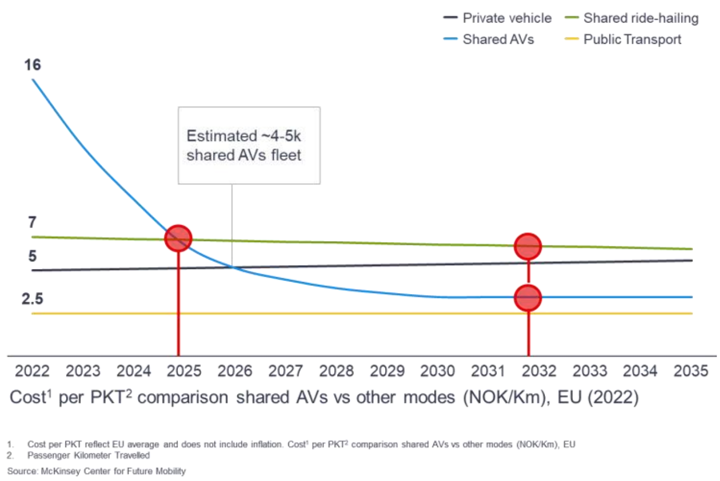

Figure 17: Cost per PKT comparison

9.2. Potential for National and Possible International Deployment of Shared Autonomous Transport Services

The pilot initiative in Oslo and Lørenskog demonstrates that shared autonomous transport services (SAVs) can be a viable complement to the public transport network, enabling more tailored, efficient, and sustainable mobility. However, moving from a pilot with a handful of vehicles to large-scale deployment (e.g., 100–500 vehicles) is a major leap—both financially and industrially. The required investment is significant for a full-scale rollout. At the same time, the current supplier market is not yet mature enough to support such volume in a scalable, cost-efficient way. For this reason, international coordination and demand-side collaboration are crucial.

Anchoring SAV development in the public domain helps safeguard democratic values such as privacy, accessibility, and environmental sustainability. It also ensures that mobility data remains under public governance, which is vital in a digital economy where data is a strategic asset.

If cities act in isolation, they risk fragmenting the market and leaving room for unregulated commercial operators with less focus on societal value. A coordinated European push could instead result in a strong, scalable, and supplier-friendly ecosystem—driven by real demand and shared public values. Acting now is essential. By aligning public sector needs, EU frameworks (e.g. the Green Deal and AI Act), and available funding instruments, Europe can build a new mobility market that supports its industrial base, climate goals, and citizens' needs.

Ultimately, if coordinated action is not taken now, Europe risks ceding leadership in this field to commercial players whose interests may not align with public transport goals or climate ambitions. With its experience, partnerships, and forward-leaning strategy, Ruter is well positioned to play a leading role—both nationally and internationally—in shaping the future of shared autonomous mobility.

9.3. An Updated Market Assessment with Regard to Competing Services

The international race for autonomous mobility is accelerating, with high-profile players in the US and China leading large-scale deployments of robotaxi services. Companies like Waymo, Zoox, Tesla, Baidu, Pony.ai, and WeRide are all pursuing commercial services centered around private, door-to-door autonomous rides. The core business model is individual, non-shared transport—robotaxis as a direct substitute for personal car ownership or ride-hailing. While technically impressive, these services are not built with public transport integration, nor do they promote shared rides.

What sets the Norwegian and broader European ambition apart is the integration of shared autonomous vehicles (SAVs) into the public transport ecosystem. The services being developed are explicitly designed for **ride-sharing**, **complementarity with existing public transport**, and **a focus on social and environmental sustainability**. This makes them fundamentally different—not just in technology, but in purpose and policy alignment.

This distinction is more than theoretical. If robotaxi services modeled on current deployments in the US and China gain a strong foothold in Europe without regulation or public counter-models, the result could be deeply counterproductive. The "Oslo study" by COWI estimated that private autonomous vehicles could severely increase congestion if they operate without restrictions. Tesla's vision of privately owned autonomous cars—rented out via app in an "Airbnb-for-cars" model—could saturate urban roads with empty vehicle trips and undermine both sustainability goals and public transport ridership.

Meanwhile, in China, players like Baidu and WeRide are scaling fast, but again with little emphasis on multi-passenger rides or integration into transit networks. In contrast, the European approach—discussed at the July 2, 2025, EU Parliament session on "Autonomous Vehicles in the EU: Driving the Future"—highlights the need for AVs to **complement** rather than replace public transport. Initiatives such as the CCAM Partnership and cross-European city coalitions emphasize scalable, user-centered, publicly anchored models for AV deployment.

In this context, the competitive pressure does not come from similar services—but from vastly different ones, with business models and incentives that may threaten the very urban transformation Europe is striving for. Europe must act swiftly to coordinate a counter-model that supports **shared, integrated, sustainable** AV mobility. The project we are building is not just a local pilot—it is a prototype for how Europe can reclaim technological sovereignty in the AV space while staying true to its public service values.

10. Summary of Budgeted vs. Actual Costs

The project's finances have been closely monitored throughout the entire period, with a focus on ensuring that funds are used in line with the project's purpose and within the allocated limits. We attach an overview of the budgeted and actual costs broken down by the three main budget categories. A more detailed breakdown at sub-category level is included in the separate audit report.

Budget Category	**Budget (MNOK)**	**Actual Expenditure (MNOK)**	**Variance (MNOK)**
1. Purchase of R&D Services	20.8	19.8	-1.0
2. Materials and Direct Costs for Production of Prototype/Pilot	48.0	48.2	0.2
3. Other Operating Costs (travel, meetings, etc.)	1.5	1.5	0.0
Total	**70.3**	**69.5**	**-0,8**

Figure 18: Budget vs Actuals

The total investment cost for the project was estimated at NOK 70.3 million, with an actual expenditure of 69.5 million. No part of the costs for industrial research by TØI and Cicero were covered, so these expenses are not included in the above overview and were fully self-financed. The total grant from Enova amounted to 25% of the eligible costs, while the remaining amount was financed by the Ruter.

10.1. Summary of Cost Categories

Purchased R&D Services

Costs related to the operator Holo are reported as purchased R&D services, as these were delivered under the R&D agreement between Holo and Ruter. This category includes parts of planning and project management, as well as operations during data collection, costs related to vehicle adaptations, HD mapping, and software adjustments.

Materials and Direct Costs for Production of Prototype/Pilot

The project invested in five vehicles equipped with self-driving technology, including adaptations to Norwegian conditions. The R&D partner Holo owns and depreciates the vehicles during the pilot, while Ruter leases the R&D service. This category also includes the cost of producing the HD maps required for vehicle operation.

Other Operating Costs

Other operating costs include the purchase of additional support for project and research management in the form of consultancy fees over a 17-month period.

11. Conclusions

The pilot had a clear objective: to prepare and validate market-leading, shared, electric, autonomous vehicle technology for Norwegian conditions and for integration into public transport operations.

It was designed to introduce a small fleet of advanced, shared, electric autonomous vehicles into a real urban environment, operating in mixed traffic without reliance on fixed routes. A central objective was to adapt the technology to Norwegian conditions—covering everything from road environment, signage, and traffic regulations to weather challenges and local driving patterns—through an extended period of real-world operation. This phase was used to train and refine the self-driving system so that it could perform reliably as part of a public transport service.

An equally important goal was to test the service with real groups of passengers, using their experiences to shape it into an attractive and accessible collective mobility option. This included developing a network of virtual pickup and drop-off points and enabling seamless booking through a dedicated app. Independent research partners were engaged to evaluate technical performance, passenger experience, and public acceptance, ensuring that the resulting solution would be not only technically sound but also aligned with user needs and expectations.

Over the course of the pilot, all major planned activities were completed: high-definition and REM mapping of the 20 km² service area, adaptation of driving policy and sensors to Nordic (winter) conditions, establishment and simulation of a large network of PUDOs, iterative testing with safety operators, and active integration of research feedback from TØI and CICERO.

The findings show that the technology is approaching readiness for driverless operation in Norwegian public transport, with strong technical performance in most scenarios and a clear path for further improvement in areas such as winter handling, complex negotiation with other road users, and refinement of passenger information. User research confirmed that trust, safety perception, and universal design are central to adoption.

The project delivers on the Enova-supported ambition to pave the way for a scalable fleet of small, shared, electric autonomous vehicles. At full deployment, such a system has the potential to significantly reduce vehicle kilometres travelled, private car ownership, and greenhouse gas emissions—while improving accessibility, especially in underserved areas.

This project has met its core goals: to demonstrate technical feasibility, to ensure the technology meets Norwegian operational requirements, and to confirm its potential as a sustainable, user-centred public transport service. The next step, which is ongoing, is scaling and integration into the broader mobility network, turning the groundwork laid here into measurable environmental and societal benefits.